B O U W K A N s

Client, in The Netherlands

Investigation of damaged Insulating Glass Units

17KB1-R1

February 10th, 2017

Project Client in The Netherlands

Subject Investigation of damaged Insulating Glass Units

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Date February 10th, 2017

Principal

Client

The Netherlands

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1 Introduction

In the year 2009 insulating glass units (IGUs) were delivered by Eco Insulating Glass Inc. from Mississauga in Ontario Canada to client from in The Netherlands. The order consisted of approximately 193 units which were placed in the villa of client.

The IGUs are "quadruple" glazing units with two panes of glass and in between them two sheets of heat mirror film. This results in three cavities which were filled with Krypton gas for optimal thermal insulating properties.

In November 2016 two IGUs had broken inside panes. It seemed that the units had im-ploded. Client noticed that many other units were concave as if they were partially vac-uum. On December 1st client estimated that 80% of the units were visibly concave. Three more imploded IGUs were reported on January 12th 2017 and another two were reported on January 20th, making it a total of 7 broken units.

Bouwkans was asked by client to investigate the broken IGUs, the glazing method and any other relevant issues that might have a relation with, or could have caused, the broken and concave IGUs.

This report describes the findings of the investigation and some references to relevant general information concerning the issue.

Small sized photos are placed in the text of the report for easy reference. Larger sized photos are added as an separate appendix.

2 Received information

Based on information that was presented by client (i.e. e-mail correspondence, ECO Insulating Glass Architect Information Binder, invoice, shipping document etc.) the following facts were established.

Dates

The IGUs were ordered on April 14th 2009 and delivered by ECO Insulating Glass Inc. at a warehouse in New York at April 30th or thereabout. In May 2009 client shipped the units from New York to the Netherlands by sea in a 40ft sea-container. The IGUs were placed in the window frames in the spring/summer of 2009.

Specification of IGUs

According to the invoice the specification of the units is:

- Quad SC 75 Krypton
- 5 mm, soft coat low-E, tempered
- 4 mm, clear, tempered
- 1¼" OA Black Spacer

During the investigation it was established that only the IGUs for the doors have tempered glass and that the specification on the invoice is not correct in this aspect.

The received information contains no data about the presence of breather tubes in the IGUs. The received information contains no specifications of the used type of perimeter edge seal-ant, spacers or drying agent. It is therefore assumed that standard Polyurethane sealing, spacer and drying agent is used.

Dates of damage

Dates of reporting broken inside panes tot ECO Insulating Glass Inc.:

- 2016, 29th December: 2
- 2017, 12th January: 3
- 2017, 20th January:2

Locations and elevations

Locations and elevations of production, shipment and placement:

Mississauga ONT, Canada	elevation 173 m above sea level
Bronx New York, USA	elevation 10 m above sea level
The Netherlands	elevation 21 m above sea level

The maximum elevation above sea level of common transport routes between Mississauga ONT and The Bronx NYC is approximately 565 m.

The elevation above or under sea level of common transport routes in The Netherlands to the destination in Blaricum vary between approximately –6 m to 22 m.

3 Investigation

On January 30th 2017 an investigation of the IGUs was performed by Bouwkans. The find-ings are presented below.
The investigation was performed visually and was non-destructive in nature.
The weather conditions were: overcast and rainy, outside air temperature 7 °Celsius, air pressure 1008 hPa, outside relative humidity 97%, wind direction changing between SW, W and NW, average wind speed 2 – 5 m/s.
The average air pressure in The Netherlands is 1013 hPa.

The villa

The villa where the units are placed was newly build in 2009 and is timber framed house.

Photos 1, 2, 3: Front side of the villa is facing NNW, backside SSE, right side WSW.

Many of the windows are placed under a canopy and are thus shielded from rain and par-tially from direct sunlight. Others are somewhat protected under roof gutters or eaves.

Photos 4, 5, 6: Shielding by canopies, eaves and gutters.

Window frames

The IGUs are placed in timber windows and doors with decorative timber crossbars glued on to both sides. On the inside the finely profiled crossbars and glazing beads are connected as a frame.
The majority of windows are sash windows and hinged vent windows. Some windows have fixed framings of which some are half round shaped. Typical sizes of the IGUs in the sash windows are 750 x 715 mm.

Photos 7, 8, 9: Bottom an top sash windows with hinged vent windows above them, fixed windows half round shaped windows. All with crossbars on both sides.

Glazing system

The rebates are closed from the inside of the house with the bead/crossbar frames that have a depth of approximately 15 mm.
From the outside weep holes for water drainage are visible on the underside of all of the in-spected window frames (sash, hinged and fixed). The number of weep holes varies from 1-3 per window frame. The weep holes were not incorporated in the framing system originally but were, according to information provided by client, drilled before the IGUs were placed as advised by the workmen hired for placing the IGUs. The size of the weep holes is approximately 6 mm.

Photos 10, 11, 12: 1-3 weep holes for water drainage per window.

All of the inspected sealant joints on the outside were intact, attached and sloping outwards.
No residue signs of stagnant water were observed.
The combination of the rebate depth and the height of the beads is such that the glass unit edge, spacer and sealant is sufficiently recessed and not visible when viewed from the front (photo 13).

Glazing

The thickness of the glass panes was measured indicatively by means of glass reflection thick-ness measurement. The outside panes were typically 5 - 6 mm and the inside panes 4 - 5 mm.In all cases the outside pane was thicker than the inside pane of the same unit. Clearly visible were the dark coloured spacer bars and copper coloured in- and outlets for the gas filling process.
The two layers of foil have a small pressure equalising hole in one of the corners.

In the doors there is an etched inscription on the glass surface among other things indicating “TEMPERED” meaning that this is a tempered glass pane.


Photos 13, 14: Spacers and gas filling holes, inscription and holes in the foil.

Broken glass panes

In total 7 broken glass panes were inspected, all of which were inside panes that had col-lapsed inwards (i.e. in the direction of the cavity). Most of the breaking patterns are very typi-cal for breakage due to an equally distributed load like exterior air pressure. No impact re-lated markings were observed.



Photos 15, 16, 17: Three imploded units (numbered 1, 2 and 3) with broken inside panes. All are hinged vent windows situated right under the large canopy on the back side of the villa (photo 4).



Photos 18, 19, 20: Three imploded units (numbered 4, 5 and 6) with broken inside panes. Situated respec-tively in a: top sash window ground floor in the office, bottom sash window and half round fixed window both in the same window frame at the first floor bedroom. All units are in the WSW facing (right side) façade.

Photo 21: Imploded unit (numbered 7) with broken inside pane. Situated in a top sash window at the first floor bedroom in the SSE facing (back side) façade.

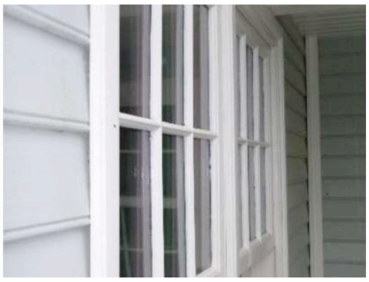
Table 1: Specifications of the broken glass panes.

Number	Orientation	Window position	Window type	Approximate size WxH
1	SSE	Under the canopy	Hinged vent	740 x 360 mm
2	SSE	Under the canopy	Hinged vent	740 x 360 mm
3	SW	Under the canopy	Hinged vent	740 x 360 mm
4	WSW	In the façade	Top sash	600 x 630 mm
5	WSW	In the façade	Bottom sash	420 x 420 mm
6	WSW	In the façade	Half round fixed	920 x 380 mm
7	SSE	In the façade	Top sash	420 x 420 mm

Concave panes, visual

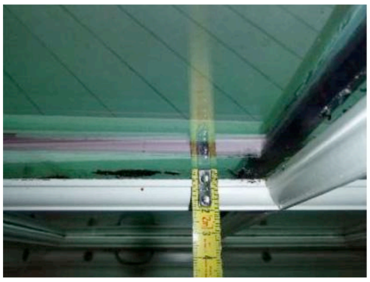
All of the inspected IGUs, except for one, had visible concave shaped glass panes. The in-side pane was always distorted considerably more than the outside pane. The quantity of dis-tortion varied considerably, but was clearly visible.





Photos 22, 23, 24: Concave shaped glass panes, clearly visible by the bent crossbars..

Due to the distortion of the panes the crossbars of many windows were detached from the glass pane.




Photos 25, 26: Detached crossbars with 5 mm spacing between crossbar and glass pane.

One of the larger half circle shaped units shows the touching of the panes clearly by the closeness of the crossbars as viewed from a side.

Photo 27: The closeness of the crossbars indicates touching panes and foils.

Some of the larger units show clear signs of touching foils and/or glass panes (i.e. Moiré or interference patterns and discoloration). Due to the decrease of the insulating properties of the greatly reduced cavity and the atmospheric conditions condensation patterns on the inside were visible on one unit.



Photos 28, 29, 30: Signs of touching foils and or glass panes inside the cavity: Moiré, interference discolora-tion and inside condensation.

Concave panes, measurements

On the ground floor near the dining table in the kitchen and in the adjacent sitting room 7 randomly selected IGUs were measured to determine the distortion of both the inside and out-side panes. The distortion was measured using a straight ruler and a sliding gage. Depth measurements between the topside of the ruler and the glass surface were taken at both edges and in the centre of a pane. The difference between the average depth of the edges and the depth of centre of the pane is the distortion or concaveness.

Table 2: Measurements of the distortion.

Number	Orientation	Window position	Window type	Approximate size WxH	Distortion (mm) of 4 mm inside pane	Distortion (mm) of 5 mm outside pane
1	SW	Under the canopy	Bottom sash	750 x 715 mm	6	4
2	SSE	Under the canopy	Bottom sash	750 x 715 mm	8	4
3	ESE	Under the canopy	Top sash	750 x 715 mm	7	4
4	SSE	Under the canopy	Door	673 x 2270 mm	5	2
5	SSE	Under the canopy	Door	673 x 2270 mm	2	1
6	SSE	Under the canopy	Door	673 x 2270 mm	4	2
7	SW	Under the canopy	Hinged vent	750 x 370 mm	4	1
8*	-	Storage	.	397 x 406 mm	3,8	-

* IGU #8 is discussed in the next paragraph.

For these 7 units the distortion was compared to the overall sizes of the unit (i.e. the diagonal and the shortest side).

Table 3: Distortion (D) related to the diagonal (d) and to the shortest side of the pane (s).

Number	D / d	D / s
1	1/173	1/119
2	1/130	1/89
3	1/148	1/102
4	1/474	1/135
5	1/1184	1/337
6	1/592	1/168
7	1/209	1/93
8*	1/149	1/104

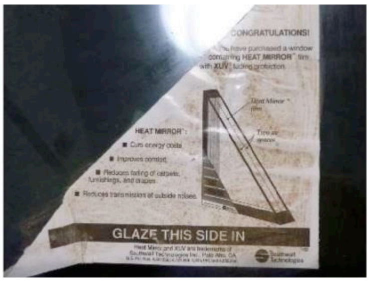
* IGU #8 is discussed in the next paragraph.

Spare IGU

There was one IGU presented that was never placed in a window. This unit was stored in-side in a dry and heated space without direct sunlight. The unit was kept as a spare or re-placement.

From the stickers on this unit a number of observations were made:

- Fabricated by ECO Insulating Glass Inc.
- Shipped to Pippa Promotions BV under order 76879
- Marked: QUAD SC75 KRYPTON 15-5/8 X 16 B2
- Marked: 5MM SOFTCOAT LOWE TEMP/4MM CLR TEMP 1-1/4”OA BLACK SPACER

Photos 31, 32, 33: The spare IGU and its stickers.

The following measurements and observations were made:

- The unit measures 396 x 407 mm.
- The distortion of the 4 mm inside pane is 3,8 mm.
- The distortion related to the diagonal and shortest side are given in tables 2 and 3.
- The spacer is curved and pulled inwards up to 4,5 mm in the centre (viewed frontally).
- The secondary sealant is distorted and shaped inwards for approximately 5 mm.

Photos 34, 35, 36: The etched markings, the inward curved spacer compared to the ruler and the inward shaped secondary sealant.

4 Causes of concave IGUs

Concave shaped IGUs are a common subject in literature and on the internet. There are three causes for concave shaped IGUs.

Differences in ambient air pressure

The ambient air pressure at the location where a IGU is placed varies due to the weather conditions. The gas content in the cavity of the IGU is constant. This causes the IGU to be convex at low ambient air pressures and concave at high ambient air pressures. This is a dynamic process whereby the IGU will eventually return to its original flat shape when the ambient air pressure is equal to the ambient air pressure at the time the unit was sealed.

These naturally occurring air pressure differences are not enough to cause breaking glass panes.

This effect will be magnified when the IGU was produced under air pressure conditions that are significantly different from the air pressure conditions under which the unit will be placed. For this reason, special care should be taken whenever IGUs are to be placed on high alti-tudes (i.e. in the mountains). In this situation, special pressure equalizing breather tubes can be installed. These breather tubes should be closed upon arrival at the location of placement. Also, when transport of the IGU takes place via high altitudes (i.e. over mountain routes) or by airplane these tubes should be applied.

The air pressure differences generated by changes in altitude have known to cause breaking IGUs.

Also, low pressure in an IGU can cause the perimeter sealant and spacer to move inwards (in fact it is sucked inwards). This will happen easier at higher temperatures when the sealant is softer. This process can lead to defects in the sealing and allow outside air to penetrate the system. When the leakage is large enough it can in time lead to condensation within the cav-ity.

Gas diffusion

The cavity of an IGU is filled with air or a special gas depending on the desired specifica-tions of the IGU. The system of primary seal, spacer and secondary seal is designed to con-tain the gasses in the cavity.

A well-known physical phenomenon is the diffusion of gasses due to differences in the partial gas pressure of that specific gas. This means that a gas (e.g. Krypton or Argon), tends to move (diffuse) from a location in which is abundant (has a high partial gas pressure) to a lo-cation where it is scarce (has a lower partial gas pressure). Special IGUs are typically filled with 80% of a gas like Krypton or Argon and 20% of air.
Air consists of 78 Nitrogen, 21% Oxygen and 1% of other gasses like Argon and 0,0001% Krypton. The ambient atmosphere is 100% air, thus creating significant partial pressure differ-ences for Krypton, Nitrogen and Oxygen. Krypton 'wants' to leave the IGU and Nitrogen and Oxygen 'want' to enter the unit.
This process can be stopped by a gas tight barrier like the edge system of an IGU is sup-posed to be. The sealants used for this purpose however, all have some permeability for these gasses. Unfortunately, the smaller gas molecules like Krypton can diffuse better through the sealant then the larger Nitrogen and Oxygen molecules. This unbalanced diffusion pro-cess results in the loss of total gas content of the IGU over time: more Krypton leaves than is compensated by the entering of air. The loss of gas causes a lower pressure in the unit and results in concave glass panes.
The gas diffusion process in IGUs is well known in literature. It is believed that a loss of gas of 1% per year is usual and acceptable in relation to the average life span of an IGU (i.e. 20 to 25 years).
Also in literature cases are mentioned where the loss rate is considerably higher. This can be the result of defects in the sealant (application issues or damages that occurred later) or a wrong or faulty type of sealant (to high gas permeability).
The air pressure differences generated by unbalanced gas diffusion are known to cause breaking IGUs. The breakage will happen most likely on a moment that the ambient air pres-sure is high, which adds to the stress level of the glass panes.
Also, the perimeter sealant and spacer can move inwards and have serious effects, as de-scribed earlier.

Gas absorption

A process that has similarities with the above described gas diffusion process is called gas absorption. In this situation, there is also a gas 'disappearing' from the cavity, although by a totally other physical phenomenon.
To prevent condensation of water vapor in the inside of the IGU the air and other gasses must be dry (contain no or a very low concentration of water vapor). This is not the case when the units are filled during assembly. To dry the gasses a drying agent is incorporated in the hollow spacer tubes. Contact with the gas is possible via tiny perforations in the tube that keep the drying agent inside. This drying agent, like silica gel, is specially designed to ab-sorb water vapor molecules. The selection of which molecules to absorb is based on the size of the molecules in relation to the physical properties of the drying agent.
In the past drying agents with wrong specifications were sometimes used. This resulted, be-sides the intended absorption of water vapor, in the unintentional absorption of gasses like Nitrogen, Argon or Krypton. Because these gasses are the main content of these IGUs the absorption or 'disappearance' leads to a lower pressure in the unit, which will lead to con-cave shaping of the IGU.

The dropping gas pressure caused by absorption of gasses in the drying agent is known to cause, or at least play an important role in, breaking IGUs. The breakage will happen most likely on a moment that the ambient air pressure is high, which adds to the stress level of the glass panes.
Also, the perimeter sealant and spacer can move inwards and have serious effects, as de-scribed earlier.

Literature
Some literature found on the internet concerning these issues are:

Vitro Glass education centre, "Pro/Cons of Gas-Filled Insulating Glass Units" http://glassed.vitroglazings.com/glasstopics/gas_insulating_glass.aspx

InterNACHI (International Association of Certified Home Inspectors, Inc.), Nick Gromicko, "Window Gas Fills: What Inspectors and Consumers Should Know" https://www.nachi.org/window-gas-fills.htm

The Snell Group, 2008, "A Unique Thermal Problem Found in Certain Double-Glazed Windows" http://www.vinylsiding.org/wp-content/uploads/2015/04/Snell-Report-on-Problem-with-Double-glass-windows.pdf

U.S. Glass, volume 34, Number 4, April 1999, Al Jaugelis, BSc (Arch): "Kaboom! There Goes Another Argon-Filled IG Unit" http://industry.glass.com/USGlass/1999/9904/9904argon.html

ECO Insulating glass with heat mirror and krypton imploding problems !!
http://insulating-glass-film-problem.weebly.com

Eco Insulating Glass Inc. problems on pintrest

Ecoglass - Eco Insulating Glass Inc. imploding problems. on YouTube

5 Summary and conclusions

IGUs and damage

In the villa of client in 2009 193 insulating glass units were placed that were manu-factured by Eco Insulating Glass Inc. Between the glass panes of these units two Heat Mirror Films are attached. The glazing has three cavities filled with Krypton gas.

From December 2016 until January 2017 in total 7 IGUs imploded by the breaking of the inside glass pane. This is 3,6% of the total number of IGUs that imploded in just two months' time. The observed breakage pattern is typical for an equally distributed load (like implosion). No signs of impact that could have caused the breakage otherwise were found.

Inspection

During the inspection performed by Bouwkans it was established that all other windows had significant concave shaped glass panes, in some cases leading to the detachment of the glued-on cross bars. Also, touching of glass panes and/or films due to the concave shape was observed in some larger units. Measurements of the concave shape were taken, show-ing deformations up to 1/90th of the shortest side of the unit. It is known that at deformations (> 1/100th) glass panes reach their strength limits and are vulnerable for breaking.

The glazing method was studied and revealed that all timber frames have sufficient weep holes and a slanted and intact outside sealing of the rebate/bead system. Many of the units, also the imploded ones, are situated under a large canopy shielding the units from water and direct sunlight. The necessary protection of the edge sealant of the IGUs from UV light is ef-fectively taken care of by the depth of the rebate in combination with the height of the beads. These findings lead to the conclusion that no faults in the glazing method are present that could have initiated a process that causes the concave shaping and subsequent breakage and implosion.

This conclusion that no external influences (or influences the owner can be held responsible for) cause the occurring damage becomes indisputable by observations made on a spare IGU that was stored inside, dry and shielded from sunlight. This unit also showed the con-cave shape an even showed deformed spacers that were pulled inwards. Both are a clear sign of a low pressure inside the unit.
The findings on this unit disqualify all other possible hypothesis linked to the placement, glaz-ing system, outside conditions etc.

Causes of concave IGUs

Three known causes for concave shaped IGUs, sometimes leading to breakage, are de-scribed in this report.

The influences of pressure differences caused by different elevations are minimal. The eleva-tions of production location, transport routes and placing location were investigated and showed that they don't differ enough for this effect to be the prime cause.

The two remaining causes for concave shaped IGUs and breaking glass are: gas diffusion and gas absorption. Both these effects are a result of an insufficient quality of the edge seal-ant/drying agent system.

Since the glazing system is in accordance to the requirements, the glazing system could not have caused any deterioration of the edge sealant system and thus has the insufficient quality of the edge sealant/drying agent system to have its origins in the production process or the applied products.

Consequences
The diffusion and/or absorption of the gas in the IGUs has many unacceptable conse-quences.
The concave shape leads to an uneven visual appearance of the villa (distorting mirrors). The touching of the heat mirror films leads to colour differences and colour patterns (interfer-ence and Moiré).
A diminished cavity results in a diminished thermal insulation. This causes visual condensation and energy loss.
Deformation of the panes leads to detachment and subsequent damage of the cross beads. The progressive diffusion process will lead to an increase of the deformation of the panes. It can end by the touching of the panes, the collapse of the weakest pane or leakage of the edge sealant system and subsequent condensation in the unit.
Up till now the imploding IGUs have caused no other material damage or personal injury. It is not to be excluded that this can happen in the nearby future.

Remedy
No known remedies exist for the diffusion/absorption process.
All IGUs must be replaced.

To prevent possible additional damage or injury it could be considered to equalise the pres-sure in the units by drilling a hole in one of the panes or via the weep holes in the edge sys-tem. This will inevitably cause the entry of water vapor and internal condensation in due time, but it eliminates the risk of imploding units until they can be safely replaced. No holes can be drilled in the tempered units used for the doors, since they will immediately shatter in this pro-cess.

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