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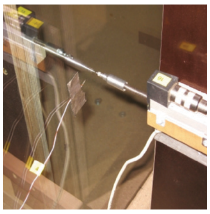
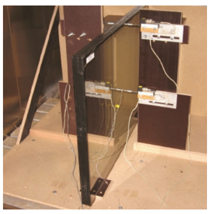
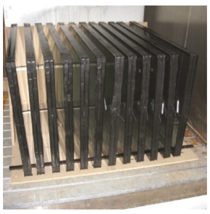
Short Report
July 2015

Pressure-equalized insulating glass units – a feasibility study





Short report
Pressure-equalized insulating glass units

Subject	**Pressure-equalized insulating glass units - a feasibility study**
Short title	Pressure-equalized IGU
Sponsored by	Research Initiative „Zukunft Bau“ of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (File reference: SWD-10.08.18.7-12.12)
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Rosenheim, July 2015

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1 Motivation and aim of project

Conventional insulating glass units (IGUs) are made of several sheets of glass separated by a spacer and sealed hermetically around the edges. The cavity between panes is usually filled with argon. The seal keeps the ingress of moisture into the cavity low to prevent water condensing on the inside surfaces of the glass panes and to avoid any corrosion of metallic low-e coatings. Further, the seal prevents the fill gas from escaping.

There is a major drawback associated with this design: an exchange of gas or air between the cavity and the atmosphere is impossible. Thus, whenever the temperature in the cavity or the external air pressure changes, the pressure in the cavity changes as well. This causes the panes to bulge inwards or out, inducing flexural stresses in them. The edge seal is subjected to tensile or compressive loads. Further, moveable solar shading devices integrated in the IGU might get trapped and damaged by panes bulging inward.

Atmospheric effects as described above increase with the inter-pane spacing. Thus, the overall depth of conventional IGUs has to be restricted to avoid any damage caused by changes in air pressure or temperature. Such restrictions would not be necessary if pressure equalization between the IGU cavity and the atmosphere could be achieved: This would result in the following advantages:

- Simplified integration of various components into the IGU, e.g. solar shading systems
- Implementation of IGUs with more than three panes without substantial restrictions on the inter-pane spacing
- Larger overall depth and thus, less thermal bridging at the connection to the supporting structure
- Reduced heat transfer coefficient compared to conventional double and triple glazing
- Improved airborne sound insulation (increases with inter-pane spacing)
- Use of thinner glass panes possible.

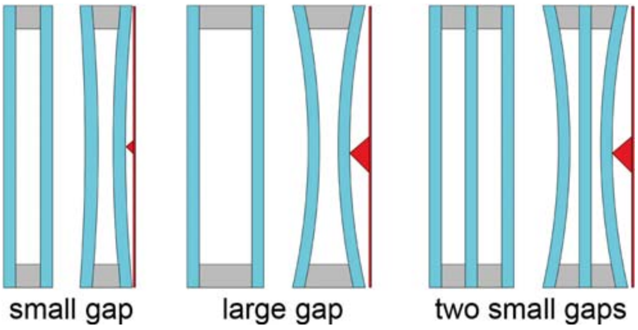

Figure 1 Effect of climatic loads on insulating glass units
Mechanical stress and deflection increase with the interpane-spacing

One-off pressure-adjusted systems are a sub-group of pressure-equalized systems. These are conventional IGUs that require a single pressure equalization because the difference in altitude between the manufacturing site and the place of installation exceeds certain limits. These limits depend on the size, the aspect ratio and the inter-pane spacing of the IGU. The pressure adjustment can take place either at the manufacturing site by over- or under-filling the cavity, or at the place of installation by briefly opening the cavity to the atmosphere. In both cases, the cavity has to be sealed hermetically afterwards. One-off pressure adjusted systems must fulfill all requirements of the product standard EN 1279, including those related to durability. It is possible and customary to fill the cavities of these IGUs with argon.

The aim of this research project was to investigate whether and by which technical means permanently pressure-equalized IGUs and one-off pressure-adjusted IGUs could be implemented for general architectural applications. Beside the actual technical realization under usual manufacturing, installation and usage conditions, questions of durability had to be addressed. For the permanently pressure-equalized systems, the moisture uptake is crucial, for the one-off pressure-adjusted systems, it is the gas retention.

2 Course of action

Most questions were approached experimentally, the actual technical implementation of pressure equalization and pressure adjustment as well as the durability testing of these systems. However, extensive numerical simulations were required when preparing the experiments and when evaluating the experimental results.

The following tasks were addressed during the course of the project:

Permanent pressure equalization via a capillary tube

- Preparation of a calculation model for the simulation of a permanent pressure equalization via a capillary tube. The model was used to assess the degree of pressure equalization and the amount of moisture uptake as well as to determine suitable dimensions for capillary tubes.
- Experimental testing of pressure equalization and moisture uptake with IGU specimens in a climate chamber
- Experimental testing of the moisture uptake with IGU specimens during natural weathering.

One-off pressure adjustment via a capillary tube

- Preparation of a calculation model for the simulation of a one-off pressure adjustment via a capillary tube
- Experimental testing of the processability of various types of capillary tubes (material, dimensions)
- Experimental testing of the durability of pressure-adjusted IGUs.

2.1 Calculation model for the simulation of a permanent pressure equalization

The function of the calculation model is to simulate the behaviour of a permanently pressure-equalized IGU with respect to the degree of pressure equalization and the moisture uptake.

In the model, an IGU is specified by its lenght, width, thickess of the glass panes and the interpane-spacing. Two devices to equalize the pressure are modelled: a capillary tube, characterized by its internal diameter and length, and a pair of check valves, characterized by their cracking pressures.

Diffusion processes through the edge seal or within a capillary tube are not represented in the model.

The simulation model is implemented as a spread sheet.

Periodic climate data like temperature, air pressure and relative humidity can be copied into the spread sheet. Time intervalls for the data are freely selectable within certain limits, e.g. 1 min, 10 min or 1 h. The model allows two temperatures to be entered, the temperature of the cavity and the external temperature.

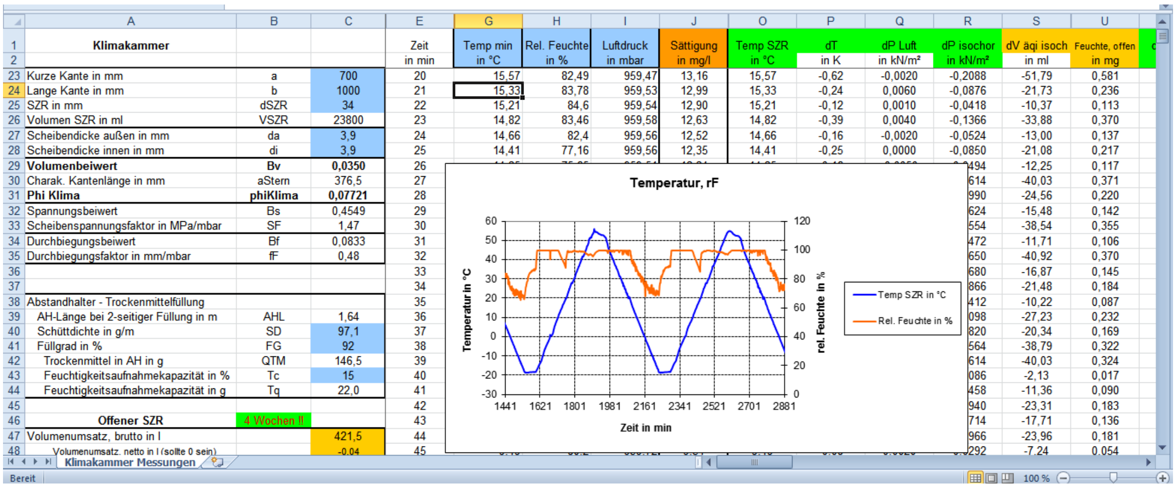

Figure 2 Detail of calculation model

2.2 Experimental studies on permanent pressure equalization

The purpose of the experimental studies on IGU specimens was to test the validity of the calculation model and to demonstrate the effectiveness of capillary tubes as a means to achieve pressure equalization in IGUs. The test conditions were close to the conditions found in a real construction. An essential objective was to attain a well-balanced ratio between pressure equalization and durability.

The experiments focussed essentially on two physical quantities, deflection of glass panes and moisture uptake. The deflection of the glass panes is a measure for the mechanical loading of the IGU components, the glass panes themselves as well as, indirectly, the edge seal. And the moisture uptake is a measure for the durability of the IGU.

Two types of experimental studies came into question, both with their own advantages and disadvantages. Natural weathering is the most realistic kind of test for building components, but it usually takes a long time, and it can be difficult to monitor physical quantities over a long period outdoors. Studies in a climate chamber are less realistic, but they are fast, and the specimens are more accessible for various measurements. As a result of these considerations, the deflection of glass panes was monitored in a climate chamber only, whereas the moisture uptake was determined on specimens weathered outdoors as well as in a climate chamber.

a.)

b.)

Figure 3 a.) IGU specimen with displacement sensors in climate chamber
b.) Natural weathering of IGU specimens

2.3 Studies on one-off pressure adjustments

Manufacturers of IGUs would like to perform the pressure adjustment with simple means at the installation site. Components which might have to be integrated into the edge seal must not disturb the production work flow significantly. At the installation site, such components must be easily accessible. The visual appearance of the window must not be compromised. The IGU must meet all requirements of the product standard EN 1279.

The glazing rebate is a rather narrow space, and the application of tools in the rebate is difficult. Therefore, installers of IGUs/windows would prefer not having to access the edge seal directly to bring about the pressure adjustment. A flexible tube, sticking out of the edge seal, which could be cut open and then pinched off hermetically again would be ideal.

The following questions were addressed as part of this project:

- What is the critical difference in altitudes between the manufacturing site and the installation site, above which a pressure adjustment is essential?
- How long does the cavity have to be open to the atmosphere to ensure pressure adjustment?
- Can the process of fitting a capillary tube into the edge seal be integrated into the widely automated manufacturing of IGUs? Is the opening and the hermetic pinch-off of a capillary tube possible under building site conditions?
- Does an IGU after a pressure adjustment and re-sealing of the edge meet the durability requirements of the standard EN 1279?

a.) b.) c.)

Figure 4 a.) Capillary tube in spacer
b.) Capillary tube in edge seal
c.) Pinched off capillary tube

3 Results

Permanent pressure equalization via a capillary tube

Capillary tubes are suitable devices to implement a permanent pressure equalization of IGUs. At the same time, they will limit the moisture uptake of an IGU considerably, so that an acceptable operating life (longer than 20 years) appears realistic. The experiments with IGUs in the climate chamber and those under natural weathering conditions confirmed the predictions of the calculation model.

The capillary tube dimensions (internal diameter, length) must be chosen with regard to the IGU's construction (width, height, thickness of glass panes, inter-pane spacing) to achieve a well-balanced ratio between pressure equalization and moisture uptake. The calculation model can be used to determine suitable capillary tube dimensions.

It is possible to choose the dimensions of the capillary tube so that the load sharing between the glass panes of the IGU (caused by the air in the cavity acting as a spring) will be retained while combining the pressure equalization with sufficient durability.

The material of the capillary tube (stainless steel or FEP polymer) has no effect on the moisture uptake of an IGU.

An important next step in the development of a commercial product would be to test a large-sized IGU specimen with a large inter-pane spacing (about 100 mm) and integrated components (e.g. sun shading) that raise the temperature in the cavity because of the absorption of solar radiation. Initially, suitable capillary tube dimensions and the necessary amount of desiccant would have to be determined with the help of the calculation model. Afterwards, specimens could be built and tested in a climate chamber or during natural weathering.

Further questions that should be addressed in a continuation project are:

- What proportion of the total moisture uptake of a pressure-equalized IGU is caused by the diffusion of moisture through the edge seal?
- Does it affect the amount of moisture uptake if the air that is sucked into the cavity comes from indoors or from the outside?

One-off pressure adjustment via a capillary tube

A one-off pressure adjustment via a capillary tube is, in principle, possible. Ideally, the pressure adjustment should happen during the ascent or descent rather than at the destination. However, the processability of metal capillary tubes is causing limitations. A metal capillary tube sticking out of the spacer can be an obstacle to the sealing robot, may even cause it to stop. To pinch off and hermetically seal a metal capillary tube turned out to be difficult. The presence of any capillary tube creates a weak spot in the edge seal.

Notably, the entry point into the spacer back and the interface with the sealant can provide a path for the escape of fill gas and the ingress of moisture. Therefore, the manufacturing quality for an IGU with a metal capillary tube in the edge seal has to be even higher than for a conventional IGU. Polymeric capillary tubes are no alternative. Although they are much easier to process, polymers are in principle not gas-tight. IGUs with a polymeric capillary tube in the edge seal cannot fulfill the requirements of the product standard EN 1279-3.

The processability of metal capillary tubes restricts their usage to a certain range of diameters and wall thicknesses. This in turn restricts the range of IGU sizes and constructions for which a one-off pressure adjustment can be realised with a capillary tube. For small- (350 mm x 500 mm) to medium-sized (700 mm x 1000 mm) IGUs, a pressure adjustment via a capillary tube is possible. Flexural loading of the glass panes is reduced considerably, and the process does not take more than a few minutes. For large-sized (1000 mm x 2000 mm) IGUs, the flexural loading of the glass panes is always much lower than for small- and medium-sized ones, but the pressure adjustment takes too long (up to several hours) to be practical at a building site.

Starting points for a continuation of the investigations are as follows:

- Analysis of the causes of gas leaks in the specimens with metal capillary tubes
- Other types of capillary tubes, especially other materials, e.g. Ni or Al
- Improvement of fitting of capillary tubes into the edge seal
- Use of wider capillary tubes is desirable to remove restrictions on IGU size and construction imposed by the limited flow of gas through a narrow capillary tube
- Other means of pressure adjustment, e.g. valves, that were considered not promising enough and/or too expensive to be followed up within the context of this project.

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