North Galaxy, Brussels
SunGuard® Solar Light Blue 52
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A series of factors and physical rules define the characteristics of insulating glass as it is used in heat and solar protection applications.

3.1 General

To achieve thermal insulation properties, several float glass panes should be combined with at least one low E coating to create an insulating glass unit.

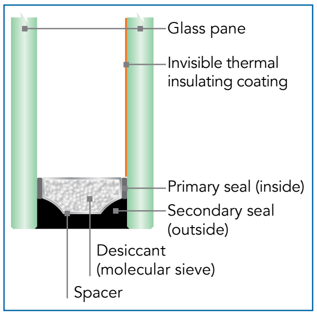
Two or more panes of the same size are aligned with each other at a defined distance and glued together. The resulting hermetically sealed interspace is filled with especially effective thermal insulating inert gas. No vacuum is generated, as laypersons often mistakenly assume.

The width of the pane interspace depends on the inert gas that is used. Argon is most frequently used, krypton more rarely. To reach its optimum thermal insulation efficiency, argon needs an interspace of 15 - 18 mm; krypton needs only 10 - 12 mm for better insulating results. The interspace is usually filled to 90 % capacity. Krypton is many times more expensive than argon since it is rarer.

The spacer that permanently separates the panes has some influence on the insulating performance and, consequently on the dew point at the edge of the glazing (→ Chapter 3.6). For the past few decades, aluminium spacers have been the industry standard. These are being replaced today by systems with lower heat conductivity.

3.2 Production

The insulating panes are glued together using the dual-barrier system, in which a spacer is used to keep the two panes separated, and a continuous string of butyl adhesive is applied around the edges of the spacer to keep both panes of glass glued together. The space that is created is filled with a desiccant that keeps the interspace permanently dry.



Insulating glass structure

During the gluing process, it is important that the coated side of the pane of float glass faces the interspace and that the adhesive is applied to this side. Some types of coatings need to be removed mechanically before the adhesive can be applied properly. Removing the coating before the adhesive is applied increases the bonding strength and protection against corrosion. The functional layer is now hermetically sealed and permanently protected. The butyl adhesive sealant, also called the inner sealant level, prevents water vapour from forming and the inert gas from escaping. After the two panes of glass are bonded together, a gas pressure press is used to withdraw some of the air from between the panes and replace it with a defined amount of inert gas. Finally the insulating pane receives its second sealant and adhesive level by filling in the hollow between the installed spacers and the outer edges of the panes. The material most frequently used is polysulfide or polyurethane.

As an alternative to these adhesive materials, a UV-resistant silicone is used in special installations that have exposed insulating glass edges. Insulating panes with a UV-resistant edge seal are often filled with air, since the gas diffusion density is lower for silicone. However, to a lesser extent, using this silicone also reduces the insulating glazing's U value (→ Chapter 3.5).

3.3 Thermotechnical function

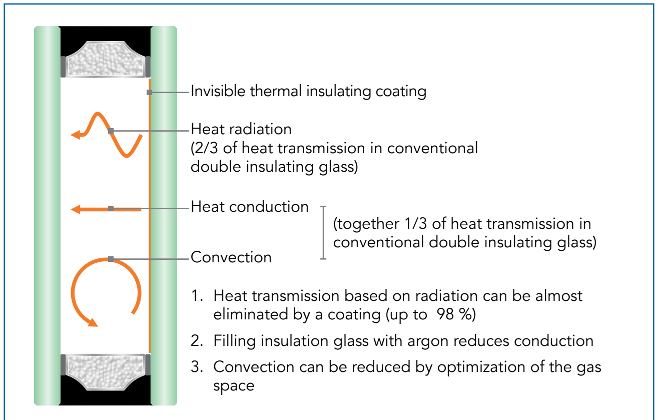
Three factors define heat transmission: heat radiation, heat conductivity and convective flow.

The electromagnetic long wave thermal radiation that every entity emits due to its temperature transfers thermal energy without transmitting the entity or medium itself.

Heat conductivity is the heat flow within a medium caused by temperature discrepancy. In this case, the energy always flows in the direction of the lower temperature.

Convective flow is a flow of gas particles in the interspace due to the difference in temperature between the inner and outer panes of insulating glass. The particles drop on the colder surface and rise again on the warmer one. Consequently, the gas circulates, creating a heat flow from warm to cold.

Insulating glass consisting of just two uncoated panes of float glass and with air filling the interspace loses about 2/3 of the heat that the room would otherwise have due to the radiation loss between the two panes, and 1/3 due to heat conductivity and heat convection to the outside air.



Heat loss in a double insulating glass

In the case of older insulating glasses, this results in an extreme difference in temperature between the inner pane and the warmer room air in the cooler seasons of the year, resulting in a massive loss of heat due to the heat transfer from the inner pane to the outer pane.

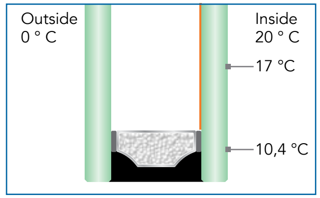
In the case of modern insulating glasses, at least one of these float glass panes is fitted with a low E layer. These coatings have emissivities of less than 0.02 (2 %) in some cases and are capable of reflecting over 98 % of the incoming long wave heat radiation, so that radiation loss is completely eliminated.

This represents an improvement of approx. 66 % as compared with traditional insulating glass. Heat conductivity and convective flow are not affected by low E coating. This heat conductivity can, however, be reduced by using an inert gas like argon. Inert gases have significantly lower heat conductivity than air, thereby reducing the heat flowing through the insulating glass system. Depending on the filling gas, involved the convective flow in the insulating glass requires a minimum amount of space with a defined pane distance between panes. This is, for example, approx. 16 mm in the case of air, 15 - 18 mm for argon and 10 - 12 mm for krypton.

3.4 Edge Seal

The solutions considered so far refer to the centre area of the panes without any influences from the insulating glass edges.

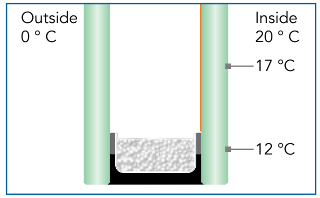
Until very recently, the majority of insulating glass was produced using aluminium spacers. Rising requirements have created thermotechnically improved alternatives that are gaining ground in insulating glass production.



Aluminium spacer

3.4.1 Stainless steel

Extremely thin stainless steel profiles with considerably reduced heat conductivity when compared to aluminium are the most widespread alternative. They are similar to aluminium, however, in terms of their mechanical stability and diffusion capability.



Stainless steel spacer

3.4.2 Metal / plastic combination

Another option is plastic spacers which offer excellent thermal insulation but do not have a sufficient gas diffusion density to ensure the life cycle of an insulating glass.

Consequently, combinations of plastic with gas-impermeable stainless steel or aluminium films are available.

3.4.3 Thermoplastic systems (TPS)

A hot extruded, special plastic substance, which is placed between two panes during production and which guarantees the required mechanical strength as well as gas diffusion density after cooling down replaces the conventional metal. The desiccant is part of this substance.

There is a wide range of disposable alternatives today that provide important reductions of the Ψ value, the unit of the heat transport in the boundary zone, when they are directly compared with each other (→ Chapter 3.5.3).

3.5 U value – heat transmittance coefficient

This value characterises the heat loss through a component. It indicates how much heat passes through 1 m² of component when there is a temperature difference of 1 K between the two adjacent sides – for example, between a room and an outside wall. The smaller this value is, the better the heat insulation.

Please note that the European U values are different from the American values. This must be taken into consideration when making international comparisons.

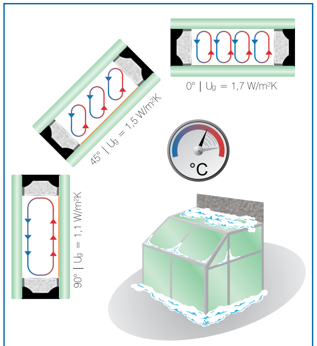
3.5.1 U_g value

The U_g value is the heat transfer coefficient for glazing. It can be determined or calculated according to defined standards. Four factors determine this value: the emissivity of the coating, which is determined and published by the producer of the float glass, the distance of the intermediate space between the panes, the filling type and the filling rate when using inert gases.

(To find the rated value for real-life usage, national aggregates need to be considered – DIN 41408-4 applies for Germany)

3.5.1.1 U_g value for inclined glass surfaces

The U_g value that is most often defined and published refers to glazing that is vertically (90°) installed. Installation with inclination changes the convection in the interspace and decreases the U_g value. The greater the glass surface inclination, the more rapid the circulation in the interspace and the greater the heat flow from the inner to the outer pane. This can reduce the U_g value by up to 0.6 W/m²K for double insulating glass.



Mounting position	Mounting angle	U_g [W/m²K]
Vertical	90°	1,1
Inclined	45°	1,5
Overhead	0°	1,7

Effect of the mounting position of the glazing U_g value

3.5.2 U_f value

The U_f value is the heat conductivity coefficient of the frame, the nominal value of which can be determined by three different ways:

- measuring according to EN ISO 12412-2,
- calculating acc. to EN ISO 10077-2,
- using the EN ISO 10077-1 definition, appendix D.

The nominal value plus the national aggregates determine the rated value for the real-life usage.

3.5.3 Ψ value

The Ψ value (Psi value) is the linear thermal bridge loss coefficient for a component. With regard to windows, it describes the interaction of insulating glass, dimensions, spacer and frame material and defines the component’s thermal bridges. The insulating glass itself has no Ψ value, as this only applies to the construction element into which it is integrated.

3.5.4 U_w value

Insulating glass is normally used in windows. The Uw value describes the heat conductivity of the construction element window. Based on the Ug value, it can be determined using three different methods:

- reading in EN ISO 10077-1, Tab. F1
- measuring pursuant to EN ISO 12567-1
- calculating pursuant to EN ISO 10077-1 as per the following formula

$$U_w = \frac{A_f \cdot U_f + A_g \cdot U_g + \Sigma(l_g \cdot \Psi)}{A_f + A_g}$$

U_w:	Thermal transmittance from the window
U_f:	Thermal transmittance from the frame (assessment value!)
U_g:	Thermal transmittance from the glazing (rated value!)
A_f:	Frame surface
A_g:	Glass surface
l_g:	Periphery for the glazing
Ψ:	Linear thermal transmittance from the glass edge

The heat loss in the edge zone is more important than in the middle of the glazing, which is why thermally improved spacers are becoming increasingly important. As with Ug and Uf, the Uw values are nominal values, which only become rated values after having added the national aggregates.

3.6 Dew point and condensation

Humidity is always present in the air and warmer air can hold more water than cooler air. Once the air cools down, the relative humidity increases, yet the water vapour volume remains the same. The dew point temperature is the temperature when the relative air moisture reaches 100 % and water vapour condenses.

This can occur at different places on the insulating glass:

3.6.1 In the interspace between the panes

This rarely occurs with today's insulating glasses, since they are hermetically sealed and filled with dried gases.

3.6.2 On the interior surface of the pane

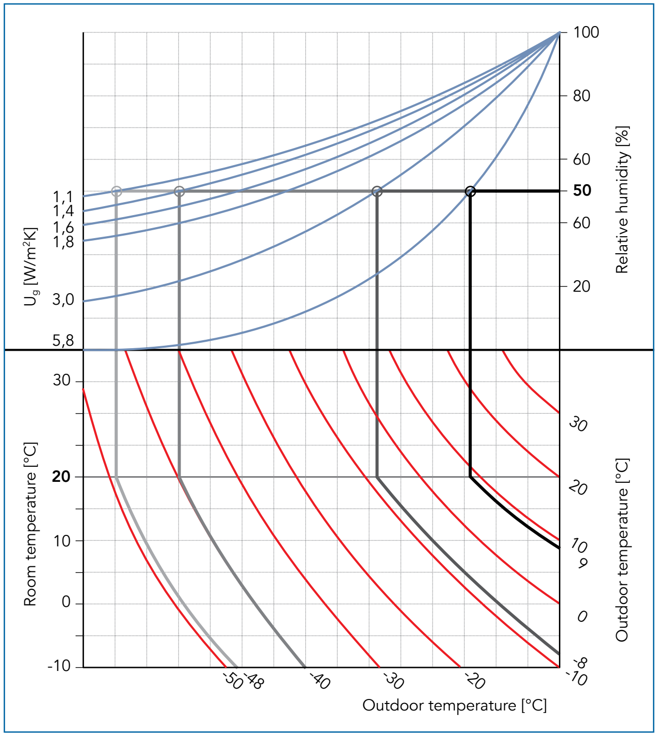
This occurs on poorly insulated windows or those with single glazing. Warm air cools suddenly near windows and transfers humidity to the cold inside pane – the temperature in winter is often below the dew point of the ambient air. The inside pane in modern insulating glass stays warm longer so that condensation rarely occurs.

If the relative air humidity is very high, for example due to cooking, washing or proximity to a swimming pool, panes may condensate more often. One way to correct this is to exchange the air by means of short and direct ventilation.

The outside temperature at which the glazing on the inner side condensates (= formation of condensation water = dew point), can be determined using the dew point graph.

Recorded examples:
- room temperature 20 °C
- room humidity 50 %
- outdoor temperature 9 °C

Dew points at:
- U_g = 5.8 W/m²K → 9 °C
- U_g = 3.0 W/m²K → -8 °C
- U_g = 1.4 W/m²K → -40 °C
- U_g = 1.1 W/m²K → -48 °C



Dew point graph

3.6.3 On the outer pane surface of the insulating glass

This effect has appeared with the advent of modern insulated glass, and is particularly noticeable during the early morning hours, when the moisture content in the outside air has sharply increased during the night.

The excellent insulating quality of these glass surfaces prohibits heat transfer to the outside, so the outer pane remains extremely cold. When the sun's rays start to heat the outside air faster than the temperature of the pane, it may lead to condensation, depending on the orientation of the building and the environment. This is not a defect, but proof of the excellent thermal insulation of the insulating glass.

GUARDIAN offers special coatings that ensure a clear view through glazing even during the morning hours (→ Chapter 4.4).

3.7 Solar factor (g value)

The total energy transmittance degree (solar factor or g value) defines the permeability of insulating glass to solar radiation. Solar protection glass minimizes the g value through the appropriate selection of glass and coatings. The g value of transparent heat insulating glass is preferably high in order to selection the energy balance of the component glass by passive solar gains.

3.8 b factor (shading coefficient)

The non-dimensional value aids calculation of the cooling load of a building and is also known as the shading coefficient. It describes the ratio of the g value of a particular glazing to a 3 mm float glass with a g value of 87 %.

Pursuant to EN 410 (2011):

$$b = \frac{g_{EN\ 410}}{0{,}87}$$

3.9 Solar energy gains

Thermal insulation glazing allows a large proportion of solar radiation into the interior of the building. Furniture and fixtures, walls and floors absorb the short wave solar radiation and convert it into long wave heat radiation. This heat radiation cannot leave the room due to the thermal insulation quality of the glazing, and it warms up the air in the room. These real solar gains support conventional heating. These gains differ, depending on the orientation of the windows, being less when the windows face east and west and greater when the glazing faces southwards. This energy is free of charge and helps to save on heating costs during the cold season. In the summer months, however, it may cause the building to heat up to an uncomfortable degree. This is called the greenhouse effect. The requirements of summer heat protection should therefore be taken into consideration (→ Chapter 5.5).

3.10 Selectivity classification figure

Solar control glass works to minimize solar heat gain while maximizing the amount if light transferal into the building. The “S” classification number represents the proportion of the total energy (g value) and light transmittance (τ_v) for a glazing. The higher this value, the better and more efficient the ratio is.

$$S = \frac{\text{light transmittance } \tau_V}{\text{g value}}$$

The latest generation of GUARDIAN’s solar control glass already exceed a ratio of 2:1, which has long been considered the maximum value.

3.11 Colour rendering index

Colour rendering is not only relevant olour rendering the physiological perception of the observer, but also aesthetic and psychological aspects. Sunlight that falls through an object or is reflected by it is changed relative to the nature of the object (→ Chapter 2.1).

The colour rendering index (R_a value) describes how much an object’s colour changes when it is observed through glazing. It defines the spectral quality of glass in transmission, and the value can range from 0 to 100. The higher the colour rendering index is, the more natural the reflected colours appear. A R_a value of 100 means that the colour of the object observed through the glazing is identical to the original colour.

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A colour rendering index of > 90 is rated as very good and > 80 as good. Architectural glass based on clear float glass generally has an R_a value > 90, and mass-coloured glass usually has an R_a value between 60 and 90.

The colour rendering index is determined according to EN 410.

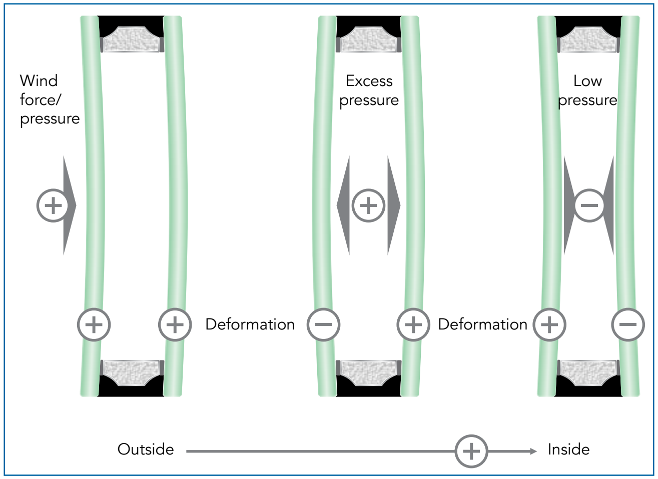
3.12 Interference phenomena

When several parallel float glass panes exist, very specific lighting conditions can cause optical phenomena to appear on the surface of the glass. These can be rainbow-like spots, stripes or rings that change their position when one presses on the glazing, phenomena also referred to as Newton rings.

These so-called interferences are of a physical nature and are caused by light refraction and spectral overlap. They rarely occur when looking through the glazing, but in reflection from outside. These interferences are no reason for complaint but rather are a proof of quality with regard to the absolute plane parallelism of the installed float glass.

3.13 Insulating glass effect

A component of every insulating glass is at least one hermetically enclosed space, the interspace. Since this space is filled with air or gas, the panes react like membranes that bulge in and out in reaction to varying air pressure in the surrounding air.



Insulating glass effect

Under extreme weather conditions, unavoidable distortions may show up despite the plane-parallel glazing. It can also occur due to extreme changes in air pressure, and influencing factors include the size and geometry of the pane of glass, the width of the interspace, and the structure of the pane of glass itself.

With triple insulation glazing, the medium pane remains nearly rigid, which is the reason why the impact on both outer panes is stronger than on double insulating glass. These deformations disappear without effect once the air pressure normalizes and, far from represent a defect, are an indication of the edge seal density.