04

SECTION 4
Products, Glazing Techniques and Maintenance

4.10 Appearance and Visual Quality for Insulating Glass Units (IGUs)

Appearance and Visual Quality Specification for Insulating Glass Units

Contents

Introduction

The appearance/visual quality of an insulating glass unit (IGU) is dependent on the following: -

- Optical quality of the component glass panes, i.e. distortion inherent during the manufacture of the glass pane;
- Visual quality of the component glass panes, i.e. number/size/type of defects;
- Inherent characteristics of an IGU, i.e. behaviour of a hermetically sealed body;
- Processing, handling, and glazing techniques.

1. Scope

This Datasheet details all appropriate optical and visual quality factors of the glasses used to manufacture the IGU that influence the appearance of an installed IGU.

The major criteria is the view through the IGU from the inside of a building. This is covered in detail within this Datasheet. However, it is appreciated that the appearance from the outside of the building, i.e. in reflection, can also be important in certain applications and some non-specific comments are made on this subject.

NOTE: Due to the specialist nature of fire resistant glass, the optical and visual quality of fire resistant IGU's is not covered in detail within this Datasheet.

2. Definitions

For the purpose of this Datasheet the following definitions apply: -

2.1 Appearance

The overall effect on the observer when looking at objects through the IGU.

2.2 Optical quality

The appearance of an object when observed through the glass.

2.3 Visual quality

The effect of faults, e.g. spot, linear extended, etc., on the vision through the glass.

2.4 Transparent glass

Glass that transmits light and permits clear vision through it.

2.5 Textured and translucent glass

Glass that transmits light with varying degrees of light scattering so that vision is not clear, providing some privacy; or glass that had been sand blasted or acid etched, or laminated glass with a white interlayer making the glass translucent.

2.6 Insulating glass unit (IGU)

An assembly consisting of at least two panes of glass, separated by one or more spacers, hermetically sealed

Glass and Glazing Federation
40 Rushworth Street, London SE1 0RB
Tel: 020 7939 9100 Fax: 0870 042 4266
www.ggf.org.uk

along the periphery, mechanically stable and durable.

2.7 IGU Types

BS EN 1279 now classifies IGUs as follows: -

Type A: Used for installation without shear load in the sealant and protected against direct UV exposure on edge seal (e.g. fully beaded window).

Type B: Used for installation with at least one edge not completely protected against direct UV radiation without permanent shear load in the sealant.

Type C: Used for installation as bonded glazing for doors, windows and curtain walling with possible shear load on edge sealant with or without direct UV radiation exposure.

2.8 Condensation

The presence of moisture and/or other liquid on a glass surface either inside or outside the IGU.

- Interstitial - Condensation that occurs within the hermetically sealed cavity of the IGU.
- Peripheral - Condensation that occurs on the inside, i.e. room surface, of the IGU around the edge of the unit adjacent to the frame.
- External - Condensation that occurs on the external, i.e. outside surface of the IGU.

3. Glass types

3.1 General

The IGU manufacturer uses glass panes within the IGU that comply with other standards as to their optical and visual quality. In general the IGU manufacturer cannot alter these quality characteristics. During the IGU manufacturing process, and in subsequent handling, there is a risk that further visual faults, e.g. scratches, scuffs, could be added to the external surfaces in addition to those already present in the components.

The standards relating to the appropriate glass products will detail their optical and visual quality appertaining to the individual pane.

3.2 Basic and special basic glasses

These are annealed glasses that comply with one of the following standards: -

BS EN 572 - Parts 2 to 6 or Part 8

BS EN 1748 - 1

BS EN 1748 - 2

BS EN 14178 - 1

BS EN 15681 - 1

NOTE: Typically annealed soda-lime silicate glass, i.e. BS EN 572 is used. Specialist glasses are normally used for specific purposes.

3.3 Toughened, toughened and heat soaked, or strengthened glasses

These are annealed glasses that have been thermally or chemically treated to modify their strength and breakage characteristics.

They will comply with one of the following standards: -

BS EN 1863 - 1

BS EN 12150 - 1

BS EN 12337 - 1

BS EN 13024 - 1

BS EN 14179 - 1

BS EN 14321 - 1

BS EN 15682 - 1

3.4 Laminated glasses

These are annealed, toughened, heat soaked or heat strengthened glasses, in any combination, that have been combined with an interlayer(s) to produce a product with modified characteristics.

These modifications will affect one or more of the following: -

- post-breakage behaviour
- spectrophotometric characteristics
- acoustic characteristics
- resistance to penetration

They will comply with the following standards:

BS EN ISO 12543 - Parts 1 - 6,

BS EN 14449

3.5 Coated glasses

A glass substrate of any of the above, that either incorporates a coating within the glass surface or has had a coating applied to the surface. The coatings are designed to modify the spectrophotometric characteristics of the glass. They will comply with the following standard: -

BS EN 1096 - Parts 1 - 3

4. Optical Quality

4.1 General

The optical quality of a glass component is the result of the following: -

- the method of manufacture of the glass component;

together with

- the effect of any subsequent processing.

4.2 Basic and special basic glasses

The optical quality of transparent glass is entirely dependent on the manufacturing method.

Generally glass made by the float process has less distortion and manufacturing faults than drawn sheet glass. Depending on the specific product, e.g. drawn sheet glass, there may be a number of classes for optical quality.

Polished wired glass can be visually as good as float glass, but the presence of the wire mesh may affect the optical appearance and it has its own section within the standards.

Translucent glasses, i.e. cast, patterned and wired patterned are all textured glasses with varying degrees of light scattering disruption.

These glasses do not have a specific optical quality as they are designed to disrupt vision through the product.

4.3 Toughened or strengthened glasses

Thermal toughening and heat strengthening processes may adversely affect the optical quality of the float or drawn sheet glass that is processed.

The heating and cooling of the glass during the process can result in imperfections that will reduce the optical quality e.g.:-

- bow, overall and/or local,
- roller wave distortion
- edge lift/dip

NOTE 1: Details on allowable bow and how it is measured are given in the product standards. Specific details relating to roller wave, edge lift/dip including the method of measurement, are given in GGF Datasheet 4.4.

NOTE 2: Any lack of flatness with thermally treated glasses can produce problems with reflected images. See Annex A for an example. Chemical strengthening is less likely to affect the optical quality of the unprocessed glass.

4.3.1 Specific effects of thermal treatment process

The process may give rise to:-

- A degree of haze, i.e. a cloudy look to the surface and/or
- Cause an effect that is known as anisotropy (iridescence).

Anisotropy is the result of stress patterns in the cross section of the glass becoming visible. These areas of stress produce a birefrigent effect in the glass, which is visible when viewed in polarised light. These areas show up as coloured zones, sometimes referred to as 'leopard spots'. The haze and bi-refrigent effects are more noticeable at glancing angles. These are not considered as faults.

4.4 Laminated glasses

The optical quality of laminated glass is dependent on the following: -

- type and number of glass panes
- type, thickness and number of interlayer(s)
- presence or not of plastic glazing sheet materials
- laminating process, e.g. folio, cast in place, etc.

Generally folio lamination processes, i.e. ones using an interlayer such as pvb, eva and pvc have only minor influences on the optical quality of the final product. The degree of influence will increase with more panes of glass and more/thicker interlayers as each ply has the potential for faults.

Details on allowable bow and how it is measured are given in the product standards. Specific details relating to roller wave, including method of measurement, is given in GGF Datasheet 4.4.

Cast in place laminating is more likely to result in a product that does not have parallel faces, and hence distortions may occur.

Problems may arise with slight discrepancies in uniformity of curing of the interlayer that may produce refractive index discrepancies.

NOTE: Further information on laminated glass is given within GGF Datasheet 4.11

4.5 Coated glasses

The optical quality of coated glass is dependent on the following: -

- type of glass substrate
- type, thickness and make-up of coating, e.g. single or multilayer,
- coating process, e.g. on-line, off-line, etc

Generally the addition of a coating to a glass substrate does not significantly alter the optical quality. Therefore the optical quality of a coated glass is that of the substrate. Coatings are added to influence thermal efficiency, solar control, reflective properties, or cleaning attributes, and may change the light transmittance or reflectance of the product. However, as the majority of coatings work due to thin film interference effects there can be a perceived change if there is a lack of uniformity in the coating. Similarly these thin coatings can offer variations in colour that can appear as a lack of uniformity.

Some low-e coatings on glass may produce a haze, i.e. a cloudy look to the surface, when viewed in oblique lighting (see 7.3).

NOTE: Pigmented or decorative coatings are not included within this reference.

5. Visual Quality

5.1 General

The visual quality of a glass component is the result of the following: -

- method of manufacture of the glass component; together with
- the effect of any subsequent processing and handling.

NOTE: Specialist glass types, e.g. fire resistant, may not have the same optical/visual qualities as basic glass.

5.2 Basic and special basic glasses

The visual quality can be found for stock and final cut sizes in the product standards (see 4.2). The exception is basic soda lime silicate glass products which are given in BS EN 572 Part 8.

Cutting down of stock plates into final cut sizes, i.e. panes for further processing, is an opportunity to reduce the number and size of inherent spot and/or linear extended faults. However, care should be taken to ensure that the cutting process does not introduce other defects, e.g. scratches.

The visual quality of textured glasses also depends on the following: -

- pattern type/depth
- directionality of the pattern
- wire mesh uniformity, squareness, alignment etc.

Quantification of these parameters can be found in the appropriate product standards.

Generally the visual quality is higher for a transparent glass than for a textured or translucent glass. With textured glasses the light scattering reduces the visible impact of the faults. Therefore the greater the degree of light scattering the less likely is it that any specific fault is visually disturbing.

5.3 Toughened or strengthened glasses

As these products are manufactured from final cut sizes then the processing should not alter the basic visual quality of the glass.

However, the cutting, edge working and toughening/strengthening could impart additional scratches/scuffs onto the glass surface.

These processing faults will affect the visual quality.

The thermal treatment process may result in small imprints in the surface ('roller pick-up'). This usually only applies to horizontally processed glass of 6mm or thicker

5.4 Laminated glasses

The visual quality of laminated glass depends on the following: -

- component glass panes
- interlayer type, thickness
- laminating process
- cutting/sawing to final cut size

The manufacture of stock size laminated glass is influenced by the visual quality of the initial stock size glass panes used. These panes will have a visual quality in accordance with the product standards (see 3.2). The visual quality of the laminated glass may be worse than that of any component pane. Therefore the greater number of glass panes within a laminated glass the greater the likely number of defects (see BS EN ISO 12543 Par t 6).

With selective cutting of finished sizes from stock plate of laminate glass some defects can be avoided in the final product.

Further faults can be introduced during the laminating process due to faults in the interlayer, and entrapment of any contamination between the layers. Defects can appear as bubbles, opaque spots, foreign bodies, and creases in the interlayer.

Cutting, sawing and edge working can impart scratches etc. The thicker/heavier the laminated glass then the higher is the probability of increasing the visual defects during these processes. This applies to all glass types.

5.5 Coated glasses

The visual quality of coated glass depends on the following: -

- component glass panes
- coating type, colour, spectrophotometric properties
- coating process
- cutting to final size

The presence of a coating on a glass substrate may increase the visibility of a spot fault or linear extended fault within the substrate.

Similarly faults within and/or on the coating, e.g. pinholes, scratches, scuffs, non-uniformities, etc., may decrease the visual quality. These effects are more pronounced with coatings that are highly coloured and/or highly reflective.

The likelihood of the visual quality being decreased is dependent on both the type of coating and the number of steps involved within the manufacturing process.

Generally on-line coating is inherently more resistant to scratching, etc. than are off-line coatings. Certain 'off-line coatings need special processing, i.e. edge deletion, prior to incorporation into an IGU.

This abrasion process can also result in decreased visual quality.

With multiple pane units any distortion or reflection is multiplied as the number of panes increases. Multiple reflections are not a fault.

In the case of heat treated glasses with coatings in multiple paned units, the effect can be significant. Any minor distortion will be exaggerated but this should not be deemed a failure.

6. Inherent characteristics of IGUs

6.1 General

An insulating glass unit as defined is a glass product that contains hermetically sealed space(s).

There are many designs of IGU. The major variations are as follows: -

- Glass components
- Glass composition e.g. soda lime silicate borosilicate

  glass ceramic alkaline earth silicate alumino silicate
- Annealed glass e.g. float drawn sheet patterned wired
- Coated glass
- Thermally treated glass
- Heat strengthened soda lime silicate glass
- Thermally toughened soda lime silicate safety glass
- Thermally toughened borosilicate safety glass
- Thermally toughened alkaline earth silicate safety glass
- Heat soaked thermally toughened soda lime silicate safety glass
- Heat soaked thermally toughened alkaline earth silicate safety glass
- Laminated glass
- Spacers
- Metallic hollow to hold the desiccant
- Composite either hollow to hold desiccant or incorporating a desiccant matrix
- Organic incorporating the desiccant
- Airspace
- Air filled
- Gas filled e.g. argon
- Vacuum
- Sealant systems
- Single seal e.g. hot melt
- Dual seal e.g. PIB as primary seal with polysulphide polyurethane silicone or hot melt as a secondary seal

The primary function of an IGU is to improve the thermal efficiency of the window

NOTE 1: IGUs incorporating more than two panes of glass have characteristics that may have an impact upon the appearance (See 6.5)

NOTE 2: IGUs which are manufactured using special glass types e.g. fire resistant, may not give the same optical/visual quality as units manufactured from soda lime silicate glass.

6.1.1 Characteristics of the hermetically sealed cavity

The properties of a hermetically sealed cavity will change dependent on the following:

- temperature and barometric pressure when the cavity was sealed
- actual air temperature and barometric pressure
- temperature of the air or gas within the cavity as a result of radiation etc.
- thickness of the glass

These changes will result in a volume change in the cavity.

This will result in the unit taking up either a concave or convex shape. This shape will cause a number of phenomena to become apparent (see 7.2, 7.3, 7.4).

6.2 Condensation

An IGU is designed to reduce the heat loss through the glazing. This means that, compared to single glazing, the incidence of moisture condensing on the room side glass surface is reduced.

However, condensation can still occur as follows: -

Interstitial - when either the unit seal has failed or the cavity is saturated with moisture. Under these conditions the appearance of condensation on one or both cavity surfaces can occur subject to the glass surface temperature.

Internal - when the relative humidity within the room is extremely high and the glass surface is cold, i.e. in a kitchen, bathroom, etc. with large amounts of steam/ moisture present.

Peripheral internal - this occurs with units having low U-values and is the result of localised heat flow through the spacer bar within the unit.

NOTE: Using a combination of a thermally efficient window profile and ‘warm edge technology’ within the IGU can help to reduce this.

External - this occurs with units having low U-values that significantly reduces heat loss. Under localised climatic conditions this can lead to moisture condensing onto the outside surface of the unit. This is not a fault, but rather demonstrates that the product is thermally efficient.

NOTE: Further information on condensation can be found within the GGF leaflet - Condensation: Some Causes Some Advice.

6.3 Fogging

Interstitial UV fogging (sometimes seen as a rainbow effect) may occur if unwanted elements are present which become visible under certain conditions or when an internal component, e.g. Georgian bars, etc., has deteriorated and given off organic solvents.

6.4 Interference phenomena

These are visual phenomena, similar to oil on water, and are the result of light interference patterns due to the IGU glass panes deflecting in relation to each other.

6.4.1 Brewster’s fringes

These are a visual effect seen as a rainbow within the unit. They are not a deterioration of the unit or the glass, but an effect created when light passes through two panes of glass that are parallel and of the same thickness. The resulting light refraction becomes visible as a rainbow effect.

Brewster’s Fringes can be confirmed by pressing one surface of the unit. The rainbow effect will move and colours change as the surface is depressed and released.

This phenomenon is not a defect of the product and is solely dependent on the laws of physics.

NOTE: The effect can be avoided by using different thicknesses of glass for each pane of the IGU.

6.4.2 Newton’s rings

This visual effect is created when the central area of the glass panes making up an IGU come into close proximity to each other or in fact touch. It will appear as a circular or semi-circular rainbow effect in central areas of the unit.

This could be the result of one or more of the following: -

- Incorrect air space for the unit size
- Manufacturing faults
- Temperature related pressure changes

- Improper pressure equalisation
- Barometric changes

6.5 Wetting of Glass Surfaces

The appearance of the glass surfaces can differ due to the effect of rollers, fingerprints, labels, suction holders, sealant residues, silicone compounds, smoothing agents, lubricants, environmental influences etc. This can become evident when the glass surfaces are wet by condensation, rain or cleaning

6.6 Multiple images

As a result of the number of reflective surfaces (four in an IGU with two glass panes manufactured from monolithic glass) there exists the likelihood of multiple images being formed. This is only of minor significance when the observer is looking directly through the IGU, i.e. at normal incidence. However this will increase considerably as the angle of incidence becomes more oblique.

The presence of other reflective surfaces, e.g. laminated glass, coatings, may enhance the phenomena. Also any deflection effect within the unit may have an influence.

As the number of panes increases, such as triple glazed IGU's, this can further enhance the presence of multiple images. These are unavoidable.

NOTE: To alleviate the risk of thermal stress to a triple glazed IGU, the centre pane would generally be heat treated. This may have an effect on the visual appearance of the unit

Annex B will give a diagrammatic representation of the phenomena resulting from the inherent properties of an insulating glass unit.

6.7 Reflected image

As a result of the hermetically sealed cavity of an IGU the glass will deflect with changes of temperature and pressure. The result of this is that the reflected images can appear separated. This will be further exacerbated by the presence of multiple images that are being displaced different amounts.

The likelihood of this occurrence is dependent on the extent of the deflection in the IGU as a result of the difference in atmospheric temperature and pressure between the manufacturing conditions and the service conditions.

The effect may be more noticeable when reflective coatings are incorporated within the IGU.

Annex B will give a diagrammatic representation of the phenomena

resulting from the inherent properties of an insulating glass unit.

7. Appearance

7.1 General

Appearance relates to the limitations that are placed upon the insulating glass unit manufacturer. These limitations are as a result of the following: -

- Incoming glass components,
- Specification of the unit,
- Inherent properties of the unit,
- Framing and glazing systems.

The perceived appearance of an installed IGU can be adversely affected by distortions induced by the framing system and the installation.

7.2 Normal incidence

The IGU should be viewed at normal incidence, i.e. at 90° to the glass surface and viewed looking through not at the glass surface.

For IGUs containing transparent glass components the appearance relates to the vision through.

For IGUs containing textured or translucent glass components the appearance relates to the visual quality of the textured or translucent glass component.

7.3 Oblique incidence

The effects such as multiple images, haze, etc. are inherent characteristics of an IGU when viewed at oblique angles of incidence.

7.4 Reflection

Not generally considered. See Annexes A and B for further information.

8. Method of assessment

8.1 General

The standards for the component glass panes detail the method of observation and the distance and criteria for acceptance. These are given in the applicable European standard, i.e. BS EN 1279-1.

NB: Damage caused by following trades after glazing will not be considered as a fault of the installer.

For example damage can be caused by impact, scratching, deposit of plaster, cement, etc. and weld spatter and spatter from cutting tools.

For this reason, viewing IGUs for scratches or other damage on the outer faces of the panes **must** be carried out before any following trade's works adjacent to the glazing, and as early as reasonably practicable following installation of the IGUs.

8.2 General Conditions for Inspection

The IGUs shall be viewed at near normal incidence, i.e. at right angles, to the glass surface from the inside the building, standing at a distance of not less than 3 metres away from the inner glass surface.The assessment of visual quality of the panes of glass should be carried out in natural daylight but not in direct sunlight and with no visible moisture on the surface of the inner or outer glass panes. The use of strong lamps and/or magnifying devices is not allowed.

It is not permissible to find defects at close range and then mark them so as to be visible from the given viewing distance.

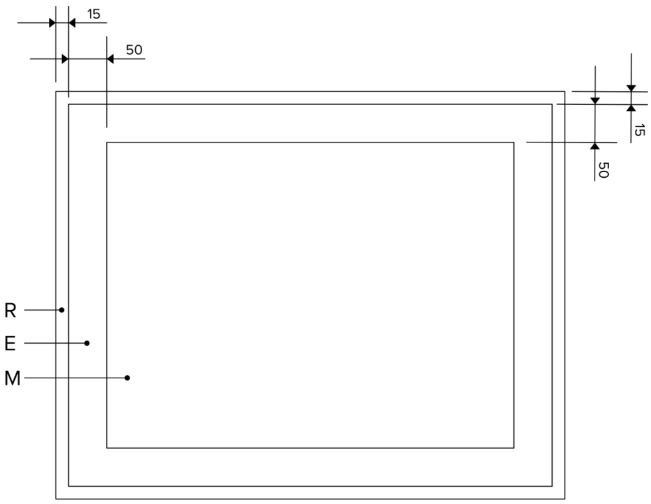
Obtrusiveness of faults shall be judged by looking through the glass, not at it.

A time limit of 1 minute per m^2 is allocated for viewing.

If IGUs have to be assessed from the outside then it will be in the installed consideration and viewed from a minimum of 3m.

NOTE 1: This does not apply to textured or translucent glasses. (See 7.2)

NOTE 2: Triple glazed IGUs have special characteristics that may affect the visual quality. (See 6.5).



8.3 Glass observation zones for inspection

Zone R represents the 15mm perimeter around the glass, normally covered by the frame, or corresponding to the edge seal.

Zone E is the area nearest to Zone R with a width of 50mm.

Zone	Size of fault (excluding halo) (⌀ in mm)	Size of the pane S (m2)			
		S ≥ 1	1 < S ≤ 2	2 < S ≤ 3	3 < S
R	All sizes	No limitation			
E	⌀ ≤ 1	Accepted if less than 3 in each area of ⌀ ≤ 20cm			
	1 < ⌀ ≤ 3	4	1 per metre of perimeter		
	⌀ > 3	Not Allowed			
M	⌀ ≤ 1	Accepted if less than 3 in each area of ⌀ ≤ 20cm			
	1 < ⌀ ≤ 3	2	3	5	5 + 2/m2
	⌀ > 3	Not Allowed			

Zone M is the main area of the IGU

Zone	Dimensions and type (⌀ in mm)	Pane area S (m2)	
		S ≤ 1	1 < S
R	All	No limitation	
E	Spots ⌀ ≤ 1	No limitation	
	Spots 1mm ⌀ < 1 ≤ 3	4	1 per metre of perimeter
	Stain 1mm ⌀ ≤ 17	1	
	Spots ⌀ > 3 and stains ⌀ > 17	maximum 1	
M	Spots ⌀ ≤ 1	Maximum 3 in each area ⌀ ≤ 20cm	
	Spots 1 < ⌀ ≤ 3	Maximum 2 in each area of ⌀ ≤ 20 cm	
	Spot ⌀ > 3 and stain ⌀ > 17	Not accepted	

Table F.1 Allowable number of Spot Faults

Table F.2 Allowable number of residue spots and stains

Zone	Individual lengths (mm)	Total of Individual lengths (mm)
R	No limitation	
E	≤ 30	≤ 90
M	≤ 15	≤ 45

Table F.3 Allowable number of linear / extended faults

8.4 Insulating glass units other than made of two monolithic glass panes.

The allowable number of discrepancies defined in F.3 is increased by **25% per additional glass component** (in multiple glazing or in a laminated glass component). The number of allowable defects is always rounded up.

Examples: -

Triple glazed unit made of 3 monolithic glass, the number of allowable faults is multiplied by 1.25%.

Double glazed unit made of two laminated glasses with 2 glass components, the number of allowable faults of F.3 is multiplied by 1.5

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8.5 IGU containing a heat treated glass

The visual quality of thermally toughened glass or heat soaked glass when assembled in an IGU or in a laminated glass within an IGU must meet the requirements of the relevant standard.

In addition, the overall bow to the total glass edge length may not exceed 3mm per metre glass edge length. This may be greater in panels square or near square panels (up to 1:1.5) and for glass with a nominal thickness < 6mm.

8.6 Edge Defects

Allowable edge defects are given in the relevant standard for each glass pane component.

External shallow damage to the edge or conchoidal fractures which do not affect the glass strength and which do not project beyond the width of the edge seal are acceptable.

Internal conchoidal fractures without loose shards, which are filled by the sealant, are acceptable.

8.7 Tolerances on spacer straightness

For double glazing the tolerance on the spacer straightness is 4 mm up to a length of 3,5 m, and 6 mm for longer lengths. The permissible deviation of the spacer(s) in relation to the parallel straight glass edge or to other spacers (e.g. in triple glazing) is 3 mm up to an edge length of 2,5 m. For longer edge lengths, the permissible deviation is 6 mm.

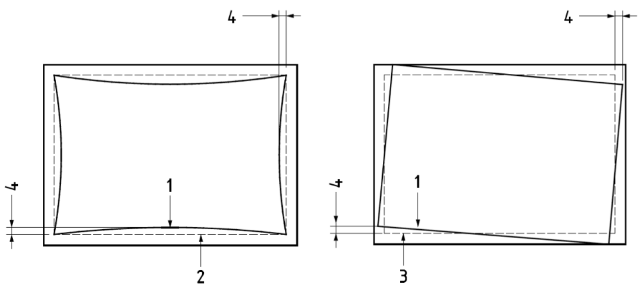

Figure F.2 shows examples of deviation of spacer position.

Figure F.2

Key
1. Spacer
2. theoretical shape of the spacer
3. theoretical position of the spacer
4. deviation

8.8 Curved IGUs

The visual quality of curved IGUs and their glass components shall fulfil the requirements of ISO 11485-1 and 11485-2.

9.0 Acceptance Criteria

Acceptance criteria relate strictly to the inherent characteristics of an IGU or of the glasses used to make up an IGU, such as: -

- totally enclosed seeds,
- bubbles or blisters;
- hairlines or blobs;
- minute embedded particles;
- inherent faults and fine scratches on coated glasses.

IGUs with optical defects such as smears, finger prints or other dirt on the cavity faces of the glass or extraneous material inside the IGU cavity are unacceptable if outwith the limits set in table F2, and this applies also to any such defects within the 50mm edge zone if they are visibly disturbing.

IGUs shall not be deemed unacceptable for any phenomena relating to the inherent characteristics of an IGU with the exception of 'Newton's Rings' (see 6.4.2.)

When viewed in accordance with Section 8.2 above the IGU will be deemed acceptable as long as, where appropriate the criteria below is followed: -

- there are no defects noticed that are mutually agreed to be visually disturbing
- any defects that are noted comply with the visual quality, (see 7 & 8), for the glass component
- any visual disturbance, e.g. from roller wave, bow, etc., is within the tolerances given in the appropriate product standard
- coated glass quality, e.g. pinholes, colour variation, etc. comply with the appropriate product quality
- there is no distortion as a result of the framing system or the installation.

NOTE 1: Condensation on the internal or external surfaces of the IGU should be removed before carrying out the inspection.

NOTE 2: Interstitial condensation is not allowed.

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[20] EN 15682-1, *Glass in building - Heat soaked thermally toughened alkaline earth silicate safety glass - Part 1: Definition and description*

[21] prEN 16612:–2), *Glass in building - Determination of the load resistance of glass panes by calculation and testing*

[22] prEN 16759, *Bonded Glazing for doors, windows and curtain walling - Verification of mechanical performance of bonding on aluminium and steel surfaces*

[23] ISO 11485-3, *Glass in building - Curved glass - Part 3: Requirements for curved tempered and curved laminated safety glass*

[24] ISO/CD 19916-1, *Glass in building - Vacuum Insulating Glass -Part 1: Basic specification of products and evaluation methods for thermal and sound insulating performance*

Annex A

Appearance in reflection

With multiple pane units any distortion or reflection is multiplied as the number of panes increases. Multiple reflections are nota fault.

The following descriptions and diagrams refer to double glazed units. Triple glazing will further enhance the effects.

1. Problem due to lack of flatness

1.1. General description

A glass, especially one that is thermally treated, can rarely be glazed perfectly flat. This may be due to the framing system, glazing system, installation and the inherent flatness of the glass.

Imagine a rectilinear feature, e.g. a telegraph pole, some 10 metres from a glazed panel. The observer is viewing the featureby reflection from a similar distance.

If the plane of the glazing changes by one tenth of one degree, 0.1° between two points on its surface, then the viewer will seeeither two images apparently displaced by 70mm or one image distorted by this amount.

1.2 Is one tenth of one degree, 0.1°, significant?

YES. This amount of flatness change is equivalent to a deflection of 0.8mm over a one-metre length.

This should be compared with the allowable deflection limits forccframing, i.e. L/125 for single glazing, L/175 for double glazing.

This would mean for an L of one metre deflections of either 8mm for single-glazing or 5.7mm for double-glazing.

Deflections of greater magnitude can occur due to wind-loading.

For thermally treated glass, i.e. thermally toughened, heat strengthened, etc., the standards allow overall bows of 2mm/metre and local bows of 3mm/metre.

For insulating glass units the deflection due to barometric/temperature effects can be significantly greater than 0.8mm/m.

1.3 Optical explanation

Figure A1 shows the geometry involved.

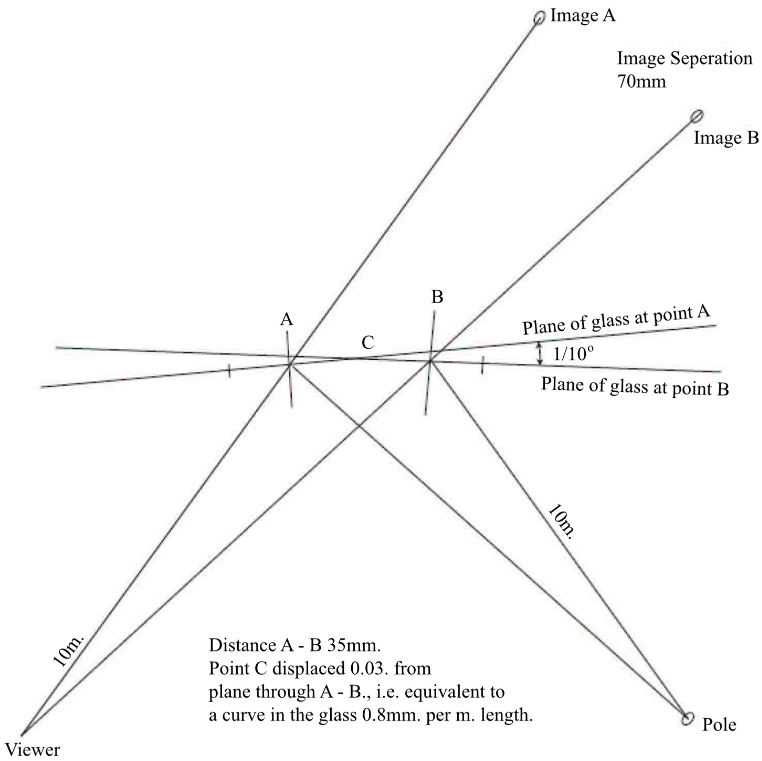

Figure A1 Explanation of lack of flatness

Annex B

Diagrammatic explanation:

With multiple pane units any distortion or reflection is multiplied as the number of panes increases.

Multiple reflections are not a fault.

The following descriptions and diagrams refer to double glazed units. Triple glazing will further enhance the effects.

1. Multiple images

1.1. General

When light meets a smooth glass surface; some is transmitted through, some is reflected and some is absorbed.

It is a law of physics that the angle of incidence is equal to the angle of reflection. Therefore if the incident ray is at normal incidence, i.e. at right angles to the glass surface then it is reflected directly back, (see Figure (B1(A)). If the incident ray falls obliquely on the surface then the reflected ray bounces back at

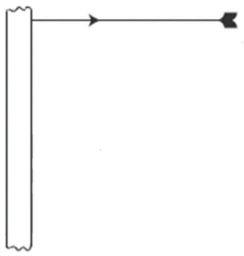

Figure B1(A)

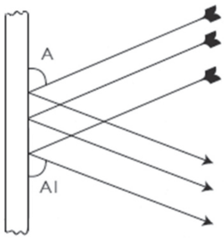

Figure B1(B)

the same angle but on the other side of the perpendicular. (See Figure (B1(B)).

1.2 Refraction

Another law of physics is that when a ray enters a medium of differing density it is bent (refracted).

When a ray enters the glass from the air the angle of refraction is less than the angle of incidence. Therefore when reflected from the second surface it is displaced with respect to the incident ray.

When the ray leaves the glass into the air the angle of refraction is greater than the angle of incidence.

Therefore when leaving the first pane of glass the ray is parallel to the incident ray but displaced.

A similar situation occurs when the ray meets the second pane.

For each pane of glass there are two reflected images, a

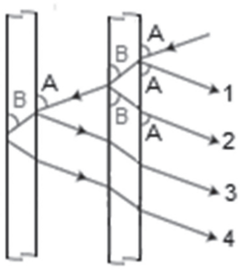

Figure B2

primary and a secondary image. The primary images result from surfaces 1 and 3 and the secondary images from surfaces 2 and 4. (See Figure B2).

1.3 Influencing factors

The following will increase the spacing between images:

- Increasing glass thickness,
- Increasing cavity width,
- Decreasing the angle of incidence.

The effects of coatings and body tints are dependent upon their spectrophotometric properties, i.e. transmittance, reflectance, absorbtance, and their position.

Generally body tinted glasses will enhance the primary image and reduce the secondary image produced by the pane. Coatings will enhance the image reflected from the coating.

2 Distorted images

2.1 General

When light rays strike a curved glass surface, they reflect in different directions. However, they will still obey the law that the angle of incidence equals the angle of reflection. Therefore the image of an object will be distorted. The curvature of the glass surface causes it to act as a lens.

2.2 Concave curvature

This is when the surface is bowed inwards.

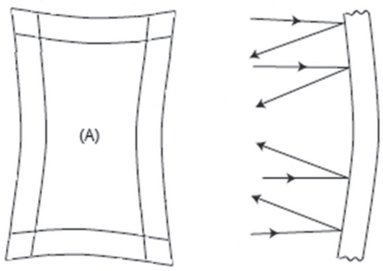

Figure B3 (A)

A concave curvature will cause the light rays to be projected inwards towards a central point. This causes the reflected image to appear short and thin. (See Figure B3 (A))

2.3 Convex curvature

This is when the surface is bowed outwards.

A convex curvature will cause the light rays to be projected outwards away from a central point. This causes the reflected image to be stretched out in all directions. (See Figure B3 (B))

The outcome of having different curvatures on the panes

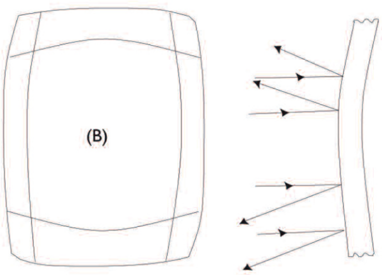

Figure B3 (B)

will result in some images being made smaller/thinner and others being stretched out.

NOTE: Figure B4 only examines the first reflection of the light ray.

2.4 Curvature in IGUs

When an IGU is subjected to barometric and/or temperature and/or altitude effects the whole unit will change shape.

If the effects on the unit cause it to shrink inwards then this

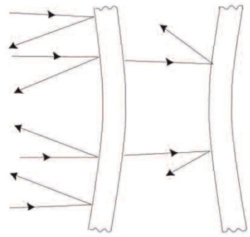

Figure B4 (A)
Surface 1 - Primary image - shrunk
Surface 3 - Primary image - spread out

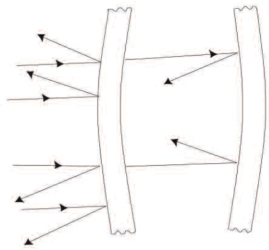

Figure B4 (B)
Surface 1 - Primary image - spread out
Surface 3 - Primary image - shrunk

will result in pane #1 being concave and pane #2 being convex, (see Figure B4 – Type (A)). Similarly if the effects on the unit cause it to swell outwards then this will result in pane #1 being convex and pane #2 being concave, (see Figure B4 – Type (B)).

The outcome of having different curvatures on the panes will result in some images being made smaller/thinner and others being stretched out.

NOTE: Figure B4 only examines the first reflection of the light ray.

3 Composite factors

The combination of multiple images, B1, and distorted images, B2, is extremely difficult to describe.

What is certain is that nothing can be done to stop these effects occurring.