FRAUNHOFER-INSTITUT FÜR SOLARE ENERGIESYSTEME, ISE

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# EAGON VIG TESTING REPORT

## THERMAL CYCLING

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## Contents



This report consists of 8 pages. Results may only be published wholly and not in a content distorting manner.


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# 1 Summary

The goal of this study was to examine the stability of VIG units produced by the company Eagon. The VIG units were assembled as hybrid units of a VIG with a conventional insulating glass unit. A total of 8 VIG units were subjected to thermal cycling tests, with a minimum temperature of -20 C and a maximum temperature of 100 C and 90 C, respectively. In addition to visual inspection, the U value of the VIG unit was determined before and after the thermal cycling test in order to detect possible failures. The first two VIG units were cycled between -20 C and +100 C. While the first unit passed the test without detectable degradation, in the second unit the conventional insulating glass unit failed. Six further VIG units were cycled between -20 C and +90 C. All of them passed the test without detectable degradation.

# 2 Measurement devices and testing procedure

## 2.1 U-value measurement

Two kinds of measurement device were employed for the U value measurement:

1. The Taurus parallel plate system.
2. The portable Netzsch system

The Taurus measurement technique uses a stationary thermal set-up. It measures the heat flux from one side of the window to the other and delivers absolute U values. However, as this method is rather time-consuming, it was used to establish reference values for the VIG units before the cycling test. Due to the measurement principle, pairs of VIG units were measured. The results are documented in detail in the enclosed U-value measurement report. An overview of the results is given in the Table 1 below.

Table 1: U values of the VIG unit pairs as measured by the Taurus system

| **VIG pair** | **V1-V2** | **V3-V4** | **V5-V6** |
|---|---|---|---|
| **U-value before thermal cycling [W/m²K]** | 0.514 ± 0.015 | 0.514 ± 0.015 | 0.513 ± 0.015 |
| **U-value after thermal cycling test [W/m²K]** | V2 broken | 0.516 ± 0.015 | 0.516 ± 0.015 |

The portable Netzsch measurement device (Netzsch Uglass) implements a transient method that is well established for insulating glass units (IGUs). It applies a temperature pulse to one side of the window and detects the temperature decay on the first side as well as the temperature rise on the other side. For IGUs the Netzsch device relies on a model fit to derive the real U value from the measured temperature curve. As there were no viable models for the VIG unit under test available, the raw $U^*$ value data are quoted for the Netzsch. Even though they differ from the absolute values given by the Taurus, they can still be used to detect relative U value changes, which allows VIG failure to be detected. As the Netzsch device makes flexible $U^*$ value measurements with short measurement times possible, it was used for measuring the $U^*$ value before and after the thermal cycling test.

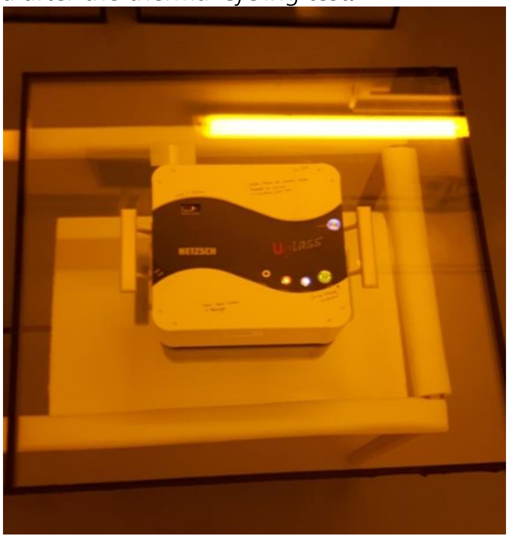

**Fig. 1:** Set-up for the Netzsch U value measurement

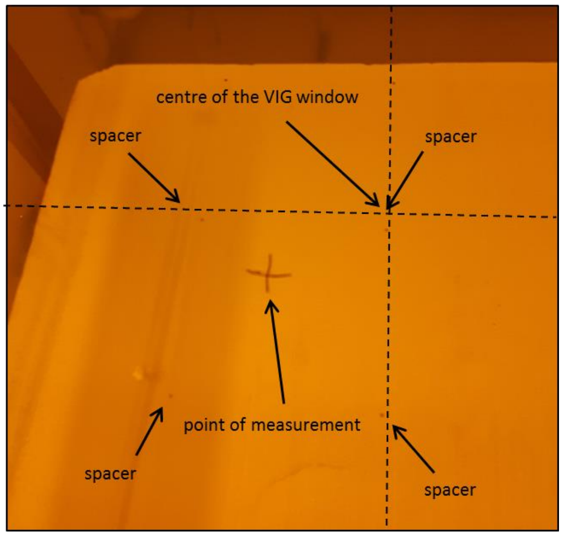


**Fig. 2:** Exact position of the measurement in the centre of four spacers, slightly offset from the centre of the entire VIG unit

In a first step the measurement layout as well as the repeatability of the Netzsch reading were checked. The measurement layout was defined as follows. The VIG unit was placed horizontally with the actual VIG facing down and the IGU facing up. The Netzsch was then placed at a well-defined position with the probe centered between four spacers (Fig. 1 and 2). The top plate was heated, while the bottom plate passively detected the transmitted temperature rise. In order to optimize the repeatability, the measurements were performed with the VIG units in thermal equilibrium in a room with tightly controlled temperature. A raw value $U^*$ between 1.15 and 1.44 W/m2K was found for the eight VIG units. The error bar given by the Netzsch device is +/- 10%. Repeatability tests of the entire set-up yielded an error range of +/- 0.06 W/m2K, i.e. +/- 5%, which is well below the quoted error bar of the device.

## 2.2 Climate chamber

For the thermal cycling tests, a Vötsch VC 4060 climate chamber was used. The climate chamber was adapted by a custom-made flange to allow for the installation of the VIG units, as depicted in Fig. 3.

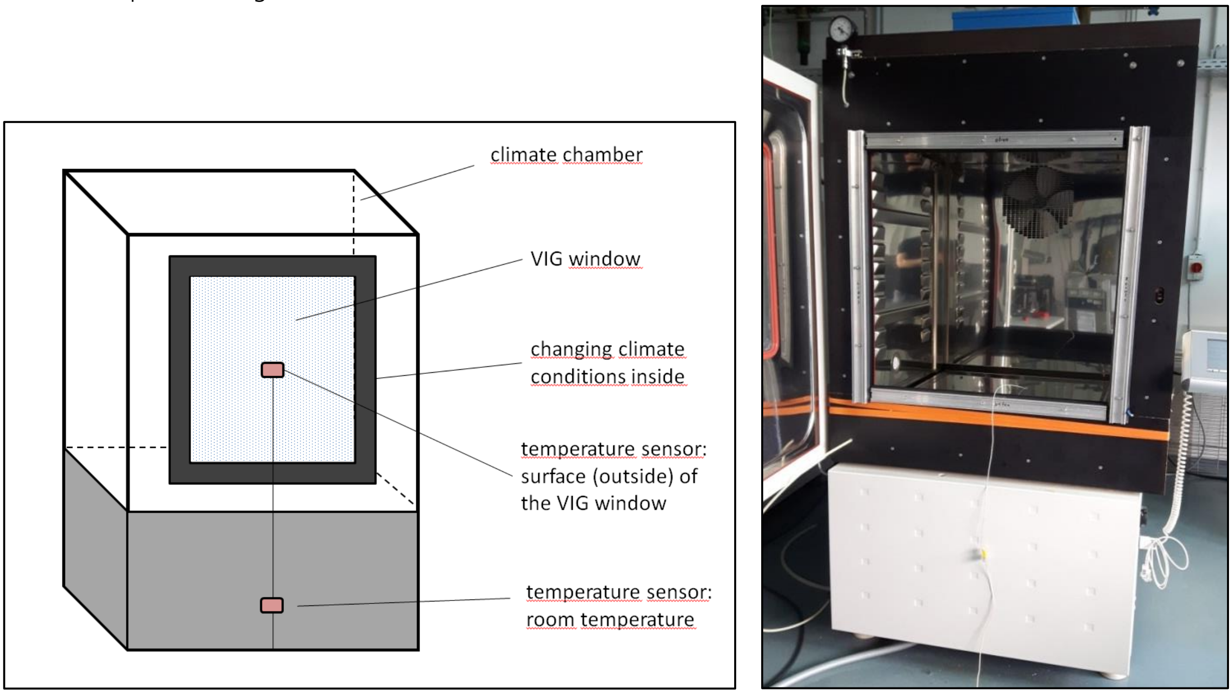


**Fig. 3:** Set-up of the climate chamber adapted for the thermal cycling test

The set-up was equipped with temperature sensors to log the outside VIG temperature as well as the room temperature. Furthermore, a video camera was used for monitoring of potential failure events.

## 2.3 Definition of thermal cycling test

According to previous experience and after thorough discussion with Eagon, the thermal cycle was defined as follows:

- Heating to 90 / 100 C
- 30 minutes flat top at 90 / 100 C
- Cool-down to -20 C
- 30 minutes flat bottom at -20 C

The heating and the cooling times were determined by the maximum heating and cooling rate of the climate chamber. A total cycle time of about 135 min was found. The thermal cycle used is shown in Fig. 4. In order to detect the possible failure of the VIG units, the $U^*$ value was measured before and after each thermal cycling test by the Netzsch device. As an example of the typical temperature trends during a cycling test, the data for V1 are plotted in Fig. 5.

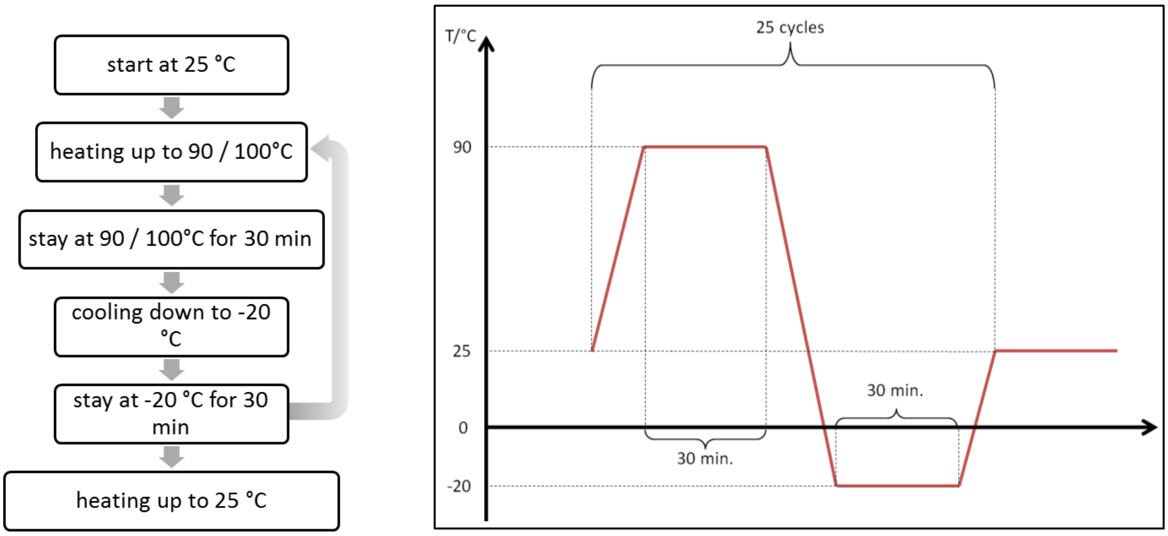


**Fig. 4:** The thermal cycle for the VIG testing

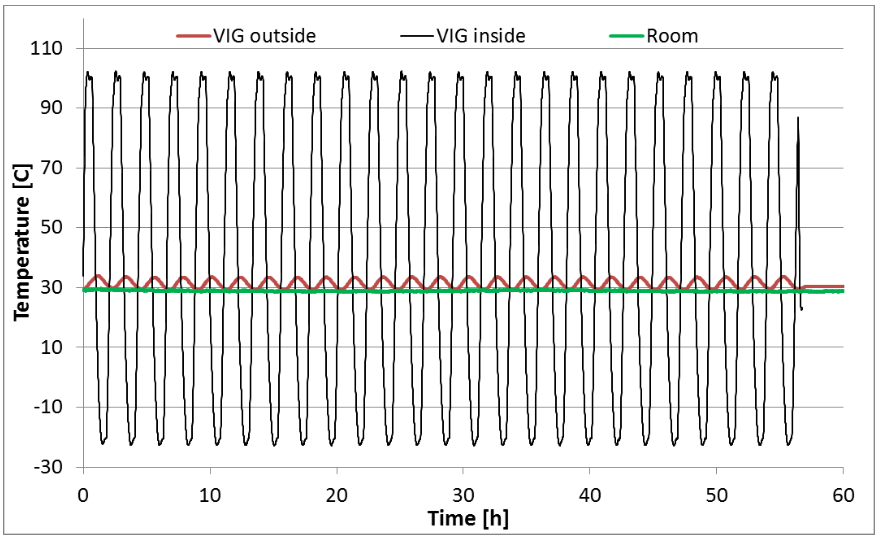


**Fig. 5:** Temperature trends during the thermal cycle test of VIG unit V1. Red curve "VIG outside": probe mounted on the outside of the VIG; black curve "VIG inside": temperature of climate chamber; green curve "Room": room temperature as measured below the VIG on the climate chamber front plate

# 3 Testing results

The first two VIG units were tested in the thermal cycle between -20 and +100 C. While the first unit V1 passed the test without significant change of the raw value U* as measured by the Netzsch device, the second unit V2 failed (Fig. 6). In this case, the outer pane of the IGU broke, i.e. the actual VIG stayed intact. The failure analysis of V2 is documented in a separate report. For the units V3 to V8, the temperature span was subsequently reduced to -20 to +90 C. All units V3 to V8 passed the test. The results are summarized in Table 2. The test results of the Taurus measurements before and after thermal cycling are given in Table 1 on page 4. These measurements confirm, that the VIG units V3, V4, V5 and V6 did not suffer any significant U value degradation upon thermal cycling testing.

Table 2: Overview of the VIG test results

| **VIG unit** | **V1** | **V2** | **V3** | **V4** | **V5** | **V6** | **V7** | **V8** |
|---|---|---|---|---|---|---|---|---|
| **U* value before cycling [W/m²K]** | 1.15 ± 0.12 | 1.25 ± 0.13 | 1.2 ± 0.12 | 1.32 ± 0.13 | 1.2 ± 0.12 | 1.48 ± 0.15 | 1.41 ± 0.14 | 1.44 ± 0.14 |
| **Testing runs** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **U* value after cycling [W/m²K]** | 1.19 ± 0.12 | broken | 1.19 ± 0.12 | 1.28 ± 0.13 | 1.2 ± 0.12 | 1.22 ± 0.12 | 1.43 ± 0.14 | 1.32 ± 0.13 |
| **Test passed** | YES | NO | YES | YES | YES | YES | YES | YES |
| | | | | | | | | |
| **T_min [C]** | -20 | -20 | -20 | -20 | -20 | -20 | -20 | -20 |
| **T_max [C]** | 100 | 100 | 90 | 90 | 90 | 90 | 90 | 90 |

**Fig. 6:** Photograph of V2 after the failure of the insulating glass unit.

# 4 Further work

In this testing campaign, only the thermal cycling of the VIG units was performed. For a more thorough characterization as well as for analysis of failure under different loads, the following tests are recommended:

- Thermal shock testing. This test simulates very fast thermal cycles. After heating to a given maximum temperature (e.g. 70-90 C), the VIG is quickly cooled by spraying with a water jet. This is a customary test which is particularly relevant for standalone VIG units.
- Freezing test: thermal cycling between -40 and +85 C at 85% relative humidity (IEC 61215-10.12).
- Wind load test
- For roof applications: snow load (EN ISO 9806) and hail resistance test (IEC 61215-10.17)

These services are also available upon request at Fraunhofer ISE.