EAD **300021-00-0404**

www.eota.eu

February 2019

European Assessment Document for

Vacuum insulating glass units

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD specifies assessment methods for vacuum insulating glass unit (further referred to in this EAD as VIG unit) and laminated vacuum insulating glass units (further referred to in this EAD as LVIG unit).

A VIG unit is a glazing product consisting of two panes of glass, separated by an array of spacer pillars and sealed along the periphery, whereby the space between the glass panes is evacuated to a pressure below 1 Pa (10^{-2} mbar).

Similarly, a LVIG unit is a VIG unit of which one or both glass panes are laminated glass panes in accordance with EN 14449 [1].

An example of the build-up of a VIG unit or LVIG unit is given in figure 1.1.1. The main components are:

- A low-emissive coating on faces 2 and/or 3
- Possibly one or several coatings on faces 1 or 4, e.g., an anti-fog coating
- Spacer pillars
- A getter material
- Glass panes
- One or two panel(s) of laminated glass pane(s)
- A hermetic edge seal
- An evacuation port

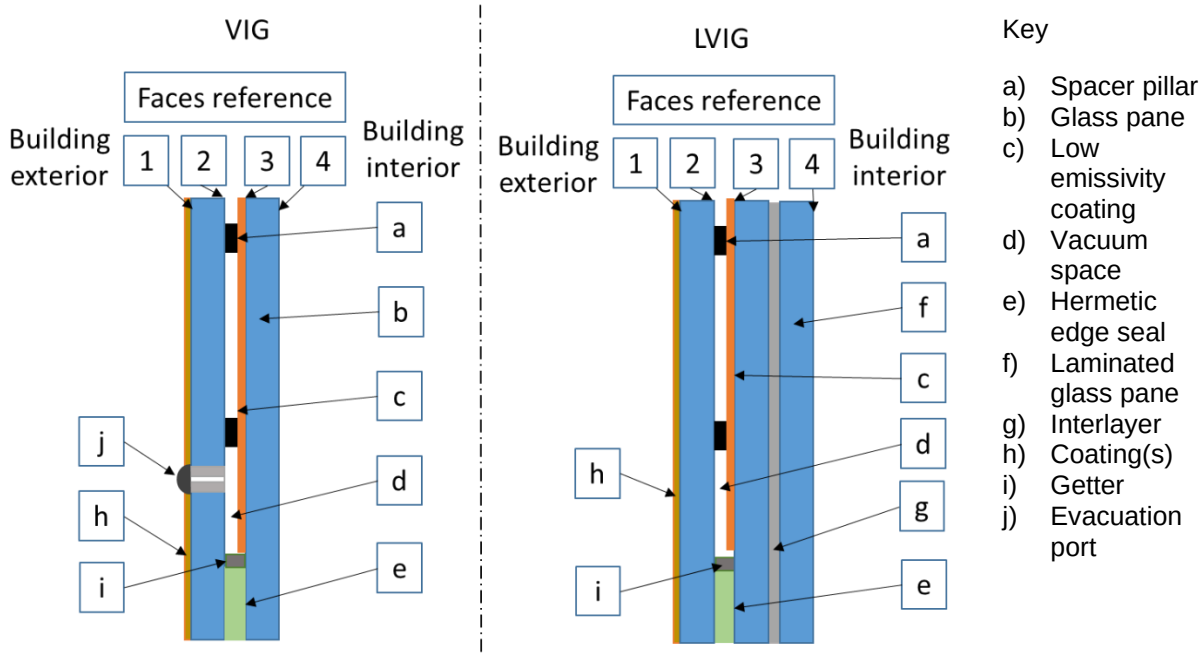


Figure 1.1.1 – Examples of a VIG unit and a LVIG unit

The hermetic edge seal is made on the basis of solder glass. The spacer pillars ensure that the panes remain separated over time.

This EAD covers products with a stable thermal performance, i.e.,

- the deviation between the average of the measured U-value on three specimens and the measured U-value of each individual specimen shall be no more than 10,0% or
- the deviation between the average of the measured U-value on three specimens and the measured U-value of each individual specimen shall be no more than 0,1 W/m²K

1 All undated references to standards in this EAD are to be understood as references to the dated versions listed in chapter 4

The type of glass used in VIG and LVIG units shall be specified by referring to the appropriate European standard, i.e., EN 572-1, EN 572-2, EN 572-9, EN 1096-4, EN 1863-2, EN 12150-2, EN 12337-2, EN 14179-2 or EN 14449.

The spacer pillars used in the VIG and LVIG units shall be specified by:

- Material or compound, the chemical family (metal, polymer, ….)
- Geometrical shape

The VIG and LVIG units shall be specified as follows:

- The type of glass, and thickness of the different parts (including, in the case of a LVIG unit, the type and number of glass panes and interlayers)
- The spacer pillars and the spacer pillar array design to maintain the width of the vacuum space

The product (VIG units and LVIG units) is not fully covered by the following harmonised technical specification: EN 1279-5, due to the explicit exclusion from the scope of the harmonised technical specification. Due the to the particular mechanical liaison between the two glass panes, the assessment methods foreseen in EN 1279-5 concerning pendulum body impact resistance (shatter properties and resistance to impact), mechanical resistance (resistance against sudden temperature changes and temperature differentials and resistance against wind, snow, permanent and imposed load and/or imposed loads), protection against noise, thermal properties and solar energy characteristics are not applicable without adaptation.

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product, as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or, in absence of such instructions, according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

VIG and LVIG units are intended to be used as infill of elements of the building envelope, including both internal and external applications, e.g., infill of windows, doors, curtain walls and greenhouses - admitting light but resisting the passage of air or other elements.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the VIG and LVIG units for the intended use of 10 years when installed in the works. These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

[2] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3 Specific terms used in this EAD

1.3.1 Spacer pillar

Pillar distributed on the glass surface in order to prevent any contact between the 2 glass panes and to maintain a regular distance between the 2 panes of glass. Spacer pillars may be manufactured from glass, solder glass, ceramics, metal and appropriately adapted synthetic materials.

1.3.2 Spacer pillar array

Spacer pillars distributed on the glass surface according to a predefined pattern.

1.3.3 Hermetic edge seal

Glass pane perimeter seal, which is intended to:

- Maintain the vacuum inside the vacuum insulting glass units; and
- Resist mechanical loadings (shear resistance, humidity and temperature, and temperature gradient).

1.3.4 Vacuum space

Space evacuated to a pressure below 1 Pa (10^{-2} mbar).

1.3.5 Getter

Substance used to sorb residual gas from a vacuum space.

1.3.6 Evacuation port

Port by which the vacuum space is evacuated. The evacuation port material may be manufactured from glass, solder glass, ceramics, metal and appropriately adapted synthetic materials.

1.3.7 Solder glass paste

Paste based on glass frit with a particularly low softening point, used to join glass pane to other glass panes, without thermally damaging the materials to be joined.

1.3.8 Glass pane

Glass component used for the fabrication of the VIG and LVIG units. The glass pane is made of monolithic glass or laminated glass.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of VIG and LVIG units is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 2: Safety in case of fire			
1	Resistance to fire	EN 1279-5 clause 4.2.2.2	Class
2	Reaction to fire	2.2.1	Class
3	External fire performance	EN 1279-5 clause 4.2.2.4	Class
Basic Works Requirement 4: Safety and accessibility in use			
4	Bullet resistance: shatter properties and resistance to attack	EN 1279-5 clause 4.2.2.5	Class
5	Explosion resistance: shatter properties and resistance to attack	EN 1279-5 clause 4.2.2.6	Class
6	Burglar resistance: shatter properties and resistance to attack	2.2.2	Class
7	Pendulum body impact resistance: Shatter properties (safe breakability) and resistance to impact	**Fehler! Verweisquelle konnte nicht gefunden werden.**	Class
8	Resistance against temperature gradient	2.2.4	Level
9	Resistance against wind, snow, permanent and imposed load and/or imposed loads of the glass unit	2.2.5	Level
Basic Works Requirement 5: Protection against noise			
10	Direct airborne sound reduction	2.2.6	Level
Basic Works Requirement 6: Energy economy and heat retention			
11	Thermal properties: declared emissivity ε	EN 12898 clause 6.2	Level
12	Thermal properties: U-value	2.2.7	Level
13	Radiation properties: light transmittance τ_v	EN 1279-5 clause 4.2.2.13	Level
14	Radiation properties: light reflectance ρ_v / ρ'_v	EN 1279-5 clause 4.2.2.13	Level
15	Solar energy characteristics: solar direct transmittance τ_e	EN 1279-5 clause 4.2.2.14	Level
16	Solar energy characteristics: solar direct reflectance ρ_e / ρ'_e	EN 1279-5 clause 4.2.2.14	Level
17	Solar energy characteristics: total solar energy transmittance (g-value)	2.2.8	Level
Aspects of durability			
18	Durability	**Fehler! Verweisquelle konnte nicht gefunden werden.**	Level

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

2.2.1 Reaction to fire

2.2.1.1 VIG unit

The VIG unit is considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire, in accordance with the EC Decision 96/603/EC, as amended by Commission Decision 2000/605/EC and Commission Decision 2003/424/EC, without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore, the performance of the product is A1.

If the conditions of said decisions are not fulfilled, the VIG unit shall be tested, using the method(s) relevant for the corresponding reaction to fire class according to EN 13501-1. The VIG unit shall be classified according to the Commission Delegated Regulation (EU) No 2016/364 in connection with EN 13501-1.

Additional guidance is provided in ANNEX E of this EAD.

2.2.1.2 LVIG unit

The LVIG unit shall be tested, using the method(s) relevant for the corresponding reaction to fire class according to EN 13501-1. The LVIG unit shall be classified according to the Commission Delegated Regulation (EU) No 2016/364 in connection with EN 13501-1.

Additional guidance is provided in ANNEX E of this EAD.

2.2.2 Burglar resistance: shatter properties and resistance to attack

Purpose of the assessment

Determination of the mode of rupture of VIG or LVIG units when subjected to a load case simulating a burglar attack.

Assessment method

EN 1279-5, clause 4.2.2.7 specifies an impact test method with a ball drop or an axe impact for insulated glass units in accordance with EN 356.

This assessment method is applicable, with the following adaptation:

- EN 1279-5 specifies that the burglar resistant property of an insulating glass unit can either be ensured by one component of the insulating glass unit only or be ensured by the complete insulating glass unit. In case of (L)VIG units, the burglar resistant property is the performance of the entire (L)VIG as it cannot be attributed to only one of its’ separate components. Therefore, (L)VIG units shall be tested as a whole.
- The classification is valid only for the impacted face, unless both panes adjoining the vacuum space are of identical composition.

Expression of results

The ETA shall state the result of the assessment according to EN 356, consisting of the category of resistance and the side of the product which was impacted. In the case both sides were assessed the ETA shall state the result of the assessment for each side separately.

2.2.3 Pendulum body impact resistance: Shatter properties (safe breakability) and resistance to impact

Purpose of the assessment

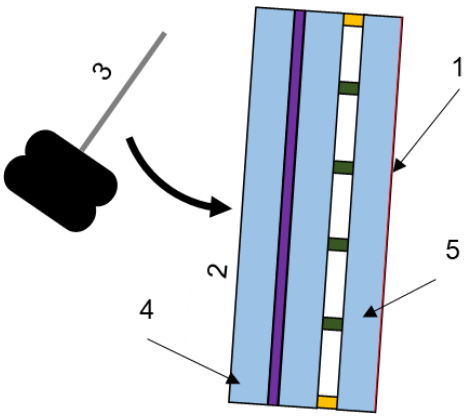
Determination of the mode of rupture of VIG or LVIG units when impacted with an impactor simulating a soft body impact.

Assessment method

EN 1279-5, clause 4.2.2.8 specifies an impact test method with a pendulum for single flat glass panes in accordance with EN 12600.

This assessment method is applicable, with the following adaptations:

- For LVIG units, the performance of the pane may not be extrapolated to the side of the unit where the pane is installed. Therefore, testing is necessary to classify the LVIG unit according to EN 12600, with the following adaptations:
  - The LVIG unit specimen tested in accordance with EN 12600 shall be placed on the test rig; the side of the LVIG to be impacted (the laminated pane or the non-laminated pane) is recorded;
  - In order to determine the type of breakage of the impacted side in accordance with the EN 12600, clause 4 a), only the fragments issued from the impacted pane shall be taken into account. Therefore, when necessary, arrangements shall be taken to make the distinction between the 2 panes fragments by applying a colouring by spraying the non-impacted pane, without disturbing the test result
  - The classification is valid for the impacted face



Key:

1. Coloured sprayed layer
2. Side submitted to evaluation
3. Impactor
4. Laminated pane
5. Monolithic pane

Figure 2.2.3.1 – Soft body impact

- The test results shall only be valid for the VIG or LVIG unit composition tested and cannot be extrapolated to other VIG or LVIG compositions.

Expression of results

The ETA shall state the result of the assessment according to EN 12600, consisting of the drop height class at which the product did not break or broke in accordance with descriptions a) or b) of EN 12600 clause 4, the mode of breakage and the highest drop height class at which the product either did not break or broke in accordance with description a) of EN 12600 clause 4. For LVIG the ETA shall state the side of the product which was impacted (the laminated pane or the non-laminated pane) or in the case both sides were assessed shall state the result of the assessment for each side separately.

2.2.4 Resistance against temperature gradient

Purpose of the assessment

Determination of the resistance against sudden temperature changes and temperature differentials of the VIG or LVIG units.

Assessment method

The resistance against temperature gradient shall be determined in accordance with ANNEX F.

Expression of results

The ETA shall state the highest value of the temperature difference ΔT_2 [°C] of the VIG or LVIG unit for the assessment where no specimens suffered mechanical failure, and the calculated arithmetic mean value ΔT_c of the relative change in surface temperature [%] during the steady state.

2.2.5 Resistance against wind, snow, permanent and imposed load and/or imposed loads of the glass unit

Purpose of the assessment

Determination of the resistance against wind, snow, permanent and/or imposed loads of the VIG or LVIG units.

Assessment method

The resistance to loads of the VIG and LVIG units shall be assessed through the following assessments:

- Determination of the equivalent thickness in accordance with ANNEX A.
- the spacer pillar compression resistance and creep resistance, as a function of the material used in accordance with ANNEX C.

Expression of results

The ETA shall state the equivalent thickness of the VIG or LVIG unit, the minimum compression breaking force of the spacer pillars and ratio of the average contact surface of the spacer pillars before and after the creep resistance assessment.

2.2.6 Direct airborne sound reduction

Purpose of the assessment

Determination of the attenuation of sound of the VIG or LVIG units.

Assessment method

The airborne sound reduction shall be assessed in accordance with ISO 19916-1, clause 8.

Expression of results

The ETA shall state the result of the assessment, consisting of the single number quantity for sound reduction index, the spectrum adaptation term for A-weighted pink noise and the spectrum adaptation term for urban traffic noise, noted as "R_w (C;C_{tr})" (dB).

2.2.7 Thermal properties: U-value

Purpose of the assessment

Determination of the thermal insulating properties of the VIG or LVIG units.

Assessment method

The thermal transmittance (U-value) shall be

- Measured according to ISO 19916-1, clause 5.2 and annex A to ISO 19916-1; or
- Calculated in accordance with annex C to ISO 19916-1, with the following adaptations: where in ISO 19916-1 reference is made to ISO 10292, as an alternative EN 673 shall be used. Both methods resulting in equivalent assessments, the reference method is ISO 10292.

Expression of results

The ETA shall state the U-value ($W/m^2 \cdot K$), truncated to 3 decimals.

2.2.8 Solar energy characteristics: total solar energy transmittance (g-value)

Purpose of the assessment

Determination of the total solar energy transmittance (g-value) of the VIG or LVIG units.

Assessment method

The total energy transmission factor, g-value, shall be assessed according to ISO 19916-1, clause 5.3, with the following adaptations: where in ISO 19916-1, reference is made to ISO 9050, as an alternative EN 410 shall be used. Both methods resulting in equivalent assessments, the reference method is ISO 9050.

Expression of results

The ETA shall state the g-value (without unit), expressed in %, rounded to 0 decimals.

2.2.9 Durability

Purpose of the assessment

The purpose of this test is to determine the durability of the hermetic seal of VIG or LVIG units.

Assessment method

The particular mechanical liaison between the two glass panes of the VIG and LVIG differs from insulating glass units covered by EN 1279-5 notably in the absence of edge sealants, spacers, dessicants and cavity fillings as described in EN 1279-1, which are integral components to a system of insulating glass units covered by EN 1279-5. As a result, the assessment of the durability specified in EN 1279-5, clause 4.2.2.15 is not applicable as it relies on the assessment of the performance of said components.

The durability shall be assessed according to ISO 19916-1, clause 7 method 2. The temperature/time relation specified in ISO 19916-1, Figure 5, applies.

Expression of results

The ETA shall state the arithmetic mean value of the absolute change in U-value ΔU ($W/m^2 \cdot K$), truncated to 3 decimals.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For VIG and LVIG units covered by this EAD the applicable European legal act is Commission Decision 2000/245/EC, as amended by Commission Decision 2001/596/EC.

The systems to be applied for the products covered by this EAD have been specified in Table 3.1.1.

Table 3.1.1 System of assessment and verification of constancy of performance applicable to VIG and LVIG units

Product(s)	Intended use(s)	Level(s) or class(es)	AVCP system(s)
VIG or LVIG units	For use in a glazed assembly intended to provide fire resistance	Any	1
	For uses subject to reaction to fire regulations	A1, A2, B, C, D, E	3
		(A1 to E) (1), F	4
	For uses subject to external fire performance regulations	Products requiring testing	3
		Products 'deemed to satisfy without testing'	4
	For use as anti-bullet, or anti-explosion glazing	-	1
	For other uses liable to present "safety in use" risks and subject or not to regulations (e.g., impact resistant glazing)	-	3
	For uses relating to noise reduction		
	For uses relating to energy conservation		
	For uses other than those specified above	-	4

(1) Products/materials that do not require to be tested for reaction to fire (e.g., products/materials of Class A1 according to Commission Decision 96/603/EC, as amended by Commission Decision 2000/605/EC).

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

Table 3.2.1 Control plan for the manufacturer; cornerstones

N°	Subject / type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
Incoming materials (VIG and LVIG unit components)					
1	Glass, coated glass, laminated glass	Check of documentation accompanying delivery, supplier certificates/report	Check of conformity with purchase order	-	Each delivery
2	Glass and coated glass	Inspection	Check of conformity with purchase order	-	Each pane
3	Solder glass paste - Identification, including packaging and label	Inspection	Check of conformity with purchase order	-	Each delivery
	- Shear resistance of the hermetic edge seal	3.4.1	Check of conformity with purchase order	-	Initial on new material
	- Thermal expansion coefficient	3.4.1	Check of conformity with purchase order	-	Initial on new material
	- Glass transition and softening point	3.4.1	Check of conformity with purchase order	-	Initial on new material
4	Getter - Identification including packaging and label	Inspection	Check of conformity with purchase order	-	Each delivery
	- Sorption capacity	3.4.3	Check of conformity with purchase order	-	Initial on new material
5	Spacer pillars - Identification, including packaging and label	Inspection	Check of conformity with purchase order	-	Each delivery
	- Verification of the dimensions	Inspection	Check of conformity with purchase order	-	Each delivery
	- Compression resistance	3.4.2	Max force N_b [N]	-	Initial on new material

N°	Subject / type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
	- Creep resistance	3.4.2	The integrity of the spacer pillars is assessed visually by the two panes not touching each other	-	Initial on new material
Production control					
6	Spacer pillars position after deposition	Inspection	Respect of manufacturer's specifications	-	On each spacer pillar array
7	Relevant process conditions	Automatic	See production instructions	-	Continuously
Final Product control					
8	Spacer pillars position	Inspection	Respect of specifications	-	Each VIG or LVIG unit
9	Sealing / vacuum level	Simplified thermal insulation test	Respect of specifications	-	Each VIG or LVIG unit

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for VIG and LVIG units are laid down in Table 3.3.1.

Table 3.3.1 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the VIG and LVIG units.	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	2/year

If the VIG or LVIG is not intended for use as anti-bullet, or anti-explosion glazing, the intervention of the notified body under AVCP system 1 is only necessary for reaction to fire for products/materials for which a clearly identifiable stage in the production process results in an improvement of the reaction to fire classification (e.g., an addition of fire retardants or a limiting of organic material).

In this case the cornerstones of the actions to be undertaken by the notified body under AVCP system 1 are laid down in Table 3.3.2

Table 3.3.2 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control carried out by the manufacturer regarding the constancy of performance related to reaction to fire *(for system 1 only)*					
1	Where the intervention of the Notified Body is necessary only because the conditions for the applicability of system 1 are fulfilled for reaction to fire, the notified body will consider especially the clearly identifiable stage in the production process which results in an improvement of the reaction to fire classification (e.g., an addition of fire retardants or a limiting of organic material).	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control carried out by the manufacturer regarding the constancy of performance related to reaction to fire *(for system 1 only)*					
2	Where the intervention of the Notified Body is necessary only because the conditions for the applicability of system 1 in the Decisions regarding reaction to fire are fulfilled, the notified body will consider especially the clearly identifiable stage in the production process which results in an improvement of the reaction to fire classification (e.g., an addition of fire retardants or a limiting of organic material)	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	2/year

3.4 Special methods of control and testing used for the verification of constancy of performance

3.4.1 Solder glass edge seal characteristics

See ANNEX B.

3.4.2 Spacer pillars' characteristics (compression and creep resistance)

See ANNEX C.

3.4.3 Getter sorption capacity

See ANNEX D.

4 REFERENCE DOCUMENTS

EN 356:1999	Glass in building – Security glazing – Testing and classification of resistance against manual attack
EN 410:2011	Glass in building – Determination of luminous and solar characteristics of glazing
EN 572-1:2012+A1:2016	Glass in building – Basic soda lime silicate glass products — Part 1: Definitions and general physical and mechanical properties
EN 572-2:2012	Glass in building – Basic soda lime silicate glass products — Part 2: Float glass
EN 572-9:2004	Glass in building – Basic soda lime silicate glass products — Part 9: Evaluation of conformity/Product standard
EN 673:2011	Glass in building – Determination of thermal transmittance (U value) – Calculation method
EN 1096-4:2018	Glass in building – Coated glass — Part 4: Evaluation of conformity/Product standard
EN 1279-1:2018	Glass in Building – Insulating glass units – Part 1: Generalities, system description, rules for substitution, tolerances and visual quality
EN 1279-5:2018	Glass in building – Insulating glass units – Part 5: Evaluation of conformity
EN 1288-3:2000	Glass in building – Determination of the bending strength of glass – Part 3: Test with specimen supported at two points (four-point bending)
EN 1863-2:2004	Glass in building – Heat strengthened soda lime silicate safety glass — Part 2: Evaluation of conformity/Product standard
EN 12150-2:2004	Glass in building – Thermally toughened soda lime silicate safety glass — Part 2: Evaluation of conformity/Product standard
EN 12337-2:2004	Glass in building – Chemically strengthened soda lime silicate glass — Part 1: Evaluation of conformity/Product standard
EN 12600:2002	Glass in building – Pendulum test – Impact test method and classification for flat glass
EN 12898:2019	Glass in building – Determination of the emissivity
EN 13823:2020+A1:2022	Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item
EN 14179-2:2005	Glass in building – Heat soaked thermally toughened soda lime silicate safety glass — Part 2: Evaluation of conformity/Product standard
EN 14449:2005/AC:2005	Glass in building – Laminated and laminated safety glass — Evaluation of conformity/Product standard
EN 13501-1:2018	Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests
EN ISO 1182:2020	Reaction to fire tests for products – Non-combustibility test
EN ISO 1716:2018	Reaction to fire tests for products – Determination of the gross heat of combustion
EN ISO 11925-2:2020	Reaction to fire tests – Ignitability of products subjected to direct impingement of flame – Part 2: Single-flame source test
ISO 9050:2003	Glass in building – Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors
ISO 9277:2022	Determination of the specific surface area of solids by gas adsorption using the BET method
ISO 10292:1994	Glass in building – Calculation of steady-state U values (thermal transmittance) of multiple glazing

ISO 19916-1:2018	Glass in building – Vacuum insulating glass – Part 1: Basic specification of products and evaluation methods for thermal and sound insulating performance

ANNEX A EQUIVALENT THICKNESS

A.1 Assessment by testing

Ten test VIG unit specimens, composed of twice the same glass thickness panes, shall be prepared.

The thickness of the 10 specimens shall be measured according to ISO 19916-1, clause 6.1.3. The measured thickness of the unit (pane) h_m is the average of 4 thicknesses measurements.

When necessary, each specimen shall be weighted with an accuracy of 10 g (see note A1.1).

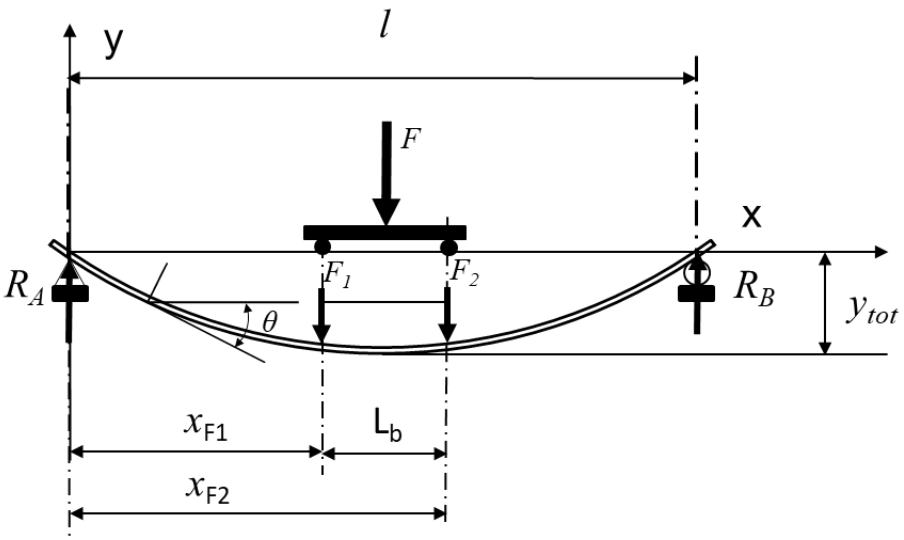
The width, B, of the specimens shall be measured in the mid-span and above the supporting rollers. The average value of the 3 measurements, b_{ave}, shall be used in the determination of the equivalent thickness, h.

The dimensional deviation limits shall be verified according to ISO 19916-1, clauses 6.2.2 to 6.2.4.

The specimens shall be tested according to EN 1288-3 until break. The load, F_{SLS}, at the maximum deflection at break shall be recorded.

In order to avoid the scattering induced by the surface flaws and the edge finishing work, the equivalent thickness shall be determined on the basis of the deflection measurement.

The static scheme of the EN 1288-3 may be represented as follows.



Key

x_{F1}	Positon of the roller 1 (400 mm)
x_{F2}	Positon of the roller 2 (600 mm)
L_b	Distance between the rollers
F	Load applied at equal distance of the rollers
y_{tot}	Total deflection of the plate under dead load and applied load
l	Distance between the supporting rollers

Figure A.1.1 – Static diagram EN 1288-3

The deflection calculated at the centre of the VIG unit under its own dead load and the applied load, F, is given by the following formulas:

$$e_{dl} = \frac{-5pl^4}{384EI} \qquad \text{(eq. A.1.1)}$$

$$e_F = -\frac{F}{96EI}(3l^2(x_{F1} + x_{F2}) - 4(x_{F1}^3 + x_{F2}^3)) \quad \text{(eq. A.1.2)}$$

$$y_{tot} = e_{dl} + e_F \quad \text{(eq. A.1.3)}$$

The equivalent thickness, h, of the VIG unit is given by the following equation

$$h = \sqrt[3]{\frac{12}{b_{ave} * y_{tot,m}} . \left[\frac{5pl^4}{384.E} + \frac{F}{96.E} . (3l^2(x_{F1} + x_{F2}) - 4. (x_{F1}^3 + x_{F2}^3))\right]} \quad \text{(eq. A.1.4)}$$

where

e_{dl}	Deflection under dead load
e_F	Deflection under applied load
y_{tot}	Total deflection
h	equivalent thickness
b_{ave}	Average width of the plate (mm)
p	Dead load over the width of the plate (N/mm), calculated from the mass of the specimen divided by the average width b_{ave}
E	The glass E-modulus (N/mm²), from the appropriate product standards (e.g., EN 572-1)
F	Load applied at equal distance of the rollers
$y_{tot,m}$	Total measured deflection of the plate, measured under dead load and applied load
l	Distance between the supporting rollers

Note A.1.1: If the displacement gauge is set to "0" after the VIG unit is in place on the supporting rollers but before the application of the load "F", the term "p" = 0 in the equation eq. A.1.4, thereby simplifying the equation.

The following averages shall be calculated

$$h_{ave} = \sum_{i=1}^{n} \frac{h_i}{n} \quad \text{(eq. A.1.5)}$$

$$h_{m,ave} = \sum_{i=1}^{n} \frac{h_{m,i}}{n} \quad \text{(eq. A.1.6)}$$

Where

h_{ave}	Average of the n "h" thicknesses (mm)
$h_{m,ave}$	Average of the n "h_m" thicknesses (mm)
n	Number of specimens (10)
h_i	h of the specimen "i" (mm)
$h_{m,i}$	h_m of the specimen "i"(mm)

The equivalent thickness shall be considered as being the thickness of the VIG unit when

$$h_{ave} = h_{m,ave} \pm 0{,}1\ mm \quad \text{(eq. A.1.7)}$$

ANNEX B SOLDER GLASS EDGE SEAL CHARACTERISTICS

B.1 Thermal expansion

B.1.1 Specimens

At least 3 specimens shall be prepared as follows:

1. The specimen material shall be poured in a mould with the best design to prepare a test specimen suitable for the Thermo-Mechanical Analysis TMA.

2. The seal paste specimen shall be subjected to the defined firing cycle as used in VIG unit fabrication.

3. The moulded specimen may be worked to obtain the wanted test specimen.

   For all specimens, test specimens may be of any convenient length. The minimum thickness of the specimen shall be 5 mm.

   Note: The length does not influence the test result. The length is the one allowing to perform the test, depending of the TMA used.

4. The initial length, l_0, of the specimen at room temperature shall be measured with an accuracy of 0,1 %.

B.1.2 Test apparatus

A thermomechanical analyser (TMA) shall be used. The accuracy of the instrument in determining length changes as a function of the temperature shall be ± 3 µm.

B.1.3 Test procedure

The test specimen shall be installed into the furnace at room temperature. The specimen is heated up with a rate of (10 ± 1) °C/min.

The temperature and the length of the specimen shall be continuously recorded from the initial room temperature up to the high temperature t_h.

The thermal dilatation coefficient is given by the relation

$$\alpha = \frac{l_h - l_0}{l_0 \times (t_h - t_0)} \text{ [1/°C]} \qquad \text{(eq. B.1.3.1)}$$

Where

α	Thermal dilatation coefficient [1/°C]
l_h	Length of the specimen measured at high temperature [mm]
l_0	Initial length of the specimen measured at room temperature [mm]
t_h	Maximum temperature at which l_h was recorded [°C]
t_0	Initial room temperature at which l_0 was recorded [°C] (room temperature)

B.1.4 Test report

The test report shall at least contain the following items:

- Specimen description
- Size of the specimen

- Description of the apparatus
- Description of the specimen preparation
- Measurement results
- Thermal dilatation coefficient α (with the initial t_0 and t_h maximum temperatures)

B.2 Softening point and glass transition temperature

B.2.1 Specimens

The specimens shall be prepared as follows:

The paste specimen material shall be poured in a specimen container and subjected to the appropriate firing in order to burn and remove all the existing organic materials.

The test specimen may be of any convenient amount.

Note: The amount does not influence the test result. The amount shall be the one allowing to perform the test, depending on the Differential Thermal Analyzer (DTA) used.

B.2.2 Test Apparatus

A Differential Thermal Analyzer shall be used.

B.2.3 Test procedure

- Measure the weight of the specimen.
- Insert the test specimen into the furnace at room temperature.
- Heat up the specimen with a heating rate of (10 ± 1) °C/min.
- Record the temperature of the furnace, and the temperature differential between the specimen temperature and the one of the reference material.

From the plot recorded by the DTA analyser, the softening point and the glass transition temperature shall be determined as follows:

- The Glass Transition temperature is the temperature T_g at the peak of the first thermal inflection point on the DTA curve.
- The Softening point temperature T_s: is the temperature at the peak of the fourth thermal inflection point on the DTA curve. In case when the fourth inflection point is not clear, the third inflection point may be used.

B.2.4 Test report

The test report shall at least contain the following items:

- Specimen description
- Weight of the specimen
- Description of the specimen preparation
- Description of the apparatus
- T_s and T_g

B.3 Shear strength of the edge seal

B.3.1 Specimens

Two glass specimens as indicated in the following figures shall be prepared. A bead of solder glass paste with an adapted section depending of the material used shall be laid down on the glass.

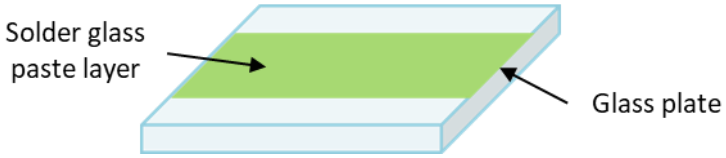


Figure B.3.1.1 – Glass plate with solder glass paste layer

Four float glass studs of (6 ± 1) mm x (6 ± 1) mm x (3 ± 1) mm per glass plate shall be lined up as shown in Figure B.3.1.2 on the layer and then soldered to the glass plate according to appropriate baking.

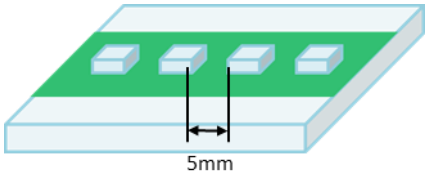


Figure B.3.1.2 – Glass plate, with soldered glass studs

B.3.2 Test procedure

The assembled glass plate, with edge seal layer and 4 lined up glass studs, shall be fixed on the test machine in order to apply a shear force parallel to the glass specimen.

A shear force, *T*, regularly distributed on a face of the glass stud shall be applied with a 'puller', described in figure B3.2.1, with a speed of approximately 10 mm/minute until break.

The shear force at break T_b is recorded.

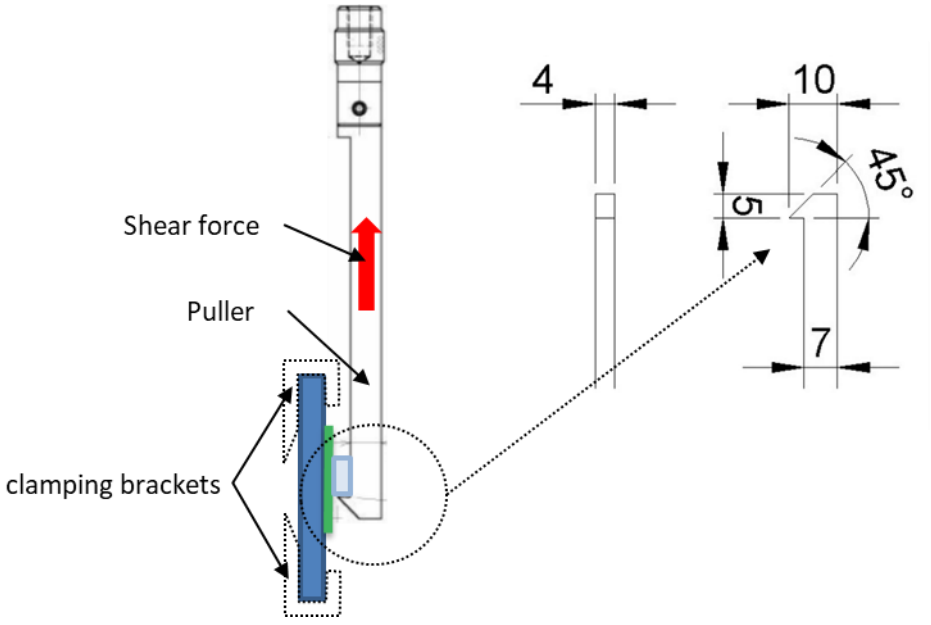


Figure B.3.2.1 – Shear test (dimensions in mm)

For each stud, the shear resistance shall be calculated as follows:

$$\tau = \frac{T_b}{S} \qquad \text{(eq. B.3.2.1)}$$

For each individual stud, the shear resistance $\tau_i \geq \tau_m$

With

- τ : shear resistance for a particular stud
- T_b : shear force at break
- τ_m: minimum acceptable shear stress

B.3.3 Test report

The test report shall at least contain the following items:

a) Description of the specimen (e.g., manufacturer's name, product name or other reference, etc.)

For each stud, the test report shall at least specify:

- The contact surface of each stud and the glass plate,
- The shear force at break,
- The type of rupture:
  - At the interface between the stud and the seal,
  - At the interface between the seal and the glass plate,
  - In the stud,
  - In the seal,
  - Or in the glass plate.

b) Description of specimen preparation,
c) Description of the test apparatus,
d) The resulting individual shear stresses.

ANNEX C SPACER PILLARS' CHARACTERISTICS

C.1 Compression resistance of the spacer pillar

C.1.1 Specimens

Three glass plates with dimensions (100 ± 2) mm x (100 ± 2) mm x (6 ± 0,2) mm, and three spacer pillars, produced with the industrial process used in practice, shall be prepared. The dimensions of the spacer pillars shall be measured, preferably using an optical microscope with a precision of 0,005 mm.

C.1.2 Test procedure

The first spacer pillar shall be placed approximately at the centre of the plate. The plate shall be clamped to the press.

A force shall be applied perpendicularly to the plate with a very low speed, approximately 10 mm/minute, until break, i.e., crushing of the spacer pillar.

The maximum force N_b is recorded.

The 2 other spacer pillars shall be tested according to the same procedure.

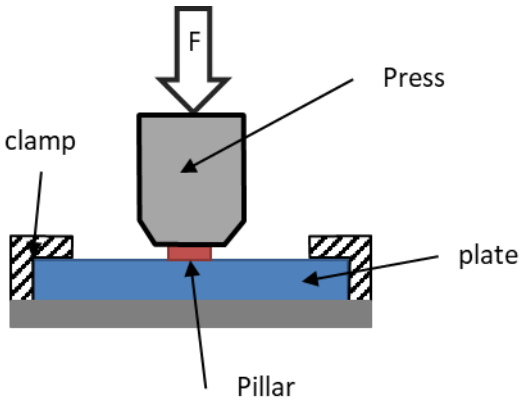


Figure C.1.2.1 – Spacer pillar compression resistance

C.1.3 Test report

The test report shall at least contain the following information:

a) Description of the specimens
b) Initial dimensions of each of the 3 spacer pillars
c) Description of the test apparatus
d) Measurement results: the compression breaking force N_b [N] for each spacer pillar

C.2 Creep resistance of the spacer pillar

C.2.1 Specimens

One VIG or LVIG unit having a size of (300 ± 2) mm x (300 ± 2) mm shall be produced, according to the process applied in practice.

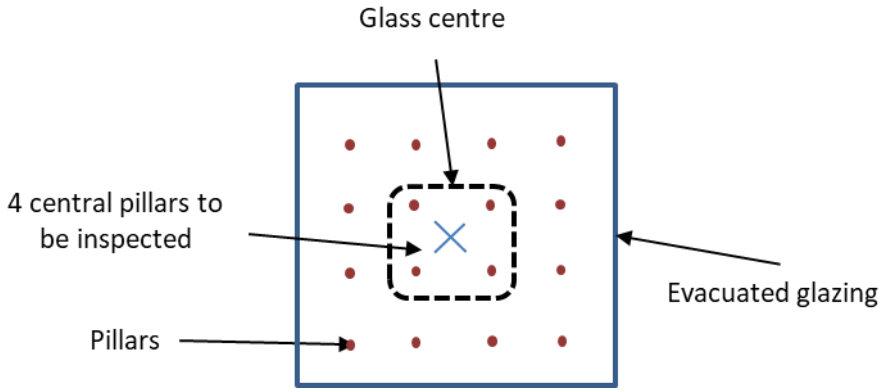


Figure C.2.1.1 – Spacer pillar creep resistance

C.2.2 Test procedure

Once the vacuum has been created, the contact surface between the 4 central spacer pillars and the glass of the unit shall be evaluated with an optical microscope, as follows (see figure C.2.1.1):

1. Place the specimen on the tray of an optical microscopic and apply a light beam perpendicular to the unit.
2. Set the optical microscope on a reflected light mode.
3. Adjust the focalization on the interface spacer pillar/glass pane.
4. Take a picture and record the image showing the contact areas between each of the 4 central spacer pillars and the glass (see figure C.2.2.1).

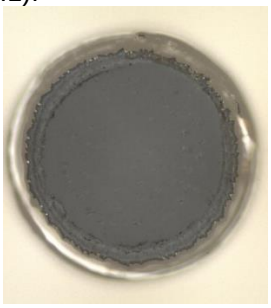


Figure C.2.2.1 – Contact surface example

The procedure above shall be applied on both sides of the 4 spacer pillars that are around the centre of the vacuum glazing.

5. Determine and record the contact areas between each end of the 4 central spacer pillars and the two glass panes of the unit using image processing.

The specimen shall then be placed in an oven to a maximum temperature of (150 ± 1) °C for (240 ± 1) hours according to the heating cycle below.

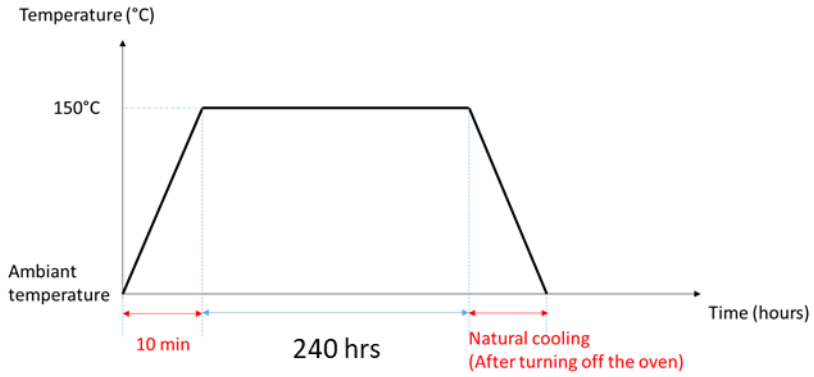


Figure C.2.2.2 – Spacer pillar creep resistance – temperature cycle

6. The temperature at the place representing the mean temperature in oven is continuously recorded.
7. After heating, each contact areas of the 4 central spacer pillars shall be inspected and the contact surface shall be recorded by repeating the stages 1) to 4) here above.
8. Check visually the integrity of the spacer pillars on the images taken after heating.
9. Check if the two panes are not touching each other by visual judgment.

C.2.3 Test report

The test report shall contain at least the following information:

a) Specimen description,
b) Dimensions of the specimen,
c) Description of the apparatus,
d) Measurement results,
e) The result of the visual inspection.

ANNEX D GETTER SORPTION CAPACITY

The getter sorption capacity shall be determined using the sorption isotherm.

The sorption capacity, i.e., the volume of gas absorbed (cm^3), shall be determined experimentally at operating temperature of the VIG unit, i.e., (23 ± 5) °C, using the static volumetric method.

D.1 Static volumetric method

The getter shall be placed in an enclosure, activated and then maintained at operating temperature. The specimen shall be allowed to reach equilibrium pressure. The equilibrium pressure might be equal to the VIG unit vacuum pressure. The apparatus in accordance with ISO 9277. The report gives sorption capacity (mm^3 STP – volume at standard temperature and pressure) at the equilibrium pressure for one gram of getter.

ANNEX E ASSESSMENT OF THE REACTION TO FIRE OF VIG AND LVIG UNITS ACCORDING TO EN 13501-1

E.1 Testing according to EN ISO 1182

This test method is relevant for determination of classes A1 and A2 according to EN 13501-1.

All substantial components of the VIG or LVIG as well as products processed from it shall be tested except in cases as prescribed below.

Components of the VIG or LVIG or products processed from it which are made of materials covered by Commission Decision 96/603/EC (as amended by Commission Decisions 2000/605/EC and 2003/424/EC) for materials classified as class A1 without the need for testing, does not need to be tested according to EN ISO 1182.

For linear components (e.g., edge sealings) or discrete components (e.g., evacuation port) their total weight (depending on the size of the final product and/or their number per glass unit) shall be used to calculate the weight per unit area and thickness as basis for the assessment whether they are to be considered as substantial or non-substantial (as defined in EN 13501-1) and need to be tested or not.

Relevant parameters for sampling and preparing the specimens of the components and the application of test results:

- Variations of a product family (as defined by a certain combination of raw materials and a certain type of production process): the variation with the highest amount of organic content shall be tested covering all variations of the same product family with lower organic content and
- Density: where relevant, the highest and lowest density shall be tested covering the whole range between those values evaluated.

All tests shall be performed in accordance with the provisions of the test standard.

E.2 Testing according to EN ISO 1716

E.2.1 Glass panes

The glass panes shall be classified as class A1 according to Commission Decision 96/603/EC, as amended by Commission Decision 2000/605/EC and Commission Decision 2003/424/EC. The heat value (PCS value) amounts to 0 MJ/kg.

E.2.2 Hermetic edge seal, getter, evacuation port

Other materials of the VIG or LVIG units (hermetic edge seal, getter, evacuation port) may be considered to satisfy any reaction to fire requirement If these components are either inorganic and therefore considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the EC decision 96/603/EC, as amended by Commission Decision 2000/605/EC and Commission Decision 2003/424/EC, or if these components are embedded in the product and may therefore be considered not to influence the reaction to fire class of the VIG or LVIG units.

In any other case, testing of the VIG or LVIG shall be performed according to EN 13823 in order to classify the construction product according to EN 13501-1.

E.2.3 Spacer pillar

If the spacer pillar material is organic but does not exceed 1,0 % by weight or volume (whichever is the lower) or if the spacer pillar material is inorganic it is therefore considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the provisions of EC Decision 96/603/EC, as amended by Commission Decision 2000/605/EC and Commission Decision 2003/424/EC .

In any other case, testing of the VIG or LVIG shall be performed according to EN 13823 in order to classify the construction product according to EN 13501-1.

E.2.4 Intermediate layers

For the intermediate layers, such as foils (e.g., PVB, EVA), the heat value (PCS value) shall be determined according to the EN ISO 1716. If the admissible PCS value for an A1 construction material is exceeded, testing the laminated glass shall be performed according to EN 13823 in order to classify the construction product according to EN 13501-1.

E.3 Testing according to EN 13823 (SBI)

E.3.1 Relevant parameters for this method

- composition of the laminated glass
- type and thickness of the glass used for the glass panes
- type (chemical composition) and thickness of the interlayer
- joint arrangement

E.3.2 General remarks on the set-up of the test specimen

A horizontal joint, as well as a vertical joint (as normally prescribed in EN 13823) on the long wing shall not be considered when preparing the SBI test specimens.

Both wings of the specimen shall be assembled according to EN 13823, Figure 2, in a freestanding position. The instructions of EN 13823, Clause 5.2.2 a), shall be considered.

The distance between backside of the specimen and backing board shall be at least 80 mm. The pointwise support of the specimen also allows for free ventilation behind the specimen.

Note: if the specimen collapses during testing, the test cannot be validated.

Testing with the smallest thickness of the glass panes (per type of glass to be used) with the interlayer which shows the largest thickness and which verify the highest heat value (PCS value) according to EN ISO 1716.

The results with the smallest thickness of the glasses will also include the use of the largest glass thickness.

The use of an interlayer with the largest thickness and the most critical heat value also includes the use of intermediate layers with the same or a smaller thickness and a lower PCS value.

E.4 Testing according to EN ISO 11925-2

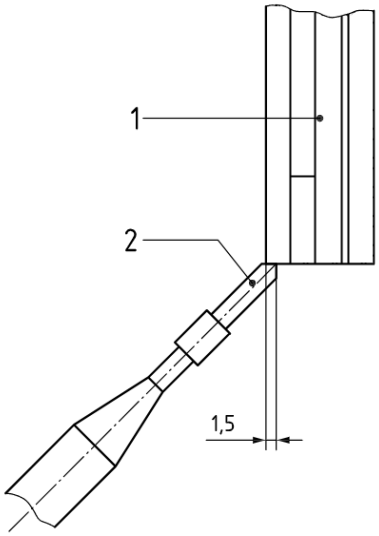
E.4.1 Relevant parameters to be observed when performing this test

- composition of the laminated glass
- type and thickness of the glass used for the glass panes
- type (chemical composition), number and thickness of the interlayer
- edge seal and sealing material (between the panes) if the edge seal is organic

E.4.2 Suggested test programme

Three tests (identified as “first series” in Figure E.4.2.1 below; surface of the specimen facing the front of the test cabinet) with edge flame attack applied to the centre of the width of the bottom edge 1,5 mm behind

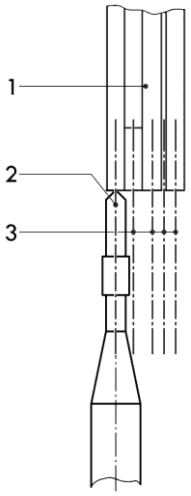
the surface and three tests on the specimens turned at 90 degrees from its vertical axis (identified as “second series” in Figure E.4.2.1 below; surface of the specimen facing the side of the test cabinet) and the flame impinging at the bottom edge of the centreline of the underside of each different layer of the (laminated) glass panes. These flame impingement points for these last three specimens shall be determined by aiming these components with the most critical result from the SBI test and/or PCS value determination, including the edge seal if the edge seal material is organic.



Side view of “first series”

1 Sample

2 Burner location



Front view of “second series”

1 Sample

2 Burner location (example)

3 Axes of alternative burner locations (examples)

Figure E.4.2.1 – Flame impingement points

From the variant which shows the most unfavourable test results regarding reaction to fire, three more tests shall be carried out. These results are consulted as basis for the classification. The result applies to all aforementioned variants and applications.

ANNEX F RESISTANCE AGAINST TEMPERATURE DIFFERENTIALS

F.1 Sampling and preparing test specimen

Three test specimens with dimensions (length and width) of (595 ± 5) mm x (595 ± 5) mm shall be prepared and stored at the room temperature at least 24 hours after the production.

The glass thicknesses used for the test shall be selected according to the following rules:

- The specimen design with the smallest total nominal thickness of the product range shall be selected;
- If the product range includes more than one specimen design of glass thickness, the specimen to be tested shall be the one with the smallest total thickness for which the nominal thicknesses of the glass panes differ the most, for example:
  VIG unit product range with following glass panes thickness of 8+8, 8+4, 6+6 and 8+6,
  The smallest total thickness is 12, 8+4 and 6+6, and between those, the 8+4 is the unit where the panes thicknesses differ the most, then test specimen chosen for the test is 8+4.

In case the units have different nominal thicknesses for the two glass panes, the thickest glass pane shall face the hot side of the apparatus.

F.2 Equipment requirements

A climate chamber with one open side shall be used. The size of the open side shall be at least 20 cm bigger than the unit, in each direction, to avoid edge effects during the heating of the unit.

A closing wall is built to close the open side of the chamber in accordance with the figure F.2.1.

This closing wall is made of a wooden batten frame, insulation panels and the VIG unit(s).

The frame has one or more openings receiving the VIG units that shall be placed vertically and fixed in the corners of the VIG unit openings according to the figure F.2.2.

The other surrounding openings are filled with insulation panels.

The climate chamber may be made from plywood. The walls of the climate chamber not in contact with the unit may be insulated to reduce heat losses.

A homogeneous distribution of temperature on the unit surfaces shall be realized.

Stresses in the specimen, induced by the testing procedure from sources, other than the temperature difference, shall be minimized as far as practically possible.

In order to avoid stresses due to convection, the heat transfer between the air and the exposed to heat surfaces of the VIG unit, during the required period of the equilibrium of temperatures (steady state), shall be by natural convection and radiation only. Heat transfer by forced convection shall be minimized, as far as practically possible. A practical way to avoid convention is to use an intermediate convection protection board which heat up the VIG unit mainly by radiation.

The gap between the specimen unit edges and the frame shall be sealed with soft material, such as tape, in order to make the joint between the unit and the frame airtight.

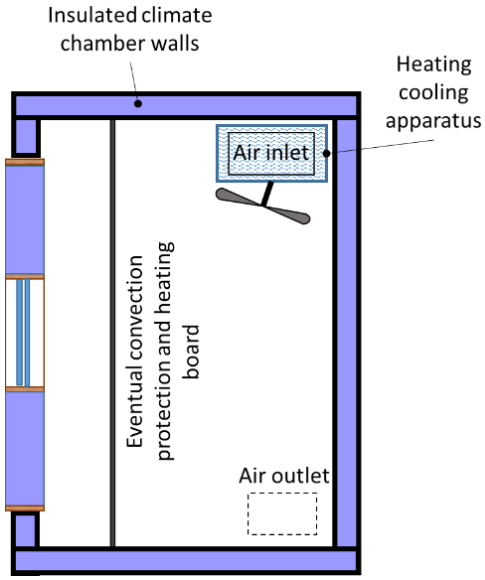


Figure F.2.1 – Example of schematic climate chamber (cross section)

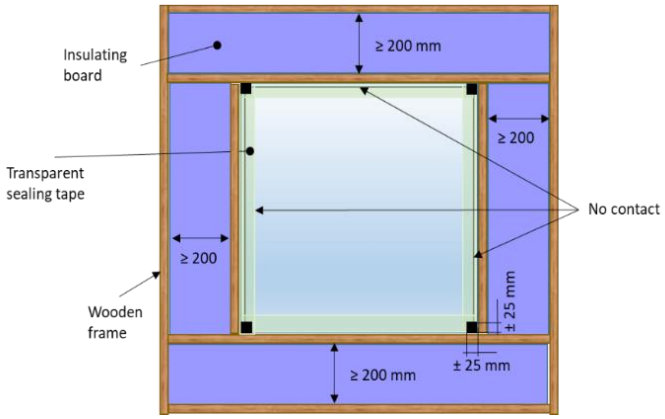


Figure F.2.2 – Example of specimen installation (front view of closing wall)

F.3 Test procedure

The U-value of the three specimens shall be measured in accordance with annex A to ISO 19916-1. The 3 test units are equipped with thermocouples on each face, in the centre of the specimens. The diameter of the thermocouples shall be no more than 0,5 mm. The wire of the thermocouples shall contact the glass surface with tape for no less than 20 mm in length.

The method of fastening shall not induce significant stress in the specimen.

The air temperature at both sides of the specimens shall be controlled at constant temperature. The starting temperature difference between the hot and cold side surfaces (during the steady state temperature condition) shall be 35 °C. The assessment can be repeated for increasing or decreasing temperature differences, in steps of 5 °C (e.g., 40 °C, 45 °C and further or 30 °C, 25 °C and further). As an option to reduce the number of assessments, the manufacturer can state a starting value for the assessments. In case of mechanical failure of any of the specimens, the test procedure is to be aborted.

Once the heating operation started:

- The inside air temperature of the chamber, controlled with an accuracy of ± 1°C, shall be recorded.
- The outside air temperature of the chamber, i.e., the laboratory room temperature, shall be constant and shall be recorded,
- The outside and inside surface temperature shall be continuously recorded from the thermocouples.

Once the equilibrium of temperatures has been obtained (beginning of steady state, left most dashed line in Figure F.4.1), the outside and inside temperature shall be maintained for at least 1 hour (end of steady state, right most dashed line in Figure F.4.1). The difference of temperature shall be controlled in the range of 5% during the steady-state temperature condition.

F.4 Determining the heat transfer coefficient

The heat transfer (surface exchange coefficients) coefficient at the centre of the specimen on the hot and cold sides, shall be calculated with the following equations:

$$h_{hot} = \frac{\frac{\Delta T_2}{\Delta T_1}}{R} \qquad \text{(eq. F.4.1)},$$

and

$$h_{cold} = \frac{\frac{\Delta T_2}{\Delta T_3}}{R} \quad \text{(eq. F.4.2)}$$

Where:

- h_{hot} is the heat transfer coefficient on the hot surface of the specimen [W/(m²K)]
- h_{cold} is the heat transfer coefficient on the cold surface of the specimen [W/(m²K)]
- ΔT_1 is the average value, under steady state temperature condition, of temperature difference between hot side air and hot side glass surface $\Delta T_1 = t_{i1} - t_{i2}$ [°C]
- ΔT_2 is the average value, under steady state temperature condition, of temperature difference between hot side glass surface and cold side glass surface $\Delta T_2 = t_{i2} - t_{e2}$ [°C]
- ΔT_3 is the average value, under steady state temperature condition, of temperature difference between cold side glass surface and cold side air $\Delta T_3 = t_{e2} - t_{e1}$ [°C]
- R is the thermal resistance of the specimen $R = 1/U$.

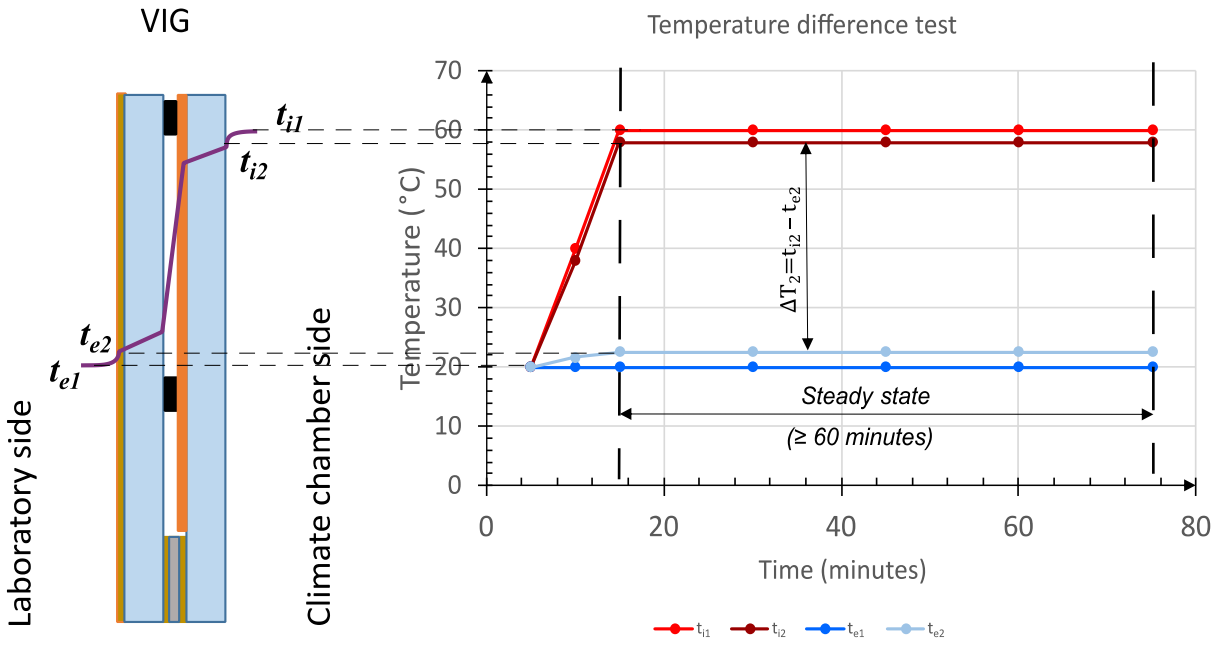


Figure F.4.1 – Temperature difference test – temperature reference and temperature conditions (example for ΔT_2 = 35 °C)

The calculated heat transfer coefficient on the hot surface of the specimen, h_{hot}, and the heat transfer coefficient on the cold surface of the specimen h_{cold} shall be maintained in the range (8,0 ± 2,0) W/(m²K), obtained by controlling the air circulation, as for higher or lower values of these heat transfer coefficients the accuracy and repeatability of the measurements are negatively influenced.

F.5 Method of assessing

During the steady state temperature condition, the invariability of the value of ΔT_2 is indicative of the invariability of the U-value of the (L)VIG. A substantial drop in the value of ΔT_2 is indicative of a substantial increase in the U-value of the (L)VIG, which itself is indicative of a mechanical failure of the (L)VIG.

The relative change in the temperature difference at hot and cold surface of the specimen ΔT_2 between the beginning and the end of the steady state temperature condition (zone between dashed lines in Figure F.4.1) ΔT_c [%] shall be calculated using the following equation:

$$\Delta T_c = \frac{\Delta T_e - \Delta T_b}{\Delta T_b} \times 100\ [\%] \quad \text{(eq. F.5.1)}$$

Where

- ΔT_b is the temperature difference between the hot and cold side of the glass surfaces ΔT_2 at the beginning of the steady state temperature condition of the test [°C]
- ΔT_e is the temperature difference between the hot and cold side of the glass surfaces ΔT_2 at the end of the steady state temperature condition of the test [°C]

The highest value of ΔT_2 for which no mechanical failure was observed shall be stated in the ETA.

F.6 Test report

The test report shall at least contain the following items:

a) Specimens description (e.g., manufacturer's name, product name or other reference, etc.)
   - length [mm],
   - width [mm],
   - nominal thickness [mm]
b) Description of the test apparatus, including:
   - manufacturer's name and model, if using a commercially available apparatus
   - inside dimensions of the chamber, i.e., height, width and depth [mm]
   - dimensions and material of the wind protection board located inside the chamber, if used [mm]
c) Measurement and calculation results
   - U-value of each specimen [W/(m²K)]
   - The temperature difference between hot side glass surface and cold side glass surface ΔT_2 during the steady state temperature condition.
   - The calculated arithmetic mean value of the relative change in surface temperature ΔT_c *[%]*
d) Any change to the aspect of the specimens, visible without instrumentation, at the end of the assessment, which would be an indication of mechanical failure of a glass pane or the hermetic edge seal.