Industry Standard
for

Visual Quality of Glass

(in Residential Buildings)

WG 46101.11-2024

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window & glass association nz

wganz.org.nz

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Introduction

Glass, whether it be clear, tinted, or coated, supplied for buildings in New Zealand is almost exclusively manufactured using the float process, where molten glass is floated on a bed of molten tin. Glass made using this process is extremely flat, however as with all manufactured products, it may contain imperfections.

The intent of this guide is to provide information for the assessment of glass glazed into frames and installed into Residential Buildings and only to the surfaces that remain visible after the installation of the pane into its supporting window or door frame.

The statements and tolerances included within the document are based on a mix of the applicable standards and industry best practices. However, in some cases this information may be overwritten by specific contractual conditions.

Consumer Expectations

Most believe glass to be a perfect invisible product that not only provides an uninterrupted view to the outdoors but also keeps the weather out. However, the reality is that like all man-made products and processes, glass is manufactured within a defined set of tolerances and will have imperfections.

It is expected that glass should be looked through and not looked at, issues often arise when a blemish or mark is noticed and they're unable to see past an imperfection.

When viewing, measuring, understanding the quality of a pane of glass, AS/NZS4667:2000 is the go-to Standard for the New Zealand glass industry. The intent of this guide is to aide in the understanding of the clauses within this standard that help explain what is acceptable and what is not.

Citing the standard offers little comfort to the consumer, because once the imperfection has been seen, it cannot be unseen, whether it is within tolerance or not.

Variety in Glass

A variety of options are available to consumers when selecting the glazing for their homes, each having their own unique function, performance, and aesthetic. Commonly used terms relating to glass might be float, annealed, laminated, toughened, and of more recent times Low-E.

Additionally, multiple panes of glass can be processed to make an insulating glass unit, referred to as an IGU, or double glazing. An IGU can be designed to enhance the glazing's acoustic, thermal, and/or structural performance.

Viewing of In-situ Glass - General

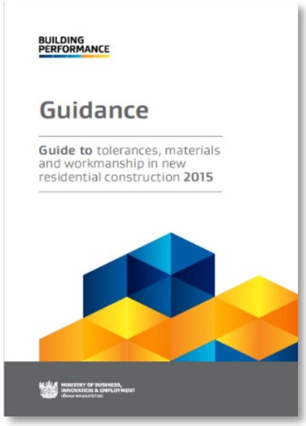
There are several standards that apply to the quality of glass, which will be referred to throughout this Technical Bulletin. This document takes reference from a number of sources to assist in the assessment of glass glazed into frames and installed into Residential Buildings. It applies only to the surfaces that remain visible after the installation of the pane into its supporting window or door frame.

What MBIE Has to Say

In 2015 the Ministry of Building, Innovation and Employment published a "Guide to tolerances, materials and workmanship in new residential construction", designed to provide assistance to contractors and homeowners who maybe unsure of what constitutes a defect under the Building Act of 2004.

The guide outlines what constitutes acceptable levels of workmanship in standard domestic construction types, under normal conditions.

Section 5 of the guide specifically relates to Windows & Doors. Naturally, glass also sits within this section and includes the following table.



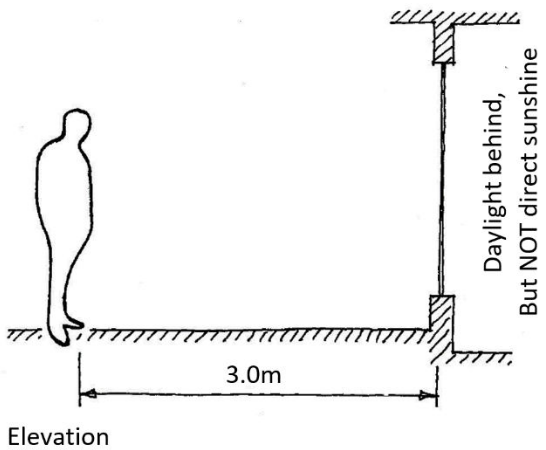
GLASS	
×	Glass is blemished, marked (e.g. scratches, mortar, stain, or paint spatter), distorts view or is poorly cut.
×	Inconsistent tint colour or appearance across the window.
×	The glass does not conform to the requirements set out in AS/NZS 4666:2012[29], or AS/NZS 4667:2000[30].
×	Where designers have provided appropriate information surrounding the end location of the glazing units, including wind zones and altitude to the manufacturer, Newtons Rings and excessive visual distortion are manufacturing defects.
✓	Brewsters fringes and preferential wetting patterns are not considered a defect.

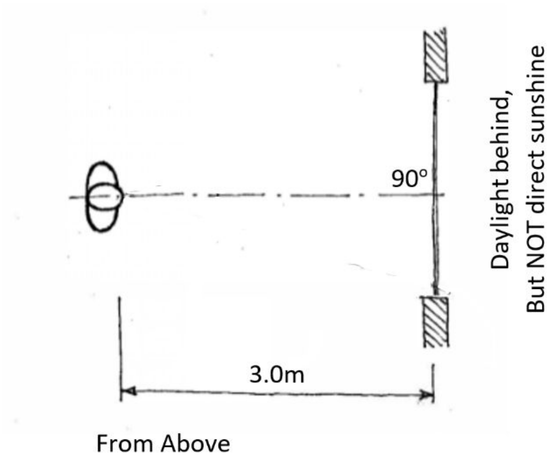
And this note…

The normal viewing position is at a distance of ≥2 m for both glass (with a sky background) and painted non-concrete surfaces (see Inspecting surfaces and fixtures).

Method of Viewing - Defect Inspection

As noted above, the MBIE guide to tolerances suggests a viewing distance of greater than or equal to 2m which is based on the viewing distances for paintwork and other surface finishes, whereas the viewing distances described within the glass standards are more appropriate when trying to understand the tolerances around glazing imperfections. The following images explain the standards.





Viewing distance and angle

Not only is the viewing distance and angle important, so too is the type of daylight you're looking into. Certainly, the glass can be viewed in the daylight, but it must not be direct sunshine.

Viewing conditions

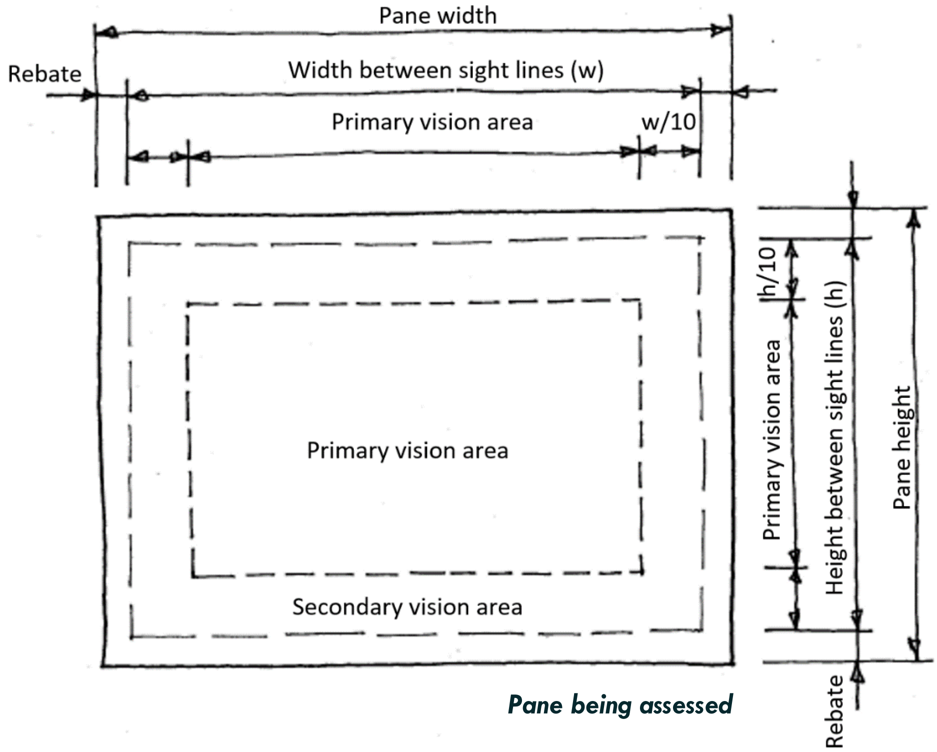
Primary Vision Area

International standards suggest any pane being assessed for defects shall meet the following criteria:

a) Defects viewed in the primary vision area are unacceptable if visible from a distance of 3m, as described in the Method of Viewing section.

b) Defects viewed in the secondary vision area may be acceptable depending on the type and size of the defect.

c) The Rebate area is the part of the pane that is contained within the frame and is not visible.



Pane being assessed

AS/NZS 4667:2000

AS/NZS4667:2000 - Quality Requirements for Cut-to-Size and Processed Glass is the go-to standard for the New Zealand glass industry. The standard describes a number of possible blemishes that may occur in flat glass.
The common blemishes are defined as follows,

Bow	Deviation for straightness or flatness.
Bubble	Gas filled cavity in the glass. May be spherical or elongated.
Distortion	Undulations in the glass which cause objects to appear distorted or wavy when viewed through the glass.
Inclusion	A particle entrapped in the glass.
Rub	Abrasion on the glass surface producing a frosted appearance. Differs from a scratch in that it has an appreciable width.
Scar	A scratch on the surface of the glass.
Scratch	Any marking of the surface produced during processing or handling appearing as though it were done by a sharp object.
Shell	A shallow piece of glass that has become detached from the plate edge.
Surface Imperfections	Slight surface imperfections that originated in the manufacturing process, which can be small particles of foreign material on either surface or surface irregularities.
Stain	Breakdown of the glass surface due to the presence of other chemicals, e.g. concrete splash.

The following clauses from AS/NZS4667:2000 are the most appropriate and provide a guide to the quality that can be expected of the glass.

> **Note**: single glazing and IGU's will have similar levels of visual quality.

Before inspection for blemishes, the glass should be cleaned in accordance with the manufacturer's recommendations.

Clause 9.2.5 - Scratches, scars and rubs
Inspect the glass held in a perpendicular position using daylight without direct sunlight, or with a background light suitable for observing any imperfections. Imperfections shall not be visible from a distance of 3m.

Clause 9.2.7 - Distortion
The manufacturer and the customer shall agree on the following:

a) The tolerances for surface distortion.

> **Note:** Clause 2.5 of AS/NZS2208:1996 refers to the flatness requirements for safety glazing materials in buildings.

b) The method of measurement and the magnitude of distortion.
Surface distortion shall not be measured within a 150mm band from the edge of the glass panel, as distortion in this area is a result of localized warpage.

> **Note:** Glass surface distortion is a normal attribute of heat-treated glass and varies between manufacturers. The distortion becomes pronounced as the angle of view becomes more acute.
> Roller wave distortion can only be measured on panes greater than 1100mm wide. It is measured at least 300mm from the glass edge and the peak-to-peak distortion should not exceed 0.2mm.
>
> **Note:** The NZ glass industry has agreed to a more stringent tolerance for distortion as noted later in this bulletin.

Distortion in Toughened Glass - Bow, Roller Waves, and Edge Kink

Glass surface distortion from bow, roller waves, and edge kink is a normal attribute of heat-treated toughened glass. It distorts objects when viewed through or reflected from the glass, and it is more pronounced when viewed from an angle.

Note: Non-coated glass may have different tolerances to coated and specialty glasses.

Acceptable bow limits are provided below in *Table 3 from AS/NZS 4667:2000*.

TABLE 3

BOW (FLATNESS) LIMITS FOR GLASS OF STANDARD NOMINAL THICKNESS (ALL TYPES)

millimetres

Glass thickness	Horizontal glass dimension		
	0 to 1500	1501 to 3000	3001 to 5000
3	1 in 200	1 in 150	—
4	1 in 200	1 in 150	—
5	1 in 300	1 in 200	1 in 200
6	1 in 350	1 in 250	1 in 200
8	1 in 400	1 in 300	1 in 250
10	1 in 400	1 in 300	1 in 250
12	1 in 400	1 in 300	1 in 250
15	1 in 400	1 in 300	1 in 250
19	1 in 400	1 in 300	1 in 250
25	1 in 400	1 in 300	1 in 250

NOTES:

1. Refer to Clause 9 for test methods.
2. Flatness measurements shall be checked against a straightedge with the panel standing within 5° of vertical and measurements taken horizontally.
3. For non-standard glass thicknesses, interpolation will be required.
4. Linear interpolation as defined in AS 1288 shall apply for non-standard thicknesses.

Note: Bow exceeding these limits *are* considered a defect.

Glass distortion can be pronounced in toughened laminated glass, especially when roller waves and/or edge kinks in the two sheets of glass coincide. Whenever possible, heat-treated glass should be installed with the roller waves positioned horizontally across the panels.

The New Zealand industry glass processers agree the tolerances on roller wave and edge kink, should be:

Roller wave = 0.15mm measured at least 300 mm from the leading or trailing edge

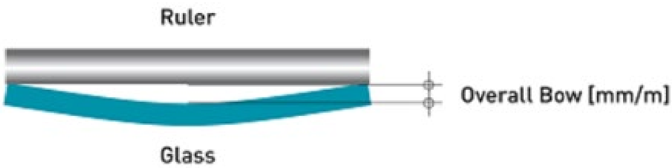
Edge kink = 0.30mm measured at least 300 mm from the leading or trailing edge

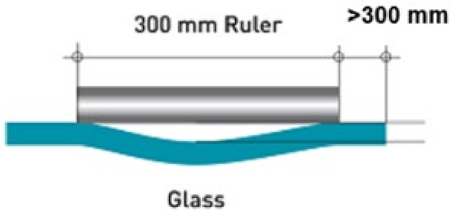
> **Note:** These tolerances may vary dependent on glass type. Consult your processer/ supplier if you have any questions.

Zebra board used for visual check of glass distortion during manufacture.

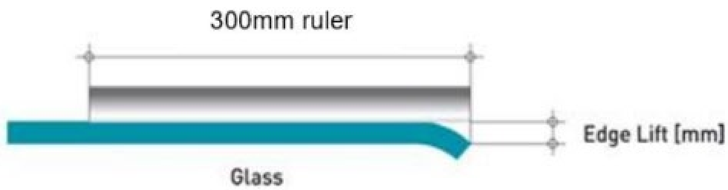
Roller wave and edge kink can be measured with a roller wave gauge, or a 300 mm steel ruler and feeler gauge as shown below.

Roller wave gauge *Feeler gauge*





Roller wave



Edge kink

Note: Glass distortion from roller wave and/or edge kink is *not* considered a defect.

Scratches, Blemishes, Marks, and Inclusions

The following section has been extracted from AS/NZS 4666:2012 - Insulating Glass Units was developed for surface imperfections and inclusions for glass up to 12 mm thick in IGUs but can also be applied to single glazed windows.

Table 5.5 from AS/NZS 4666:2012 describes allowable scars, bubbles, seeds and scratches within the primary vision zone and the periphery secondary zone.

Scratches to the primary vision area are unacceptable if visible when viewed for not more than 60 seconds in a perpendicular position from a distance of 3m using a daylight background.

Accumulative faults apply to any given glass size.

TABLE 5.5

ALLOWABLE SURFACE IMPERFECTIONS AND INCLUSIONS FOR GLASS UP TO 12 mm NOMINAL THICKNESS INTENDED FOR USE IN RESIDENTIAL INSULATING GLASS UNITS

IGU size mm (Up to)	Central primary vision zone mm	Ream		Scars		Bubbles		Seeds		Scratches	
		Primary mm	Secondary mm	Primary mm	Secondary mm	Primary mm	Secondary mm	Primary mm	Secondary mm	Primary mm	Secondary mm
500 × 350	500 × 350	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
750 × 550	650 × 500	Nil	Nil	Nil	Nil	Nil	1 × 0.3	Nil	Nil	Nil	Nil
1000 × 700	900 × 600	Nil	Nil	Nil	Nil	Nil	1 × 0.3	Nil	1 × 0.3	Nil	1 × 50 × 0.75
1250 × 900	1100 × 750	Nil	Nil	Nil	1 × 3	1 × 0.3	2 × 0.3	Nil	1 × 0.3	1 < 50 × 0.5	1 × 50 × 0.75
1500 × 1000	1300 × 850	Nil	Nil	Nil	1 × 3	1 × 0.3	2 × 0.3	Nil	1 × 0.3	1 < 50 × 0.5	1 × 50 × 0.75
2000 × 1200	1800 × 950	Nil	Nil	Nil	1 × 5	1 × 0.3	2 × 0.5	Nil	1 × 0.5	1 < 50 × 0.5	1 × 75 × 0.75
2500 × 1500	2200 × 1200	Nil	Nil	Nil	1 × 5	2 × 0.5	3 × 0.5	Nil	1 × 0.5	1 < 75 × 0.5	1 × 75 × 0.75
3000 × 1800	2700 × 1500	Nil	Nil	Nil	2 × 5	2 × 0.5	4 × 0.5	Nil	2 × 0.5	1 < 75 × 0.5	1 × 75 × 0.75
3500 × 2500	3000 × 2000	Nil	Nil	Nil	2 × 5	3 × 0.5	4 × 0.5	Nil	2 × 0.5	1 < 75 × 0.5	1 × 75 × 0.75

NOTES:

1 Scratches to the primary vision area are unacceptable if visible from a distance of 3 m. If detailed inspection is required, glass shall be viewed in a perpendicular position using a daylight background. Glass panes requiring this degree of inspection should not be viewed when they are standing in direct sunlight and the viewing period should not be more than 60 seconds.

2 For all coated glass types individual pin holes up to 1.5 mm in diameter are acceptable. In secondary vision areas, individual pinholes up to 2 mm are acceptable. The maximum number of pinholes allowed for panes up to 3 m^2 of glass is three pinholes, separated by a minimum distance of 500 mm. For each 1 m^2 of glass over this area one extra pinhole is allowed. A single cluster of pinholes may exist in the secondary vision area providing it consists of no more than five pinholes of less than 0.75 mm in diameter that are not visible from a distance of 3 m. If detailed inspection is required, glass shall be viewed in a perpendicular position using a daylight background. Glass panes requiring this degree of inspection are not to be viewed when they are standing in direct sunlight and the viewing period shall not exceed 60 seconds.

3 Measurements of fault sizes are recommended to be performed using a PEAK LUPE seven times magnifier or equivalent.

4 Accumulative fault conditions apply to any given glass size, i.e. 1000 mm × 700 mm may contain 1 mm × 3 mm seed, plus one 50 mm × 0.75 mm scratch to the secondary vision area whilst also containing one by less than 50 mm × 0.5 mm scratch to the primary viewing area.

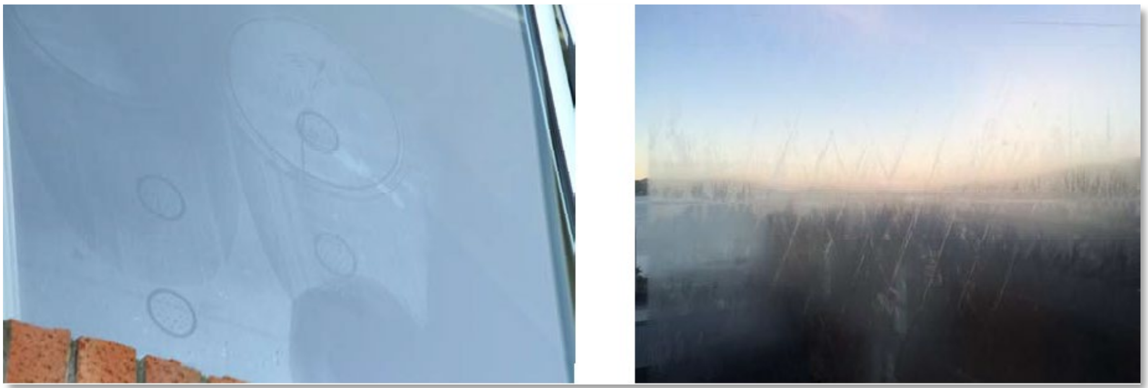
5 For units exceeding 3500 mm × 2500mm, the primary vision zone rests 300 mm from all four edges and acceptable fault conditions shall remain the same as for 3500 mm × 2500 mm size units.

Preferential Wetting Patterns

These patterns are visible when the glass surface gets wet from rain, condensation or washing and are caused by manufacturing tools and equipment, and devices such as vacuum lifters and separation pads, that came into contact with the glass during manufacture, handling and installation.

Although the tools, equipment, and devices used in this process did not leave a visible residue on the glass, they have changed the surface condition, and this creates patterns on the glass surface when it gets wet.

These patterns do not affect the functionality, performance or longevity of the units, and may dissipate in time.



Preferential wetting patterns

> **Note:** These patterns are **not** considered a defect.

Photoelasticity or Anisotropy

The variation of stress across the surface of toughened glass from the toughening process can result in light and dark areas being visible (sometimes known as 'leopard spots') when polarised light is incident on the glass. This phenomenon is known as photoelasticity.

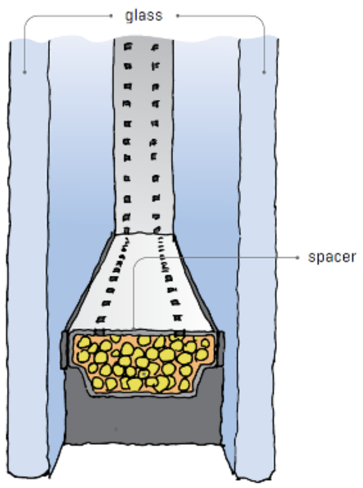
The photoelastic effect is an inherent characteristic of all heat-treated glass, and is more noticeable on thicker glass, coated glass, and laminated glass through polarized glasses. The effect may be accentuated when there are two or more layers of toughened glass in an IGU.

Photoelasticity or Anisotropy

Note: Photoelasticity or anisotropy is ***not*** considered a defect.

IGUs – Overview

Insulating glass units, or IGUs, are made of two or more panes of glass, separated by an air space containing air, argon, and sometimes other insulating gases. This configuration is used to not only improve the thermal efficiency but can also assist in reducing sound transmission.



IGU cross section

With different configurations, there will be some changes in appearance, too. Some of these visual effects are present in traditional single glazed units but can be exaggerated as panes are layered up in an IGU. As described in the sections above, these are often not considered as defects, but rather effects generated by the makeup of the window and/or the glass used. Case in point, Low-E glass, referred to later in this Bulletin, which should only be used within an IGU, has a slight visible colour from the metal oxide layers used to create it, and can become more pronounced when two or more layers are installed together.

AS/NZS 4666:2012 - IGUs

This Standard sets out the requirements and guidelines for the long-term type test, glazing, periodic manufacturing testing and other associated aspects to do with insulated glass units (IGU's).

> **Note:** single and double glazing will have similar levels of visual quality, although there are some characteristics that are specific to IGU's.

The following descriptions have been derived from "Appendix D - Visual Characteristics" of the Standard.

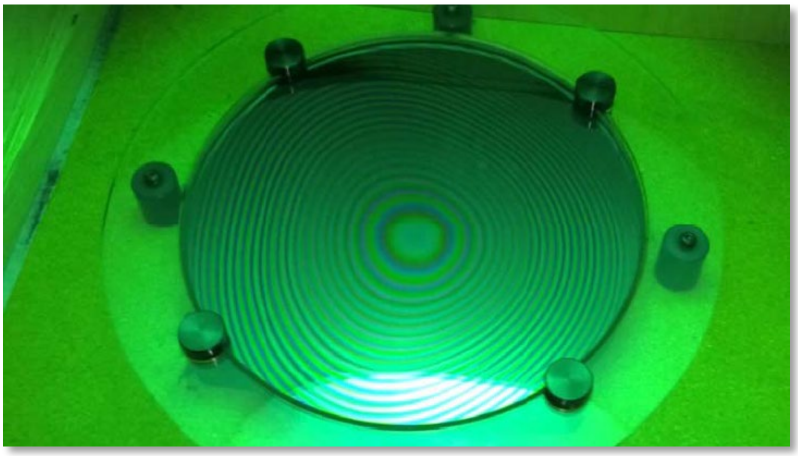
Deflection and Reflection

Small changes in temperature and pressure can cause glass to bow outwards or inwards and change the images reflected from the window. These distortions are an inevitable consequence of the laws of physics and cannot be eliminated.

Note: Excessive deflections are not considered a defect unless the customer has provided the end location and altitude of the glazing, and design wind pressures to the supplier for design of the IGU.

Newton's Rings

In a large IGU, the two glass panes may be displaced by air pressure until they come close to touching in the middle. When this happens, Newton's Rings are an optical phenomenon, which are roughly circular and coloured bands, and may form in the centre of the unit.
Newton's Rings can easily be avoided in large IGUs by allowing cavities that suit the design wind pressures of the project.

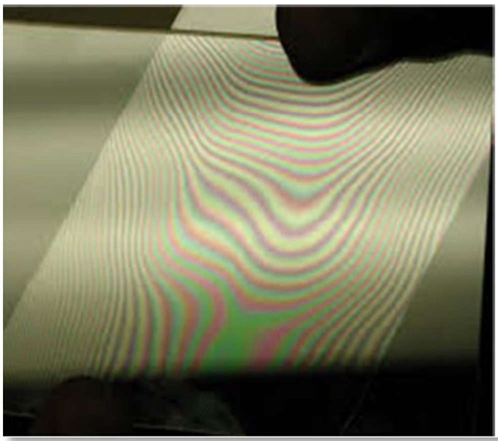


Note: Newton's Rings are a naturally occurring phenomenon and are ***not*** usually considered to be a defect.

Brewster's Fringes

Under certain lighting conditions, Brewster’s fringes are sometimes visible when multiple light reflections occur in IGUs of high-quality float glass panes of identical thickness (for example 4 mm float on 4 mm float from the same stock sheet).

These interference fringes are faint coloured bands of irregular shapes, and they can be located anywhere over the surface.



Note: Brewster’s fringes are *not* considered a defect.

External Condensation

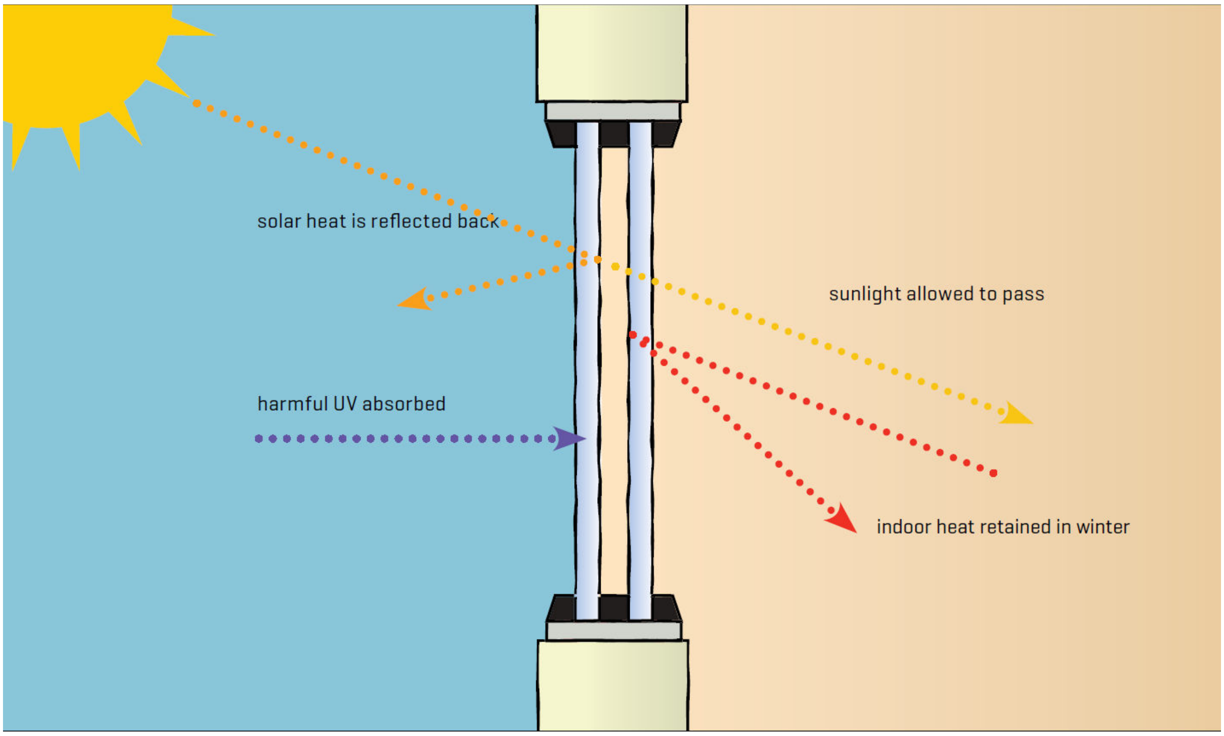
The presence of water droplets forming on glass surfaces is a result of condensation, a natural process in which moisture accumulates on a surface that is colder than the air that it’s in. This can happen on the glass surface both indoors and outdoors, but “external” condensation refers to the appearance of moisture on the external surface of the glazing unit.

The external condensation on windows is dew and is caused by the same thing as dew on the grass, what we call night sky cooling. When you have a clear night sky, the grass gets colder than the surrounding air. Water in the surrounding air then condenses on the grass as dew. With glazing this usually occurs in the morning, when the surrounding air warms up faster than solid surfaces such as windows and glass. External condensation is not a defect of the unit.

Low-E Glass

Low emissivity, or Low-E glass, differs from other glass types in its enhanced ability to reduce the amount of heat emission that occurs through it, hence its name “Low-E”. It achieves this through a thin, transparent layer of metals including a mixture of zinc, silver, and tin oxides. As this changes its behaviour towards light, it gives the glass a slight tinge of colour.

With the recent changes in thermal efficiency requirements, Low-E glass has become an increasingly popular choice for glazing, especially in new buildings but also for additions and alterations to existing houses. Two or more panes of Low-E glass are installed as part of an insulating glass unit, or IGU, to maximise its thermal properties, either by reducing the entry of heat from incoming sunlight during the summer or preventing excess heat loss from the interior during winter, as shown below.



The coating gives the glass a slightly different colour compared to traditional clear glass, and there can be variation in colour between other Low-E glass with different coating techniques, but this is not very visible under most lighting conditions. Slight hazing (see page 19) can also be present when viewed under strong sunlight but is not a sign of a defective unit. Consumers may still view this as undesirable, so they should double check with their suppliers if they are comfortable with these effects being present if Low-E is their choice of glazing.

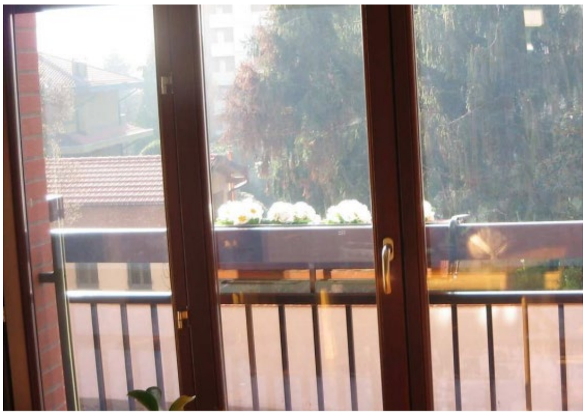
Aspects of Color Variation in Low-E Glazing

Due to the inherent manufacturing process, that is, the application of a thin coating of metal oxides, this will produce a slightly visible color on the glass surface, which can vary as a result of numerous factors. For example, differences in substrate used for the coating, notably the iron oxide content, can lead to changes in the glass opacity and shade of color, as shown in the image below. If thicker glass panes are used, this can also have an effect on how the coating will look once applied. Additionally, glazing units, especially those comprised of multiple layers of glass, can appear different when viewed from different angles. This is partially a result of the aforementioned Brewster's fringes (see page 16), and other visual phenomena that arise from light diffraction and interference.

Low-E glass will have a range of different colours.

Hazing

Hazing is a result of light scattering on the glass surface, which produces a milky/cloudy look. Notably, glass with a rougher surface is more prone to this scattering effect.



One type of Low-E glass has a smooth outer coating, which can reduce UV transmission by up to 70% compared to uncoated glass and has the additional benefit of reduced hazing. This coating is applied retroactively, following the manufacture of the pane. As the conditions used for this process are mild, a smooth finish can be achieved, which gives the glass its characteristic look and functionality. This also makes it more delicate, so the coating always faces the inside of an IGU. In contrast, the coating of hard-coated Low-E glass is fused to the glass surface while the glass is still in a molten state. The coating is very durable, and can withstand the elements when installed facing outwards, but at a microscopic level the surface is rougher, and the hazing effect is more obvious compared to soft-coated.

Nonetheless, hazing is merely the result of how Low-E glass is manufactured, and is not a sign of a defective unit.

Exaggerated Roller Wave Distortion

As outlined above (page 8), distortion resulting from the use of roller waves can appear in glass that has been heat treated, and Low-E is no exception. But as Low-E glass, especially soft-coated, have a much stronger reflectivity (read: performance), these distortions can appear more pronounced despite the actual amount of distortion not being significantly different than other glass types. As long as they are within tolerated values, roller waves are not considered defects.