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GUARDIAN
Glass • Automotive • Building Products

GUARDIAN

GlassTime

TECHNICAL MANUAL

Without glass,
the world ends at the wall.

Copenhagen Opera House
GUARDIAN ExtraClear®
Henning Larsen Architects

GUARDIAN InGlass® – Design and function for all areas of life

In addition to the broad production pallet typically associated with the building envelope, GUARDIAN InGlass offers the equivalent for living with glass inside the building structure.

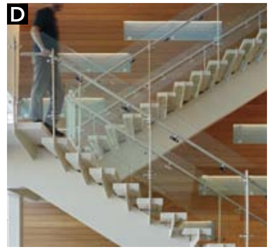
GUARDIAN InGlass offers hundreds of colours, textures and surfaces to fire your imagination and provide the basis for today's interior spaces.

This information is only an introduction to the possibilities inherent in our InGlass collection. Specific documents and a large assortment of samples and options are available from your Guardian InGlass Support.
Please send us an email at inglass.europe@guardian.com.


A


B


C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GUARDIAN INGLASS
ADVANCED INTERIOR GLASS

More information is available at

GuardianInGlass.com

GUARDIAN InGlass collection:

A DiamondGuard®
New glass is beautiful. Ours stays that way. DiamondGuard glass, fused with the strength of carbon, has an extremely low coefficient of friction that permanently protects it from normal wear.

B ShowerGuard®
Special glass for the shower. The refined surface preserves the glass from stains caused by hard water, heat, humidity and cleaning products, maintaining its stunning clarity for years to come.

C DecoCristal®
Lacquered float glass adapts to any interior, shining with colours and reflections for every wall covering.

D UltraClear™
Extremely white glass for clear design and unsurpassed light transmission.

E SatinDeco®
The satin-smooth, translucent finish of SatinDeco obscures the view through the glass while maintaining a high level of light transmittance.

F Berman Glass Edition
The edition produced by the Joel Berman Glass Studios inspires with a unique look at affordable prices.

G UltraMirror®
Highly reflective mirror providing consistent protection against corrosion, chemicals, moisture and abrasion.

H GUARDIAN LamiGlass®
Whether you are looking for transparent colour or enhanced safety and security, GUARDIAN LamiGlass offers true performance and extensive design flexibility.

Office Park, Vienna
SunGuard® HP Light Blue 62/52
Prof. Holzbauer Architects

GlassTime

TECHNICAL MANUAL

2nd Edition 2013

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Ramboll, Copenhagen
SunGuard® SN 70/41
Dissing + Weitling architecture

Without glass, the world ends at the wall.

Preface

Lajos Sapi
Group Vice President – Europe

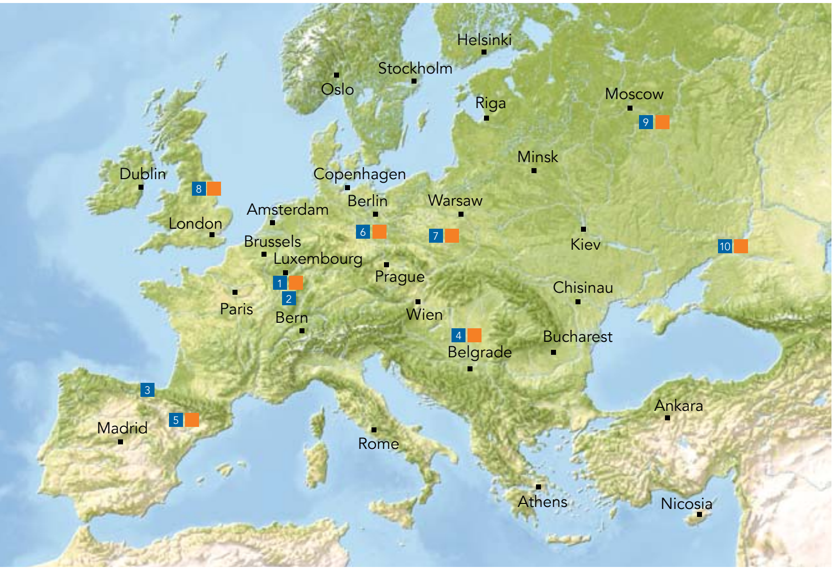
It is impossible to imagine our world without glass. The invention of the float glass process in the middle of the last century ushered in its use in every conceivable area. Today's modern architecture takes special advantage of this building material, using it to create residential and commercial oases whose transparency and spaciousness guarantee protection while providing openness and access to the outdoors.

In contrast to the caves of the Stone Age with actual stone boundaries, the "stones" that shape and form our modern buildings today consist of glass, providing excellent protection against the elements. Whereas in earlier times the protective elements were rocky, stony and opaque, now they are transparent and can be variably configured. While building envelopes use glass to shape their outer architecture, interiors also take advantage of this material, with glass increasingly being used to reflect our modern lifestyle.

Glass doors, glass showers, glass furniture, glass partitions and glass accessories are an accepted and everyday part of this generation's living and working environment. High-tech functional elements such as display screens, glass surfaces for modern control and communication and solar, thermal and photovoltaic elements make up a broad spectrum of energy components that shape our world today. There is no end in sight for the creative uses of this dynamic product.

The basic material is typically industrially manufactured float glass which is further coated or processed into innovative building and functional elements. It is not an overstatement to term the beginning of the twenty-first century the "GlassTime" or, even better, the Age of Glass. This solidified liquid with a 7,000-year tradition will continue to make its triumphal march through this century and conquer new areas, a success story to which we have contributed for more than eight decades.

We therefore hope to impart some of our knowledge of glass and its uses to our customers and those who use our products through this manual. We do not restrict ourselves to core business issues in this respect, but rather highlight the essential aspects of this versatile material in its many processed forms. This first edition will certainly not be able to cover all issues in depth, but it will provide answers to many questions relating to glass – true to the title "**GlassTime**".



1 **GUARDIAN Luxguard I**
Bascharage
Start: 1981

2 **GUARDIAN Luxguard II**
Dudelange
Start: 1988

3 **GUARDIAN Llodio**
Start: 1984

4 **GUARDIAN Orosháza**
Start: 1991

5 **GUARDIAN Tudela**
Start: 1993

6 **GUARDIAN Flachglas**
Bitterfeld-Wolfen
Start: 1996

7 **GUARDIAN Czestochowa**
Start: 2002

8 **GUARDIAN UK Goole**
Start: 2003

9 **GUARDIAN Steklo Ryazan**
Start: 2008

10 **GUARDIAN Rostov**
Start: 2012

Float glass line
Glass coater

As of: May 2013

From humble beginnings to global presence

GUARDIAN Industries began life as the GUARDIAN Glass Company in 1932. Back then, we made windshields for the automotive industry. Today, GUARDIAN Industries Corp. is a diversified global manufacturing company headquartered in Auburn Hills, Michigan, with leading products comprising float glass, fabricated glass products, fiberglass insulation and other building materials for the commercial, residential and automotive markets.

In 1970, we opened our first glass plant in Carleton, Michigan, and began manufacturing float glass, a product achieved by floating molten glass on a bath of liquid tin. At the time, we were the first company to enter the US primary glass industry in nearly 50 years. Today, we have 28 float glass lines and 13 glass fabrication plants around the world.

The focus at the turn of the century was on value-added product innovation. GUARDIAN opened its Science and Technology Center in Carleton, Michigan in the year 2000 to address this need. It has expanded and enhanced our product spectrum in the commercial, residential, interior, solar, electronics and automotive segments.

With hundreds of new patents, scores of fresh products and several new facilities around the world, GUARDIAN is poised to meet the challenges of the coming decades. Our products and systems grace vehicles, homes and construction projects all over the world. Having accomplished so much in such a short time, identifying and mastering the latest demands and requirements is a constant challenge.

GUARDIAN's extensive European network of glass and automotive manufacturing facilities and sales and distribution operations means we are always close at hand to address customer and market needs. Since entering the European market in 1981 with our first float glass plant in Bascharage, Luxembourg, GUARDIAN has expanded its operations into eight countries throughout Europe to better serve the building products, commercial and residential glass markets and the automotive industry.

Today, GUARDIAN operates 10 float glass lines and produces high-quality coated glass products with state-of-the-art off-line glass coaters in 8 locations all over Europe.

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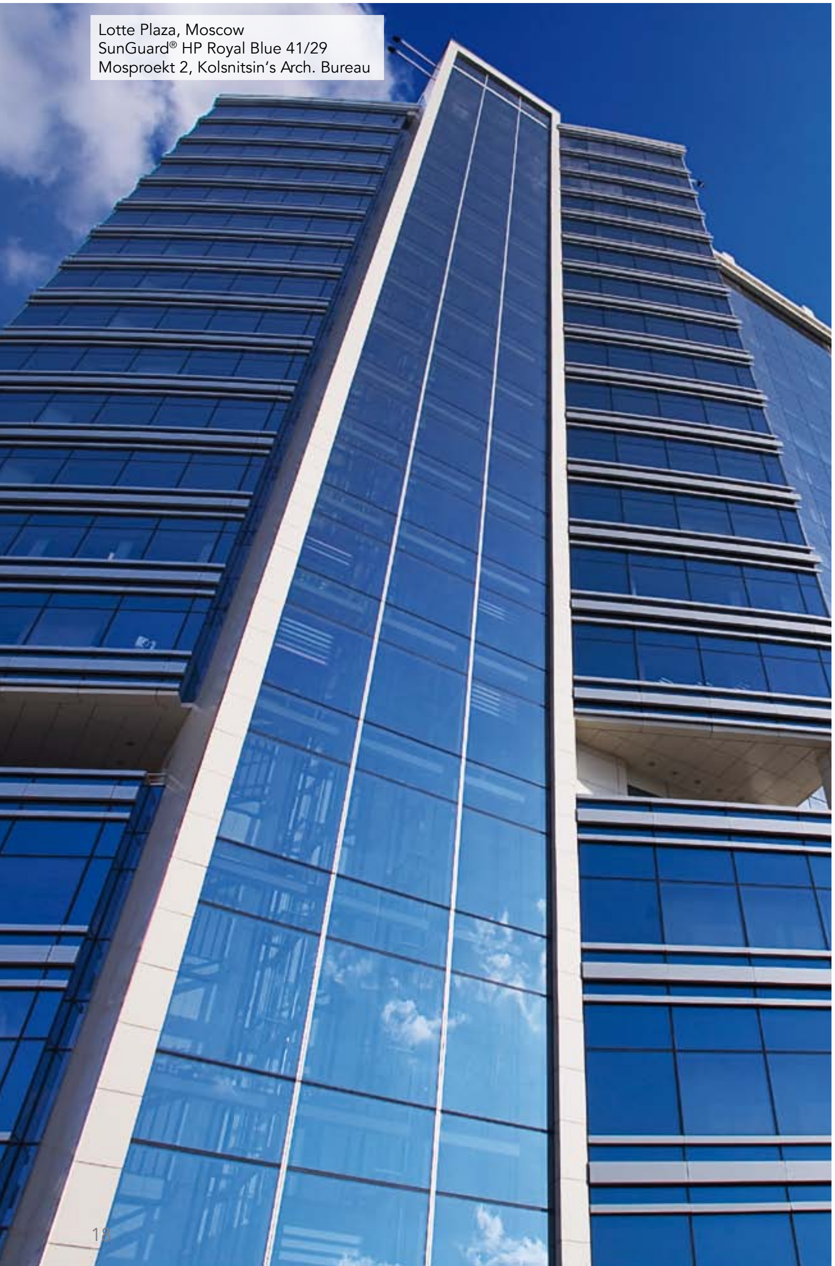


Lotte Plaza, Moscow
SunGuard® HP Royal Blue 41/29
Mosproekt 2, Kolsnitsin's Arch. Bureau

1. Basic types of Glass

1.1 History

The history of glass production dates back to about 5000 BC. Glass beads discovered in ancient Egypt and early Roman sites bear witness to a long tradition of drawing and moulding techniques used in glass production. For centuries, however, individual craftsmanship dominated manufacturing processes that ranged from using blowpipes and cylinder blow moulding techniques to the crown glass method. These manual production methods resulted in small quantities and small window panes which were almost exclusively used in stained glass windows in churches.

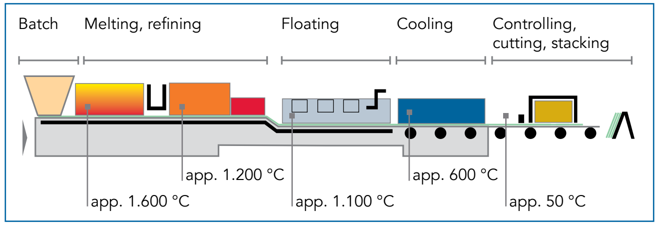
Demand for glass during the seventeenth century rose because in addition to master church builders using glass in church windows, builders of castles and stately townhouses were now discovering how to use glass to enclose spaces as well. French glassmakers first developed a glass rolling process that produced 1.20 x 2 m glass panels, a size that until then had seemed impossible. Glass production did not become industrialised until the twentieth century when 12 x 2.50 m sheets of glass later began to be mass produced on a large scale using the Lubbers and Fourcault methods of glass production, advancing to the more recent technologies developed by Libbey-Owens and Pittsburgh.

All of these methods had one distinct disadvantage: manufactured glass panels had to be ground and polished on both sides to obtain distortion-free and optically perfect mirror glass, a process that was extremely time consuming and expensive.

1.2 Float glass

Industrial glass – which today would be glass used in the automotive and construction industries – was originally manufactured using a system known as float glass. This floating process, which reached its peak in 1959, revolutionised glass production methods. Until this float process was developed, glass panes were produced by drawing or moulding molten glass, and then polishing it.

This new method allows the glass to "float", with the molten glass spreading out evenly over the surface of a liquid tin bath. Due to the inherent surface tension of the liquid tin, and the fact that glass is only half as dense as tin, the molten glass does not sink into the tin bath, but rather floats on the surface, thereby moulding itself evenly to the surface shape of the liquid tin. This method creates absolute plane parallelism which guarantees freedom from distortion and crystal clear transparency. Reducing the temperature in the tin bath from approx. 1000 °C to approx. 600 °C turns a viscous mass of molten glass into a solid glass sheet that can be lifted right off the surface of the tin bath at the end of the floating process.



Floating process (schematic representation)

Tin is ideal for shape forming because it remains liquid throughout the entire shape forming process and does not evaporate, thanks to its low vapour pressure. In order to prevent the tin from oxidising, the floating process takes place in a protective gas atmosphere of nitrogen with a hydrogen additive.

View of the melting process

The molten process precedes form shaping by floating glass in a tin bath. This process begins with an exact proportion of the raw materials based on about 60 % quartz, 20 % soda and sulphate and 20 % limestone and dolomite. These materials are crushed in huge agitators and processed into a mixture. A blend comprising approx. 80 % of this mixture and 20 % of recycled scrap glass is fed into the furnace and melted at about 1600 °C. The result is a soda-lime-silica glass that is conforms to EN 572-2.

After gassing the molten mixture, which is referred to as refining, the molten glass is fed into the conditioning basin and left to cool to approx. 1200 °C before flowing over a refractory spout into the float bath. This mixture is constantly fed, or "floated" onto the tin surface, a method that can be likened to a tub that overflows due to constant water intake. An infinite glass ribbon of about 3.50 m width is lifted off the surface at the end of the float bath.

At this point, the glass ribbon is approx. 600 °C and is cooled down to room temperature using a very precise procedure in the roller cooling channel to ensure that no permanent stress remains in the glass. This operation is extremely important for problem-free processing. The glass ribbon is still approx. 50 °C at the end of the 250 m long cooling line and a laser inspects the glass to detect faults such as inclusions, bubbles and cords. Faults are automatically registered and scrapped when blanks are later pre-cut.

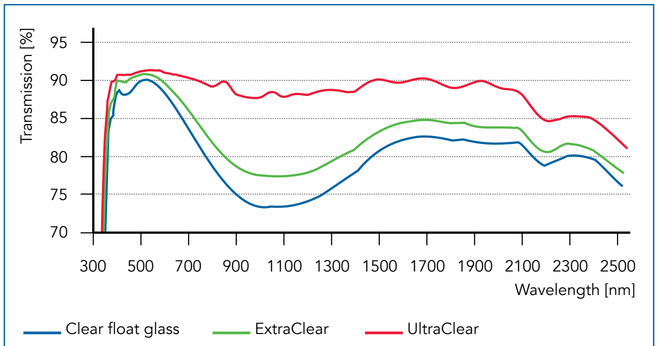
Pre-cuts are usually realised at intervals of 6 metres or less, with the glass being cut perpendicular to the endless ribbon. Both edges of the ribbon are also trimmed, generally producing float glass panes of 3.21 m x 6 m which are then immediately processed or stored on frames for further processing. Longer plates of 7 or 8 m are also produced.

An average float glass line is about 600 m long and has a capacity of approx. 70,000 m² with a thickness of 4 mm.

1.2.1 Colouring

Normal float glass has a slightly greenish tint. This colouring can be mainly seen along the edge of the glass and is caused by naturally existing ferric oxide in the raw materials. By selecting extremely ferric oxide-poor raw materials, or by undergoing a chemical bleaching process, the melt can be turned into an absolutely colour-neutral, extra-white glass. GUARDIAN produces this type of glass under the name GUARDIAN UltraClear™. Interiors and special solar products are the widest areas of application.

GUARDIAN also provides GUARDIAN ExtraClear®, a third float glass alternative that distinguishes itself from the competition because of its reduced iron content. In terms of colour and spectral properties, this glass falls between the UltraClear white float and the standard Clear float. Due to its interesting combination of properties, Float ExtraClear is used as the base material for ClimaGuard® thermal insulating and SunGuard® solar control coatings. This improves the selectivity and colour neutrality, irrespective of the particular coatings, especially for glass used in facades.



Colouring

In addition to these three versions of float glass, tinted glass can be produced using coloured mass. Chemical additives in the mixture allow green, grey, blue, reddish and bronze-coloured glass to be produced during certain production floating line periods. Changing glass colour in the vat naturally entails a considerable degree of effort and increased cost due to scrap and loss in productivity. It is therefore only produced for special campaigns.

1.2.2 Properties

Most of today’s glass production is float glass, with thicknesses usually ranging from 2 – 25 mm and a standard size of 3.21 x 6 m that is used for further processing. The glass has the following physical properties:

1.2.2.1 Density

The density of the material is determined by the proportion of mass to volume and is indicated using the notation “ρ”. Float glass has a factor of $\rho = 2{,}500$ kg/m³. That means that the mass for a square metre of float glass with a thickness of 1 mm is 2.5 kg.

1.2.2.2 Elasticity module

The elastic module is a material characteristic that describes the correlation between the tension and expansion when deforming a solid compound with linear elastic properties. It is designated with the formula symbol “E”. The more a material resists deformation, the higher the value of the E-module. Float glass has a value of $E = 7 \times 10^{10}$ Pa and is defined in EN 572-1.

1.2.2.3 Emissivity

Emissivity (ε) measures the ability of a surface to reflect absorbed heat as radiation. A precisely defined “black compound” is used as the basis for this ratio. The normal emissivity of float glass is $\varepsilon = 0.89$, which means 89 % of the absorbed heat is re-radiated (→ Chapter 3.3)

1.2.2.4 Compressive strength

As the term implies, this indicator demonstrates the resistance of a material to compressive stress. Glass is extremely resilient to pressure, as demonstrated by its 700 - 900 MPa. Flat glass can withstand a compressive load 10 times greater than the tensile load.

1.2.2.5 Tensile bending strength

The tensile bending strength of glass is not a specific material parameter, but rather an indicated value which, like all brittle materials, is influenced by the composition of the surface being subjected to tensile stress. Surface infractions reduce this indicated value, which is why the value of the flexural strength can only be defined using a statistically reliable value for the probability of fracture. This definition states that the fracture probability of a bending stress of 45 MPa for float glass (EN 572-1) as per the German building regulations list may be a maximum 5 % on average, based on a likelihood of 95 % as determined by statistical calculation methods.

σ = 45 MPa
as measured with the double ring method in EN 1288-2.

1.2.2.6 Resistance to temperature change

The resistance of float glass to temperature differences over the glass pane surface is 40 K (Kelvin). This means that a temperature difference of up to 40 K over the glass pane has no effect. Greater differences can cause dangerous stress in the glass cross section, and this may result in glass breakage. Heating devices should therefore be kept at least 30 cm away from glazing. If this distance cannot be maintained, the installation of single-pane safety glass is recommended (→ Chapter 7.1). The same applies in the case of solid, permanent and partial shading of glazing, due, for example, to static building elements or to nearby plants.

1.2.2.7 Transformation area

The mechanical properties for float glass vary within a defined temperature range. This range is between 520 - 550 °C and should not be compared with the pre-tempering and form shaping temperature, which is about 100 °C warmer.

1.2.2.8 Softening temperature

The glass transition or softening temperature of float glass is approx. 600 °C.

1.2.2.9 Length expansion coefficient

This value indicates the minimum change in float glass when the temperature is increased. This is extremely important for joining to other materials:

$9 \times 10^{-6}\ K^{-1}$ pursuant to ISO 7991 at 20 - 300 °C

This value gives the expansion of a glass edge of 1 m when the temperature increases by 1 K.

1.2.2.10 Specific heat capacity

This value determines the heat increase needed to heat 1 kg of float glass by 1 K:

$C = 800\ J \cdot kg^{-1} \cdot K^{-1}$

1.2.2.11 Heat transmittance coefficient (U value)

This value is calculated in accordance with DIN 4108-4 to EN 673. The value for float glass with a thickness of 4 mm is 5.8 W/m²K.

1.2.2.12 Acid resistance

Chart: Class 1 acc. to DIN 12116

1.2.2.13 Alkali resistance

Chart: Class 1-2 acc. to ISO 695

1.2.2.14 Water resistance

Chart: Hydrolytic class 3-5 acc. to ISO 719

1.2.2.15 Fresh, aggressive alkaline substances

These include substances washed out of cement which have not completely hardened and which when they come into contact with the glass, attack the silica acid structure that is part of the glass structure. This changes the surface as contact points become rougher. This effect occurs when the liquid alkaline substances dry and is completed after the cement has fully solidified. For this reason, alkaline leaching substances should never come into contact with glass or any points of contact should be removed immediately by rinsing them off with clean water.

1.3 Coatings on float glass

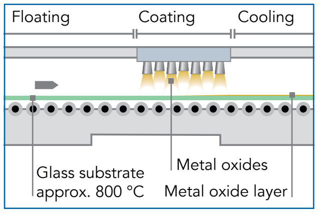
Industrial coatings for float glass are produced in huge quantities, primarily using 2 techniques. One is the chemical pyrolysis process, also called hardcoating. The second is a physical process called vacuum deposition or magnetron sputtering.

Depending on the coating used, materials in both methods result in a neutral and coloured appearance, whereby the coloured effects are less obvious when viewing the glass head-on and are easier to note when looking at reflections on the surface of the glass. These two technologies are base glass oriented and not to be confused with surface coating applied through spraying, rolling or imprinting processes (→ Chapter 8.2).

1.3.1 Pyrolytic method

This type of float glass coating process occurs online during glass production on the float line. At this point, the glass surface is still several hundred degrees Celsius when metal oxides are sprayed onto it. These oxides are permanently baked onto the surface and extremely hard (hardcoatings) and resistant, but their properties are very limited due to their simple structure.

Multi-layer glass systems are used to meet the higher requirements that are generally demanded today. They are produced offline under vacuum in the magnetron sputter process.



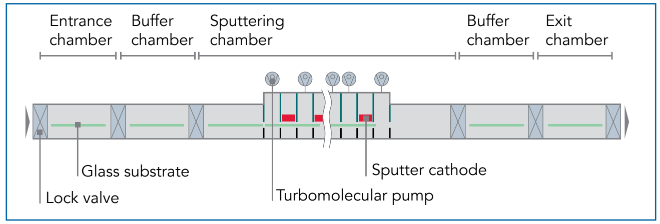
Pyrolytic method (online)

GUARDIAN therefore focuses solely on the coating technology described below.

1.3.2 Magnetron process

The magnetron process has many appellations, one of which dates back to the beginning of this technology when this process was termed softcoating, as opposed to hardcoating. Today, this definition is misleading, since extremely resistant magnetron sputter films now exist which are in all cases composed of individual ultra-thin layers of film.

No other technology is capable of coating glass so smoothly and with such outstanding optical and thermal properties.

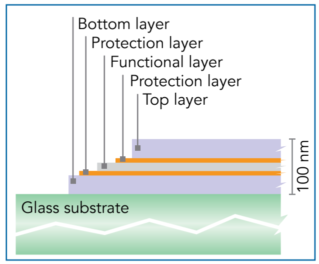


Cross-section of a magnetron coating line

The material (i.e. the target, which is a metal plate) that is to be deposited on the glass surface is mounted on an electrode with a high electrical potential. Electrode and target are electrically isolated from the wall of the vacuum chamber. The strong electrical field (fast electrons) ionizes the sputter gas argon. The accelerated argon ions are capable of breaking off material from the target by colliding with it, and this then comes into contact with the glass where it is deposited onto the surface.

Metals and alloys are spattered with or without additional reactive gases (O_2 or N_2). It is now possible to deposit metals, metal oxides and metal nitrides.

1.3.2.1 Typical assembly of a Magnetron-Sputter-Coater



Layer srack of high performance coated glass

Bottom and top layer:

- Influences the reflectance, transmittance and colour of the coating
- Silicone nitride top layer for very high mechanical durability

Functional layer:

e.g. silver and nickel chromium

- Responsible for the reflection of long wave and short wave radiation
- Strong influence on heat transition (U-value), energy transmission (g-value) and light transmission

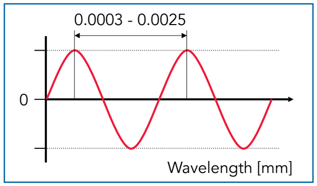
Protection layer:

- Protection of the functional layer against mechanical and chemical influences


Dream House, Moscow
SunGuard® HP Light Blue 62/52
Murray O'Laoire Architects

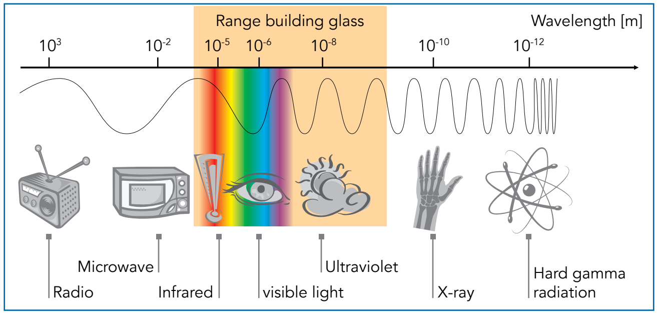
The physical definitions of light, energy and heat describe defined areas of the electromagnetic spectrum.

The area relevant to architectural glass in connection with light and solar energy falls within a 300 - 2,500 nm (0.0003 mm - 0.0025 mm) wavelength.



In this spectrum, UV radiation lies between 300 and 380 mm (300 nm = 0.0000003 m), visible light between 380 and 780 mm and near IR between 780 and 2,500 mm. Heat is long wave radiation in the far IR wavelength areas of approx. 5,000 and 50,000 nm (0.005 mm - 0.05 mm).

Longer wavelengths are termed radar, micro and radio waves, while shorter wavelengths are known as x-ray and gamma radiation.



Wave spectrum

2.1 Light

The small area of the solar spectrum that can be seen by the human eye is called (visible) light.

Unbroken (visible) light hitting the human eye is perceived as white light. It is, however, composed of a light spectrum where the various wavelengths – each representing a defined energy – flow into each other:

Colour	Wavelength [nm]
violet	380 - 420
blue	420 - 490
green	490 - 575
yellow	575 - 585
orange	585 - 650
red	650 - 780

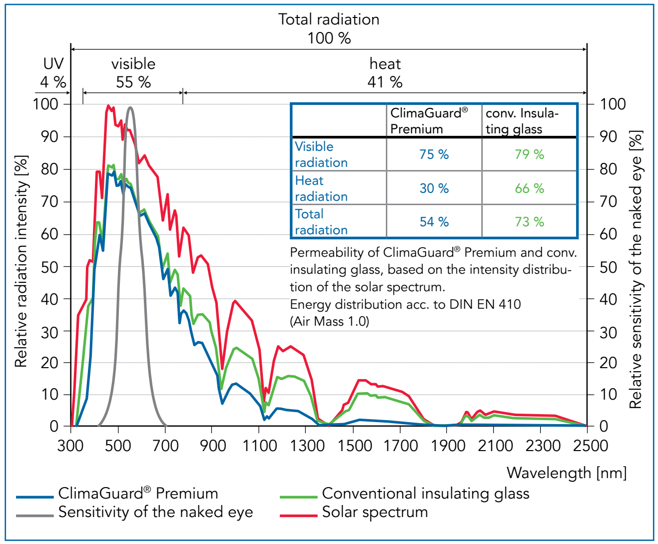
When light hits an object, the object absorbs part of the energy spectrum. Glass, however, transmits light, reflecting the rest of the energy. Depending on the nature of the object, certain wavelengths are reflected and others absorbed. The eye perceives the reflected colour as being the colour of the object.

Artificial lighting can result in colour misinterpretation due to missing wavelength ranges. A well-known example is low-pressure sodium vapour lamps. Since they lack blue, green and red wavelengths, everything appears in monochromatic yellow tones.

2.2 Solar energy

The radiation emitted by the sun that strikes the earth is called solar energy. This wavelength range has been defined through international standardisation (EN 410) as ranging from 300 to 2,500 nm and includes the UV, visible light and near infrared light categories.

The worldwide accredited global radiation distribution curve (acc. to C.I.E., Publication No. 20) shows the intensity of total solar radiation in its respective wave ranges. Fifty-two per cent of these wavelengths are visible and forty-eight per cent are invisible.



Global radiation distribution curve (C.I.E., Publication No. 20)

The shorter the wave length, the more energy is transported. That means that there is a considerable quantity of energy in the visible portion of the radiation. Therefore, light and energy cannot be separated from each other. This is a critical aspect in using and improving architectural glass.

Important properties that are critical for characterising the nature of architectural glass such as solar energy transmission, reflection and absorption and total energy transmittance, can be derived from the solar energy in the global radiation wavelength range (300 - 2,500 nm) and its interactions with glass (➞ Chapter 5.4).

2.3 Heat

Heat or heat radiation are a wavelength range that is not part of the solar spectrum. Heat radiation has far longer wavelengths and is to be found in the far infrared range. In the European standard EN 673, this range is defined as being between 5,000 and 50,000 nm.

Its interaction with heat defines the insulation characteristics of architectural glass and is influenced by heat radiation, heat conduction and convection. The U_g value – the coefficient of heat conductivity – is the fundamental characteristic for judging the glass construction material's heat insulation capability (➞ Chapter 3.5).

2.4 UV radiation

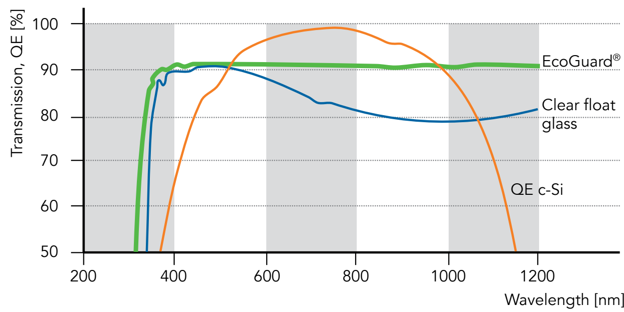
The wave range between 315 and 380 nm is known as UV-A. If If the intensity is too great, this radiation has not only a more or less destructive impact on the skin but also on many other elements (paintings, sealing material, etc.).

Normal insulating glass with 2 panes reduces this radiation by more than 50 %, and when combined with laminated safety glass, the radiation is almost completely filtered out (➞ Chapter 7.4).

2.5 Photovoltaics

Another interesting range of the light spectrum falls between approx. 500 and 1,000 nm, where certain semiconductors are able to generate electric current from solar radiation. The most popular forms are various silicon crystals which are to be found packed between panes of glass, in numerous façade balustrades and on roofs.

Developments in recent years continue to expand this technology through other n-semiconductors like indium sulphide which are mounted directly on base glass on a large scale using the magnetron process. GUARDIAN offers a wide range of these types of coatings for float glass, including special, light-deflecting and transmission optimising ornamental glass.



EcoGuard® smooth or structured glasses enable significantly higher energy transmission than normal clear glass over the wavelength range, a decisively important factor fpr photovoltaic modules.

EcoGuard® pattern transmission vs. clear glass

North Galaxy, Brussels
SunGuard® Solar Light Blue 52
Jaspers-Eyers & Partner Architects
Montois Partners Architects
Art & Build Architect

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.

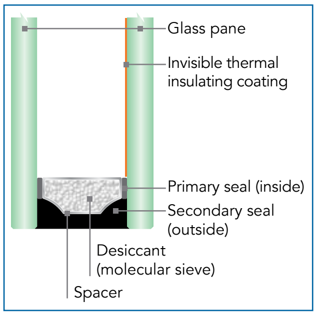
Two or more panes of the same size are aligned with each other at a defined distance and glued together. The resulting hermetically sealed interspace is filled with especially effective thermal insulating inert gas. No vacuum is generated, as laypersons often mistakenly assume.

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

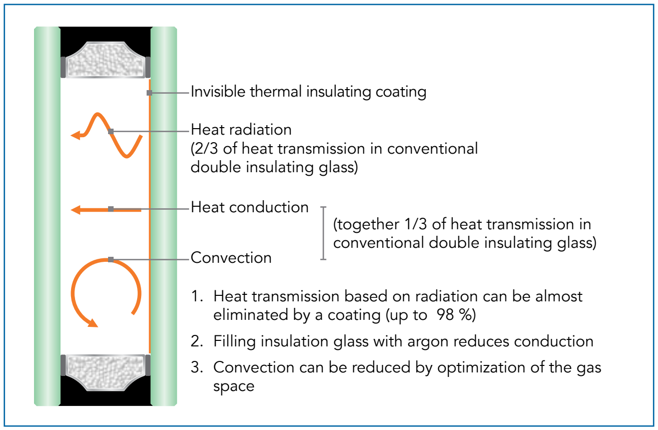
Three factors define heat transmission: heat radiation, heat conductivity and convective flow.

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.

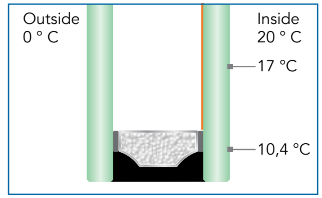
In the case of modern insulating glasses, at least one of these float glass panes is fitted with a low E layer. These coatings have emissivities of less than 0.02 (2 %) in some cases and are capable of reflecting over 98 % of the incoming long wave heat radiation, so that radiation loss is completely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

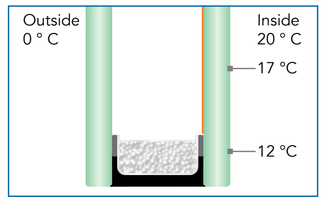
Until very recently, the majority of insulating glass was produced using aluminium spacers. Rising requirements have created thermotechnically improved alternatives that are gaining ground in insulating glass production.



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.

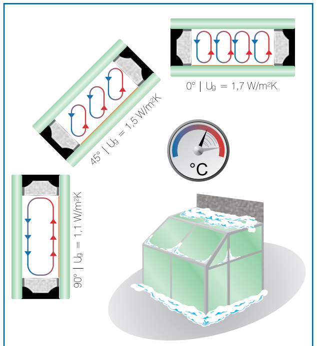
3.5.1 U_g value

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

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

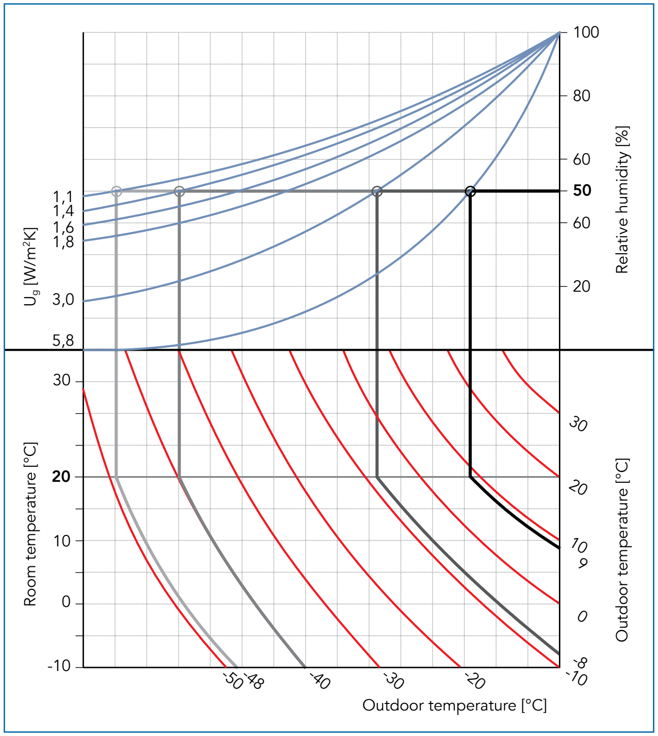
This occurs on poorly insulated windows or those with single glazing. Warm air cools suddenly near windows and transfers humidity to the cold inside pane – the temperature in winter is often below the dew point of the ambient air. The inside pane in modern insulating glass stays warm longer so that condensation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

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

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.

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.

A R_a value of 100 means that the colour of the object observed through the glazing is identical to the original colour.

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.

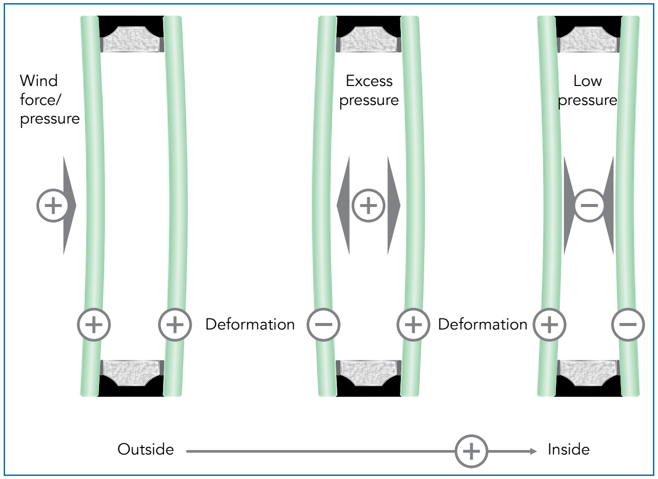
3.12 Interference phenomena

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.

Süddeutscher Verlag, Munich
SunGuard® Solar Neutral 67
Gewers Kühn + Kühn Architects

Saving energy is a hot topic worldwide and the thermal insulation of building envelopes is an important part of contemporary architecture. Yet advances in glass transparency, an architectural achievement of the last three decades should not be pushed back in favour of energy saving. "Transparent insulation" was therefore developed and designed to offer not only unique economic and environmental benefits, but also to guarantee both comfort and convenience.

4.1 Economy

Technological advances of the last three decades have produced systems and equipment that can coat high-tech insulating glass with razor-thin, neutral coatings using low-cost processes. This has optimised the "ε" emissivity capability of thermal insulation to as low as 0.02 and even below, whereas for normal float glass, ε is 0.89.

From an economic perspective, however, this development and its application in new buildings is only the first step. The next step should be to integrate this new glass technology into the millions of square meters of glazed areas of windows and façades. This process is nearly automatic for new buildings today. However, existing buildings represent a much greater challenge, and a lot of work to be done in terms of explanation and persuasion so that ecological, economic and climate goals can be achieved.

In times of steadily increasing heating energy costs, this economic benefit represents a persuasive argument. Just making a simple change, such as glazing involves a rather short amortisation period and also offers the occupants remarkable improvements in convenience and comfort (➞ Chapter 5.3).

The following formula offers one possibility for estimating the energy savings potential provided when replacing outdated glass with modern thermal insulation:

$$E = \frac{(U_a - U_n) \cdot F \cdot G \cdot 1.19 \cdot 24}{H \cdot W} = \frac{l}{HP}$$

E	Savings
U_a	U value of your existing glazing
U_n	U value of your future glazing
F	Glazing area in m²
G	Heating degree day number pursuant to VDI 4710
1.19	Conversion of kilograms to litres: 1 litre = 1.19 kg fuel oil
H	Heat value of fuel: light fuel oil at approx. 11,800
W	Heating system efficiency: oil heater at about 0.85
l	Litre
HP	Heating season

4.2 Ecology

Every litre of fuel oil or cubic metre of natural gas that can be saved through using advanced glazing reduces CO_2 emissions and benefits the environment. Fossil fuel resources are also saved by reducing their consumption and, in addition, glass is one hundred per cent recyclable because it is made from natural raw materials. Due to its natural ingredients and superior energy balancing properties, glass should not be overlooked or dismissed as a viable material in globally recognised certification programs for sustainable and environmentally friendly building.

Leadership in Energy and Environmental Design (LEED) is a leading system in this field. Other systems, include DGNB or Breeam. Buildings realised in compliance with these systems use resources more efficiently than conventional techniques because they take every phase in the life cycle of a building into account – starting with design and construction to renovation and eventually, demolition and disposal.

4.3 Comfort

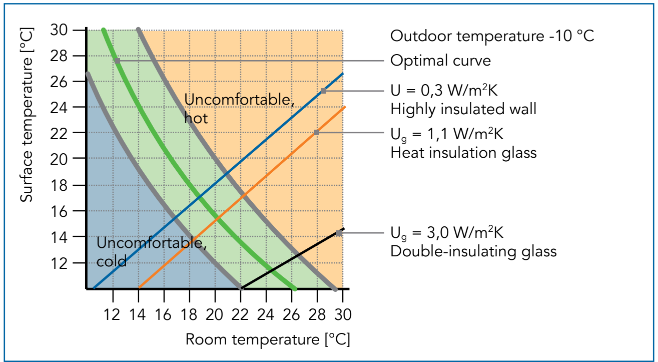
Apart from its economic and ecological aspects, one important goal of building with glass is the tangible improvement in living and working environments. Tinted float glass installed in insulated glass (➞ Chapter 3.2) increases the glazing's room-side surface temperature, thus minimising unpleasant drafts considerably in an area where glazing is present.

Outside air temperature [°C] Type of glass	0	-5	-11	-14
Single-pane glass, U_g = 5,8 W/m²K	+6	+2	-2	-4
2-pane insulated glass, U_g = 3,0 W/m²K	+12	+11	+8	+7
2-pane coated insulating glass, U_g = 1,1 W/m²K	+17	+16	+15	+15
3-pane coated insulating glass, U_g = 0,7 W/m²K	+18	+18	+17	+17

Surface temperature at 20 °C room temperature [°C]

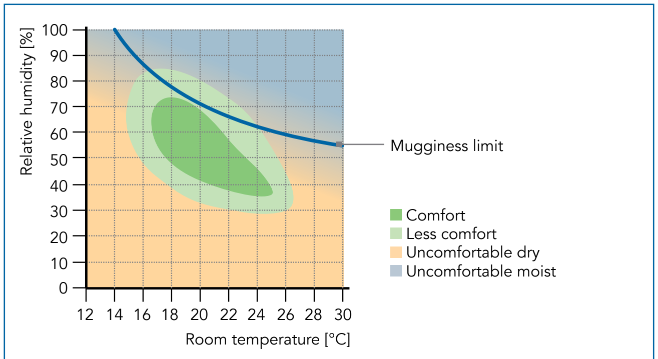
Modern glass increases this temperature to a near room temperature level and significantly improves the comfort level of one's home. The decisive factor in comfort is the temperature difference between ambient air and the adjacent wall and window surfaces.

Most people find a room to be particularly comfortable when the temperature differences between wall (glass) and room air is not more than 5 °C not more than 3 °C between foot and head height.



Comfort chart according to Bedford and Liese

The diagram above shows the range where ambient air feels most comfortable. Humidity should always be viewed as dependent on room temperature. When the air temperature is cooler, the humidity should be higher for the space to feel comfortable. Where the room temperature is higher, the humidity should be lower.



Comfort as a function of room temperature and humidity

4.4 GUARDIAN product range for thermal insulation

GUARDIAN provides a broad range of state-of-the-art thermal insulation layers normally applied toExtraClear® float glass which enable the realisation of a range of modern thermal insulation glasses by our customers. The following are our options regarding thermal insulating glass:

- **ClimaGuard® Premium**

  Today's standard product in modern glazing.

  This insulating glass offers excellent thermal insulation and best light efficiency. That means that a standard insulating glass filled with argon has a U_g value of 1.1 W/m²K at high light and solar energy permeability. GUARDIAN also offers Premium T, a heat treatable version of ClimaGuard Premium.

- **ClimaGuard® 1.0**

  With a U_g-value of 1.0 W/m²K for an argon-filled double insulated glass ClimaGuard 1.0 offers the physical maximum, but without using the expensive krypton gas filling. With ClimaGuard 1.0 T a heat treatable version is available.

- **ClimaGuard® nrG**

  Modern buildings are constructed to low energy and passive house standards and require high-tech glazing in triple pane construction with U_g values ≤ 0.8 W/m²K with maximum transparency in terms of light and solar energy (g value up to 62 %). GUARDIAN also offers ClimaGuard nrG T, a heat treatable version.

- **ClimaGuard® Solar**
  (where appropriate based on climate and / or construction norms)

  A product optimised for the change of seasons. Possesses excellent thermal insulation during cold weather and excellent solar protection for the summer months.

- **ClimaGuard® Neutral 70**
  (where appropriate based on climate and / or construction norms)

  This durable product features low processing requirements. It was developed mainly for markets where not only ease in handling but also heat and solar protection are critical. ClimaGuard Neutral 70 can be heat treated and bent.

- **ClimaGuard® Dry**

  ClimaGuard Dry is a coating, especially designed for surface #1 (outer side) which permanently minimizes condensation on the outer surface. The photo-spectrometric values are scarcely affected.

  The coating should be heat treated in order to be activated and can be combined with any heat treatable ClimaGuard® coating and, as SunGuard® Dry, with any SunGuard® solar control coating on the same glass pane.

- **ClimaGuard® EcoSun**

  ClimaGuard EcoSun was designed especially for large-scale glazing facing in a southerly direction to meet the increasingly stringent requirements for summer thermal protection in residential properties. Maximum transparency combines with reduced energy permeability and an U_g value of 1.0 W/m²K to meet the highest of expectations.

Please see ➞ Chapter 10 for details on all products and their relevant values.

4

Dexia, Brussels
SunGuard® SN 62/34
Jaspers-Eyers & Partner Architects

Modern architecture is today characterised by spaciousness and transparency. Ever larger glass elements for the outer building envelope appear to merge the exterior with the interior. This is reflected worldwide in office and administration buildings of the last two decades, but also in private housing that includes atriums, gables and winter garden glazing using increasingly large glass components. This style of construction only became feasible with the advent of solar protection glasses. These types of glass reduce the greenhouse effect that occurs mainly in summer due to the fact that rooms can heat up to the point that they become unpleasant to be in.

5.1 Economy

Large window and façade surfaces allow a great deal of light deep into a building's interior, thereby avoiding excessive use of artificial lighting. Despite this light penetration, one decisive benefit of using sun protection glass is the immense number of options now available for minimizing the amount of heat energy that penetrates a building, limiting the extreme costs of air conditioning, since it costs much more to cool the interior of a building than to heat it.

5.2 Ecology

Wherever energy is saved – whether by reducing the amount of cooling power used or reducing the phases of artificial light the environment also benefits as a result. In this context, it is a logical consequence to certify these types of sun protection glass products according to for example, LEED, Breeam, DGNB or other worldwide-approved certification systems for sustainable construction. (➞ Chapter 4.2).

5.3 Comfort

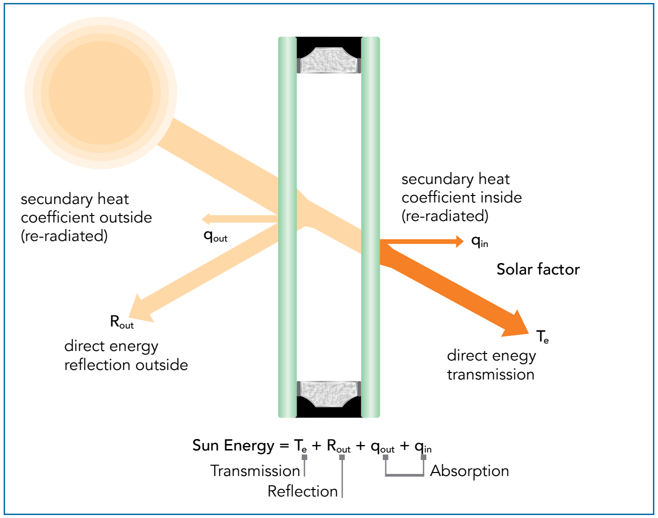
Super-cooled interiors and overheated rooms are both uncomfortable environments to be in, and when rooms are overheated, it can be due to too much incoming solar energy (➞ Chapter 4.3). The floor, walls and furniture absorb solar energy and reflect it as long-wave heat radiation. For this reason, every effort should be made to keep this energy outside interior rooms to achieve an acceptable room climate – without air conditioning. This was previously achieved by constructing buildings using opaque building components that only had small openings in the walls.

Today's architecture which strives to create living and working environments that are close to nature open and spacious has shifted away from this opaque manner of construction towards transparency. Therefore it is essential to master the significant parameters of sun protection using glass to create a functional and comfortable interior while also meeting other requirements, such as structural-physical guidelines and achieving energy efficiency.

5.4 Energy flow through glass

An interaction occurs whenever solar radiation strikes a window: one part of this radiation is reflected back into the environment, another part is allowed to pass through unhindered, and the rest is absorbed. The sum of all three parts is always 100 %:

> transmission + reflection + absorption = 100 %



Solar performance of glass

5

5.5 Sun protection in summer

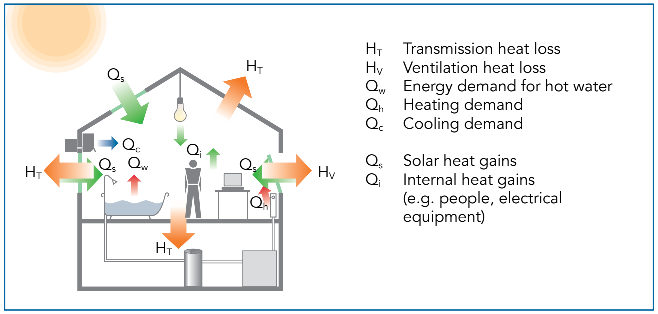
Modern insulated glass allows short wave **solar** radiation to pass through without hindrance, but the majority of short wave **heat** radiation is reflected. This results in solar heat gain in the cold seasons. In summer, however, this solar radiation can result in overheating. Therefore, specific requirements need to be met to prevent this overheating that can result from these larger glass surfaces, starting with the solar input factor S, which should be determined as follows:

$$S = \frac{\Sigma_j (A_{Wj} \cdot g_{total})}{A_G}$$

A_W: Glazed area in m²
A_G: Total area of the room behind the glazing
g_{total}: Total energy penetration degree of the glazing incl. solar protection, calculated according to equation (*) resp. acc. to EN 13363-1 or adjusted to EN 410 resp. warranted manufacturer details.

$$* \quad g_{total} = \frac{g}{F_C}$$

g: Total solar energy transfer of glazing acc. to EN 410
F_C: Reducing coefficient for solar protection equipment to table 8



Representation of the energy demand

In addition to other energy sources (see figure above), the position and size of the glazing are critical. In general, windows or façades with large areas of glazing that face east, west and, especially, the south should be equipped with suitable sun protection glazing.

5.6 Sun protection using glass

Early production of sun protective glass was based on glass coloured in the compound. Compared with clear glass, coloured glass increases solar radiation absorption, but it also has a significant effect on the transmitted visible light. As monolithic glass, it reduces the transfer of energy to approx. 60 %, and in insulating glass, combined with a normal pane of clear float glass, it reduces the solar energy transmission to approx. 50 % when the coloured glass thickness is 6 mm. The thicker the glass, the higher the energy absorption and the lower the transmission. Green, grey and bronze-coloured glass is most frequently used. Due to their own inherent colouring, they can significantly change the way interior colours are perceived. Advances in glass coating technology have produced a much broader range of colours that are also considerably more neutral in terms of the effect they have on interior colours.

Today's sun protection glazing is based on coated glass rather than on coloured glass, and is produced using the magnetron-sputter-process (→ Chapter 1.3.1).The multitude of coating varieties can be used for special applications. GUARDIAN is focusing on this technology and developing new glass for a large variety of requirements.

In addition to actual solar protection, which is constantly being refined, a great deal of research and development effort is invested in optimising storage life, processing and resistance to mechanical influences. Another essential requirement with regard to coating is to supply versions for all products that can be laminated, tempered and bent. Only through these parameters can the broad spectrum of modern architecture be addressed in every aspect.

Sun protection coatings are normally used on the outer pane and oriented towards the interspace (insulating glass position #2). A 6 mm thick outer pane is standard. A thinner counter pane works against optical distortion caused by the insulating glass effect (→ Chapter 3.1.3). If the interspace is bigger than 16 mm due to fixtures in the interspace or for sound damping purposes, this effect should be considered during planning. Static requirements often demand thicker glass.

5.7 Solar control glass as design component

The trend today is toward design-oriented façades, which entail new designs in solar control glass.

Glass with low outside reflection can be manufactured, depending on the coating that is used. Glass façades can be built to neutralise the visible borders between inside and outside, yet remain energy efficient.

On the other hand, there are mirroring or colour-reflecting coatings that allow for some architectural license, including realising unconventional design concepts. Colour-coordinated balustrades, for example, enlarge the range of solar control glass (➞ Chapter 8.2).

Such creative and additive glass designing is generally project-related and feasible once the physical construction rules have been taken into consideration. Digital or screen print techniques are available, along with laminated safety glass. Please refer to ➞ Chapter 8.3 for more information.

5.8 SunGuard® sun protection glass

No matter what the architecture or building physics requirements, the broad SunGuard® glass range can provide an optimum transparent solution.

- **SunGuard® eXtra Selective**

  SunGuard eXtra Selective offers a unique symbiosis of transparency, thermal insulation and solar protection. The focus is on the extremely high selectivity – the ratio of light to solar energy transmission. "SNX" stands for the latest generation glasses with a spectral selectivity greater than 2. All technical data is extremely close to physical feasibility. "SNX-HT", a thermal pre-tempered variant, is also available.

- **SunGuard® SuperNeutral**

  In addition to high spectral selectivity, the most important feature of this product line based on ExtraClear® float glass is its neutral appearance combined with minimal reflection. In double insulating glass, U_g values of up to 1.0 Wm^2K are achieved with different light transmission values.

  All SunGuard SuperNeutral types are available as "SN-HT", a thermal pre-tempered variant.

- **SunGuard® High Performance**

  SunGuard High Performance is a product line of selective combination coatings with a broad variety of colours and reflection grades. All of this glass can be tempered, bent and imprinted using a ceramic process.

  Thanks to the consistency of the coating, many SunGuard High Performance types are compatible with a broad range of insulating glass sealants and structural silicones, making them ideal for structural glazing facades. Many of these coatings can be used to create the PVB film of laminated glass.

  In a double-glazed insulating glass unit $_g$ values lie between 1.5 and 1.1 Wm^2K without additional thermal insulation as a counterpane, τ_L-values are between 60 and 30 % and g-values between approx. 50 - 20 %, depending on the intensity of colouring and reflection grade.

- **SunGuard® Solar**

  Providing the highest flexibility for use and processing, SunGuard Solar is our series of pure control coatings. The whole spectrum of every conceivable process, including lami nating, tempering, bending or imprinting, can be realised with SunGuard Solar glass. It tolerates nearly all glazing materials and sealants.

  In double-insulating glass and with a counter pane of ClimaGuard® Premium, the SunGuard Solar series provides a U_g value of 1.1 Wm^2K with τ_L values of approx. 10 to 60 % and g-values of < 10 up to approx. 50 %.

- **SunGuard® High Durable**

  SunGuard High Durable are pure solar control glasses which, in terms of visual characteristics and aesthetics, essentially correspond to the SunGuard® Solar series. The important difference is the fact that these glasses can be used for monolith installations, due to the use of innovative new materials.

Please see ➞ Chapter 10 for details on all products and their relevant values.

KIA European Headquarters, Frankfurt
SunGuard® SN 51/28
Yutake Omehara architect
Jochen Holzwarth architect

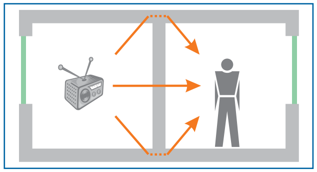
Raiffeisen International "Die Welle", Vienna
SunGuard® Solar Royal Blue 20
Hans Hollein Architect

6.1 Human aspects

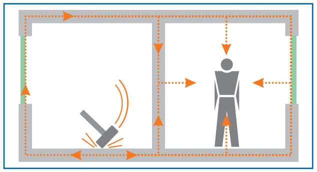
In the past few decades, our environment has become much louder as a result of mobility and industrialisation. This development has since become a severe problem for many people. Permanent noise represents two key dangers. Once a person's sense of hearing is damaged, it can start to diminish unnoticed over time, which can lead to worsening tinnitus and anblyacousia. Hearing loss may also contribute to mental illnesses that can start with insomnia, inability to concentrate (due to the tinnitus), all of which can further lead to allergies, circulation diseases, high blood pressure, even to an increased risk of heart attack.

6.2 Sound wave characteristics

Noise is a mixture of different sound waves that arise in solid compounds, liquids or gases (air). Depending on the way they are transmitted, the waves are called airborne or structure-borne noise.



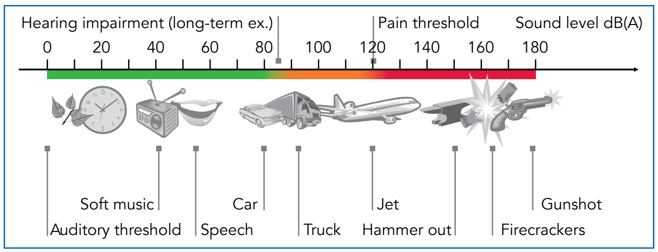
Airborne sound



Structure-borne sound

6.2.1 Limits

Sound is normally transported both through air and solid objects. The intensity of pressure fluctuations is called sound pressure measured in Decibels (dB) and can vary extremely, from ticking of a clock to the crack of a gunshot.

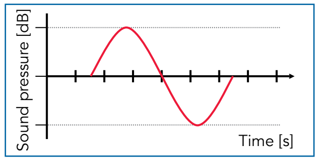


Decibel meter

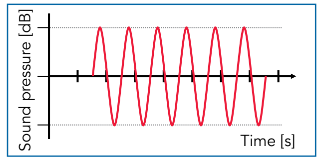
Sound source	Distance app. [m]	Sound level dB(A)
Rustling leaf	1	10
Clock ticking	1	20
Soft music	1	40
Normal speech	1	50 - 60
Car	7	80
Heavy truck	7	90
Jackhammer	7	90 - 100
Police siren	10	110
Jet	20	120 - 130
Hammer out	5	150
Firecrackers	0	170
Gunshot	0	180

Noise source and sound level

Frequency is the number of waves or vibrations per second and is measured in Hertz (Hz). Sound or noise is composed of many waves of different frequencies. Deep tones are low frequencies and high tones are high frequencies.



Bass (low-pitched) tones



Treble (high-pitched) tones

6.2.2 Detection

The mix of these frequencies in a sound can be represented as a frequency spectrum. The frequency spectrum of sounds that the human ear can hear falls between 20 and 20,000 Hz. Only the highest range, which lies at around 4 kHz and then dissipates rapidly in both directions, is relevant when it comes to protecting against structural noise. Sound insulation ratings, therefore, mainly take the range between 100 and 5000 Hz into account. Moreover, as the human ear registers high frequencies more readily than low frequencies, appropriate consideration is taken of this auditory sensation, a capacity which is expressed in terms of dB(A). "A" stands for adjusted in this respect. Defining sound reduction does not follow a linear path, but rather is a logarithmic function. Two sources of sound that are each 80 dB, for example, do not add up to 160 dB, but only to 83 dB. Thus, the human ear registers a difference of ± 10 dB as a doubling halving of the volume.

Generally, the following rating applies based on logarithmic assessments:

Insulation	Noise reduction
10 dB	50 %
20 dB	75 %
30 dB	87.5 %
40 dB	94.25 %

Since a large percentage of soundproof glass insulation installed today is rated for 40 dB, this type of glass only permits about 6 % of external noise to penetrate to the inside.

6.3 Sound ratings for buildings

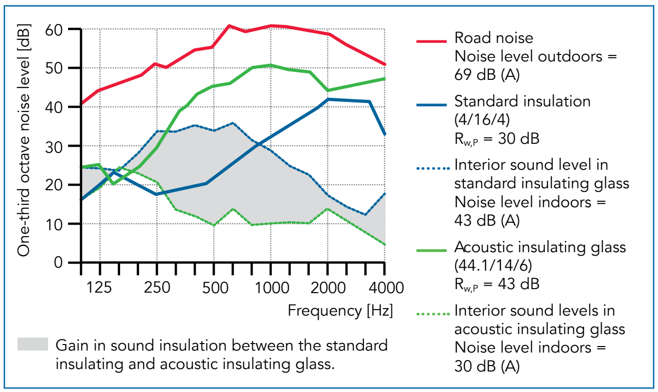
A building component (e.g. glass) with a noise reduction capacity rating of 40 dB will reduce the 70 dB of outside noise to 30 dB on the inside of the building, a noticeable reduction which is one sixteenth the outdoor noise level.

When working with buildings, it is not possible to consider the individual building in terms of noise level. One should take the entire periphery around the building into account to calculate the total dB possible for sound reduction.

6.3.1 Medium noise reduction factor (R_w)

The noise for solid objects is defined acc. to EN 20 140, EN ISO 717 and EN ISO 140 and indicated as R_w in dB.

This is done by measuring and comparing a reference curve. R_w represents an average sound insulation over the relevant frequencies.



Comparison soundproofing between standard insulating and acoustic insulation

Here, the reference curve is moved vertically as long as the lower deviation does not exceed 2 dB. Overshooting is not taken into consideration. The value of the ordinates of the moved reference curve at 5,000 Hz then complies with the average evaluated noise reduction value of R_w. Additionally, especially in Germany,

DIN 4109 has to be considered. It defines the following nomenclature:

R_w = evaluated noise reduction extent in dB with no noise transfer over the adjacent components (just the net glass value, for example)

R'_w = weighted sound reduction index in dB with sound transmission via adjacent structural components (for example windows)

$R'_{w,res}$ = resulting sound reduction index in dB of the entire structural component (e.g. entire wall incl. Windows consisting of frames with glass and structural connections)

$R_{w,P}$ = weighted sound reduction index in dB, determined on the test station

$R_{w,R}$ = weighted sound reduction index in dB, calculation value

$R_{w,B}$ = weighted sound reduction index in dB, values measured on the construction

6.3.2 Correction factors (C, C_{tr})

This correlation can be used to compare and calculate individual acoustic components to arrive at the total sound level. However, real-life application has shown that, depending on the noise source for these R_w mean values, there are certain correction factors that should be taken into consideration which are also defined in the EN.

Source of the noise	Spectrum adaptation value
Normal frequency noise levels such as talking, listening to music, radio and TV	
Children playing	
Railcars moving at an average and high speeds*	C
Highway traffic travelling at over 80 km/hr*	
Airplanes using jet propulsion from a short distance	
Production plants, which emit predominantly medium to high-frequency noise	Spectrum 1
Inner city street noise	
The sound made by railcars moving at a slow speed	
Prop planes	C_{tr}
Airplanes using jet propulsion from a great distance	
Disco music	
Manufacturing companies with predominantly low-frequency noise radiation	Spectrum 2

Spectrum adaptation value

* In several EU countries, there are computational methods for the fixation of octave band sound levels for road and rail traffic noise. These can be used for comparison with the spectra of 1 and 2.

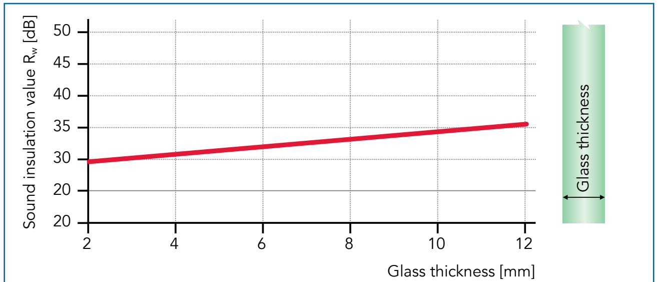
These correction factors, i.e. spectrum adaptation values C and C_{tr}, reduce the sound reduction index R_w of the component if the noise sources conforming to the EN list are causative. This means that a component with the values R_w (C,C_{tr}) = 40 (-2,-8) has an average insulating capacity of 40 dB, especially for noise sources at higher pitches. However, the noise reduction is 2 dB lower and mainly for those with lower frequencies, even 8 dB lower.

6.4 Influence factors and production varieties

The following parameters affect noise reduction via glazing.

6.4.1 Weight of the pane

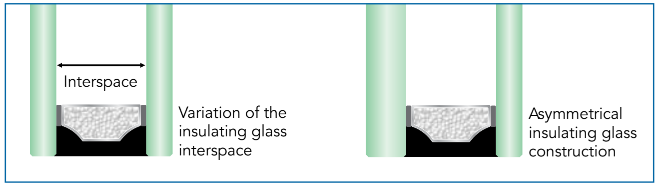
It generally follows that the thicker the pane per surface unit is, the greater the noise reduction. Therefore, insulation efficiency increases as glass thickness rises.



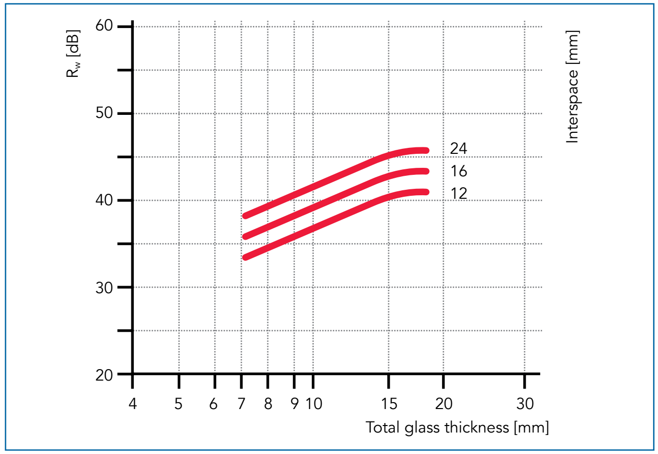
Insulating performance as a function of the glass thickness

6.4.2 Insulating structure / Interspace

Double or triple insulating glass is a mass-spring-mass system. Both outer panes (masses) are separated from each other by the air or gas that fills the interspace. The interspace muffles the vibrations from the outer pane before they reach the inner second pane, with the rule being the greater the interspace, the more effective the noise reduction. But this is only possible to a limited degree, since this process not only reduces thermal insulation (→ Chapter 3.3) but also increases the climate's impact on the unit. A moderate increase of the interspace with an asymmetrical insulating structure already achieves excellent glazing noise reduction values.



Insulating glass constructions

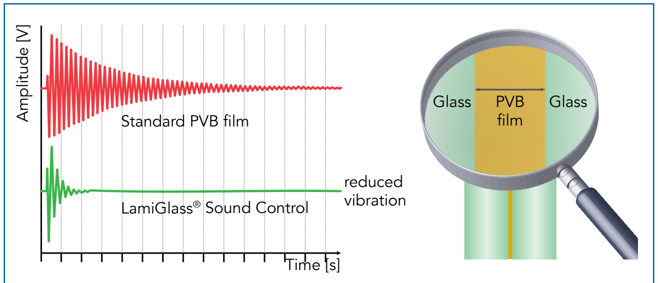


R_w of double insulated glass

6

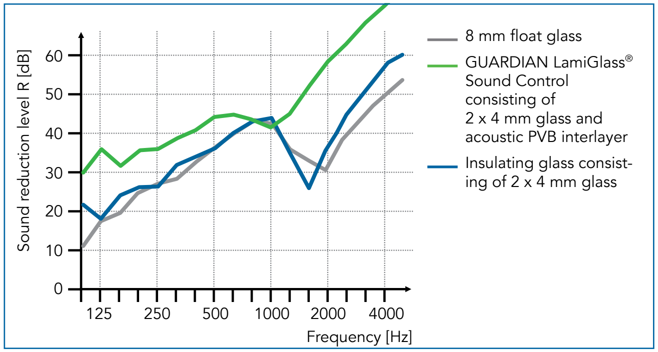
6.4.3 Decoupled single panes

The noise reducing effect of thicker, heavier glass may be further optimised by using a flexible interlayer (PVB) to connect two single panes of glass. With this solution, the thickness and weight per unit area remain the same. The pane, however, becomes "softer", thus increasing its insulating capacity in terms of sound waves.



Decoupling of single panes

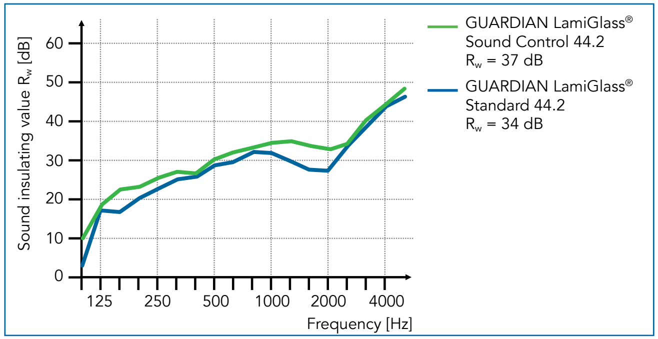
Special noise protection films are also used in addition to the commercially available PVB films which have been utilised to produce laminated safety glass for many years. In addition to the safety aspect, they also increase noise protection.



Comparison soundproofing

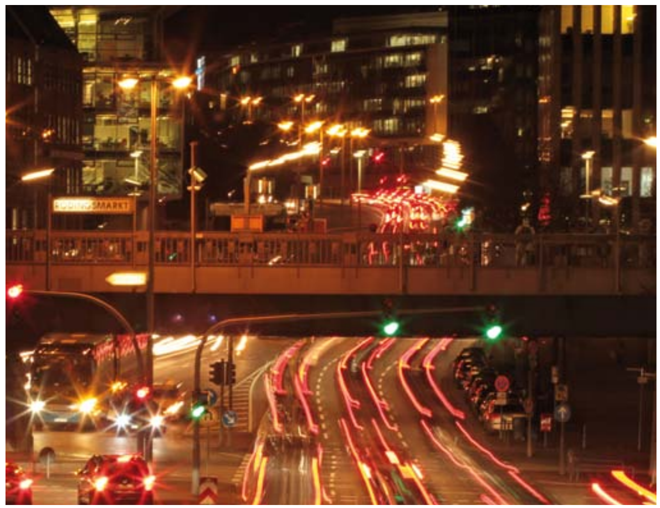
6.5 GUARDIAN sound protection glass

The GUARDIAN base line of products uses two different versions for manufacturing noise control products. The first version is for manufacturing laminated safety glass products that provide improved sound insulation because they are made using the proven polyvinyl butyral film (PVB) (→ Chapter 7.4).



Comparison between GUARDIAN LamiGlass® Standard and GUARDIAN LamiGlass® Sound Control

Another improvement to the products is the replacement of standard films with sound-optimised versions. Depending on the structural requirements of the building, you can choose between different types of glass, since a wide range of functional glass is created (→ Chapter 10).



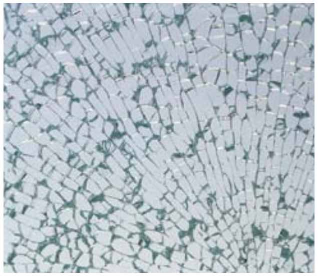
International House of Music, Moscow
SunGuard® HP Light Blue 62/52
Architects Yuriy P. Gnedovski + Vladlen D. Krasilnikov

A component should be reliable if it is going to be safe to use. Glass manufacturers recognised this fact more than 100 years ago and apply this principle to automotive glass manufacturing today. A wide range of safety glass is available that is used either individually or in combination with other types of glass in building construction. The three main types of glass are tempered safety glass, laminated safety glass and heat-strengthened glass.

7.1 Fully tempered glass

This glass type can be manufactured from float glass or practically every known flat structured ornamental and cast glass. In this process, the basic glass is thermally treated (tempered), lending it three outstanding characteristics. The tensile strength is four to five times greater than annealed glass of the same thickness allowing it to handle much higher suction or blunt impact forces. Tempering also makes glass more resistant to severe, short-term fluctuations in hot and cold temperatures, as well as enhancing its capability to handle large differences in temperature within the pane of glass itself.

However, should failure occur due to overloading, the glass will fracture into a blunt-edged mass of loosely connected pieces that pose a lesser risk of injury than the sharp-edged shards produced by shattered conventional glass.

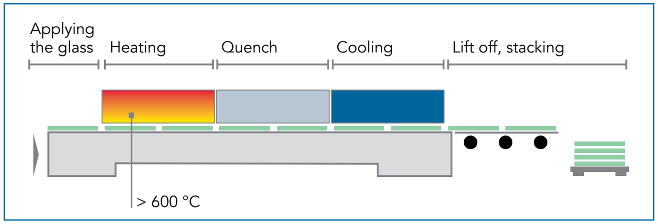


Fracture tempered glass

7.1.1 Production

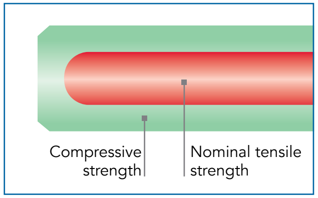
The only glass panes that reach the tempering unit are those cut from basic glass. These glasses are precisely measured, the edges have already been worked, and drilled holes and boundary cuts have already been made.

These panes are heated to approx. 600 °C using controlled and uniform heating, then rapidly cooled using cold air and finally "quenched" through rapid cooling with cold air back to room temperature.



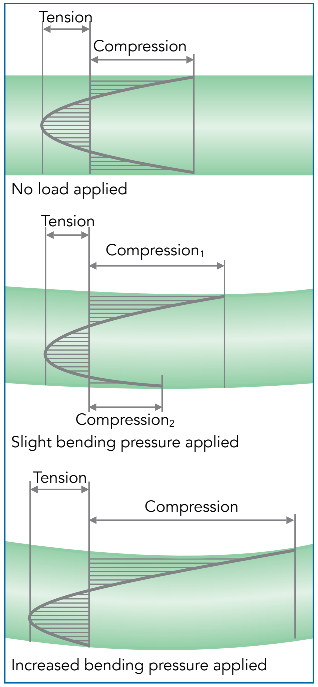
Manufacturing process of tempered glass (schematic representation)

This "quenching" or, in professional terms, blow off causes the glass surface to cool down faster than the centre of the glass, creating a durable tensile strength in the glass. The tensile stress of glass surfaces subject to compressive force increases relative to the core of the glass cross section.

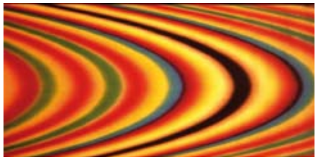


Tension dynamic

This tension structure gives the glass its outstanding features and also explains why all machining should be carried out on the glass in advance. If drilling, for example, is carried out on the glass after it has been tempered, the entire glass will shatter as drilling breaks up, or interrupts, the tension structure, causing the glass to break apart. The tension zones are visible under polarised light and can be viewed at certain angles as coloured, optical effects.



Tensile strength distribution



Tension dynamic – visible

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7.1.2 Building physical characteristics

Thermal conductivity, light and energy permeability, thermal expansion, compressive strength and elastic modulus remain identical in the basic glass, as do the weight, sound insulation characteristics and the chemical properties. Other parameters, however, will vary considerably.

7.1.3 Resistance to impact and shock

Fully tempered glass is resistant to shocks from soft, deformable objects like the human body and conforms to EN 12 600 (the pendulum impact test for glass in buildings). The respective field of application determines the required glass thickness.

7.1.4 Tensile bending strength

Fully tempered glass can be made out of various basic types of glass and is also frequently coated with ceramic colours. The tensile bending strength should therefore be classified according to the design:

- Tempered glass made from float glass
  σ = 120 MPa
- Tempered glass made from ornamental glass
  σ = 90 MPa
- Tempered glass made from enamelled plane glass, whereby the enamelled side is under tensile stress
  σ = 75 MPa

7.1.5 Resistance to ball impact

At 6 mm thick, fully tempered glass is especially suitable for use in large surface glass applications in gyms and sports halls as is typical in countries such as Germany (in acc. with DIN 18 032 "Test of safety against throwing balls").

7.1.6 Heat influence

Fully tempered glass is capable of resisting temperatures exceeding 300 °C for brief periods of time, and temperatures exceeding 250 °C for extended periods of time. The resistance versus temperature differences within a glass pane, between the centre and the edge of the pane, for example, is very high, at 200 Kelvin (K), compared with 40 K for float glass.

7.1.7 Anisotropies (strain pattern)

These are unavoidable irisation formations on thermally tempered glass due to the internal stress distribution in each pane. Depending on the viewing angle, dark-coloured rings or stripes are visible in polarized light.

7.1.8 Optical quality

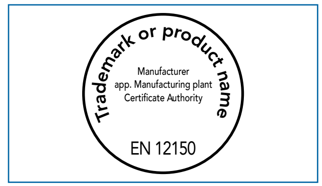
Minor surface changes can occur in tempered glass, as it is moved about on wheels during manufacturing. These minor surface changes are referred to as "roller waves", result from physical and production influences and are unavoidable. This is the same reason why, in exceptional cases, dots known as roller pickup can also form on the glass surface and are visible under adverse lighting conditions.

7.1.9 Moisture film on tempered glass

The wettability of the surface can differ due to pressure from rollers, suction cups, trowelling compounds or lubricants. During subsequent formation of a moisture film on the glass surface, this varying wettability within a glass surface is visible but does not indicate any deficiency.

7.1.10 Identification

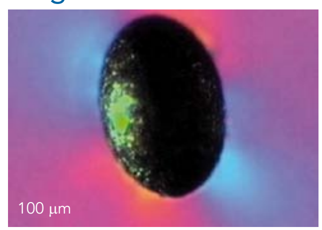
Each tempered piece of glass must be clearly and permanently marked in accordance with EN 12150.



Identification of tempered glass

7.2 Heat-soaked tempered glass

Each basic glass contains extremely low quantities of nickel sulphide crystals that are inevitably introduced into the glass via the raw materials. In normal float or patterned glass, these crystals do not have any relevance.



Nickel sulphide – particel in float glass with mechanical stress

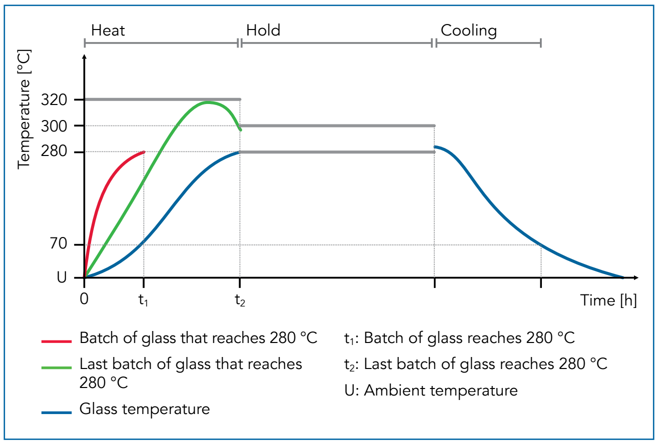
The extremely rapid cooling off period during the tempering process "freezes" the NiS particles in a high temperature crystal modification. When heat is later applied through solar energy absorption, for example, this crystal structure may change because the volume of the crystals change, i.e. increases, and this may cause the glass to suddenly burst apart as soon as the particles exceed a critical size.

Any safety-relevant glazing and panes, such as façade glass, which are exposed to high temperature fluctuations should therefore be subjected to the additional heat soak test.

This test is carried out acc. to EN 14 179 and should be documented. This test forces the nickel sulphide crystals that may be present to react quickly. Those panes of glass that do have these invisible crystals are intentionally destroyed during this test.

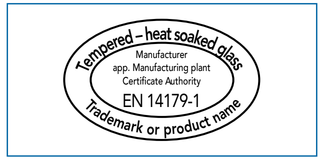

Heat-soak oven

For this purpose, the tempered glass panes are heated to a defined 290 °C ± 10 % for at least 2 hours. In Germany, this test is conducted according to the local list of construction rules, so that the test may even last as long as 4 hours to achieve the regulated building product "tempered – heat soaked glass".



Temperature curve heat-soak test

This process is monitored by internal and external controllers and should be permanently documented for each pane supplied. Moreover, these panes should be visibly marked with the tempered glass label.



Identification of tempered – heat soaked glass

7.3 Partially tempered glass (heat strengthened glass)

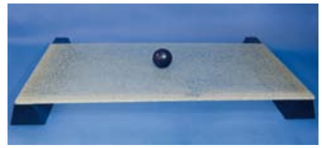
According to EN 1863, as single pane, heat strengthened glass is not classified as safety glass, but as a combination element, indispensable in the glazing construction business.

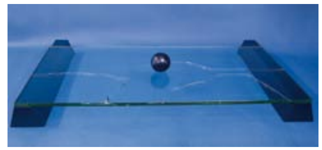
7.3.1 Production

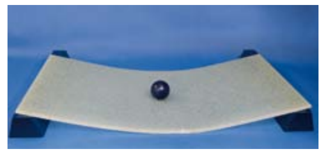
Production is the same as for fully tempered glass, but the cooling-off process is slower, which means that the stress differences in the glass are lower. You could even rank heat strengthened glass between float and fully tempered glass. The values for temperature change resistance and the flexural tensile strength are proof of this. The structure after a fracture occurs is similar to that of a float glass pane. The fracture radiates outward from the point where the impact/fracture occurred to the edges of the pane.

Thanks to the fracture characteristics of heat strengthened glass, which are different from tempered glass, a single unit of laminated safety glass made of heat strengthened glass has excellent residual load-bearing properties.

In the event of the failure of one of two heat strengthened panes in laminated safety glass only minor deflection occurs, contrary to the sagging of laminated safety glass made of tempered glass. That is


Laminated safety glass made of 2 x tempered glass – top pane broken


Laminated safety glass made of 2 x heat strengthened glass – top pane broken


Laminated safety glass made of 2 x tempered glass – both panes broken


Laminated safety glass made of 2 x heat strengthened glass – both panes broken

7

why heat strengthened increasingly replaces tempered glass in laminated glass when increased flexural tensile strength and alternating temperature loading are required.

Slower cooling down during the production process avoids the risk of a spontaneous breakage by NiS inclusions.

7.3.2 Tensile bending strength

- Heat strengthened glass made of float glass
  σ = 70 MPa
- Heat strengthened glass made of ornamental glass
  σ = 55 MPa
- Heat strengthened glass made of enamelled plane glass whereby the enamelled side is under tensile stress
  σ = 45 MPa

7.3.3 Heat influence

The failure strength of a heat strengthened glass against temperature differences in the glass space can be assessed at 100 K.

7.4 Laminated safety glass

Since its invention in 1909, and after more than a century of continuous improvement, laminated safety glass is a key component in the realisation of modern architecture. The permanent connection of two or more single pane glasses with sticky, elastic, highly tear-resistant polyvinyl-butyral-foils (PVB) makes a multi functional element from the glass, which can handle high static forces and constructive tasks in addition to its given transparency. Any conceivable type of plate glass can be laminated to laminated safety glass, no matter whether it is float or flat structural patterned glass, coated or printed.

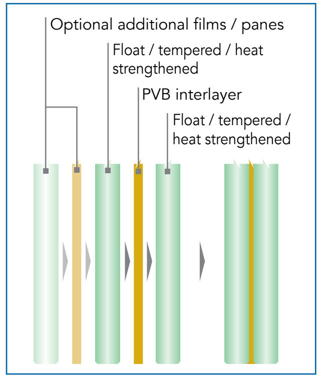
The safety effect of laminated safety glass is based on the extremely high tensile strength of the PVB interlayer and its excellent adhesion to the adjacent glass surface. In terms of mechanical stress such as shock, impact or influence from other forces breaking the glass, though, the fragments adhere to the PVB layer, so that the laminated safety glass will usually retain its stability under load.

This leaves the glazed opening closed, which sharply reduces the risk of injury due to chips adhering. Depending on the use of laminated safety glass, multiple PVB interlayers can be placed between two glass surfaces in order to meet more stringent requirements.

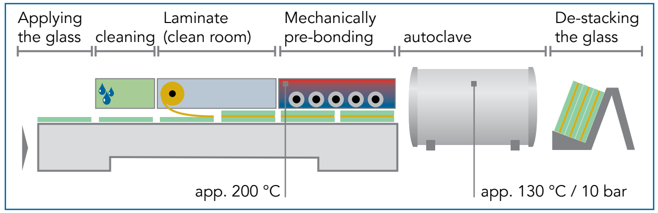
7.4.1 Production

Laminated safety glass is produced according to the stipulations of EN 14 449. Two or more thoroughly cleaned panes, each with one or more PVB interlayers are mounted on each other in a clean room. This sandwich is then pre-strengthened in a rolling process at approx. 200 °C heat. This is referred to as a mechanical pre-bonding unit.

The resulting transparent glass-film unit is now transported with many others on a glass rack to the autoclave, a high pressure aggregate, where the transparent pre-bonding unit is subjected to approx. 10 bar of pressure and heated to 130 °C, producing an absolutely transparent laminated safety glass.



Construction of laminated safety glass



Production process for laminated safety glass (schematic representation)


Production of laminated safety glass – clean room

7.4.2 Building physical characteristics

Compressive strength, thermal conductivity, thermal expansion, modulus of elasticity and mass per unit area and chemical characteristics are similar to individual basic glass properties. The light transmission is also a result of the values of the processed basic glass and the PVB films. Depending on the thickness of the assembly, the light transmission is between 90 - 70 %. The light transmission and the colour rendering impression – especially when the assemblies are thicker with several panes and many films – can be improved by using Float ExtraClear® and primarily Float UltraClear™.

7.4.3 Impact resistance

To simulate the impact of a human body, EN 12 600 stipulates a pendulum test for glass for buildings. Constructions audited by GUARDIAN that meet these requirements are contained in ➞ Chapter 10.6.

7.5 Safety with and through glass

In the past, large glass surfaces could be a weak link in a building's outer shell against attacks of any kind. Modern, new-age glazing has now taken remedial measures. Basically, safety when working with glass is broken down into using glass properly within the building structure and employing it on the outside of the building. Details are listed in ➞ Chapter 7.6.

7.5.1 Active safety

The task is to use glass as an active barrier against dynamic attacks. To the primary aim is to prevent penetration over a defined period of time, but also in the case of selective, short term peak loads. To resist such forces in case of emergency, EN standards prescribe test criteria which individual types of glass have to fulfil.

7.5.1.1 Resistance to manual attack (ball drop) acc. to EN 356

Impact resistant glass is tested with a steel ball weighing 4 kg with a diameter of 10 cm (ball drop test). To distinguish between different resistance classes, this ball is dropped in free fall from different heights and several times onto the same point. The following specifications result from this test:

Resistance class acc. to EN 356	Drop height (hits)
P1 A	1,500 mm (3)
P2 A	3,000 mm (3)
P3 A	6,000 mm (3)
P4 A	9,000 mm (3)
P5 A	9,000 mm (9)

Qualified types of glass see ➞ Chapter 10.6.

7.5.1.2 Resistance to manual attack (axe strokes) acc. to EN 356

Another test method is used to meet the increasing demands of penetration prevention. Depending on the resistance class, the test glass should resist a number of defined hits at the same spot with a mechanically driven 2 kg axe. After having reached the defined number of hits, only a maximum opening of ≤ 400 x 400 mm is allowed.

Resistance class acc. to EN 356	Number of hits by axe
P6 B	30
P7 B	51
P8 B	70

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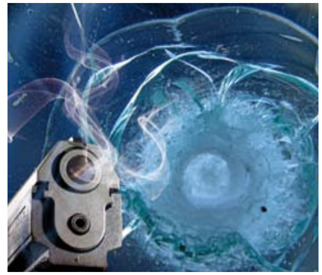
7.5.1.3 Bullet resistance acc. to EN 1063

EN 1063 governs the safety of people and goods in case of direct fire by different weapons and calibres from different distances. Each test pane is fired at three times in a predefined hit pattern at room temperature. The glass should not be penetrated in this test. Where people are directly behind such glazing in case of an attack, a differentiation is made between "shatterproof" (NS) and "non-shatterproof" (S).

All laminated safety glass types used in this application have laminated, asymmetric assemblies, and automatically have outstanding penetration prevention.



Calibre	Projectile			Firing class		Firing distance [m]	Speed [m/s]
	Type		Weight [g]	Splintering	No splintering		
.22 LR	L/RN	Lead round nose bullet	2.6 ± 0.10	BR1-S	BR1-NS	10	360 ± 10
9 mm x 19	VMR/Wk	Full metal jacket flat nose bullet with soft core	8.0 ± 0.10	BR2-S	BR2-NS	5	400 ± 10
.357 Magn.	VMKS/Wk	Full metal jacket cone pointed nose bullet with soft core	10.25 ± 0.10	BR3-S	BR3-NS	5	430 ± 10
.44 Magn.	VMF/Wk	Full metal jacket flat nose bullet with soft core	15.55 ± 0.10	BR4-S	BR4-NS	5	440 ± 10
5.56 x 45	FJ/PB/SCP 1	Full jacket pointed bullet with lead core with steel insert	4.0 ± 0.10	BR5-S	BR5-NS	10	950 ± 10
7.62 x 51	VMS/Wk	Full jacket pointed bullet with soft core	9.45 ± 0.10	BR6-S	BR6-NS	10	830 ± 10
7.62 x 51	VMS/Hk	Full jacket pointed bullet with a hard core	9.75 ± 0.10	BR7-S	BR7-NS	10	820 ± 10
Shotgun 12/70*	Brenneke		31.0 ± 0.50	SG1-S *	SG1-NS *	10	420 ± 20
Shotgun 12/70	Brenneke		31.0 ± 0.50	SG2-S	SG2-NS	10	420 ± 20

* The test is performed using a single shot

7.5.1.4 Explosion resistance acc. to EN 13 541

This European requirement specifies the qualifications and the methods for blast resistant security glazing products for building applications. The classification applies only to the dimension of a specimen of about 1 m². The aim here is also to automatically achieve excellent penetration resistance parallel to the types of glass supplied.

Type classification number	Characteristics of a flat compression wave Minimum values for the		
	Pos. max. compression of the reflected shock wave (Pr) [kPa]	Pos. specific impulse (i+) [kPa x ms]	Pos. pressure phase period (t+) [ms]
ER 1	50 ≤ Pr < 100	370 ≤ i+ < 900	≥ 20
ER 2	100 ≤ Pr < 150	900 ≤ i+ < 1,500	≥ 20
ER 3	150 ≤ Pr < 200	1,500 ≤ i+ < 1,500	≥ 20
ER 4	200 ≤ Pr < 250	2,200 ≤ i+ < 3,200	≥ 20

In accordance with EN 13 541

7.5.2 Passive safety

In contrast to active safety glass, which is more likely to fail as a result of a major, deliberate impact, passive safety glass is more likely to suffer everyday involuntary failure.

7.5.2.1 Protection against injury

In each application, whether involving full glass doors, showers, parts of furniture or large-scale glazing in public areas, glass should not be applied in a way which creates sharp-edged shards that could cause massive injuries in case of breakage or shattering. This is why tempered, heat strengthened and laminated safety types of glass are supplied in very different assemblies, depending on their intended use.

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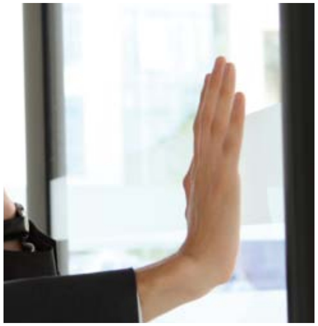
7.5.2.2 Glazing for protecting people against falling out



Clear regulation parameters govern the installation of glass elements in areas where there is a risk of falling. These areas range from simple railings and barriers to room-high glazing installed more than approx. one meter above solid ground. In Germany, the "Technical rules for safety barrier glazing – TRAV" govern these types of installations, and these will be replaced soon by DIN 18 008, part 4. This new DIN is based on unified European standards which all EU countries will have to implement in the short to medium-term. This legal specification regulates in detail the kind of glass and assembly, depending on its area of application. Glazing that deviates from this legal specification is of course allowed, but should be inspected and tested in each single case and approved by the authorities (→ Chapter 7.6).

7.5.2.3 Overhead glazing

Any glazing installed on an incline of ± 10° relative to the vertical is referred to as overhead glazing. In addition to having to withstand the usual types of forces, such as wind, varying weather conditions and snow, the glass must be able to hold up under its own construction load. Therefore, these types of glass should be treated differently to those installed vertically. It is critical that in case of failure, this type of overhead glazing can be guaranteed not to shower down glass splinters, shards or jagged pieces.

The "Technical rules for the use of linear-supported glazing – TRLV currently govern these types of installations in Germany. These technical rules will be replaced soon by DIN 18 008, part 2. This new DIN is a national norm but based on designated European standards which should be implemented in the medium term by all EU countries.

It is a general rule that today's overhead glazing should consist exclusively of laminated safety glass, with a minimum of 0.76 mm PVB for the lower pane. Static requirements may even demand higher standards.

The specifications for "walk-on glazing" are similar to those for overhead glazing. These are glass constructions that can be walked on for a short period of time for cleaning and maintenance purposes. The area underneath the glassed-in walk-on area on is blocked off (→ Chapter 7.6).

7.5.2.4 Post - glass breakage performance / residual strength

Residual stability refers to the characteristic of an installed glass element to remain standing for a defined, limited period of time without exerting any load. This applies only to vertical glazing. Overhead glazing's residual capacity refers to the fact that in case of failure, the glass should bear its own weight over a defined period of time. The requirements and installation situations always determine the respective kind of glazing that should be used. The following charts give a broad overview of this type of implementation.

7.6 Recommendations for certain glass implementations

Detailed specifications for glass construction and the measuring of glass are based on the respective rules and are not stated here in detail. If, for example, additional specifications, fire protection or object-specific requirements exist, they must also be observed.

The following recommendations may partially exceed the legal requirements, based on practical experience.

Key for the tables below

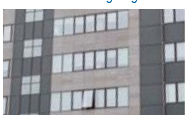
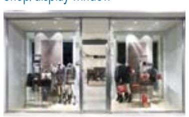
Colour	Explanation
	Minimum required type of glass
	Recommended type of glass
	Alternative type of glass
	Inadmissible type of glass

Colors used

Abbreviation	Explanation
EG	Single-pane glass
MIG	MIG Multi-pane insulated glass
abZ	General approval by a construction supervising body
ZiE	Approval on individual case basis
TG	Tempered glass
TG-H	Tempered – heat-soaked glass
HSG	Heat strengthened glass
LSG	Laminated safety glass

Abbreviations used

7.6.1 Vertical glazing without protection against crashing

Application	Float	TG[1]	TG-H	LSG made of: Float	LSG made of: TG[2]	LSG made of: HSG	Note
Window above railing height 							
Shop/display window 							A minimum glass thickness of 10 mm float glass and/or 12 mm laminated safety glass is recommended due to lack of a corresponding regulation

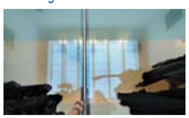
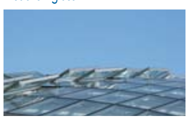
Application		Float	TG[1]	TG-H	LSG made of: Float	LSG made of: TG[2]	LSG made of: HSG	Note
Level glazing[3] 								e.g. French doors, front doors (for burglar-resistant glazing see sec. "Specific safety glass")
Noise protection wall 								Technical rules for the use of linear-supported glazing – TRLV, ZTV-Lsw 06
All-glass door system 								"Points of sale" govern of the Occupational Health and Safety Executive (BGR 202), and/or Workplace Directive (ArbStättV) with ASR 10/5
Cladding for external walls 								DIN 18516-4 Application of laminated safety glass only with a general approval (abZ) or approval in specific case (ZiE)
Sealant glass facade[3] 	internal							ETAG 002 "Structural sealant glazing systems (SSGS)"
	external							
Point-supported facade 	EG							According to abZ or ZiE Important: according to TRPV only laminated safety glass made of tempered or heat strengthened glass!
	MIG							

[1] Important! According to technical rules for the use of linear-supported glazing – TRLV: non heat-soaked single-pane safety glass should only be used for an installation height above public area < 4 m and where no persons are standing directly under the glazing, otherwise tempered – heat-soaked glass must be used!

[2] Important! Laminated safety glass made of 2 x tempered glass does not have a residual load-bearing capacity. In particular, the installation requirements shouldshould particularly be observed.

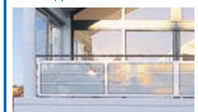
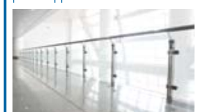
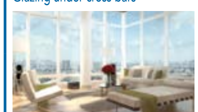
[3] Glass used pursuant to Chapter "Glazing in buildings used for special purposes" takes priority.

7.6.2 Horizontal / overhead glazing

Application		Float	TG	TG-H	LSG made of: Float	LSG made of: TG[2]	LSG made of: HSG	Note
Skylights 								Only for flats and rooms of similar type of use (e.g. hotel and office rooms) with a light surface (internal frame dimension) < 1,6 m2, otherwise see horizontal glazing
Horizontal glazing 	oben							Technical rules for the use of linear-supported glazing – TRLV/DIN 18008
	unten							Other glasses possible provided that falling of larger glass parts on public areas is avoided by suitable measures (e. g. nets with mesh width ≤ 40 mm)
Projecting glass roof 								Linear supported pursuant to TRLV/DIN 18 008 Point supported pursuant to TRPV/ DIN 18008: only laminated safety glass made of tempered glass or heat strengthened glass! lamps not allowed
Glass slats 								Linear supported pursuant to TRLV/ DIN 18008 Point supported pursuant to TRPV/ DIN 18008: only laminated safety glass made of tempered glass or heat strengthened glass! Clamps not allowed
Walk-on glass 								Technical rules for the use of linear-supported glazing – TRLV/DIN 18008 Top pane of the 3 panes made of Tempered glass or Heat strengthened glass; sufficient skid resistance should be ensured; deviating design: abZ or ZiE
Tread-on glass 								ZiE generally required, less requirements compared to walk-on glass

[2] Important! Laminated safety glass made of 2 x tempered glass does not have a residual load-bearing capacity. In particular, the installation requirements shouldshould particularly be observed.

7.6.3 Glazing for protecting people against falling out

Application		Float	TG[1]	TG-H	LSG made of: Float	LSG made of: TG[2]	LSG made of: HSG	Note
Room-height glazing  (category A pursuant to TRAV)	EG							Technical rules for safety barrier glazing – TRAV/DIN 18008
	MIG							Applies to pane of glass on the attack, or side most likely to absorb the impact; pane on non-attack side variable; If laminated safety glass on non-attack side then tempered glass or laminated safety glass on attack side;
All-glass balustrade with fitted rail  (category B pursuant to TRAV)								Technical rules for safety barrier glazing – TRAV/DIN 18008 Laminated safety glass made of Float glass only with abZ or ZiE
Balustrade with glass bracing linear supported  (category C1 pursuant to TRAV)								Technical rules for safety barrier glazing – TRAV/DIN 18008 If not linear supported on all sides, laminated safety glass must be used. Free edges must be protected by the balustrade structure or adjacent panes from unintended shocks.
Balustrade with glass bracing point-supported  (category C1 pursuant to TRAV)								Technical rules for safety barrier glazing – TRAV/DIN 18008 Edge protection is not necessary.
Balustrade with glass bracing supported with clamp  (not regulated pursuant to TRAV)								Pursuant to abZ or ZiE Free edges must be protected by the balustrade structure or adjacent panes from unintended shocks; Tempered glass can be used if approved by abZ.
Glazing under cross bars  (category C2 pursuant to TRAV)	EG							Technical rules for safety barrier glazing – TRAV/DIN 18 008; If not linear supported on all sides, laminated safety glass must be used.
	MIG							Applies to pane of glass on the attack, or side most likely to absorb the impact; pane on non-attack side variable; If laminated safety glass on non-attack side then tempered glass or laminated safety glass on attack side;

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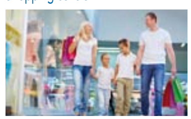
Application		Float	TG[1]	TG-H	LSG made of Float	LSG made of TG[2]	LSG made of HSG	Note
Room-height glazing with superior rail  (category C3 pursuant to TRAV)	EG							Rail at the required height pursuant to building requirements.
	MIG							Applies to pane of glass on the attack, or side most likely to absorb the impact; pane on non-attack side variable; If laminated safety glass on non-attack side then tempered glass or laminated safety glass on attack side;
Double facade 	internal[3]							Internal facade without fall protection, consultation with the local building control authority and principal recommended
	external							External facade as fall protection, Technical rules for safety barrier glazing – TRAV pursuant to category A or C
Lift shaft 								Technical rules for safety barrier glazing – TRAV/DIN 18008 and EN 81
French balcony[3] 								Building component on impact opposite side of the glazing fully acts as fall protection

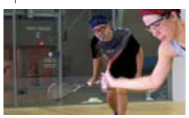
[1] Important! According to technical rules for the use of linear-supported glazing – TRLV: non heat-soaked single-pane safety glass should only be used for an installation height above public area < 4 m and where no persons are standing directly under the glazing, otherwise tempered – heat-soaked glass must be used!

[2] Important! Laminated safety glass made of 2 x tempered glass does not have a residual load-bearing capacity. In particular, the installation requirements shouldshould particularly be observed.

[3] Glass used pursuant to Chapter "Glazing in buildings used for special purposes" takes priority.

7.6.4 Glazing in buildings used for special purposes

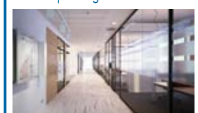
Application	Float	TG[1]	TG-H	LSG made of Float	LSG made of TG[2]	LSG made of HSG	Note
Office, walls or doors made of glass 							Workplace Directive (ArbStättV) GUV-I 8713 Administration
Entrance halls/foyers 							Rule of the Occupational Health and Safety Executive (BGR 202) and/or Workplace Directive (ArbStättV) with ASR 10/5
School 							GUV-SR 2002; up to a height of 2.00 m safety glass or sufficient screening
Playschool 							GUV-SR 2002; up to a height of 1.50 m safety glass or sufficient screening
Hospital/care facility 							According to the Ordinance governing Hospital Buildings (KhBauVO) for particular areas (e.g. in stairwells) and for special purposes (e.g. children's ward) BGI/GUV-I 8681
Shopping centre 							"Points of sale" rule of the Occupational Health and Safety Executive (BGR 202)
Retail 							Workplace Directive (ArbStättV) "Points of sale" rule of the Occupational Health and Safety Executive (BGR 202) or sufficient screening

Application	Float	TG[1]	TG-H	LSG made of			Note
				Float	TG[2]	HSG	
Car park 							Workplace Directive (ArbStättV) annex 1.7 (4); ASR 8/4 and ASR 10/5
Bus parking 							Workplace Directive (ArbStättV) annex 1.7 (4); ASR 8/4 and ASR 10/5
Swimming pool 							GUV-R 1/111, DIN 18361; up to a height of 2 m safety glass or sufficient screening In case of sports pool additionally safety against ball throwing (water polo) pursuant to DIN 18032-3
Gymnasium 							DIN 18032-1; up to a height of 2 m planar, closed and shatterproof; safety against ball throwing pursuant to DIN 18032-3
Squash hall 							Glass parts of the rear wall must be made of min. 12 mm tempered glass

[1] Important! According to technical rules for the use of linear-supported glazing – TRLV: non heat-soaked single-pane safety glass should only be used for an installation height above public area < 4 m and where no persons are standing directly under the glazing, otherwise tempered – heat-soaked glass must be used!

[2] Important! Laminated safety glass made of 2 x tempered glass does not have a residual load-bearing capacity. In particular, the installation requirements shouldshould particularly be observed.

7.6.5 Glazing for interior works without fall protection

Application	Float	TG[1]	TG-H	LSG made of			Note
				Float	TG[2]	HSG	
Walk-on glass/glass stairs 							ZiE required TRLV, list of technical building regulations; admissible tensions according to horizontal glazing pursuant to TRLV; laminated safety glass with PVB films of the minimum nominal thickness = 1.5 mm
Shower wall 							EN 14428/A1
All-glass door 							Workplace Directive (ArbStättV) with ASR 10/5, „Points of sale" rule of the Occupational Health and Safety Executive (BGR 202), if required
Door opening 							Workplace Directive (ArbStättV) with ASR 10/5, „Points of sale" rule of the Occupational Health and Safety Executive (BGR 202), if required
Office separating wall 							ASR 8/4
Draft lobbies 							„Points of sale" rule of the Occupational Health and Safety Executive (BGR 202), and/or Workplace Directive (ArbStättV) with ASR 10/5

[1] Important! According to technical rules for the use of linear-supported glazing – TRLV: non heat-soaked single-pane safety glass should only be used for an installation height above public area < 4 m and where no persons are standing directly under the glazing, otherwise tempered – heat-soaked glass must be used!

[2] Important! Laminated safety glass made of 2 x tempered glass does not have a residual load-bearing capacity. In particular, the installation requirements shouldshould particularly be observed.

7.6.6 Special safety glasses

Application	Float	TG	TG-H	LSG made of			Note
				Float	TG	HSG	
Burglar resistance 							EN 1627
Fling resistance 							EN 356 VdS regulation 2163
Break resistance 							EN 356 and/or EH VdS regulation
Shot resistance 							EN 1063, EN 1522
Explosion resistance 							EN 13541, EN 13123

7.6.7 Structural glass construction

Application	Float	TG	TG-H	LSG made of			Note
				Float	TG[2]	HSG	
Glass sword, supporting glass 							ZiE required
All-glass structures 							ZiE required
Special glass structures 							ZiE required

[2] Important! Laminated safety glass made of 2 x tempered glass does not have a residual load-bearing capacity. In particular, the installation requirements shouldshould particularly be observed.

(Excerpt leaflet V.05.2009-09 of the VFF e.V.)

Appropriate GUARDIAN glasses and glass combinations for these application areas can be found in → Chapter 10.

7

Central Station, Berlin
SunGuard® HP Neutral 60/40
Van Gerkan, Marg und Partner Architects

For centuries, generations have used glass for filling "light holes" in solid outer walls. This has drastically changed in the last three decades. Today, glass itself forms and shapes space and creates room enclosures, thus creating transparent architecture that allows people to feel close to nature. Experts use the generic term "façade" to describe any external architectural construction that serves as protection against weather and dangers of any kind.

In addition to science, research and technology, art and architecture in particular have given rise to a host of possibilities when it comes to façades made from glass. Aesthetics, functionality and construction are the most important aspects of using glass as an architectural element, and all of these factors must be precisely defined at the start of planning. A glass's finish on a façade always influences its reflective properties, which can range from being produced so that the glass is very reflective, reflects an overall colour or has weak reflection. The change of daylight due to weather, the sun's changing position in the sky, the colour of the sky and the seasonal change of vegetation influence reflection, and interior light conditions also impact on glass's appearance from the outside. Glass façades are generally composed of transparent and opaque areas that can be produced so that interior spaces are visible, or are "optically neutralised" and rendered "invisible" by using a specific type of glass. Reflections during the daytime also influence whether a person on the street can see into the interior.

The coloured adjustment between a translucent window and an opaque balustrade is only approximately possible as the colour impression of the translucent pane is always affected by the room behind the pane and its light conditions. In addition to the original function of a façade to provide protection, further decisive criteria relating to functionality are also in focus, especially for glass façades. Not only is there a possibility of obtaining energy from the façade, but one must also consider protection from heat during the summer (➞ Chapter 5.5). With regard to the constructive periphery of concrete, steel or aluminium, it should always be assured that, in addition to static loads caused by wind, suction and snow the glass weight can also be considered.

8.1 Facades

Generally, glass façades must be looked at from two perspectives, namely function and construction.

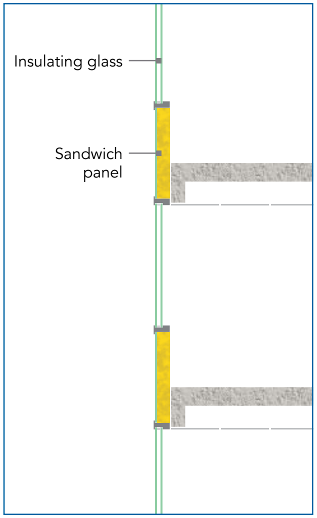
8.1.1 Façade functions

The façade function describes the mode of operation of the building shell. There are generally three different possibilities:

8.1.1.1 Warm façade

The warm façade describes a single-shell system in which thermal insulation with an interior vapour barrier is connected to a balustrade panel (sandwich panel). This single-shell system is located behind an opaque pane of glass that protects it from the weather.

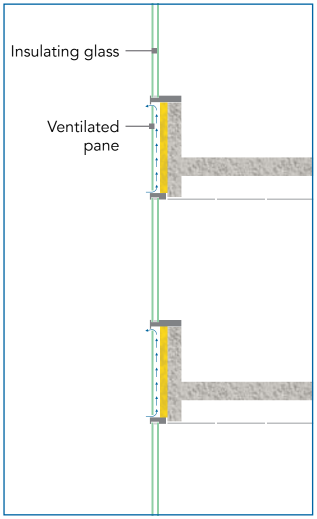
This sandwich panel is installed in the façade construction as a whole below the transparent insulating glass and attached using clamping strips. The sill's vapour diffusion resistance is achieved by applying a sealer and edge lipping. Thus, the opaque and transparent elements serve not only to enclose the room and protect it against weather, but also to protect the room from excessive heat, noise and, if need be, to keep fire from penetrating into the room. These opaque panels need a four-sided frame in the form of post-and-beam construction.



Warm façade

8.1.1.2 Cold façade

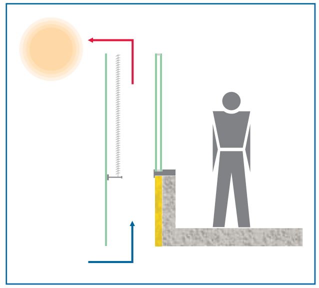
The physical construction and technical functions are performed in the sill area of a two-shell construction. The outer shell is used for weather protection as well as the visual design. It is designed with a ventilated glass window so that trapped heat and moisture can be removed. This pane is usually made of solar control glass and colour coordinated with the transparent window. Installation options range from all-sided, two-sided to supporting systems attached at various points, which allows for a broad spectrum of individual design. Underneath the transparent insulating glass windows, the thermal insulation of the wall area is realised with insulating opaque wall areas behind these parapet planes.



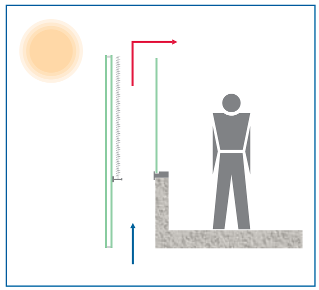
Cold façade

8.1.1.3 Double skin façade

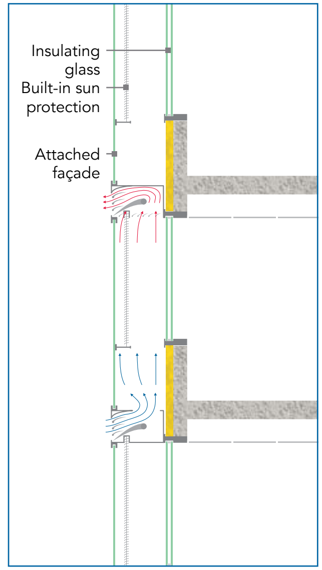
This kind of façade goes by many names. It is also referred to as "second skin" or "attached façade". This construction method principally consists of a flash-off façade similar to the cold façade described above, but the interspace between the two shells for the railing is broader and the transparent façade construction elements, i.e. insulation glass windows are integrated. The attached façade can be installed outside in front of an existing façade for visual and acoustic reasons. This design is called an interactive façade. The interspace is generally used to install additional solar protection devices such as blinds. The potential hot air and condensate are gradually transported to the outside.


Interactive façade

The alternative is an inner skin of additional solar protection in the interspace. This construction, however, allows the warm air generated by solar radiation to escape in a targeted manner. The air is then transmitted via appropriate aggregates to the energy management of the building. This method is called active double skin façade and can reduce the operational costs of the building.


Active façade

In the past, inner skin shells were mostly made out of solar protection single-pane safety glass. The tendency today is to use laminated safety glass consisting of two pre-tempered glasses due to the increased structural stability that is present in case of failure.



Double skin façade

The function of a glass façade is strongly influenced by the glass that is used. In the past, "simpler" glass was preferred for production reasons. Today, GUARDIAN offers a broad range of suitable solar control glass with highly effective coatings.

This range is generally based on ExtraClear® float glass in order to give the outer shell in a ventilated façade as much neutrality as possible. This combination reduces the transmission of short wave solar energy by reflection but ensures the unhindered emission of the long wave heat radiation from the interspace to the environment. The stronger these reflections the less additional sun protection devices between the glass panes are needed and unobstructed views are possible. This range is listed in → Chapter 10.

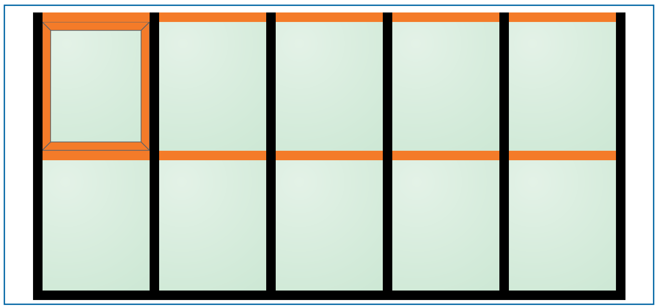
With this development of high-tech coatings on glass and their tempering and laminating options and bendability, we offer our customers enormous competitive advantages and new impulses for façade construction. A large number of these types of glass can be finished with many design components to individualise them (→ Chapter 8.3).

8.1.2 Façade constructions

Joining the glass to the building and the shell is as important as the function.

8.1.2.1 Stick-System-Façade (Mullion-Transom-System)

The majority of today's glass façade still consists of post and beam. Here, the load-bearing posts extend from the foundation to the roof of the building in a fixed, aesthetically pleasing manner and at a statically determined and technically feasible distance from each other. These posts are anchored to the building design and transfer all applied loads into it. The "long fields" that thus react to the top are then intersected by a defined number of horizontal beams that bear the weight of the glass and convey it into the posts. After installing the glass and precisely placing the glazing blocks, pressure pads are fixed with screws, both on the posts and on the beams. The pressure pads fasten the glass elements and seal them. In order to derive the built up humidity caused by condensation water in the rebate area, an inner drainage is installed with an opening to the outside. The optical closing is generally made by cover strips which have to be fixed by clips and are available in nearly all anodised colours. These strips mainly influence the outer colour scheme.



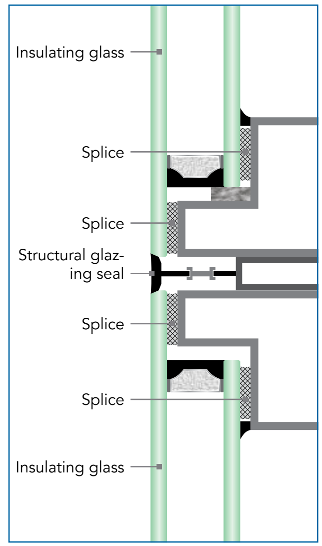
Stick-System-Façade

A large number of systems are available on the market. They range from extremely small to very large, depending on the desired visual façade's appearance and function. Generally, the extremely small profiles do not have an obvious window function and are installed in ventilated or air conditioned buildings in order not to interrupt the sophisticated grid design. Post and beam constructions are approved systems and can in most cases be used without any legal restrictions.

Stick-System-Façade
Intersection – visual impression

8.1.2.2 Structural glazing façade

Whereas clamping and cover strips project from the glass surface on the stick system façade described above, the benefit of this bonded façade is that it appears absolutely uniform. In this design, an aluminium adapter frame, into which the glass element is bonded, invisibly supports the glass load. This module is then mounted in front of a post and beam construction into which the loads are conveyed. The complexity of this façade technique, together with the long term experience of leading glue and sealant producers, make it feasible that structural glazing façades can only be executed as integral systems. The manufacturers of such systems have the concession of the building inspection authorities. Otherwise, an



Structural glazing façade

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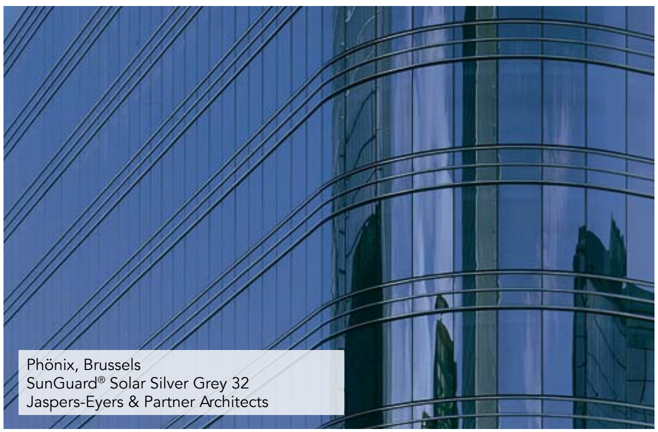
acceptance test has to be made in an individual case before installation.

The glass weight, and the weight of the outer pane which appears not to be fixed has to be distributed generally via mechanical fastening angles into the construction. Such façades, even without the mechanical holding of the outer pane, can be installed in countries such as Germany up to a total building height of eight meters.

In this case, most glazing consists of a special stepped insulating glass with UV resistant edge bonding (→ Chapter 3.4) which can absorb loads which arise and convey them. As outer pane, a one pane safety glass with a thickness of at least 6 mm has to be used. Because of this construction, there are all sided free glass edges which stand in a determined distance to the next element and are sealed with special structural glazing silicone. It is very important to ensure the adhesion from silicone with the glass edges and the compatibility of all used materials (→ Chapter 9.10).

Structural glazing façade
Intersection – visual impression

The final visual appearance is a plain glassy area, in which the "silicone-seams" nearly disappear. Especially for this façade system, GUARDIAN offers a variety of coated glass with the appropriate authorisations.

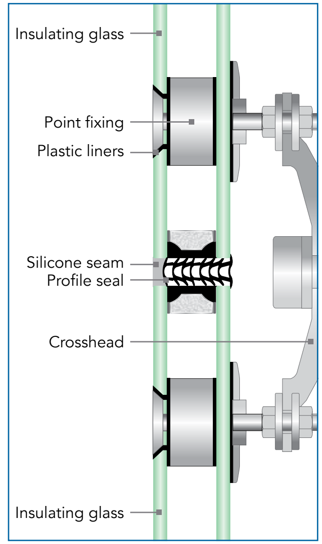


Phönix, Brussels
SunGuard® Solar Silver Grey 32
Jaspers-Eyers & Partner Architects

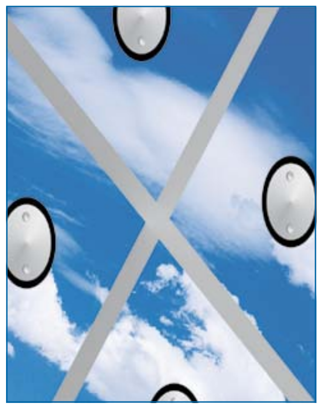
8.1.2.3 Point supported façade

This façade technique, of recent development, is based on point-fixed bearing connections as single holders. In this system, the active strengths of the glazing are transmitted to a mostly moveable mounted point supporting button that transports the active strengths via a metallic conjunction into the massive substructure.

In the conventional method, anchor bolts are mounted through the glazing, covered with an elastic core to avoid glass/metal contacts and fixed with counter panes. These covering and fixing panes project from the surface. An alternative is conical perforations that gain stability with special conical fittings by the clamping power on the edges of the boreholes. This form allows even façade surfaces without any outstanding elements.



Point supported façade



Point supported façade
Intersection – visual impression

Another development is holding points, which are placed on the level of PVB films and thus form a laminated safety glass, of which the outer pane is plain and the backside pane has outstanding connecting threads for mounting. The dimensions of the glazing for such construction account for the allowed deformation of the panes and the flexibility of the fittings. The stresses arising from loads are induced through the holding buttons without any restraint into the load bearing construction. The joints between the individual glassy façade elements are sealed with UV-resistant closing systems. In this fashion, attached façades out of monolithic glasses can be built as well as insulating glazing façades. In the latter, the glass rebate is ventilated through appropriate systems and enables the condensation water to be diverted.

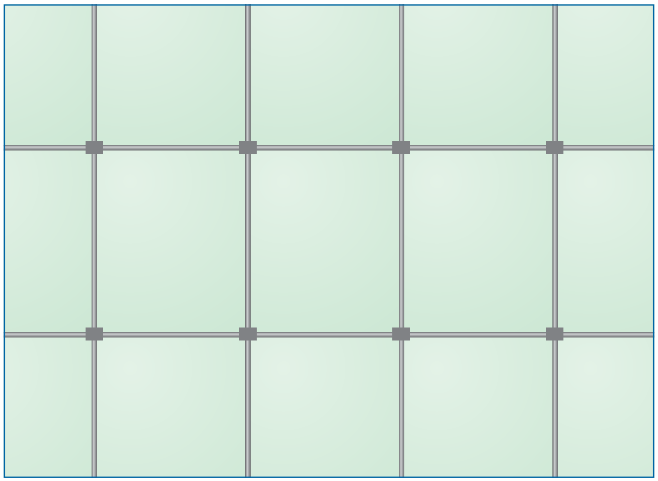
Point-supported façades in countries such as Germany do not belong to regulated construction products (as to the legal construction regulations) and therefore need approval for construction in each particular case.

8.1.2.4 Membrane façade

A variation of the point-supported façade with drill holes in the glazing was developed in the past few years. Like a tennis racket, the whole façade is strung with a network of steel cables in the grid dimension of the glass panes.

The joints of the horizontal and vertical cables are fixed with fasteners which serve at the same time as fittings for the façade glass in the relevant four corners. Loads affecting the façade are transported through these fittings into the cables from where they are conducted into the bearing frame construction. Thanks to the sealing of the joints, similar a point supported design, the network of cables disappears optically behind the glass edges and offers a construction-free perspective through the façade.

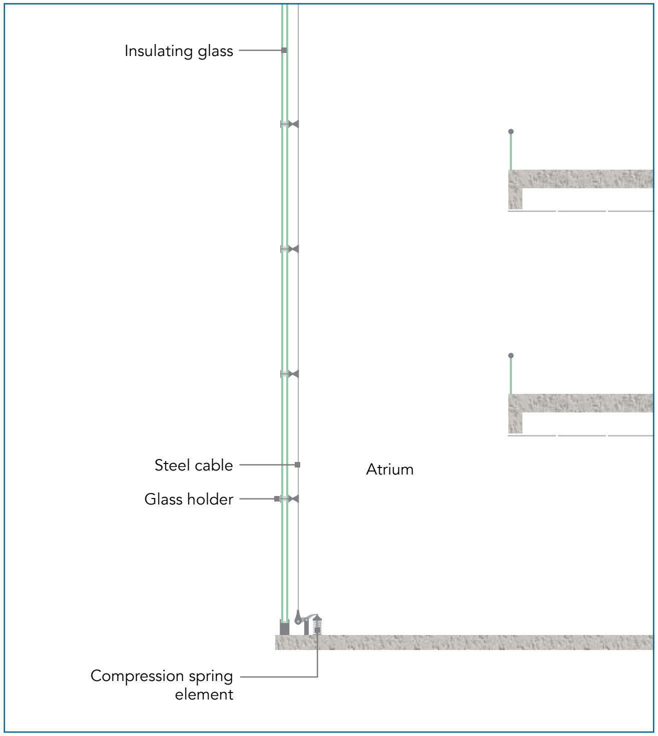
The corner positioning of the glass elements without boreholes avoids increased stress concentrations and enables greater dimensioning freedom.



Membrane façade from construction site

Prestressing of the ropes is realised to ensure that the whole area can be deformed under load and all functions are maintained before the load peaks are conveyed via the vertical ropes into the grounding and the roof frame. This construction requires approval in each individual case.

Membrane façade
Intersection – visual impression



Membrane façade

8.2 Parapet glass (spandrels)

Spandrels are often complete glass panels which in addition to concealing constructive and functional parts of the building such as paving tiles, pillars, heating ventilation and air-conditioning elements also hide electrical wire ducts and tubes. As a result, opaque parapet glasses are frequently installed in front of intermediate ceilings on each floor of a building in the façade thus interrupting the transparent glass elements. The desired optical effect can thus be adapted to or contrasted with the transparent glazing.

For larger projects, it is recommended that a 1:1 sample presentation be created to achieve the desired optical appearance in the later façade. The outer parapet is normally a single pane of safety glass to avoid thermally influenced glass breakage. The opacity of these glasses can be achieved through various production modes, depending on which optical effects are to be achieved. Regardless of the production technique, the adhesion and compatibility of the typical colours on the particular glass coating are important, as along with their tempering capability.

GUARDIAN has broad experience both in coating of float glass and further processes such as bending, tempering, laminating and various colour applications to achieve opacity or translucency. The most frequently used colours are ceramic colours which can be coated in different technics on the back side of the pane. Various technics are available, namely, roller coating, spraying, printing or curtain coating.

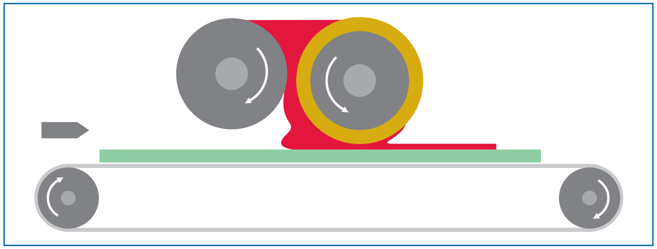
8.2.1 Colour application on SunGuard® coatings

Many SunGuard coatings with the special Silacoat® coating system can be printed with ceramic paints. Ceramic paints can react with the glass coating during the burning-in process, and that may lead to dulling, cloudiness or, in the worst case, complete degradation of the layer. It is therefore very important to test the compatibility of the particular paint type and the coating under production conditions. Improper tempering conditions may also cause poor results (penetration, colour, homogeneity, consistency, tightness). Moreover, each printing of a coated surface can lead to colour drifting after the burning-in process. Therefore adequate sampling should be made, as the processor is responsible for the final product and has to control its quality.

Detailed information as to the production of SunGuard glasses for parapets (spandrels) and special notes concerning the choice of colours can be found in the technical manual "Ceramic print – spandrel glass".

8.2.2 Roll technique (roller coating)

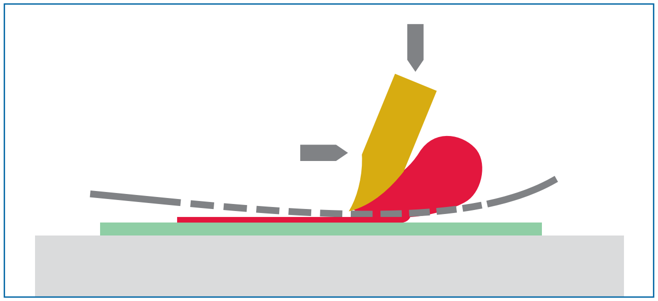
The colour application with rollers using the roll technique provides an outstanding and even visual appearance, both during subsequent varnish coating and the application of ceramic colour which bonds firmly with the glass surface and coating in the following tempering process. This technology is adopted for larger quantities and is ideal for parapet glasses.



Roll technique, schematic representation

8.2.3 Screen-Print technique

The screen-print which is mainly dedicated for painting partial areas and used for specific design components is less suitable for larger areas and homogeneous painting (→ Chapter 8.3.1).



Print technique, schematic representation

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8.2.4 More production techniques

Another technology is based on a uniform and permanently flowing curtain of colours over the whole pane width. The pane is passed evenly under this colour curtain and covered homogeneously by it. This process is mainly used for large format colour applications to achieve the highest possible homogeneity, with thicker paint application over the whole pane. This method results in an extremely high material usage and is therefore rarely used today. The spray technique for colour application on small series and individual panes such as samples represents an alternative.

This method is mainly used when working with varnish and guarantees a nearly homogeneous application thickness and consequently, a good visual appearance.

Parapet panes can be fixed in many ways and used as a single pane in attached and cold facades or as a parapet panel on warm façades (➞ Chapter 8.1). A large range of such glasses from GUARDIAN is to be found in ➞ Chapter 10, where – depending on the project – alternative adaptations can be made at any time following individual consultation and agreement.

8.3 Design glass

Not only are the design of parapet panes is further refined in functional terms in modern architecture. Transparent elements are also receiving more and more visual and functional decoratiive facets. Glass offers a variety unlike any other construction material. From etching shot blasting and ceramic screen printing to laminated glass with internal films, the design achieved can be a decorative ornament or symbol or even an all over illustration or matting.

The areas which can be designed with decoration glass are multifaceted. In modern apartments, offices, restaurants and hotels, for example, design glasses as partition and covering keep the balance between separating and joining with individual emphasis. Glasses with such design components achieve a high aesthetic effect and additional solar protection. In addition, they guarantee, at the same time,consistency and colourfastness. In combination with solar control glass, they offer extensive, individual impulses for modern façades design.

8.3.1 Production techniques

In addition to edging and shot blasting, five further very different process are currently available for the production of design glasses.

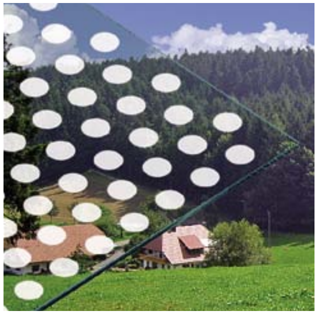
There are certainly additional possibilities which may be, however, too technical or not yet technically matured.

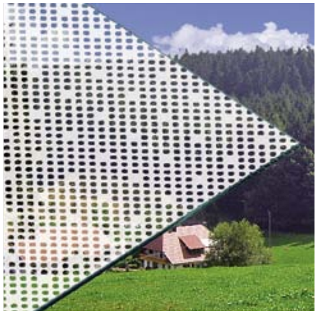
8.3.1.1 Screen-print directly onto the glass

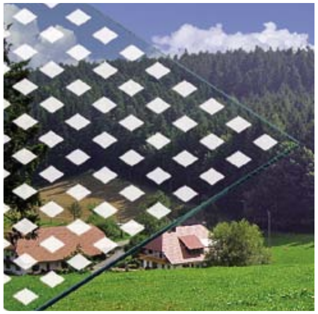
One colour screen print printing directly onto glass has a long tradition. The enamel or ceramic paint, which is a mixture of finely milled glass and bonding colour pigments is pressed with a scraper through the open parts of the sieve onto the glass. First, this sieve is photo technically prepared in open, i.e. sections to be printed and closed, not to be printed areas.

The open sections form the motif to be printed in this respect with the aid of the colour. In the subsequent pre-tempering process, the motif is permanently joined to the glass surface by melting.

Many SunGuard® coatings are compatible with ceramic paint and are suitable for printing on (➞ Chapter 8.2.1)







8.3.1.2 Transfer colour print on glass

The transfer print offers an alternative to achieve a multi-coloured print instead of single colour screen printing. In addition, enamel and ceramic colours can also be transferred through digital printing onto transfer films, thus reproducing multi-coloured motifs. These printed films are then fixed on glasses to be tempered. During the tempering process, these transfer films burn residue-free and the painted colours bond as previously described. Besides all kinds of ornaments, this method can also generate illustrations which have the same quality as coloured photos.

8.3.1.3 Design laminated safety glass

Large sized illustrations, like the photographic slides technology of the past, are produced with the same digital print method but with other paint components and films. The illustrations are inserted between the PVB films of the laminated safety glass and then compressed. Colours and films are lightfast and UV resistant and create a decorative pane which retains its individuality. Despite this additional laminate, the laminated glass retains its outstanding characteristics (→ Chapter 7.4.2), supplemented by the individual design component.

8.3.1.4 Coloured films in laminated glass

The same lamination process can today avail of a large range of different colour films which can be combined to achieve every conceivable colour in laminated glass. This method enables the creation of completely transparent coloured glass. In addition, with supplementary dispersion films to further define translucency, products such as colourful blinds can be produced. These films are also UV resistant for outdoor use, thus preserving their radiant colour effect without affecting the characteristics of the laminated glass.

8.3.1.5 Decorative laminated glass

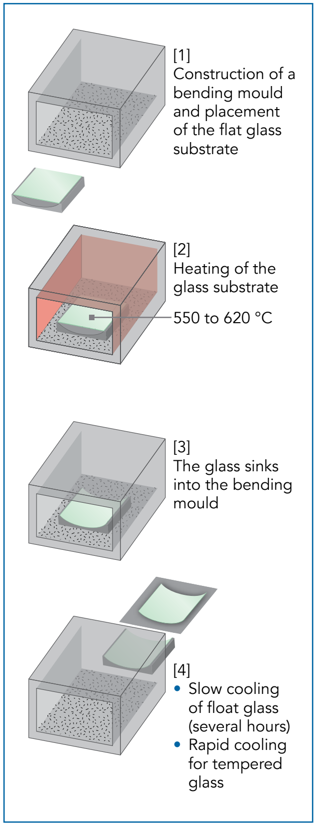
An alternative to these safety glasses are laminated glasses which are produced by filling the interface of two panes with resin. Decorative elements (e. g. mesh wire or other plain accessories) can be integrated into the resin and give the resulting glass sandwich a unique decorative configuration. These laminated glasses are typically not safety glasses (as defined in applicable laws relating to safety glass) and may be installed as such only when they are legally approved for construction.

8.4 Bent architectural glass

Architects and designers love to interrupt straightness, corners and edges with soft curves. This is why, in addition to round interior glass products and accessories, curved glass façades also exist. By the middle of the 19th century, architects were bending glass, a technique developed in England, and this exists today in a slightly modified form.

In building envelope applications, glass is generally bent through a thermal gravity process.

The procedure is as follows: a glass pane is laid over a bending form and heated to 550 - 620 °C in the bending oven. Having reached the softening temperature, the plain pane descends (through gravity) slowly into the bending mould and adopts its shape. The subsequent cooling down phase defines the shape of the glass. Slow cooling, free from residual stress, produces a glass which can be further processed, whereas fast cooling creates a partially or fully tempered glass which is not suitable for further processing (→ Chapter 7.1).



Fabrication steps

8.4.1 Requirements

Generally, bent glass is not a regulated building material, and it should ensure functionality such as thermal insulation, solar and noise protection. In addition, it must meet the requirements of building laws, such as fall prevention measures and load bearing regulations, to the same extent as plane glass.

To verify this and be allowed to install bent glasses, manufacturers must provide an AbZ (general approval by a construction supervising body), an ETA (European Technical Approval) in Europe, or a permit should be obtained in each case before construction can begin.

Comprehensive standards for bent glasses are not available at present, but full usability should be documented in all cases.

8.4.2 Glass types

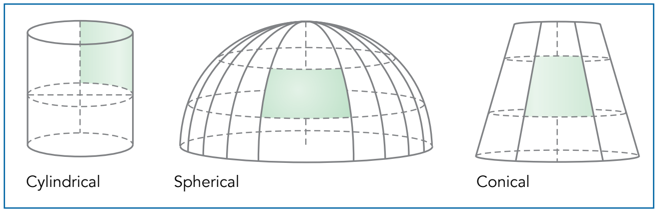
In principle, all plane types of glass which are used in construction are bendable. However, slight restrictions apply to panes fitted with combination functional coatings. Individual parameters like bending radius, bending shapes, glass thicknesses and coatings should be aligned in advance. Bent glasses are indeed special high-tech products and therefore require very careful preparation in the early planning stage, along with the agreement of all those involved. In addition to types of glass already mentioned (normal glass, laminated glass and tempered glass), bent laminated glass and insulating glasses can also be produced. In the case of the last two mentioned, increased tolerances need to be considered for installation. The varying reflection characteristics of plain and bent glasses should also be taken into consideration. Glasses of the same type standing side by side can have a slightly different optical appearance. 1:1 sampling is recommended for larger projects. The design possibilities for the glass areas mentioned in 8.9 may also be utilised, with some restriction depending on the bending involved.

Basically all coated architectural glass from GUARDIAN SunGuard® and many from GUARDIAN ClimaGuard® can be bent or have a bendable alternative. GUARDIAN will directly inform you about the restrictions of the individual types concerning ways and shapes of bending.

8.4.3 Types of bending

A distinction is generally made between bent glass, slightly bent glazing with a bending radius of more than two meters and severely bent glass with small radii.

Moreover there is a difference between glass which is bent cylindrically and spherically. Cylindrically bent glass is bent along one axis, and spherically over two axes.



Types of bending

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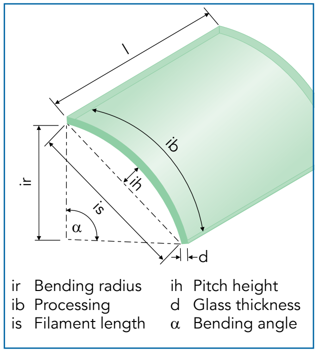
Float glass is, in principle, suitable for all these bending shapes. Due to the production technology involved, fully tempered and heat strengthened glass are used mainly for cylindrical bending. This process is also recommended for glass with coatings, as the production process is short and thereby more "gentle" on the layers. Spherical and conical bendingproduction durations and are frequently more difficult to realise with coated glass types.

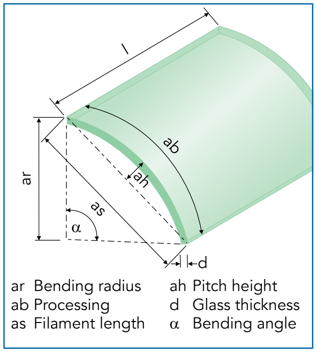
The smallest possible bending radius is approx. 100 mm for glass with a thickness < 10 mm and about 300 mm for glass > 10 mm thick. These possibilities depend on the manufacturer and should be checked in advance.

8.4.4 Determination of shape

Exact descriptions of the dimensions are required for the shape determination of bent glass. In addition to thickness of the glazing, the height of the panes and the width of at least another two of the five dimensions needs to be determined in the following drawing for inner and outer execution. It should always be noted that, with the exception of the opening angle, all data refers to the same surface (concave = inside, convex = outside).

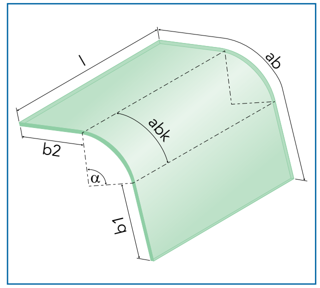


Interior Dimensions



External dimensions

The standard bend is the cylindrical execution referred to in the definitions. All other geometrical shapes, such as spherical bends, should be estimated by an exact drawing, so that shape and size can be well determined. Linear elongations of cylindrical shapes (b1, b2) are to be displayed separately.



Arch with straight extensions

8.4.5 Specifics

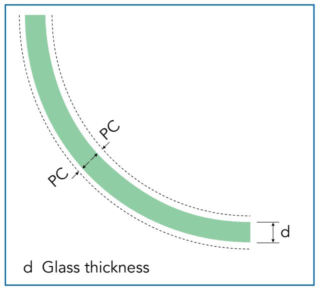
Special tolerances and production shaping conditions, which should be strictly considered, apply to bent glasses:

8.4.5.1 Local optical distortions

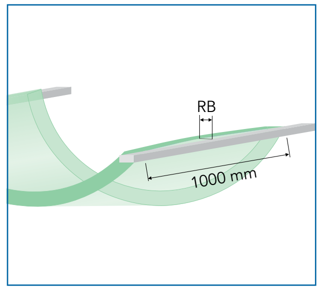
The local distortions of fully tempered and heat strengthened glass may differ from the specifications for plain glasses, as glass geometry, size and thickness may have a greater influence on bending than with the plain design. These should be agreed in advance with the manufacturer in all cases.

8.4.5.2 Outline precision

Outline precision means the accuracy of bending. This should be within a tolerance range of ± 3 mm in relation to the target contour so that the glass can be processed further without any difficulties.



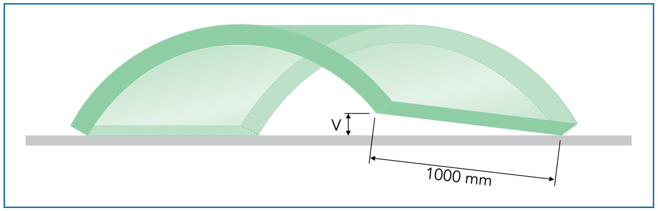
Contour accuracy (PC)



Straightness of the edge height (RB)

8.4.5.3 Torsion

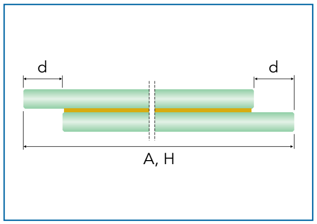
Torsion describes the exactness to the plane parallelism of the edges or unbent edges. In this case, the largest irregularity after bending should also not exceed ± 3 mm per metre glass edge.



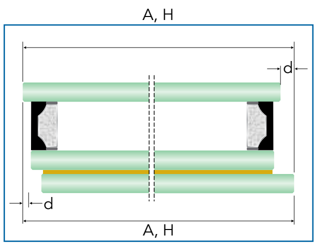
Twist (V)

8.4.5.4 Edge displacement

Diverging from the specifications of plain laminated and insulating glass, the displacement at the edges may increase after bending. It is absolutely necessary to find common conformity in advance.



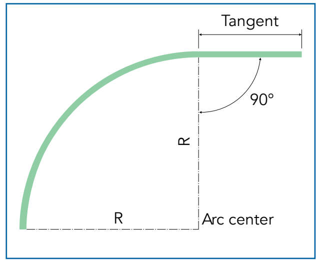
Displacement in laminated glass (d height)



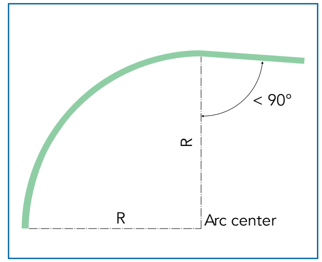
Displacement in insulating glass (d height)

8.4.5.5 Tangential junctions

The tangent is the straight line which has its origin in a particular point of the curve. Thereby the line is perpendicular compared with the bent radius of the curve. Without this tangential transition there would be a sharp angle at this spot which can be achieved with glass, but is not advisable. There are normally larger tolerances at the sharp angle than with tangential transitions.



With tangential transition



No tangential transition

8.4.6 Static specifics

The deformation and mechanical stress of a bend can be defined through finite element models with the aid of the shell theory. The curvature, depending on installation conditions in the case of monolithic glass, can have a positive effect due to the shell bearing impact, namely in the direction of thinner glasses. Insulating glass, however, does not achieve this effect as readily.

The curvature of the glass means that the bending strength is increased and, consequently, extremely high climatic loads can arise. This must be considered, especially when units have tangential attachment pieces at a curvature. This can result in broader edge seals which affect later glass installation.

8

8.5 Special glass applications

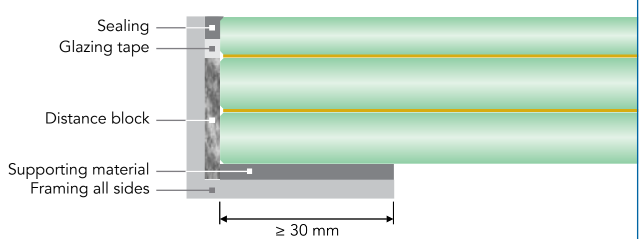
Thanks to continuous improvements in engineering and architecture, hardly any limits exist to construction with glass. Even areas of a high security relevance are constructed today with glass constructions and controlled by climatic zones. The following provides a brief insight into the technologically ambitious regions of building with glass.

8.5.1 Walk-on glazing

Walk-on glazing generally involves horizontal glass installations which are designed for regular personnel and heavy load traffic. They should be evaluated differently from tread-on glazing, which is only designed for short-term accessing for cleaning and maintenance purposes.

Walk-on glass superstructures generally consist of laminated safety glass with an additional upper protective pane. This bonded protective pane should consist of at least 6 mm fully tempered or heat strengthened glass, should not be included statically in any evaluation and very often has a permanent anti-skid-coating.

In order to be allowed to install this pane pursuant to TRLV (technical guidelines for linear supported glazing), it should consist of at least 10 mm fully tempered or heat strengthened glass. The laminated safety glass unit, coupled underneath, with at least 2 panes of 12 mm thickness, forms the bearing capacity which may be considerably thicker or have more panes, depending on demand and execution. Mostly float glass panes with each 1.52 mm PVB film interlayers are used for this unit. The basis for the installation of walk-on glazing are an absolute bending rigidity substructure, an elastomer bearing material with 60 - 70 shore A-hardness and a minimum bearing with a width of 30 mm.



Glass structure from top to bottom:
Protective pane protects the supporting glass composite against damage. Min. thickness 6 mm, tempered or heat strengthened with / without print. Supporting glass composite of two or three glass panes which are connected together with PVB films. Hardness of the elastomer support material: 60 ° to 70 ° Shore A

Requiring approval glazing recommendation

8.5.2 Glass elevators

One highlight of today's architecture is transparent elevators, which gives users the feeling of floating. In this application, the shafts, lifts and cars are made of glass. These types of constructions must meet a number of safety and mechanical requirements that are regulated in the European elevators directives 95/16 EC 7/99 and EN 81 02/99.

Additional national requirements may exist, such as building regulations of the respective federal state in Germany. For a glass shaft, proof of stability for an applied force of 300 N on an area of 5 cm^2 is required. Depending on the size of the cars, the walls, which are fixed and mounted on all sides, create different demands on the characteristics of the laminated glass to be used. If the glazing stretches from the floor to the ceiling, a crosspiece should be installed in the vicinity of a height of 0.90 - 1.10 m which should not be supported by glass.

Doors, on the other hand, need to meet special requirements which should be assessed according to the fixture, mechanism and dimensions. Lifts made of glass are always custom-made products which can only be realised together with everybody involved. All lift glass components should have a permanent and visible identification marking.

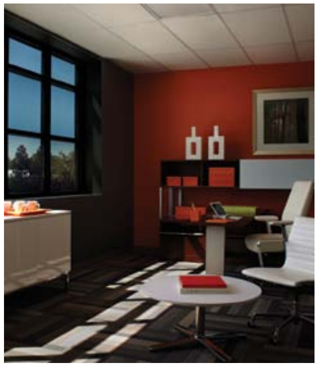
8

8.5.3 Switchable glass

A recent development is switchable, electrochromic glass, where a special magnetron coating is made to change its solar energy transmission when electrical voltage changes. The g-value of the glazing can be adapted accordingly to suit the season or weather relevance (summary heat protection ➞ Chapter 5.5).

The g-values of such glasses, which are integrated into a two pane insulating glass construction, are approx. 35 % without electrical voltage and 6 % during peak current supply. Naturally enough, light transmission also changes in this context. This development is certain to continue in the coming years and thus create even more options for façade constructions with glass.

Please address inquiries referring to your project directly to GUARDIAN.



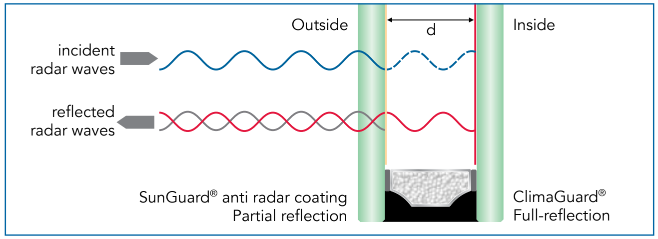
8.5.4 Electromagnetic damping glasses, Radar reflection damping glass

Modern wireless communication is based on electromagnetic waves. In addition, high-voltage power lines and ordinary electrical equipment also emit these waves. Therefore, it is becoming frequently more necessary to reduce this unavoidable but unwanted radiation here in certain building areas. This can be done in tap-proof rooms in high security areas, even up to a complete level of shielding, or close to airports for a targeted reduction of fields to avoid interference and incorrect signals during radar communication with aircraft.

Determination of electromagnetic waves is realised in a similar fashion to sound waves using a logarithmic scale, so that a considerable reduction can be achieved with even limited damping. The following applies in this respect:

Damping [dB]	Reduction [%]
5	app. 38
10	app. 90
15	app. 97
20	app. 99

This damping is achieved by special, different glass coating on outer and inner panes which lead to phase displacements through a determined distance of the interface, and that effects an erasement of the resulting, reflecting, electromagnetic radiation.



Behavior of radar waves in a solar control glass

GUARDIAN provides a range of specially coated SunGuard® solar control glasses, some of which have properties for reducing the radar reflection in some glass constructions. An overview is contained in ➞ Chapter 10.3.

Please contact GUARDIAN for further information and advice.

ClimaGuard® Premium or ClimaGuard 1.0 heat protection glasses SunGuard® HP or SunGuard High Selective solar control glasses with a coating surface resistance < 5 Ohm provided excellent insulation against high frequency radiation, or so-called electrical smog, especially in residential areas.

A triple glazing with two heat protection coatings achieved HF-transmission reductions of approx. 42 dB for 900 MHz (GSM 900 mobile service) and about 47 dB in the vicinity of 1900 MHz (GSM 1800 mobile service). In contrast to that, a simple double glazing with only one sun protection coating achieves a HF transmission reduction of approx. 32 dB at 900 MHz and about 28 dB at 1900 MHz. It has to be considered, that only system solutions in the closed window with, for example, steel reinforced frames and posts and grounding of the system will grant an efficient protection against electric smog.

Please contact GUARDIAN directly for further information on additional options.

Glass structures with these special coatings and corresponding edge connections make their contribution today in the area of transparent façades. However, no defined product range is available, but rather only a glass combination which must be determined in advance in terms of the following criteria:

- What exactly must be shielded and where?
- Which frequency ranges must be damped and to what extent?
- How can the edge parameters for glass windows and window brickwork be realised?
- Which other functions must the glass comply with, (e. g. heat, noise and solar protection, etc.)?

Electromagnetic damping glazing therefore refers in all cases to a glass element produced for use in a particular building which should be defined in all cases in the initial planning phase.

8.5.5 Anti-reflection glazing

Despite the excellent transparency of modern glazing, the view from the bright exterior to the darker interior may be hindered by reflection, depending on the viewing angle and incidence of light. Shop window glazing in particular can diminish the view of items behind the glass due to reflections. A newly developed coating from GUARDIAN provides the remedy. The coating on both glass surfaces reduces the degree of reflection on glazing with one pane to less than 1 %. This type of glazing is especially suitable for:

- items displayed in shop windows
- glazed openings in control rooms and visitor terraces
- show cases and protective panes in museums
- partition glazing in stadiums
- interior partition glazing in hospitals and clean rooms
- zoological gardens and aquariums
- protection glazing for direction signs and display panels

Generally speaking, it is observed that insulating glazing is only effective when all installed glass areas in the system are coated in this manner. This new coating is also combinable and can be pretempered as tempered glass. For more information and the availability of anti-reflection coated glass, please contact GUARDIAN.

Hanseatic Trade Center, Hamburg
SunGuard® Solar Light Blue 52
NHT Nägele, Hoffmann, Tiedemann Architects

8

MAIN TOWER, Frankfurt/M.
SunGuard® Solar Light Blue 52
Schweger + Partner Architects

9

Naturally enough, the rapid development of glass as a building material means that the rules governing its use are becoming more stringent and comprehensive. European standards now cover most aspects of the application and testing of various types of glass in the construction industry. But beyond this, a host of national and country-specific regulations and guidelines also exists which should be consulted, depending on the application. Regardless of the testing and usage regulations, purely glass-specific parameters must also be observed, and these can have a major influence on the function and longevity of glass products, as has been illustrated in previous chapters.

9.1 European-relevant norms for glass

The most important international norms for the assessment and the use of glass in connection with buildings are:

EN 81	Safety rules for the construction and installation of lifts
EN 101	Ceramic tiles; Determination of surface scratch hardness according to the Mohs scale
EN 356	Glass in building – Security glazing – Testing and classification of resistance against manual attack
EN 410	Glass in building – Determination of luminous and solar characteristics of glazing
EN 572	Glass in building – Basic soda lime silicate glass products
EN 673	Glass in building – Determination of thermal transmittance (U value) - Calculation method
EN 674	Glass in building – Determination of the thermal transmittance (U value) - Guarded hot plate method
EN 1063	Glass in building – Security glazing – Testing and classification of resistance against bullet attack
EN 1096	Glass in building – Coated glass
EN 1279	Glass in building – Insulated glass units
EN 1363	Fire resistance tests
EN 1364	Fire resistance tests on non loadbearing elements
EN 1522/1523	Windows, doors, shutters and blinds – Bullet resistance
EN 1627 - 1630	Burglar resistant construction products – Requirements and classification, test methods for the determination of resistance under static and dynamic loading and to manual burglary attempts
EN 1748	Glass in building – Special basic products
EN 1863	Glass in building – Heat strengthened soda lime silicate glass
EN 10204	Metallic products – Types of inspection documents
EN 12150	Glass in building – Thermally-tempered soda lime silicate safety glass
EN 12207	Windows and doors – Air permeability – Classification
EN 12208	Windows and doors – Watertightness – Classification
EN 12412	Thermal performance of windows, doors and shutters
EN 12488	Glass in building – Glazing requirements – Assembly rules
EN 12600	Glass in building – Pendulum tests
EN 12758	Glass in building – Glazing and airborne sound insulation
EN 12898	Glass in building – Determination of the emissivity
EN 13022	Glass in building – Structural sealant glazing
EN 13123, Teile 1 - 2	Windows, doors and shutters – Explosion resistance
EN 13501	Fire classification of construction products and building elements
EN 13541	Glass in building – Security glazing – Testing and classification of resistance against explosion pressure
EN 14179	Glass in building – Heat-soaked thermally tempered soda lime silicate safety glass
EN 14449	Glass in building – Laminated glass and laminated safety glass
EN 15434	Glass in building – Product standard for structural and/or ultra-violet resistant sealant
EN 15651	joint sealants for non load bearing applications in buildings and on pedestrian paths
EN 20 140	Acoustics – Measurement of sound insulation in buildings and of building elements
EN ISO 140- 3	Acoustics – Measurement of sound insulation in buildings and of building elements – Laboratory measurements of airborne sound insulation of building elements
EN ISO 717-1	Acoustics – Rating of sound insulation …
EN ISO 1288, Teile 1 - 5	Glass in building – Bending strength of glass
EN ISO 9050	Glass in building – Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors
EN ISO 10077	Thermal performance of windows, doors and shutters
EN ISO 12543	Glass in building – Laminated glass and laminated safety glass
EN ISO 13788	Hygrothermal performance of building components and building elements

9

9.2 Tolerances for standardised requirements

The basic principles for tolerances are specified in the applicable standards. However, these standards are not always sufficient in actual practice. This chapter therefore describes those applications that are listed in the standards where they are not clearly defined or are not specified at all, and breaks them down into two categories:

- **Standard tolerances**
  Standard tolerances are tolerances that can be ensured during the normal course of production.
- **Special tolerances**
  Special tolerances can be realised during production with additional precautionary measures and must be agreed upon on a case-by-case basis.

9.2.1 Basic glass

EN 572 is a normative standard for basic glass.

These standards specify the deviation limits for nominal thicknesses for various glass products. Furthermore, requirements for quality as well as optical and visible flaws in basic glass products are defined in these standards.

The following tolerances of the nominal thickness also apply:

Nominal thickness [mm]	Deviation limit [mm]
2	± 0.2
3	± 0.2
4	± 0.2
5	± 0.2
6	± 0.2
8	± 0.3
10	± 0.3
12	± 0.3
15	± 0.5
19	± 1.0

Tab. 1: Deviation limits for glass thicknesses

No differentiations are made between standard and special tolerances when considering the deviation limits.

9.2.2 Cutting

EN 572 and general length dimensions also apply in all cases

± 0.2 mm / m edge length.

9.2.2.1 General

The angular break must be taken into consideration! This type of break depends on glass thickness and the quality of the basic glass.

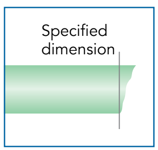


Fig. 1: Overbreak

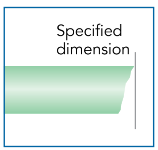


Fig. 2: Underbreak

Glass thickness [mm]	Maximum value [mm]
2, 3, 4, 5, 6	± 1.0
8, 10	± 1.5
12	± 2.0
15	± 2.0
19	+ 5.0 / - 3.0

Tab. 2: Angular break values

These factors must be taken into consideration when providing information on tolerances, i. e. glass dimensions may change with a raised edge by twice the value of the angular break.

As for non-rectangular elements, the following tolerances shown in Tab. 2a can apply to the given angles (similar to cutback). The geometry of the elements remains the same.

9.2.2.1.1 Possible break-off for float glass

α	x
≤ 12.5°	- 30 mm
≤ 20°	- 18 mm
≤ 35°	- 12 mm
≤ 45°	- 8 mm

Tab. 2a: cutback

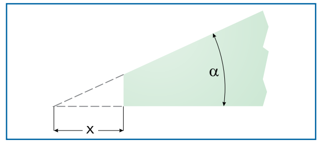


Fig. 3: cutback

9.2.2.1.2 Acute angle of tempered glass, laminated safety glass, IGU – cutback – zone not to be assessed

Due to manufacturing reasons, the glass manufacturer reserves the right to cut back, according to Table 2b. If such a cutback is not performed, the measurements listed in Table 2b are considered zones that are not to be assessed. In this case, unevenness at the edges (e.g. upper breaks) and on the surface may occur and are not a reason for complaint.

α	x
≤ 12.5°	- 65 mm
≤ 20°	- 33 mm

Tab. 2b: cutback

If the angle is > 25°, the cutback equals the break-off. The tolerances listed in → Chapter 9.2.3.1.4, Table 6 should not be added to the tolerances mentioned above in Tables 2a and 2b.

9.2.2.2 Length, width and perpendicularity

Based on the nominal dimensions of the length H and width W, the glass pane should fit into a rectangle that has been enlarged in size by the upper deviation limit and reduced in size by the lower deviation limit.

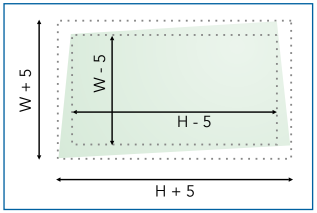


Fig. 4: Angularity

The sides of this rectangle should be parallel to each other and share a common middle point (see fig. 4). The rectangles also describe the limits of perpendicularity. The deviation limits for the nominal dimensions of length H and width W are ± 5 mm.

9.2.3 Processing

The tolerances depend on the respective type of edge processing.

In addition, EN 14 179 and national requirements, such as DIN 1249, Part 11 in Germany, also apply.

9.2.3.1 Edge processing qualities

(➞ Chapter 9.3.2)

9.2.3.1.1 Standard tolerances

Edge processing is divided into bordered, ground, smooth ground and polished. Therefore, there are two tolerance categories:

- The tolerance with angular break indicated in "cutting" (➞ Chapter 9.2.2) applies to bordered edges.
- The following table applies to smooth ground / polished edges.

Edge length [mm]	t ≤ 12 mm [mm]	t = 19 mm [mm]
≤ 1000	± 1.5	± 2.0
≤ 2000	± 2.0	± 2.5
≤ 3000	+ 2.0 / - 2.5	± 3.0
≤ 4000	+ 2.0 / - 3.0	+ 3.0 / - 4.0
≤ 5000	+ 2.0 / - 4.0	+ 3.0 / - 5.0
≤ 6000	+ 2.0 / - 5.0	+ 3.0 / - 5.0

Tab. 3: Standard rectangle deviations

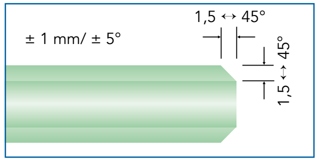


Fig. 5: Edge processing

The diagonal deviation is derived from $\sqrt{w^2 + h^2}$

Example:
glass pane w x h
= 1,000 x 3,000 mm

therefore:

plus dimension: $\sqrt{1,5^2 + 2,0^2}$
= +2,5 mm

minus dimension: $\sqrt{1,5^2 + 2,5^2}$
= -2,9 mm;

therefore:
diagonal deviation: + 2,5 / - 3,0 mm

9.2.3.1.2 Special tolerances

The tolerances listed in Table 4 can be realised with an increased effort. This special effort is necessary because the first glass pane must be measured exactly. Unground glass panes should be recut in this respect.

Edge length [mm]	t ≤ 12 mm [mm]	t = 15 + 19 mm [mm]
≤ 1000	+ 0.5 – 1.5	+ 0.5 – 1.5
≤ 2000	+ 0.5 – 1.5	+ 0.5 – 2.0
≤ 3000	+ 0.5 – 1.5	+ 0.5 – 2.0
≤ 4000	+ 0.5 – 2.0	+ 0.5 – 2.5
≤ 5000	+ 0.5 – 2.5	+ 0.5 – 3.0
≤ 6000	+ 1.0 – 3.0	+ 1.0 – 3.5

Tab. 4: Special rectangle deviations

9.2.3.1.3 Special shapes

The following table applies to 15 and 19 mm glass:

Edge length			
Standard [mm]		Special (CNC) [mm]	
≤ 1000	± 2.0		+ 1.0 / - 1.0
≤ 2000	± 3.0		+ 1.0 / - 1.5
≤ 3000	± 4.0		+ 1.0 / - 2.0
≤ 4000	± 5.0	≤ 3900	+ 1.0 / - 2.5
≤ 5000	+ 5.0 / - 8.0	≤ 5000	+ 2.0 / - 4.0
≤ 6000	+ 5.0 / - 10.0	≤ 6000	+ 2.0 / - 5.0

Tab. 5: Special shapes

9.2.3.1.4 Edge processing

α	x
≤ 12.5°	- 15 mm
≤ 20°	- 9 mm
≤ 35°	- 6 mm
≤ 45°	- 4 mm

Tab. 6 (Legend Figure 3, page 133)

9.2.3.2 Processing

Processing can involve corner cut-outs, surface cut-outs and edge cut-outs in a glass pane. Positions and dimensions of processing should, where not standardised, be agreed to suit each production situation.

As for corner and edge cut-outs, the minimum radius of the processing tool should be considered. The hole position and/or position tolerances of processings equal the edge processing tolerances.

9.2.3.2.1 Corner cut-off, bordered < 100 x 100 mm

Standard deviation ± 4 mm

9.2.3.2.2 Edge cut-out, bordered

Standard deviation ± 4 mm to position/deviations

9.2.3.2.3 Edge cut-out, bordered

9.2.3.2.3.1 Standard deviation for manual processing – cut-out dimensions

Cut-out length [mm]	Deviation [mm]
≤ 1000	± 6.0

Tab. 7: Edge cut-out deviation HB, bordered

9.2.3.2.3.2 Standard deviation for CNC processing – cut-out dimensions

Important: Minimum dimension with internal radii: 15 mm

Cut-out length [mm]	Deviation [mm]
≤ 2000	± 4.0
≤ 3400	± 4.0
≤ 6000	± 5.0

Tab. 8: Edge cut-out deviation CNC processing centre, bordered

9.2.3.2.4 Edge cut-off, bordered

Standard deviation ± 2 mm

(Edge cut-off < 100 x 100 mm, otherwise special shape)

Special deviation ± 1.5 mm

Production performed in CNC processing centre.

9.2.3.2.5 Edge cut-off, polished – CNC processing centre

9.2.3.2.5.1 Standard

Standard deviation ± 2 mm

(Edge cut-off < 100 x 100 mm, otherwise special shape)

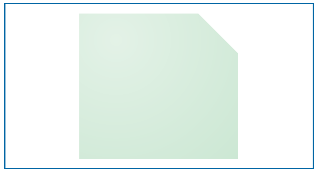


Fig. 6: Special shape

9.2.3.2.5.2 Special deviation

Deviation ± 1,5 mm

9.2.3.2.6 Corner cut-out, bordered

9.2.3.2.6.1 Standard

Depending on the glass thickness, minimum distance with internal radii:

≤ 10 mm: R 10
≤ 12 mm: R 15
Deviation of size ± 2 mm
Deviation of position ± 3 mm

9.2.3.2.6.2 Special deviation

Minimum dimension with internal radii: 17.5 mm, deviation 1.5 mm.

Special processing is performed in the CNC processing centre.

9.2.3.2.7 Corner cut-out, polished – CNC processing centre

Minimum dimension with internal radii: 17.5 mm

9.2.3.2.7.1 Standard

Deviation ± 2 mm

9.2.3.2.7.2 Special deviation

Deviation ± 1,5 mm

9.2.3.2.8 Edge cut-out, smooth ground or polished – CNC processing centre

9.2.3.2.8.1 Standard deviation

Minimum dimension with internal radii: 17.5 mm

Cut-out length [mm]	Deviation [mm]
< 500	± 2.0
≤ 1000	± 3.0
≤ 2000	± 3.0
≤ 3400	± 4.0

Tab. 9: Edge cut-out deviation CNC processing centre, smooth ground or polished

9.2.3.2.8.2 Special deviation

Minimum dimension with internal radii: 17.5 mm, Deviation ± 1.5 mm

9.2.3.3 Drilled holes

The hole position and/or position tolerances of the processings equal the edge processing tolerances.

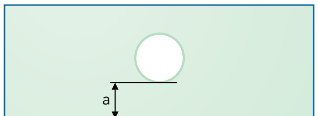
9.2.3.3.1 Diameters of drilled holes

The diameters Ø of drilled holes should not be smaller than the glass thickness. Please enquire separately from the manufacturer regarding small diameters of drilled holes.

9.2.3.3.2 Limitation and position of the drilled hole

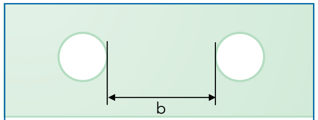
The position of the drilled hole (edge of the hole) relative to the glass edge, glass corner and next hole depends on:

- glass thickness (t)
- diameter of the drill hole
- form of the glass pane
- number of drill holes



a ≥ 2t
The distance of the well shall not be less than 2 x t

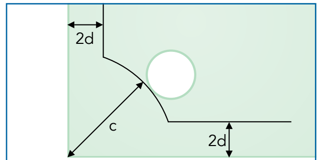
Fig. 7: Position of hole relative to edge



b ≥ 2t

The distance of the holes to each other should not be less than 2 x t

Fig. 8: Position of adjacent holes



c ≥ 6t
The distance of the borehole edge to the corner of the glass should not be less than 6 x t

Fig. 9: Position of hole relative to corner

Nominal diameter t [mm]	Deviation [mm]
4 < t < 20	± 1.0
20 < t < 100	± 2.0
100 < t	Request from manufacturer

Tab. 10: Drill hole deviations

9.2.3.3.3 Deviations in drill hole positions

Deviations in the position of individual drill holes equal those of width (W) and length (H) from Tab 11.

Nominal dimensions of side W or H [mm]	Deviation t [mm]	
	Nominal thickness t ≤ 12	Nominal thickness t > 12
≤ 2000	± 2.5 (horizontal manufacturing processes)	± 3.0
	± 3.0 (vertical manufacturing processes)	
2000 < W or H ≤ 3000	± 3.0	± 4.0
> 3000	± 4.0	± 5.0

Tab. 11

The position of the holes is measured in perpendicular co-ordinates (X & Y-axis) from the reference point to the centre of the hole. The reference point is generally an existing corner or an assumed fixed point. The position of the holes (X, Y) is (x ± t, y ± t), where x & y are the required distances and t is the deviation.

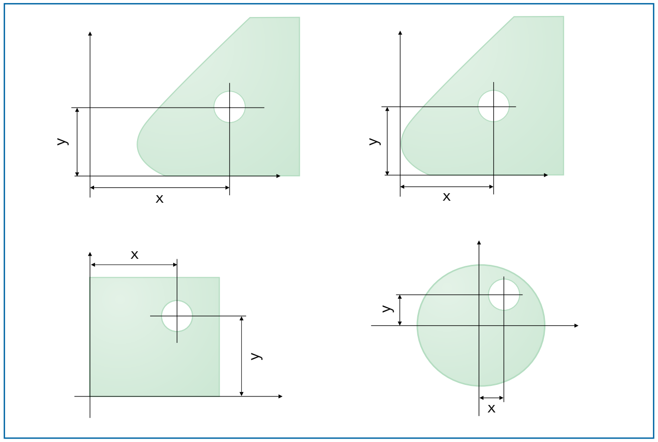


Fig. 10: Hole position

9.2.3.3.4 Drilled hole positions

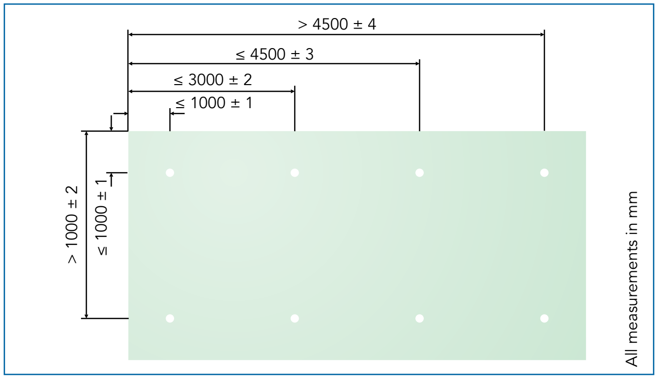


Fig. 11: Drilled hole positions

9.2.3.3.5 Drilled countersunk hole in diameters

Diameter:
≤ 30 mm ± 1 mm,
> 30 mm ± 2 mm.

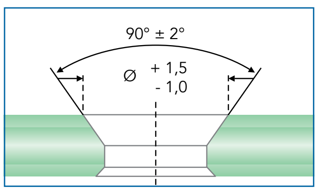


Fig. 12: Countersunk hole deviation

9.2.3.3.6 Drilled counter-sunk holes in laminated safety glass

The cylindrical drilled hole of the opposite glass pane must have a 4 mm larger diameter compared to the core diameter of the drilled countersunk hole.

$$X = \frac{\text{countersunk hole Ø - core Ø}}{2}$$

min. glass thickness = X + 2 mm

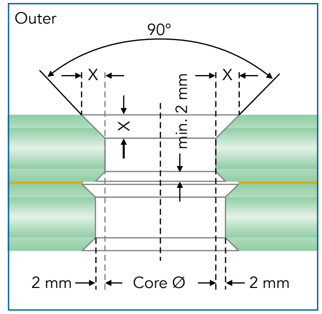


Fig. 13: Drilled countersunk holes in laminated safety glass

9.2.4 Tempered glass, tempered – heat-soaked glass and heat-strengthened glass

Single-pane safety glass, additionally valid: EN 12 150-1/-2 for tempered glass. EN 14 179 for tempered – heat-soaked glass and EN 1863 for heat strengthened glass.

9.2.4.1 General distortion – valid for float glass units

Standard 0.3 % of the measured length.

To be measured at the edges and diagonal, where none of the measured values may exceed 0.3 % of the measured length.

With square formats with side ratios between 1:1 and 1:1.3 and with glass thicknesses ≤ 6 mm, the deviation from the straightness is larger compared to narrow rectangular formats due to the toughening process.

9.2.4.2 Local distortion – valid for float glass units

Standard 0.3 mm over 300 mm of the measured length.

The measurement must be performed with a min. distance of 25 mm to the edge.

9.2.4.2.1 Recommended minimum glass thicknesses depending on the external glass pane dimension

Due to the thermal tempering process, we recommend the following size-dependent minimum glass thicknesses. In this context, application requirements are not considered.

Min. glass thickness t	Max. external pane dimension
4 mm	1000 x 2000 mm
5 mm	1500 x 3000 mm
6 mm	2100 x 3500 mm
8 mm	2500 x 4500 mm
10 mm	2800 x 5000 mm
12 mm	2800 x 5900 mm

Tab. 12: Minimum glass thicknesses

9.2.5 Insulating glass units (IGU)

Basis, the standards EN 1279-1 to -6, EN 1096-1, supplemented by national requirements.

9.2.5.1 Edge seal

The structure of the edge seal corresponds to the system specifications of the manufacturer. The maximum deviation of the edge seal width is ± 2.5 mm.

9.2.5.2 Thickness tolerances in the edge area of the unit

The actual thickness should be measured at each corner and near the midpoints of the edges between the outer glass surfaces. The measured values should be determined to an accuracy of 0.1 mm. The measured thickness values may not deviate from the nominal thickness specified by the manufacturer of the insulating glass units by more than the deviations specified in Table 13.

The thickness tolerances of insulating glass units with multiple pane cavities are ensured by adhering to the following rules:

a) determine the tolerances of every single glass/cavity/glass formation pursuant to Table 13

b) calculate the squares of these values

c) sum the square values

d) take the square root of this sum

	First pane*	Second pane*	IGU thickness deviation [mm]
a	Annealed glass	Annealed glass	± 1.0
b	Annealed glass	Tempered or heat-strengthened glass**	± 1.5
c	Annealed glass, tempered glass or heat-strengthened glass thickness ≤ 6 mm	Laminated glass with films*** Total thickness ≤ 12 mm	± 1.5
	Other cases		± 2.0
d	Annealed glass	Patterned glass	± 1.5
e	Tempered or heat-strengthened glass	Tempered or heat-strengthened glass	± 1.5
f	Tempered or heat-strengthened glass	Glass/plastic composite****	± 1.5
g	Tempered or heat-strengthened glass	Patterned glass	± 1.5
h	Glass/plastic composite	Glass/plastic composite	± 1.5
i	Glass/plastic composite	Patterned glass	± 1.5

* Pane thicknesses given as nominal values.
** Thermally tempered safety glass, heat-strengthened glass or chemically-tempered glass.
*** Laminated glass or laminated safety glass, consisting of two annealed float glass panes (maximum thickness 12 mm each) and one plastic film interlayer. For laminated glass or laminated safety glass of varying composition, see EN ISO 12 543-5 and the calculation rule according to 9.2.5.2 should be applied subsequently.
**** Glass/plastic composites are a type of composite glass that contains at least one pane of a plastic glazing material; see EN ISO 12 543-1.

Tab. 13: Thickness tolerances of IGU when using float glass

9.2.5.3 Dimension tolerance / offset

The dimension tolerances are calculated from the tolerances of the primary products used in insulating glass units plus the possible offset dimensions from insulating glass unit assembly.

2000 mm ≥ Edge length	2.0 mm
3500 mm ≥ Edge length > 2000 mm	2.5 mm
Edge length > 3500 mm	3.0 mm

Tab. 14: Maximum offset dimension – rectangles

2000 mm ≥ Edge length	2.0 mm
3500 mm ≥ Edge length > 2000 mm	3.0 mm
Edge length > 3500 mm	4.0 mm

Tab. 15: Maximum offset dimension – special shapes

9.2.6 Laminated safety glass units

Laminated safety glass units consist of two or more glass panes that are connected to an inseparable unit by means of one or several polyvinyl butyral (PVB) films. A distinction is made between glass with a PVB film thickness of 0.38 mm and glass with a PVB film thickness of at least 0.76 mm.

9.2.6.1 Dimension tolerances

The tolerances generally comply with EN ISO 12 543.

Laminated safety glass is distinguished according to its structure: Laminated safety glass 0.38 PVB, laminated safety glass from 0.76 PVB, laminated safety glass with sound protection film (sound control laminated safety glass) and laminated safety glass with colour film (coloured PVB films).

The respective dimension tolerances of the semi-finished products used in the laminated safety glass element apply, and additionally the permissible displacement tolerances as shown in Tables 16 and 17.

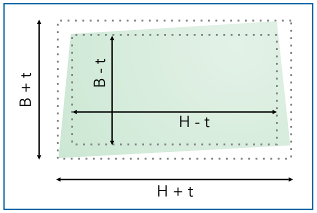


Fig. 14: Limit sizes for dimensions of rectangular panes

Example:
Laminated safety glass made of 6 mm tempered glass / 0.76 PVB / 6 mm heat-strengthened glass; polished edges. Deviation of the single pane: ± 1.5 mm, additional offset tolerance: ± 2.0 mm.
The permissible offset tolerance adds up to ± 3.5 mm

9.2.6.2 Displacement tolerance (offset)

The individual panes might be displaced during the laminating process for manufacturing reasons. With laminated safety glass consisting of two or more glass panes, every single pane is processed pursuant to DIN 1249, Part 11 as standard.

The cutting tolerances are added to the displacement tolerances. The longest edge of the element is used in Tables 16 and 17.

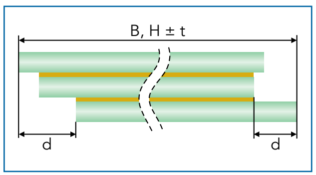


Fig. 15: Offset

Edge length l [mm]	Permissible maximum dimensions for displacement per laminated safety glass nominal thickness		
	≤ 8 mm	≤ 20 mm	> 20 mm
l ≤ 2000	1.0	2.0	3.0
2000 < l ≤ 4000	2.0	2.5	3.5
l > 4000	3.0	3.0	4.0

Tab. 16: Permissible maximum dimensions for displacement: rectangles

Edge length l [mm]	Permissible maximum dimensions for displacement per laminated safety glass nominal thickness		
	≤ 8 mm	≤ 20 mm	> 20 mm
l ≤ 2000	1.5	3.0	4.5
2000 < l ≤ 4000	3.0	4.0	5.5
l > 4000	4.5	5.0	6.0

Tab. 17: Permissible maximum dimensions for offset: special shapes

9.2.6.3 Thickness tolerance

The thickness deviation of laminated safety glass should not exceed the sum of the individual glass panes, which is specified in the standards for basic glass (EN 572). The tolerance limit of the intermediate layer must not be taken into account if the thickness of the intermediate layer is < 2 mm. For intermediate layers ≥ 2 mm a deviation of ≤ 0.2 mm is taken into account.

9.3 Glass edges

The quality of glass edges of single panes that are built into a glass system has enormous influence on the longevity of the product. Glass edges without further processing may show micro cracks, which have negative effects and can lead in an extreme case to breakage. The quality depends on the status of the cutting tools as well as on further edge processing. Definitions must be found in EN 12 150.

9.3.1 Edge types

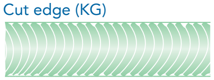
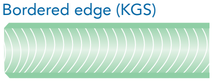
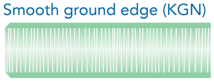
- **Round edges (RK)**
This edge surface grinding is somewhat rounded. The most popular type by far is the "C edge". The "Flat-round" or "half-round" types of edges can be made on agreement.

- **Straight edge (K)**
The straight edge forms an angle of 90° to the glass surface.

- **Mitre edge (GK)**
The mitre edge forms an angle between < 90° and ≥ 45° to the glass surface. There is no sharp edge but always a bevel of 90° to the glass surface.

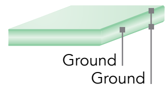
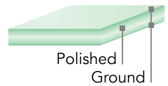
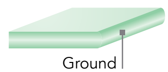
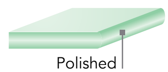
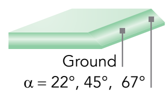
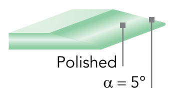
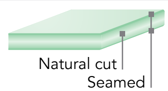
- **Facet edge (FK)**
In this case, there will be an optional angle deviating from 90° to the glass surface. Depending on the facet width, differentiations are made between flat and steep facets. In addition, the faceted edge runs towards a remaining 90° edge, thus a bevel that may also be rounded.

9.3.2 Edge processing

Indication	Definition according to EN 12150
Cut edge (KG) 	The cut edge is an unprocessed glass edge that is produced when flat glass is cut. The margins of the cut edge are sharp-edged. The edge has slight wave lines which run transversely to its margins. Generally speaking, the cut edge has a clean break but there may also be irregular breakages caused at contact points of cutting tools, which is the case with thick glass panes and non-straight format glass panes. Other processing characteristics may result, for example, from breaking the glass by means of tongs. Projecting unevenness may be levelled (ground). A laminated safety glass comprising of glass panes with cut edges normally has an edge mismatch complying with the cutting tolerance.
Bordered edge (KGS) 	The cut edges are trimmed. The glass edge can be smooth ground in full or in part.
Ground edge (KMG) 	The cut edges are trimmed. The glass edge can be smooth ground in full or in part.
Smooth ground edge (KGN) 	The edge surface is smooth ground by means of a fine grinding wheel getting a frosted (satined) surface finish. Blank spots and shells are not admissible.

Indication	Definition according to EN 12150
Polished edge (KPO) 	The polished edge is a smooth ground edge refined by polishing. Frosted spots are not admissible. Visible and noticeable polishing marks and scorings are admissible. Due to manufacturing reasons, the edges of a glass pane can be processed by different or several machines. This may result in a different appearance of smooth ground and polished edges. This is not a reason for complaint.

9.3.3 Edges presentation and typical application

Edge diagram	Description	Typical application
	Smooth ground edge, KGN	Structural glazing with exposed edges
	Edge polished, KPO	Structural glazing where edge condition is critical for aesthetic purposes
	Round edge (C edge) smooth ground, RK	Mirrors, decorative furniture glass
	Round edge (C edge) polished, RK	Mirrors, decorative furniture glass
	Facet edge, steep smooth ground	Structural glazing
	Facet edge, flat polished	Mirrors, decorative furniture glass
	Bordered edge, KGS	Normal edge treatment for hard-treated glass

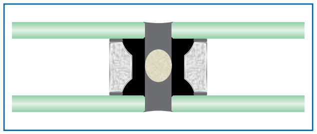
9.4 Glass corners and joints

This form of modern architecture is characterised by the fact that there is no vertical post, header or load-bearing beam behind the corner or the joint to hide them, nor is there a front cover. Therefore, the glass that is used should generally have UV-resistant edge seals (→ Chapter 3.4) and all materials utilised should be compatible with each other. The conditions for forming the rebates between the adjoining glass elements for sealing are identical with glazing held in frames. The same applies to structural analysis verification and specifications relating to heat – and noise reduction where appropriate.

The design possibilities are multifaceted and should be defined clearly when planning commences. Following are some examples for possible implementations.

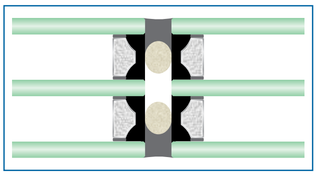
9.4.1 Glass joint with sealant joint and weather stripping for double insulating glass

Suitable for vertical use, not for roof glazing as there is no ventilation or drainage in the rebate area.



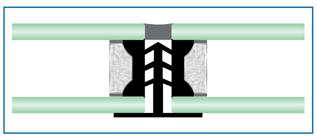
9.4.2 Glass joint with sealant joint and weather stripping for triple insulating glass

Suitable for vertical use, not for roof glazing as there is no ventilation nor drainage in the rebate area.



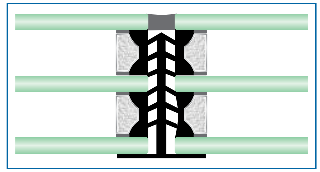
9.4.3 Glass joint with sealant joint and preformed seal for double insulating glass

Ventilation and drainage of the rebate fold is possible, and designed so that it is conveyed to the outside, especially in the joint intersections.



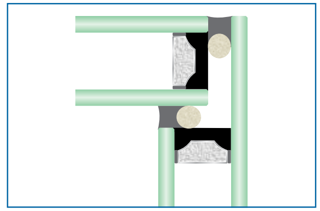
9.4.4 Glass joint with sealant joint and preformed seal for triple insulating glass

Ventilation and drainage of the rebate fold are available and following the construction to the outside, especially in the joint intersections.



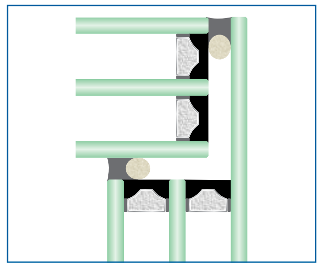
9.4.5 All-glass corner with double-stepped glazing unit

No ventilation and drainage of the rebate area possible, therefore not suitable for angular glazing.



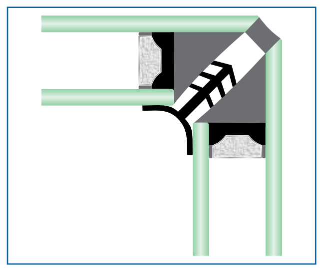
9.4.6 All-glass corner with triple-stepped glazing unit

No ventilation and drainage of the rebate area possible, therefore not suitable for angular glazing.

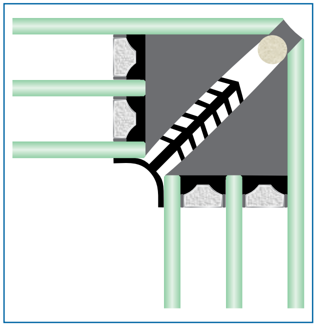


9.4.7 All-glass corner with preformed seal for double-insulated glass with stepped edges

Moisture removal and ventilation of the rebate area possible designed so that it is conveyed to the outside; therefore, suitable for vertical as well as for angular glazing.



9.4.8 All-glass corner with preformed seal for triple-insulated glass with stepped edges



Humidity removal and ventilation of the rebate area possible and constructed so that it is conveyed to the outside; therefore, suitable for vertical as well as for angular glazing.

Detailed explanations of this subject matter regarding national rules (e.g. in Germany) are contained in the V.07 leaflet from the window + façade association or can be defined together with GUARDIAN during the planning stage.

9.5 Dimensioning of glass thickness

The installed glass are subject to different loads and should therefore be dimensioned according to the conditions. In addition to positive/negative wind and snow loads, its own weight and when using insulating glass, the climatic loads in the interface should also be considered. The following variants should in general be considered when calculating dimensions. GUARDIAN is also be happy to help with the following:

- Geographical location and installation position of the glazing
- Load distribution, if it is not 50:50
- Pane interface contraction and expansion due to fluctuating weather conditions (changes in temperature and air pressure)
- Glass bearing on all sides or partially
- thermally increased glass stress

National guidelines and rules governing the precise dimensioning of glass should be introduced and adapted gradually in the medium-term in all EU countries. Germany is therefore transferring its existing technical rules to the new DIN 18 008. These types of calculations may only be realised by engineering companies and should be checked by the building inspection authorities.

9.6 Surface damage to glass

Like all other high-quality plate glass, glass surfaces can be exposed to mechanical, thermal or chemical stress. Past experience has shown that this level of damage generally occurs during the construction period and seldom once the building has been completed. Mechanical surface damage is generally due to inappropriate transport at the construction site, storage or installation or by the sliding of one glass surface on another when there is dust from the construction site on the panes.

In addition, using unsuitable tools like glass planers or blades to remove persistent dirt on glass can cause mechanical damage to the surface. The most frequent cause of this type of damage on construction sites is that the glass comes into contact with fresh cement, mortar or chalk. Corrosion is left behind after these types of materials have dried on the glass surface and are then removed.

Thermal damage, however, can occur when welding work or metal cutting is carried out near glass that is not protected against flying sparks. In addition, unsuitable sealing material may cause irreparable streaking, as can aggressive cleaning agents which may possibly contain hydrofluoric acid, an agent that is often used for cleaning brick façades.

To prevent these possible scenarios, the glass should be protected with films if it is installed at an early stage of the building phase cleaned later using only suitable cleaning agents and an appropriate amount of clean water (→ Chapter 9.11).

9.7 Guidelines for assessing the visibility quality of glass in buildings

(Extract from “Guideline to Assess the Visibility Quality of Glass in Buildings” BIV/BF/VFF 2009)

9.7.1 Scope

This guideline applies to assessment of the visibility quality of glass in buildings (used in building shells and in finishing of buildings / structures). The assessment is made according to the following testing principles, along with the permitted discrepancies listed in the table in Section 9.7.3.

Glass surfaces that remain visible after installation are subject to assessment. Glass products constructed with coated glass panes, tinted glass, laminated glass or tempered glass (single safety

9

glass, heat-strengthened glass) can also be assessed using the table in Section 9.7.3.

The guideline does not apply to specially constructed glass units, such as glass units with elements installed in the gas-filled cavity or in the laminate, glass products using patterned glass, wired glass, special safety glazing, fire-resistant glazing and non-transparent glass products. These glass products should be assessed taking into consideration the materials used, the production processes and relevant information from the manufacturer.

Assessing the visible quality of the edges of glass products is not the subject of this guideline. The rebate zone does not apply as an assessment criterion to edges without frames in constructions that are not framed on all sides. The intended use should be indicated in the order.

Special conditions should be agreed upon for inspecting the outward appearance of glass in facades.

9.7.2 Testing

In testing, visibility through the pane i. e. the view of the background is the generally decisive criterion, not the appearance in reflection. The discrepancies should not be specially marked in this respect.

The glazing units should be tested according to the table in section 9.7.3 from a distance of minimum 1 metre from the inside to the outside at an angle which corresponds to the normal usage of the room. The test is carried out under diffused daylight conditions (e.g. overcast sky), without direct sunlight or artificial illumination.

Glazing units in rooms (indoor glazing) should be inspected with normal (diffused) illumination intended for the use of the rooms at a viewing angle that is preferably vertical to the surface.

If glazing is assessed from the outside, they should be examined in the installed condition, taking into consideration the usual viewing distance. Inspection conditions and viewing distances taken from requirements in product standards for the examined glazing may differ from these and are not taken into consideration in this guideline. The inspection conditions described in these product standards frequently cannot be adhered on the building.

9.7.3 Permitted discrepancies for the visible quality of glass in buildings

Table prepared for coated or uncoated float glass, single-pane safety glass, heat-strengthened glass, laminated glass, laminated safety glass

Zone	The following are permitted per unit:
R	External shallow damage to the edge or conchoidal fractures which do not affect the glass strength and which do not project beyond the with of the edge seal.
R	Internal conchoidal fractures without loose shards, which are filled by the sealant.
R	Unlimited spots or patches of residue or scratches.
E	Inclusions, bubbles, spots, stains, etc.: Pane area ≤ 1 m²: max. 4 cases, each < 3 mm Ø Pane area > 1 m²: max. 1 cases, each < 3 mm Ø per metre of perimeter
E	Residues (spots) in the gas-filled cavity: Pane area ≤ 1 m²: max. 4 cases, each < 3 mm Ø Pane area > 1 m²: max. 1 cases, each < 3 mm Ø per metre of perimeter
E	Residues (patches) in the gas-filled cavity: max. 1 case ≤ 3 cm²
E	Scratches: Total of individual lengths: max. 90 mm – individual length: max. 30 mm
E	line scratches: not allowed in higher concentration
M	Inclusions, bubbles, spots, stains etc.: Pane area ≤ 1 m²: max. 2 cases, each < 2 mm Ø 1 m² < Pane area ≤ 2 m²: max. 3 cases, each < 2 mm Ø Pane area > 2 m²: max. 5 cases, each < 2 mm Ø
M	Scratches: Total of individual lengths: max. 45 mm – individual length: max. 15 mm
M	Hair-line scratches: not allowed in higher concentration. Maximum number of permitted discrepancies as in zone E
E+M	Inclusions, bubbles, spots, stains etc. of 0.5 to 1.0 mm are permitted without any area-related limitation, except when they appear in higher concentration. „Higher concentration“ means at least 4 inclusions, bubbles, spots, stains, etc. are located within a diameter of ≤ 20 cm.

Comments:

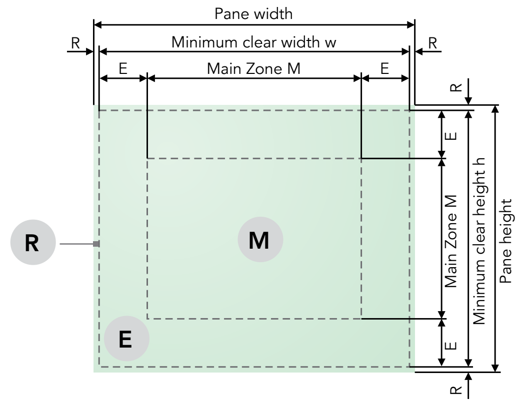
Discrepancies ≤ 0.5 mm will not be taken into account. The optically distorted fields they cause may not be more than 3 mm in diameter.

Allowances for triple-layer thermal insulating glass, laminated glass and laminated safety glass:

The permitted frequency of discrepancies in the E and M zones increases by 25 % of the aforementioned values per additional glass unit and per laminated glass pane. The results are always rounded up.

Single-pane safety glass, heat-strengthened glass, laminated glass and laminated safety glass made from single-pane safety glass and/or heat-strengthened glass:

1. Local roller wave distortion on the glass surface (except for patterned single safety glass and patterned heat-strengthened glass) may not exceed 0.3 mm in relation to a length of 300 mm.
2. The warp relative to the all-glass edge length (except for patterned single-pane safety glass and patterned heat-strengthened glass) may not be greater than 3 mm per 1000 mm glass edge length. Greater warps may occur for square or near square formats (up to 1:1.5) and for single panes with a nominal thickness < 6 mm.



R = Rebate zone:
the visually concealed area in the installed state (no limits on discrepancies, with the exception of mechanical damage to the edges)

E = Edge zone:
Area around edge with width w/10 or h/10 respectively – see diagram (less stringent assessment)

M = Main zone:
(most stringent assessment)

Fig.: Zones in glass

9.7.4 General comments

The guideline is a measure for assessing the visible quality of glass in building. In assessing an installed glazing product, it is assumed that, in addition to the visible quality, the characteristics required for the glazing product to fulfil its function will also be taken account.

The characteristic values of glazing products such as sound insulation, thermal conductivity and light transmission values which are documented for the corresponding function, refer to test panes as specified by the applicable testing standard. Other pane dimensions and combinations, installation types and external influences can result in differences to the specified values and optical impressions.

The multitude of diverse glazing products means that the table in section 9.7.3 cannot be applied without restrictions. In some circumstances an assessment referring to the specific product is necessary. In such cases, e.g. for special safety glazing, the particular specifications should be assessed on the basis of the function and the installation situation. In assessing certain properties, the product-specific characteristics should be observed.

9.7.4.1 Visible properties of glazing products

9.7.4.1.1 Intrinsic colour

All materials used in glazing products have an intrinsic colour which is determined by the raw materials and which becomes increasingly evident as the thickness increases. Coated glass is used for functional reasons. Coated glass also has its own intrinsic colour. This intrinsic colour can vary, depending on whether the coating is transmitting and/or reflecting. Fluctuations in the colour impression are possible due to the iron oxide content in the glass, the coating process, the coating itself, variation in the glass thickness and the unit construction, none of which can be avoided.

9.7.4.1.2 Differences in coating colours

An objective assessment of the differences in colour with coatings requires the difference in colour to be measured or examined under conditions that have been exactly defined (glass type, colour, illuminant). Such an assessment cannot be the subject of this guideline.

9.7.4.1.3 Assessment of the visible section of the edge seal of the insulating glass unit

Features on the glass and spacer resulting from production processes can be recognised in insulating glass units in the visible section of the edge seal. By definition, this section is not included in the area between the sight lines that is subject to assessment. If the edge seal of the insulating glass unit is exposed on one or more sides due to design requirements, features resulting from production processes may be visible in the area of edge seal.

The permissible deviation of the spacer(s) in relation to the parallel straight glass edge or to other spacers (e.g. in triple insulating glass) is 4 mm up to an edge length of 2.5 m. For longer edge lengths, the permissible deviation is 6 mm. For double insulating glass, the tolerance of the spacer is 4 mm up to an edge length of 3.5 m, and 6 mm for longer edge lengths.

If the edge seal on the insulating glass unit is exposed due to design requirements, typical features of the edge seal may become visible that are not covered by this guideline. In such cases, individual arrangements should be agreed on.

9.7.4.1.4 Insulating glass units with internal muntins

Due to climatic influences (e.g. insulated glass effect), shocks or manually generated vibration, clapping noise may occur in the muntins. The production process produced visible saw cuts and the slight removal of paint near the saw cuts.

In assessing deviations from right angles and misalignment within the glazing zones, the manufacturing and installation tolerances and the overall impression must be taken into account.

Effects due to temperature-related changes in the lengths of muntins in the gas-filled cavity are basically unavoidable. Misalignment of muntins caused by production cannot be ruled out.

9.7.4.1.5 Damage to external surfaces

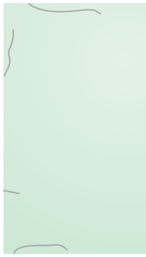
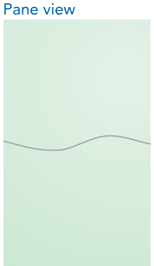
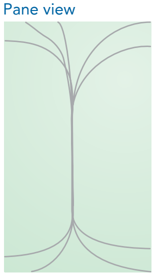
The cause of mechanical or chemical damage to the external surfaces recognised after installation must be determined. These discrepancies can be assessed according to the criteria of section 9.7.3.

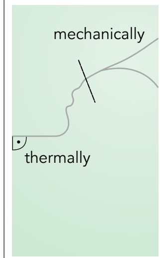
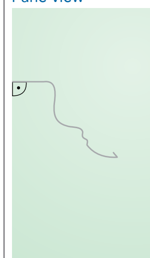
In other respects, national standards and guidelines.

9.8 Glass breakage

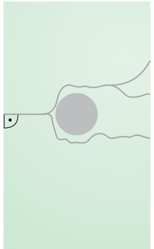
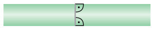
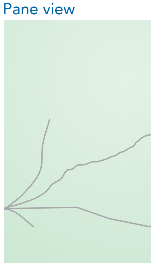
Glass is a brittle construction material and therefore does not allow for excessive deformations. Exceeding the elasticity border due to mechanical or thermal influences immediately leads to breakage.

Kind of glass breakage		Representation
Example:	Edge breakage float glass Mechanical point load • short term • weak to medium intensity Happens with float glass, laminated safety glass, Laminated glass, cast resin panes and ornamental glass	Pane view 
Reason:	Little stones between glass panes, Hammer blow on glazing bead, Other blow and collision effects	
Characteristics:	Feeding angle all directions, out of square, Continuous angle out of square, Origin to be seen in the edge area, Shells possible in the breakage centre	Fracture cross section 
Example:	Edge breakage heat strengthened glass Mechanical point load • short term • weak to medium intensity Happens only with partially prestressed glass per DIN EN 1863	Pane view 
Reason:	Little stones between glass panes, hammer blow on glazing bead, other blow and collision effects	
Characteristics:	Feeding angle all directions, out of square, Continuous angle out of square, Origin to be seen in the edge area, Shells to be found often in the breakage centre	Fracture cross section 

Kind of glass breakage	Representation
Example: Clamping crack Mechanical point or line load • short term dynamic • long lasting static Happens with float glass, laminated safety glass, Laminated glass, cast resin panes and ornamental glass Reason: Too small or wrong blocks and very high glass weight, Wrong handling of the block lever, Length change of glass/frame not considered Characteristics: Feeding angle all directions, out of square, Continuous angle out of square, Origin to be seen in the edge area, Shells possible in the breakage center	Pane view  Fracture cross section 
Example: Torsion breakage Mechanical line load • short term • dynamic To be found at float glass, laminated safety glass, Laminated glass, cast resin panes and ornamental glass Reason: Glass thickness not sufficient, specially when mounted on two sides, Twisted and jamming casement frames, Movements in the structure with load transfer to the pane Characteristics: Feeding angle all directions, out of square, Continuous angle out of square, Generally not clearly allocated	Pane view  Fracture cross section 
Example: Area pressure breakage Mechanical distributed load • long lasting • dynamic/statical To be found at float glass, laminated safety glass, Laminated glass, cast resin panes and ornamental glass Reason: Too high load of the insulating glass by temperature, air pressure and/or Altitude differences between production and installation location, Undersized aquarium pane supported on four sides Characteristics: Feeding angle all directions, out of square, No breakage center to be seen, Continuous angle rectangular, No shells at glass edge	Pane view  Fracture cross section 

Kind of glass breakage	Representation
Example: Hybrid crack Thermal/mechanical loads • overlapping To be found at float glass, laminated safety glass, Laminated glass, cast resin panes and ornamental glass Reason: Several effects by area load (squall) on undersized and already thermally, Charged pane Characteristics: Feeding pane rectangular, Continuous angle out of square, No edge shells, No breakage center to be seen	Pane view  Fracture cross section 
Example: Thermal normal crack Thermal line load • weak to medium intensity To be found at float glass, laminated safety glass, Laminated glass, cast resin panes and ornamental glass, Wired glass may differ due to the network. Reason: Partial covering of the pane in the interior during solar irradiation, Glazing depth too low, as package stored sound-, heat- and solar protection glazing (especially insulating glass) without protection against direct solar irradiation. Characteristics: Feeding angle rectangular, Continuous angle rectangular, Edge shells not to be found at incoming	Pane view  Fracture cross section 
Example: Delta breakage Mechanical line load • long lasting • static/dynamic • two sides bearing Happens with float glass, laminated safety glass, laminated glass, ornamental and wired glass. Reason: Long-lasting, high snow load on overhead glazing being mounted on two or three sides Characteristics: Feeding angle out of square, Continuous angle out of square, No shells on glass edge, Breakage center on non mounted edge	Pane view  Fracture cross section 

9

Kind of glass breakage	Representation
Example: Thermal line crack Thermal line load • weak to strong intensity to be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass, wired glass differs possibly due to wire net work Reason: Partial covering of the glass pane with interior decoration, dark spots (stickers, advertisements) on the glass pane, a large plant leaf or likewise inside directly on the glass pane Characteristics: Feeding angle rectangular, Continuous angle rectangular, Edge shells not to be found at incoming	Pane view  Fracture cross section 
Example: Edge joint breakage Mechanic point load • short term • weak to strong intensity to be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass Reason: Placing panes on stone or metal parts, Edges hit by metal part, Mishandling of tensioning strips of transport racks Characteristics: Feeding angles all directions, out of square, continuous angle out of square, edge shells to be seen at crack in different sizes depending on the power of force effect, Very obvious centre seen at the edge	Pane view  Fracture cross section 
Example: Edge pressure breakage Mechanical point load • short term or long term aggressive • weak to medium intensity to be seen at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass Reason: undersized blocks for high glass weight, too high clamping pressure by screw connection, too high clamping pressure by using nails for wood strips without preformed tape Characteristics: Feeding angle out of square, continuous angle out of square, shells of edge not or seldom present, origin at edge to be seen	Pane view  Fracture cross section 

The defined guidelines referring to this must be followed precisely. For thermal load, the normal float glass used for facades which are partially in the shade may be exposed to a maximum temperature delta of 40 K. If the glass is exposed to temperature changes exceeding 40 K, then this float glass should be replaced with tempered glass in order to increase this delta. This is especially essential in the case of absorbing solar protection glasses.

Another danger which may lead to glass breakage is on the construction site when modern, coated insulating glass packages on racks are unprotected against the sun. The sun heats the glass packs and, due to the coatings, the heat is unable to dissipate. This inevitably results in glass breakage. Therefore, glass packs standing in the open must be covered with opaque material. Also, small-sized insulating glass panes with unfavourably proportioned sides and asymmetric structures need a thinner tempered glass pane to prevent breakage.

Glass breakage formerly caused by residual stress is practically ruled out, due to today's glass production. But both unqualified finishing of edges with nearly invisible micro cracks and mechanical surface damage may lead to medium-term pane failure. The same applies to incorrect transport und edge damage. In such a case, the failure may not become obvious immediately, but only at a later point in time. Breakage out of the material itself can only occur with tempered glass, and so-called "spontaneous" breakage occurs where nickel sulphide inclusions are present (→ Chapter 7.2).

Generally, it can be said that glass breakage is almost 100 % preventible if it is handled appropriately with advance planning, correct dimensioning and proper use and maintenance.

9.9 CE qualification

CE is the abbreviation for Conformité Européenne. Products are identified with CE when they correspond with the coordinated European product norms. It is neither an emblem of origin nor a quality signet but rather declares that a particular product complies with the Building Products Directive (BPR). This BPR confirms that the product can be marketed in all EU countries without any reservation. National special requests, however, may define additional specifications for use of these products. This is for example the Construction Rules List in Germany. With the CE identification the manufacturer declares that the product complies with the underlying product norms.

Proof of this compliance is made on very different levels, two of which are relevant for glass:

- Level 1:
  First check with own and foreign control
- Level 3:
  Producer declaration after first check with own control

The requirements of the BPR are defined in the following product rules:

Product standard	Titel	Level
EN 572	Basic soda lime silicate glass products (e.g. float glass)	3
EN 1096	Coated glass	3
EN 1279	Multi-pane insulated glass	3
EN 1863	Heat strengthened soda lime silicate glass	3
EN 12150	Thermally tempered single-pane safety glass	3
EN 14179	Heat-soaked thermally tempered soda lime silicate safety glass	3
EN 14449	Laminated glass and laminated safety glass	3 or 1

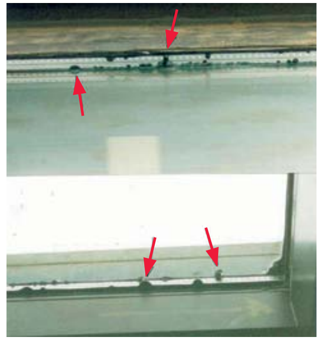
The introduction of these rules has replaced the national norms which were valid so far. These EN norms have common characteristics like:

- Asking for a new management quality system
- Definition of quality characteristics
- To define quality characteristics

9.10 Materials compatibility

As a building material, glass comes into direct or indirect contact with a number of other materials such as PVB films, insulating glass edge seal, blocks, press sealing of pressure glazing or sealing mass and elements at joint gaps and glass corners. Preconditions should be checked as to whether the individual materials have no harmful interactions between them.

Interactions are all physical, physical-chemical or chemical processes that, in the short, medium or long term, may lead to changes in the structure, colour or consistency. Even materials which are not in direct contact, but merely in the vicinity, can generate interactions through migration. Especially those products which contain softeners may, in the case of incompatibility, result in other adjacent materials absorbing these softeners as solvents and changing their consistency completely.



Decomposition of the butyl sealing through migration

Block after harmful interactions

As the components used during the construction phase rarely come from the same producer, these compatibilities should be checked – by testing if necessary. Generally speaking, it is imperative to plan carefully and realise work with the assistance of all participants and their product specifications. The more complex the installed glass systems, the more essential this requirement is in order to guarantee longevity and lasting functionality.

A broad range of tested products (including specifications of their mutual compatibility) is available.

9.10.1 Compatible insulating glass sealant and structural glazing silicone for SunGuard® High Performance

This list is for information purposes only, and GUARDIAN assumes no responsibility for its content and completeness. GUARDIAN grants a limited product guarantee for SunGuard®, but not for any intended further processing or the final product. The fabricator bears complete responsibility in this regard.

All SunGuard Solar types can be used with any sealant and SG silicone. Sealant can be applied directly to the coating or appropriate frame enamelling. Appropriate ETAG test results are available.

Manufacturer	Sealant type	Application	HP Light Blue 62/52	HP Neutral 60/40	HP Neutral 52/41	HP Neutral 50/32	HP Silver 43/31	HP Neutral 41/33	HP Royal Blue 41/29	HP Amber 41/29	HP Bright Green 40/29	HP Bronze 40/27	HP Royal Blue 38/31	HP Silver 35/26
DOW-Corning	DC 993	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
DOW-Corning	DC 791	Weather-seal (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
DOW-Corning	DC 895	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
DOW-Corning	DC 991	Weather-seal (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
DOW-Corning	DC 3362	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
SIKA (Wacker)	SG 500	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
SIKA (Wacker)	SG 20	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
SIKA (Wacker)	IG 25	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
SIKA (Wacker)	IG 25 HM	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
Tremco	Proglaze II	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Tremco	Spectrem 2	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Tremco	Proglaze Vec 90	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Tremco	Proglaze Vec 99	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Tremco	Proglaze 580	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
Tremco	JS 562	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Tremco	Proglaze LMA	Weather-seal (silicone)	•	•	•	•	•	•	•	•	•	•	•	•

Manufacturer	Sealant type	Application	HP Light Blue 62/52	HP Neutral 60/40	HP Neutral 52/41	HP Neutral 50/32	HP Silver 43/31	HP Neutral 41/33	HP Royal Blue 41/29	HP Amber 41/29	HP Bright Green 40/29	HP Bronze 40/27	HP Royal Blue 38/31	HP Silver 35/26
Tremco	JS 442	IG sealant (polyurethane)	•	•	•	•	•	•	•	•	•	•	•	•
Momentive	SSG 4000 E	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Momentive	SSG 4400	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Momentive	IGS 3723	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
Ramsauer	Neutral 120	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
Ramsauer	Alkoxy 130	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
Ramsauer	Structural 350	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Ramsauer	Randverbund 380	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
H.B. Fuller	PS-998R	IG sealant (polysulfide height)	•	•	•	•	•	•	•	•	•	•	•	•
Fenzi	Thiover	IG sealant (polysulfide height)	•	•	•	•	•	•	•	•	•	•	•	•
Fenzi	Hotver 2000	IG sealant (hot melt height)	•	•	•	•	•	•	•	•	•	•	•	•
Kömmerling	GD 116 IG	IG sealant (polysulfide height)	•	•	•	•	•	•	•	•	•	•	•	•
Kömmerling	GD 677 IG	IG sealant (polyurethane)	•	•	•	•	•	•	•	•	•	•	•	•
Kömmerling	GD 920 IG	IG sealant (silicone)	•	•	•	•	•	•	•	•	•	•	•	•
Kömmerling	Ködiglaze S	Structural silicone	•	•	•	•	•	•	*	•	*	•	•	•
Kömmerling	Isomelt	IG sealant (hot melt height)	•	•	•	•	•	•	•	•	•	•	•	•
Bostik	Sealomelt	IG sealant (hot melt height)	•	•	•	•	•	•	•	•	•	•	•	•
Bostik	Evo-Stik Hiflo	IG sealant (hot melt height)	•	•	•	•	•	•	•	•	•	•	•	•
Bostik	Evo-Stik Hotmelt	IG sealant (hot melt height)	•	•	•	•	•	•	•	•	•	•	•	•
Bostik	Bostik 5000	IG sealant (hot melt height)	•	•	•	•	•	•	•	•	•	•	•	•
IGK	IGK 130	IG sealant (polyurethane)	•	•	•	•	•	•	•	•	•	•	•	•
MC Bauchemie	Emcepren 200	IG sealant (polyurethane)	•	•	•	•	•	•	•	•	•	•	•	•
Kadmar	Polikad-M	IG Dichtstoff IG sealant (polysulfide height)	•	•	•	•	•	•	•	•	•	•	•	•

• Compatible sealant / silicone - SunGuard® High Performance successfully combined

* For edge deletion corresponding SunGuard® High Performance product necessary

9

9.11 Glass cleaning

No matter what the area of application is, glass can be fascinating to look at and through – if it is clean. Regular cleaning is therefore absolutely essential. During and immediately after the construction phase, building material on the glass surfaces, e.g. fresh cement, plaster etc. should be swabbed off with clean water in order to avoid corrosion. Dust or other sediments should never be removed when they are in a dry state. The best protection during the construction phase is to cover glass using protection films. This facilitates initial cleaning considerably once construction has been completed.

Professional cleaning using clean water should be realised in a manner suitable for the particular glazing and throughout the service life of the building. Tools may include soft, clean sponges, cloths or leather and properly handled rubber wipers and neutral household cleaning agents that contain no aggressive substances. Stubborn soiling as well as grease or sealant residue can be removed using alcohol or spirits in connection with water, but never alkaline lyes or acids. Pointed and sharp metallic objects such as blades and planers should never be used. If soiling cannot be removed using the methods described, an expert should be contacted, since further attempts on one's own may damage the glass irreparably.

9.12 Transport and storage

Glass should generally be transported standing on edge. This edge generally stands parallel on two cushioned supports. Every contact the glass panes make with metal or each other is damaging. Panes in glass packets should therefore be separated using suitable spacers.

If insulating glass is transported over height differences of more than 500 metres, a special insulating glass production unit should be made. The distances between the stacked panes should also be enlarged.

Panes should be stored on edge, just as they are during transport. Warehousing should be dry and, if possible, not exposed to direct solar radiation. If stored outdoors, it is recommended that the glass packet be covered with an opaque awning. If stacked glass is exposed to humidity, there is a risk that sodium hydroxide could be generated which irreparably damages the panes during prolonged exposure. The stacks should therefore be opened and the individual panes of glass dried out and restacked. Moreover, our storage instructions for individual glass products should always be taken into consideration.

Tour Madou Plaza, Brussels
SunGuard® Solar Neutral 67
Robert Goffaux Architect
Assar Architects
Archi 2000 Architects

Previous chapters have illustrated the variety of production, processing and application options which can be exploited using glass. GUARDIAN offers concrete products for all these options with the relevant data for planning and applications. This chapter contains a selection of important facts and factors in tabular form.

However, deviating requirements and continuous further development may at any time lead to the creation of alternative products.

Deviating requests, as well as a permanent future development, may create alternatives at any time.

10.1 Float glass

Table 1: "Clear" float glass , 2 - 15 mm

Thickness	Light Transmission	Light Reflection	Colour Rendering Index Ra	Direct Energy Transmission	Energy Reflection	Energy Absorption	Solar Factor (g) EN 410	Shading Coefficient [g / 0.87]	UV transmission
[mm]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		[%]
2	91	8	100	88	8	4	89	1.02	78
3	90	8	99	86	8	6	88	1.01	73
4	90	8	99	84	8	8	86	0.99	69
5	89	8	99	82	8	10	85	0.98	66
6	89	8	98	82	7	11	85	0.97	64
8	88	8	98	79	7	14	82	0.95	61
10	87	8	97	76	7	17	80	0.92	58
12	86	8	97	73	7	20	78	0.90	54
15	85	8	96	70	7	23	75	0.87	51

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

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Table 2: „ExtraClear®“ float glass, 2 - 15 mm

Thickness	Light Transmission	Light Reflection	Colour Rendering Index Ra	Direct Energy Transmission	Energy Reflection	Energy Absorption	Solar Factor (g) EN 410	Shading Coefficient [g / 0.87]	UV transmission
[mm]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		[%]
2	91	8	100	89	8	3	90	1.03	81
3	91	8	99	88	8	4	89	1.02	77
4	91	8	99	87	8	5	88	1.01	74
5	90	8	99	86	8	6	87	1.00	71
6	90	8	99	84	8	8	86	0.99	69
8	90	8	99	83	8	9	85	0.98	65
10	89	8	98	80	8	12	83	0.95	61
12	88	8	98	78	8	14	82	0.94	59
15	87	8	97	74	7	19	79	0.91	55

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

Table 3: „UltraClear™“ float glass, 2 - 15 mm

Thickness	Light Transmission	Light Reflection	Colour Rendering Index Ra	Direct Energy Transmission	Energy Reflection	Energy Absorption	Solar Factor (g) EN 410	Shading Coefficient [g / 0.87]	UV transmission
[mm]	[%]	[%]	[%]	[%]	[%]	[%]	[%]		[%]
2	92	8	100	91	8	1	91	1.05	85
3	91	8	100	90	8	1	91	1.04	83
4	91	8	100	90	8	1	90	1.04	81
5	91	8	100	90	8	2	90	1.04	79
6	91	8	100	89	8	3	90	1.03	77
8	91	8	100	89	8	4	89	1.03	74
10	91	8	100	88	8	4	89	1.02	71
12	90	8	99	87	8	5	88	1.01	69
15	90	8	99	86	8	6	87	1.00	66

All GUARDIAN flat glass products correspond to the EN 572-2: 1994 "Glass in Building - Basic Soda Lime Silicate Glass Products - Part 2: Float Glass" and DIN 1249-10: 1990 "Glass in Building: Chemical and Physical Properties" standards.
The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

10.2 Thermal insulating glasses

Table 4: ClimaGuard® – Thermal insulating glass

Product	Glass substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Refelction outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Air Krypton² [W/m²K]	U value (EN 673): Argon [W/m²K]	Heat treatable¹	Bendable¹	Edge deletion¹	Ceramic print on coating¹
Double Glazing 4-16-4, coating on surface #3																	
NRG	ExtraClear	neutral	81	13	13	98	66	19	15	74	0.85	1.5	1.3	HT	HT	Yes	No
PREMIUM	ExtraClear	neutral	80	12	12	97	55	29	16	63	0.72	1.4	1.1	HT	HT	Yes	No
1.0	ExtraClear	neutral	70	20	23	98	45	38	17	53	0.61	1.3	1.0	HT	Yes³	Yes	No
Double Glazing 4-16-4, coating on surface #2																	
EcoSun	ExtraClear	neutral	70	12	13	94	36	43	21	38	0.44	1.3	1.0	No	No	Yes	No
Solar	ExtraClear	neutral	67	27	24	96	41	43	16	42	0.49	1.3	1.0	No	No	Yes	No
Neutral 70	ExtraClear	neutral	70	12	11	96	51	20	29	55	0.63	1.6	1.4	Yes	Yes	No	Yes
Triple Glazing 4-14-4-14-4, coating on surface #2 + #5																	
NRG	ExtraClear	neutral	73	16	16	96	54	22	24	62	0.71	0.6²	0.7	HT	HT	Yes	No
PREMIUM	ExtraClear	neutral	71	15	15	96	42	32	26	49	0.56	0.5²	0.6	HT	HT	Yes	No
1.0	ExtraClear	neutral	55	30	30	96	30	46	24	37	0.42	0.4²	0.6	HT	Yes³	Yes	No

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[2] Krypton
[3] on request

10.3 Solar control glass

Table 5: SunGuard® eXtra Selective

Product	Glass substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Refelction outside [%]	Solar energy: Absorption [%]	g value (EN 410) [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Air Krypton² [W/m²K]	U value (EN 673): Argon [W/m²K]	Heat treatable	Bendable	Edge deletion	Ceramic print on coating
Double Glazing 6-16-4, coating on surface #2																	
SNX 60/28	ExtraClear	neutral	60	12	14	93	26	40	34	28	0.30	1.3	1.0	HT	HT¹	Yes	No
Triple Glazing 6-12-4-12-4, SunGuard SuperNeutral on surface #2 + ClimaGuard® Premium on surface #5																	
SNX 60/28	ExtraClear	neutral	53	14	17	92	22	41	37	26	0.30	0.5²	0.7	HT	HT¹	Yes	No

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[2] Krypton

Table 6: SunGuard® SuperNeutral

Product	Glass substrate	Colour	Visible light				Solar energy			g value (EN 410)	Shad. Coefficient g EN/0.87	U value (EN 673)		Heat treatable	Bendable	Edge deletion	Ceramic print on coating
			Transmission [%]	Reflection outside [%]	Reflection inside [%]	Colour rendering index	Direct transmission [%]	Refelction outside [%]	Absorption [%]	[%]		Air Krypton[2] [W/m²K]	Argon [W/m²K]				
Double Glazing 6-16-4, coating on surface #2																	
SN 70/41	ExtraClear	neutral	70	11	12	97	39	34	27	41	0.47	1.4	1.1	HT	HT[1]	Yes	No
SN 70/37	ExtraClear	neutral	70	11	12	93	35	39	26	37	0.43	1.3	1.0	HT	HT[1]	Yes	No
SN 62/34	ExtraClear	neutral	62	15	17	95	32	37	31	34	0.39	1.3	1.0	HT	HT[1]	Yes	No
SN 51/28	ExtraClear	neutral	51	12	23	93	26	37	37	28	0.32	1.3	1.0	HT	HT[1]	Yes	No
SN 40/23	ExtraClear	neutral blue	40	16	32	92	21	36	43	23	0.26	1.3	1.0	HT	HT[1]	Yes	No
SN 29/18	ExtraClear	neutral blue	29	17	27	90	16	33	51	18	0.21	1.4	1.1	HT	HT[1]	Yes	No
Triple Glazing 6-12-4-12-4, SunGuard SuperNeutral on surface #2 + ClimaGuard® Premium on surface #5																	
SN 70/41	ExtraClear	neutral	62	13	15	95	32	35	33	37	0.43	0.5[2]	0.7	HT	HT[1]	Yes	No
SN 70/37	ExtraClear	neutral	62	13	15	92	29	40	31	34	0.39	0.5[2]	0.7	HT	HT[1]	Yes	No
SN 62/34	ExtraClear	neutral	56	16	19	93	27	38	35	31	0.36	0.5[2]	0.7	HT	HT[1]	Yes	No
SN 51/28	ExtraClear	neutral	45	14	24	91	22	38	40	25	0.29	0.5[2]	0.7	HT	HT[1]	Yes	No
SN 40/23	ExtraClear	neutral blue	36	16	31	90	18	37	45	21	0.24	0.5[2]	0.7	HT	HT[1]	Yes	No
SN 29/18	ExtraClear	neutral blue	26	18	27	88	13	33	54	16	0.18	0.5[2]	0.7	HT	HT[1]	Yes	No

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[2] Krypton

Table 7: SunGuard® High Performance

Product	Glass substrate	Colour	Visible light				Solar energy			Solar factor (g) EN 410	Shad. Coefficient g EN/0.87	U value (EN 673)		Heat treatable	Bendable	Edge deletion	ceramic print on coating
			Transmission [%]	Reflection outside [%]	Reflection inside [%]	Colour rendering index	Direct transmission [%]	Refelction outside [%]	Absorption [%]	[%]		Air Krypton[2] [W/m²K]	Argon [W/m²K]				
Double Glazing 6-16-4, coating on surface #2																	
HP Light Blue 62/52	ExtraClear	blue neutral	62	16	11	96	48	17	35	52	0.60	1.7	1.5	Yes	Yes	No[1]	Yes[1]
HP Neutral 60/40[4]	ExtraClear	neutral	60	25	20	96	38	35	27	40	0.46	1.4	1.1	Yes	Yes	No[1]	Yes[1]
HP Neutral 52/41	ExtraClear	neutral blue	52	18	10	94	38	21	41	41	0.47	1.6	1.4	Yes	Yes	No[1]	Yes[1]
HP Neutral 50/32	ExtraClear	neutral	50	23	22	95	29	37	34	32	0.37	1.4	1.1	Yes	Yes	No[1]	Yes[1]
HP Silver 43/31	ExtraClear	silver	43	32	13	96	29	36	35	31	0.36	1.4	1.2	Yes	Yes	No[1]	Yes[1]
HP Neutral 41/33	ExtraClear	neutral	41	22	12	92	29	24	47	33	0.38	1.6	1.4	Yes	Yes	No[1]	Yes[1]
HP Royal Blue 41/29	ExtraClear	deep blue	41	26	32	94	26	27	47	29	0.33	1.4	1.1	Yes	Yes	No[1]	Yes[1]
HP Amber 41/29	ExtraClear	light bronze	41	25	17	87	27	36	37	29	0.33	1.4	1.1	Yes	Yes	No[1]	Yes[1]
HP Bright Green 40/29	ExtraClear	bright green	40	37	24	96	26	24	50	29	0.33	1.4	1.1	Yes	Yes	No[1]	Yes[1]
HP Bronze 40/27	ExtraClear	dark bronze	40	15	26	90	24	27	49	27	0.31	1.4	1.1	Yes	Yes	No[1]	Yes[1]
HP Silver 35/26	ExtraClear	silver	35	44	23	98	24	43	33	26	0.30	1.4	1.2	Yes	Yes	No[1]	Yes[1]

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[4] Values after heat treatment (Tempered glass, heat strengthened glass, bending)

Table 7: SunGuard® High Performance

Continued

Product	Glass substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Refelction outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Air Krypton[2] [W/m²K]	U value (EN 673): Argon [W/m²K]	Heat treatable	Bendable	Edge deletion	ceramic print on coating
Triple Glazing 6-12-4-12-4, coating on surface #2 + ClimaGuard® Premium on surface #5																	
HP Light Blue 62/52	ExtraClear	blue neutral	55	17	15	94	34	45	30	41	0.47	0.6[2]	0.8	Yes	Yes	No[1]	Yes[1]
HP Neutral 60/40[4]	ExtraClear	neutral	53	26	21	92	30	37	33	36	0.41	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Neutral 52/41	ExtraClear	neutral blue	46	19	14	92	28	23	49	34	0.39	0.6[2]	0.8	Yes	Yes	No[1]	Yes[1]
HP Neutral 50/32	ExtraClear	neutral	44	24	23	93	24	38	38	28	0.32	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Silver 43/31	ExtraClear	silver	38	33	18	94	22	38	40	27	0.31	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Neutral 41/33	ExtraClear	neutral	36	23	15	90	22	26	52	27	0.31	0.6[2]	0.8	Yes	Yes	No[1]	Yes[1]
HP Royal Blue 41/29	ExtraClear	deep blue	36	27	31	92	21	28	51	26	0.30	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Amber 41/29	ExtraClear	light bronze	36	26	19	86	21	37	42	27	0.31	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Bright Green 40/29	ExtraClear	bright green	36	38	25	94	20	25	55	25	0.29	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Bronze 40/27	ExtraClear	dark bronze	36	16	26	88	19	27	54	24	0.28	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]
HP Silver 35/26	ExtraClear	silver	31	44	24	96	18	44	37	23	0.26	0.5[2]	0.7	Yes	Yes	No[1]	Yes[1]

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values according to EN 410 ; U-values according to EN 673.
All information regarding further processing is for general information only. For further information please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[2] Krypton 90 %
[4] Values after heat treatment (Tempered glass, heat strengthened glass, bending)

Table 8: SunGuard® Solar

Product	Glass substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Refelction outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Air [W/m²K]	U value (EN 673): Argon [W/m²K]	Heat treatable	Bendable	Edge deletion	ceramic print on coating
Double glazing 6-16-4, SunGuard® Solar on surface #2																	
Solar Neutral 67	ExtraClear	neutral	61	20	21	98	54	16	30	59	0.68	2.7	2.6	Yes	Yes	No	Yes[1]
Solar Neutral 60	ExtraClear	neutral	56	26	18	97	48	19	33	53	0.61	2.6	2.5	Yes	Yes	No	Yes[1]
Solar Light Blue 52	ExtraClear	neutral blue	47	15	17	94	38	13	49	44	0.51	2.6	2.4	Yes	Yes	No	Yes[1]
Solar Silver Grey 32	ExtraClear	light grey	30	23	21	90	23	20	57	29	0.33	2.4	2.2	Yes	Yes	No	Yes[1]
Solar Royal Blue 20	ExtraClear	deep blue	20	18	36	96	17	18	65	23	0.26	2.2	2.0	Yes	Yes	No	Yes[1]
Solar Silver 20	ExtraClear	silver	20	35	25	88	15	33	52	20	0.23	2.2	2.1	Yes	Yes	No	Yes[1]
Solar Bright Green 20	ExtraClear	bright green	19	35	16	97	14	19	67	22	0.22	2.1	1.9	Yes	Yes	No	Yes[1]
Solar Bronze 20	ExtraClear	bronze	20	18	15	94	14	20	66	22	0.22	2.1	1.9	Yes	Yes	No	Yes[1]
Solar Gold 20	ExtraClear	gold	21	24	15	93	16	18	66	22	0.26	2.1	1.9	Yes	Yes	No	Yes[1]
Silver 08	ExtraClear	silver	8	43	34	99	7	35	58	12	0.14	2.0	1.8	Yes	Yes	No	Yes[1]

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values according to EN 410 ; U-values according to EN 673.
All information regarding further processing is for general information only. For further information please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN

Table 8: SunGuard® Solar

Continued

Product	Glass substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Refelction outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Air [W/m²K]	U value (EN 673): Argon [W/m²K]	Heat treatable	Bendable	Edge deletion	ceramic print on coating
Double Glazing 6-16-4, SunGuard® Solar coating on surface #2, ClimaGuard® Premium on surface #3																	
Solar Neutral 67	ExtraClear	neutral	59	19	17	97	40	23	37	47	0.54	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Neutral 60	ExtraClear	neutral	54	24	15	96	36	24	40	42	0.49	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Light Blue 52	ExtraClear	neutral blue	46	14	14	94	29	15	56	36	0.41	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Silver Grey 32	ExtraClear	light grey	29	22	18	90	18	21	61	23	0.26	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Royal Blue 20	ExtraClear	deep blue	19	18	31	95	13	19	68	18	0.21	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Silver 20	ExtraClear	silver	19	34	21	88	12	33	55	17	0.20	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Bright Green 20	ExtraClear	bright green	19	35	14	97	10	20	70	16	0.15	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Bronze 20	ExtraClear	bronze	19	18	13	94	11	21	69	16	0.15	1.4	1.1	Yes	Yes	No	Yes[1]
Solar Gold 20	ExtraClear	gold	20	24	12	93	13	18	69	18	0.21	1.4	1.1	Yes	Yes	No	Yes[1]
Silver 08	ExtraClear	silver	8	43	29	98	6	35	59	9	0.10	1.4	1.1	Yes	Yes	No	Yes[1]

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN

Table 8: SunGuard® Solar

Continued

Product	Glass substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Refelction outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Air [W/m²K]	U value (EN 673): Argon [W/m²K]	Heat treatable	Bendable	Edge deletion	ceramic print on coating
Double Glazing 6-16-4, SunGuard® Solar coating on surface #2, ClimaGuard® 1.0 on surface #3																	
Solar Neutral 67	ExtraClear	neutral	52	24	28	98	33	28	41	40	0.46	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Neutral 60	ExtraClear	neutral	47	28	25	97	30	28	42	36	0.41	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Light Blue 52	ExtraClear	neutral blue	40	17	25	94	25	18	57	31	0.36	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Silver Grey 32	ExtraClear	light grey	25	23	28	91	16	22	62	20	0.23	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Royal Blue 20	ExtraClear	deep blue	17	19	39	96	11	20	69	16	0.18	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Silver 20	ExtraClear	silver	17	35	31	89	11	34	55	15	0.17	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Bright Green 20	ExtraClear	bright green	16	36	25	98	9	20	71	15	0.14	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Bronze 20	ExtraClear	bronze	17	19	24	95	9	21	70	15	0.14	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Gold 20	ExtraClear	gold	18	24	19	90	10	19	70	16	0.18	1.3	1.0	Yes	Yes	No	Yes[1]
Solar Silver 08	ExtraClear	silver	7	43	37	99	5	35	60	8	0.09	1.3	1.0	Yes	Yes	No	Yes[1]

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN

Table 9: SunGuard® Solar Laminated Glass

Product	Glass Substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering Index	Solar energy: Direct transmission [%]	Solar energy: Reflection outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient g EN/0.87	Heat treatable / Bendable	Edge deletion	ceramic print on coating	General approval[2]
Laminated Glass 88.4, coating on surface #2															
SOLAR NEUTRAL 67	ExtraClear	neutral	69	12	10	97	53	10	37	62	0.71	Yes	No	Yes[1]	Yes
SOLAR NEUTRAL 60	ExtraClear	neutral	63	16	8	96	48	12	40	57	0.65	Yes	No	Yes[1]	Yes
SOLAR LIGHT BLUE 52	ExtraClear	neutral blue	52	14	8	95	38	12	50	49	0.57	Yes	No	Yes[1]	Yes
SOLAR SILVER GREY 32	ExtraClear	light grey	32	24	14	93	23	21	56	36	0.41	Yes	No	Yes[1]	No
SOLAR ROYAL BLUE 20	ExtraClear	deep blue	22	24	28	98	16	21	63	31	0.35	Yes	No	Yes[1]	No
SOLAR SILVER 20	ExtraClear	silver	19	32	25	92	14	29	57	27	0.31	Yes	No	Yes[1]	No

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[2] DIBt regulated product in Germany

Table 10: SunGuard® for Radar reflection damping

Product	Glass Substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering Index	Solar energy: Direct transmission [%]	Solar energy: Reflection outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient g EN/0.87	U value (EN 673) Argon 90 % [W/m²K]	Heat treatable / Bendable	Edge deletion	ceramic print on coating	General approval[2]
Double Glazing 88.2-16-6, SunGuard® laminated glass on surface #2, ClimaGuard® Premium on surface #5																
RD 60	ExtraClear	neutral	56	18	12	94	33	18	49	39	0.45	1.1	Yes	No	Yes[1]	Yes
RD 55	ExtraClear	neutral blue	53	15	13	94	32	16	52	38	0.44	1.1	Yes	No	Yes[1]	Yes
RD 50	ExtraClear	neutral blue	46	15	12	92	27	15	58	33	0.37	1.1	Yes	No	Yes[1]	Yes

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN
[2] DIBt regulated product in Germany

Table 11: SunGuard® High Durable – monolithic deployable solar control glass

Product	Glass Substrate	Colour	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering Index	Solar energy: Direct transmission [%]	Solar energy: Reflection outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient g EN/0.87	Heat treatable / Bendable	Edge deletion	ceramic print on coating
Single Glazing 6 mm. coating on surface #2														
HD Silver 70	ExtraClear	bright silver	70	27	28	96	71	21	8	72	0.83	Yes	No	Yes[1]
HD Neutral 67	ExtraClear	neutral	66	16	18	99	63	13	24	69	0.79	Yes	No	Yes[1]
HD Light Blue 52	ExtraClear	neutral blue	51	16	15	98	47	13	40	56	0.65	Yes	No	Yes[1]
HD Silver Grey 32	ExtraClear	light grey	33	21	19	94	30	17	53	41	0.47	Yes	No	Yes[1]
HD Silver 20	ExtraClear	silver	20	33	25	92	17	28	55	28	0.33	Yes	No	Yes[1]
HD Royal Blue 20	ExtraClear	deep blue	23	20	29	97	19	20	61	31	0.35	Yes	No	Yes[1]

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.

All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

[1] Consult GUARDIAN processing directives or contact GUARDIAN

[2] DIBt regulated product in Germany

Table 12: SunGuard® Dry

Product	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Reflection outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient g EN/0.87	U value (EN 673): Air [W/m²K]	U value (EN 673): Argon [W/m²K]
Double Glazing 6-16-4. SunGuard® Dry on surface #1, SunGuard® SuperNeutral or HP on surface #2											
SNX 60/28	58	14	15	93	25	36	39	27	0.32	1.3	1.0
SN 70/41	68	12	13	96	37	30	33	40	0.46	1.4	1.1
SN 70/37	68	14	15	94	35	32	33	37	0.43	1.3	1.0
SN 62/34	61	16	18	95	31	34	35	33	0.38	1.3	1.0
SN 51/28	49	14	23	92	25	33	42	27	0.31	1.3	1.0
SN 40/23	39	17	32	91	20	32	48	23	0.26	1.3	1.0
SN 29/18	28	18	27	90	15	30	55	18	0,20	1.4	1.1
HP Neutral 60/40	59	25	21	94	36	32	32	39	0.45	1.4	1.1
HP Neutral 50/32	49	24	22	95	28	34	38	31	0.36	1.4	1.1
HP Silver 43/31	42	32	16	95	28	34	38	31	0.36	1.4	1.2
HP Royal Blue 41/29	40	27	33	94	25	26	49	28	0.32	1.4	1.1
HP Bright Green 40/29	39	38	24	96	25	24	51	28	0.32	1.4	1.1
HP Bronze 40/27	39	16	24	90	23	24	53	26	0.30	1.4	1.1
HP Silver 35/26	34	44	24	98	23	40	37	26	0.30	1.4	1.2

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.

All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

Table 12: SunGuard® Dry

Continued

Product	Visible light: Transmission [%]	Visible light: Reflection outside [%]	Visible light: Reflection inside [%]	Visible light: Colour rendering index	Solar energy: Direct transmission [%]	Solar energy: Reflection outside [%]	Solar energy: Absorption [%]	Solar factor (g) EN 410 [%]	Shad. Coefficient gEN/0.87	U value (EN 673): Krypton [W/m²K]	U value (EN 673): Argon [W/m²K]
Triple Glazing 6-12-4-12-4. SunGuard® Dry on surface #1, SunGuard® SuperNeutral or HP on surface #2, ClimaGuard® Premium on surface #5											
SNX 60/28	52	15	18	91	22	37	39	25	0.29	0.5	0.7
SN 70/41	60	15	16	94	31	32	37	36	0.41	0.5	0.7
SN 70/37	60	16	17	93	29	33	38	34	0.39	0.5	0.7
SN 62/34	54	18	20	93	26	35	39	30	0.34	0.5	0.7
SN 51/28	44	15	24	91	21	34	45	25	0.29	0.5	0.7
SN 40/23	35	18	31	90	17	33	50	21	0.24	0.5	0.7
SN 29/18	25	17	27	88	13	30	57	16	0,18	0.5	0.7
HP Neutral 60/40	52	27	22	92	29	34	37	34	0.39	0.5	0.7
HP Neutral 50/32	43	25	23	93	23	35	42	28	0.32	0.5	0.7
HP Silver 43/31	37	33	18	94	21	35	44	26	0.30	0.5	0.7
HP Royal Blue 41/29	35	28	31	93	20	27	53	25	0.29	0.5	0.7
HP Bright Green 40/29	35	38	25	94	20	25	55	24	0.28	0.5	0.7
HP Bronze 40/27	34	17	26	89	19	25	56	23	0.26	0.5	0.7
HP Silver 35/26	30	44	24	96	18	41	41	22	0.25	0.5	0.7

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.

All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

Table 13: ClimaGuard® Dry

Product	Visible light: Transmission [%]	Visible light: Reflection [%]	Solar factor (g) EN410 [%]	U value (EN 673): Argon [W/m²K]
Double Glazing 4-16Ar-4				
ClimaGuard Premium (on surface #3)	78	13	60	1.1
ClimaGuard 1.0 (on surface #3)	68	24	51	1.0
ClimaGuard Premium T2 (on surface #2)	78	15	56	1.1
Triple Glazing 4-12Ar-4-12Ar-4				
ClimaGuard Premium T2 (on surface #2) ClimaGuard Premium (on surface #5)	69	18	48	0.7
ClimaGuard Premium T2 (on surface #3) ClimaGuard Premium (on surface #5)	69	17	51	0.7
ClimaGuard nrG T (on surface #2) ClimaGuard nrG (on surface #5)	71	18	59	0.8
ClimaGuard nrG T (on surface #3) ClimaGuard nrG (on surface #5)	71	18	61	0.8

The performance values shown are nominal and subject to variations due to manufacturing tolerance. Spectra-photometric values conform to EN 410 ; U-values conform to EN 673.
All details relating to further processing is provided for general information purposes only. For further information, please consult GUARDIAN processing directives for coated glass or contact GUARDIAN's technical department.

10.4 Parapets

Table 14: Recommended enamel combinations for SunGuard® spandrels

SunGuard® Insulating Glass	Ceramic Frit - Monolithic Glass	Ceramic Frit - Insulating Glass
SunGuard® eXtra Selective		
SNX 60/28	SSG 52 on #2 + Ferro System 140 11 4060	SNX 60/28 on #2 + Frit on #4
SunGuard® SuperNeutral		
SN 70/41	SSG 52 on #2 + Ferro System140 15 4001 on #2	SG SN 70/41 on #2 + Frit on #4
SN 70/37	SSG 52 on #2 + Ferro System140 15 4001 on #2	SG SN 70/37 on #2 + Frit on #4
SN 62/34	SSG 52 on #2 + Ferro System140 15 4001 on #2	SG SN 62/34 on #2 + Frit on #4
SN 51/28	SG Solar Royal Blue 20 on #2 + Ferro System 140 15 4001 on #2 SSG 52 on #2 + Ferro System 140 12 4061	SG SN 51/28 on #2 + Frit on #4
SN 40/23	SG Solar Royal Blue 20 on #2 + Ferro System 140 15 4001 on #2	SG SN 40/23 on #2 + Frit on #4
SN 29/18	SG Solar Royal Blue 20 on #2 + Ferro System 140 15 4001 on #2	SG SN 29/18 on #2 + Frit on #4
SunGuard® Solar		
Solar Neutral 67	SSG 52 on #2 + Ferro System140 12 4061 on #2	SG Solar Neutral 67 on #2 + Frit on #4
Solar Light Blue 52	SSG 52 on #2 + Ferro System140 12 4061 on #2	SG Solar Light Blue 52 on #2 + Frit on #4
Solar Silver Grey 32	SG Solar Silver Grey 32 on #2 + Ferro System 140 15 4001 on #2	SG Solar Silver Grey 32 on #2 + Frit on #4
Solar Royal Blue 20	SG Solar Royal Blue 20 on #2 + Ferro System 140 12 4060 on #2	SG Solar Royal Blue 20 on #2 + Frit on #4
Solar Silver 20	SG Solar Silver 20 on #2 + Ferro System 140 15 4001 on #2	SG Solar Silver 20 on #2 + Frit on #4
Solar Bright Green 20	SG Solar Bright Green 20 on #2 + Ferro System 140 15 4001 on #2	SG Solar Bright Green 20 on #2 + Frit on #4
Solar Bronze 20	SG Solar Bronze 20 on #2 + Ferro System 140 15 4001 on #2	SG Solar Bronze 20 on #2 + Frit on #4
Solar Gold 20	-	SG Solar Gold 20 on #2 + Frit on #4
Solar Silver 08	SG Solar Silver 08 on #2 + Ferro System 140 15 4001 on #2	SG Solar Silver 08 on #2 + Frit on #4

Table 14: Recommended enamel combinations for SunGuard® spandrels
Continued

SunGuard® Insulating Glass	Ceramic Frit - Monolithic Glass	Ceramic Frit - Insulating Glass
SunGuard® High Performance		
HP Light Blue 62/52	-	SG HP Light Blue 62/52 on #2 + Frit on #4
HP Neutral 60/40	SG Solar Silver Grey 32 on #2 + Ferro System140 15 4001 on #2	SG HP Neutral 60/40 on #2 + Frit on #4
HP Neutral 52/41	SSG 52 on #2 + Ferro System140 12 4061 on #2	SG HP Neutral 52/41 on #2 + Frit on #4
HP Neutral 50/32	SG Solar Silver Grey 32 on #2 + Ferro System140 15 4001 on #2	SG HP Neutral 50/32 on #2 + Frit on #4
HP Silver 43/31	-	SG HP Silver 43/31 on #2 + Frit on #4
HP Neutral 41/33	SG Solar Silver Grey 32 on #2 + Ferro System140 15 4001 on #2	SG HP Neutral 41/33 on #2 + Frit on #4
HP Royal Blue 41/29	SG Solar Royal Blue 20 on #2 + Ferro System140 12 4060 on #2	SG HP Royal Blue 41/29 on #2 + Frit on #4
HP Amber 41/29	-	SG HP Amber 41/29 on #2 + Frit on #4
HP Bright Green 40/29	SG Solar Green 07 on #2 + Ferro System140 15 4001 on #2 SG Solar Bright Green 20 on #2 + Ferro System140 15 4001 on #2	SG HP Bright Green 40/29 on #2 + Frit on #4
HP Bronze 40/27	Farbglas Bronze + Ferro System140 15 4001 on #2 SG Solar Bronze 20 on #2 + Ferro System 140 15 4001 on #2	SG HP Bronze 40/27 on #2 + Frit on #4
HP Silver 35/26	SG Solar Silver 08 on #2 + Ferro System140 15 4001 on #2	SG HP Silver 35/26 on #2 + Frit on #4

Increased energy absorption in IGU spandrels may result in both lites requiring heat treatment. The air gap should be limited, where possible, to 8 mm. It must be ensured that SunGuard® spandrels are not exposed to any aggressive media before, during and after installation.

10.5 Sound protection glass

Table 15: GUARDIAN LamiGlass® Sound Control

Type	Design	Interlayer	Thickness [mm]	R_w [dB]	C [dB]	C_{tr} [dB]	U_g value EN 673 [W/m²K]	Safety level: Ball drop EN 356	Safety level: Pendulum impact EN 12600
Single Glazing									
SR 33.1	3/0.50/3	SR	6	36	-1	-4	5.7	-	1(B)1
SR 33.2	3/0.76/3	SR	7	36	-1	-4	5.7	P2A	1(B)1
SC 44.2	4/0.76/4	SC	9	37	-1	-3	5.7	P1A	1(B)1
SR 44.1	4/0.50/4	SR	8	38	-1	-4	5.7	P1A	1(B)1
SR 44.2	4/0.76/4	SR	9	38	-1	-4	5.7	P2A	1(B)1
SR 44.4	4/1.52/4	SR	10	38	-1	-4	5.7	P4A	1(B)1
SR 55.1	5/0.50/5	SR	10	39	-1	-4	5.6	P1A	1(B)1
SR 55.2	5/0.76/5	SR	11	39	-1	-3	5.6	P2A	1(B)1
SR 66.1	6/0.50/6	SR	12	39	-1	-3	5.6	P1A	1(B)1
SR 66.2	6/0.76/6	SR	13	39	0	-3	5.6	P2A	1(B)1
SR 88.2	8/0.76/8	SR	17	41	-1	-3	5.4	P2A	1(B)1
SR 1010.2	10/0.76/10	SR	21	43	-1	-3	5.2	P2A	1(B)1

Table 15: GUARDIAN LamiGlass® Sound Control

Continued

Type	Design	Interlayer	Thickness [mm]	R_w [dB]	C [dB]	C_{tr} [dB]	U_g value EN 673 [W/m²K]	Safety level: Ball drop EN 356	Safety level: Pendulum impact EN 12600
Double Glazing[1]									
25/36	44.2/12/4	PVB	25	36	-2	-5	1.3 (Ar)	P2A	1(B)1
27/37	33.4/16 /4	PVB	27	37	-2	-6	1.1 (Ar)	P4A	1(B)1
32/39	44.4/16/6	PVB	32	39	-2	-6	1.1 (Ar)	P4A	1(B)1
29/39	44.2/16/4	SC	29	39	-1	-5	1.1 (Ar)	P1A	1(B)1
31/41	44.2/16/6	SC	31	41	-2	-6	1.1 (Ar)	P1A	1(B)1
33/41	44.2/18/6	SC	33	41	-2	-7	1.1 (Ar)	P1A	1(B)1
31/42	44.2/16/6	SR	31	42	-2	-6	1.1 (Ar)	P2A	1(B)1
30/42	44.1/16/6	SR	30	42	-2	-6	1.1 (Ar)	P1A	1(B)1
35/42a	44.2/16/8	SR	35	42	-3	-7	1.1 (Ar)	P1A	1(B)1
35/42b	55.2/16/8	SC	35	42	-2	-6	1.1 (Ar)	P1A	1(B)1
33/42	44.2/16/8	SC	33	42	-2	-7	1.1 (Ar)	P1A	1(B)1
29/43	44.1/14/6	SR	29	43	-3	-8	1.1 (Kr)	P1A	1(B)1
34/43	44.1/20/6	SR	34	43	-2	-7	1.1 (Ar)	P1A	1(B)1
37/43a	55.2/18/8	SC	37	43	-2	-6	1.1 (Ar)	P1A	1(B)1
37/43b	55.2/18/8	SR	37	43	-1	-6	1.1 (Ar)	P2A	1(B)1
37/43c	66.2/16/8	SC	37	43	-2	-6	1.1 (Ar)	P1A	1(B)1
37/43d	66.3/16/8	SC	37	43	-2	-6	1.1 (Ar)	P1A	1(B)1
34/44	44.1/16/10	SR	34	44	-2	-6	1.1 (Ar)	P1A	1(B)1
35/44b	44.2/16/10	SC	35	44	-2	-6	1.1 (Ar)	P1A	1(B)1
36/44	44.1/20/8	SR	36	44	-3	-7	1.1 (Ar)	P1A	1(B)1

Table 15: GUARDIAN LamiGlass® Sound Control
Continued

Type	Design	Interlayer	Thickness	R_w	C	C_{tr}	U_g value	Safety level	
							EN 673	Ball drop EN 356	Pendulum impact EN 12600
			[mm]	[dB]	[dB]	[dB]	[W/m²K]		
36/45	44.1/18/10	SR	36	45	-2	-6	1.1 (Ar)	P1A	1(B)1
36/46	44.4/16/55.2	PVB/SC	36	46	-3	-8	1.1 (Ar)	P1A	1(B)1
39/45a	44.2/20/10	SC	39	45	-2	-6	1.1 (Ar)	P1A	1(B)1
39/45b	66.3/16/10	SC	39	45	-1	-4	1.1 (Ar)	P1A	1(B)1
37/45	55.2/16/10	SC	37	45	-2	-7	1.1 (Ar)	P1A	1(B)1
34/46	55.1/16/44.1	SR/SR	34	46	-2	-7	1.1 (Ar)	P1A	1(B)1
43/46	66.2/20/10	SR	43	46	-2	-6	1.1 (Ar)	P2A	1(B)1
38/47	44.2/16 /66.2	SC / SC	38	47	-2	-6	1.1 (Ar)	P1A	1(B)1
38/48	44.2/16/66.3	SC /SC	38	48	-3	-8	1.1 (Ar)	P1A	1(B)1
46/49	88.2/20/44.2	SC/SC	46	49	-1	-5	1.4 (Air)	P1A	1(B)1
41/49	44.2/20/66.2	SC/SC	41	49	-2	-7	1.1 (Ar)	P1A	1(B)1
38/49	44.3/16/ 66.3	SC/SC	38	49	-3	-7	1.1 (Ar)	P1A	1(B)1
44/49	66.2/20/55.2	SR	44	49	-2	-6	1.1 (Ar)	P2A	1(B)1
42/50	44.3 /20 / 66.3	SC / SC	42	50	-2	-7	1.1 (Ar)	P1A	1(B)1
46/50	88.2/20 /44.2	SC / SC	46	50	-1	-6	1.1 (Ar)	P1A	1(B)1
46/51	88.2/16/66.2	SC /SC	46	51	-1	-5	1.1 (Ar)	P1A	1(B)1
48/51	88.4/20/55.2	SR	48	51	-2	-6	1.1 (Ar)	P4A	1(B)1
52/52	88.2/24/46.2	SR	52	52	-2	-6	1.1 (Ar)	P2A	1(B)1

Table 15: GUARDIAN LamiGlass® Sound Control
Continued

Type	Design	Interlayer	Thickness	R_w	C	C_{tr}	U_g value	Safety level	
							EN 673	Ball drop EN 356	Pendulum impact EN 12600
			[mm]	[dB]	[dB]	[dB]	[W/m²K]		
Triple Glazing[1]									
48/37	6 /14/ 44.1/14 /6	SR	48	37	-2	-5	0.6 (Ar)	P1A	1(B)1
45/42	44.2 /12/4/12/8	SC	45	42	-2	-6	0.7 (Ar)	P1A	1(B)1
53/42	44.2/18/4/16/6	PVB	53	42	-1	-5	0.5 (Ar)	P2A	1(B)1
55/42	44.2/18/4/16/44.1	PVB	55	42	-2	-5	0.5 (Ar)	P2A	1(B)1
46/43	44.2/12/5/12/8	SC	46	43	-3	-7	0.7 (Ar)	P1A	1(B)1
47/43	44.1/14/4/14/6	SR	47	43	-1	-7	0.6 (Ar)	P1A	1(B)1
47/44	44.1/12/6 /12/ 8	SR	47	44	-2	-7	0.7 (Ar)	P1A	1(B)1
48/46	44.1/12/6/12/10	SR	48	46	-2	-7	0.7 (Ar)	P1A	1(B)1
48/47	44.1 /12/6/12/10	SR	48	47	-2	-7	0.5 (Kr)	P1A	1(B)1

(PVB) Polyvinyl-Butyral film
(SR) Acoustic PVB film
(SC) Sound control PVB film

(Ar) Argon filling
(Kr) Krypton filling
RWP value per EN ISO 140-3 and 717

[1] With ClimaGuard® Premium – coating on #3 (Triple Glazing: #2+5). GUARDIAN LamiGlass® Sound Control can be combined with all GUARDIAN insulated coatings.

The displayed function values are nominal values. Individual values might deviate due to production and manufacturing tolerances.
The specifications for lighting, solar energy and thermal properties were determined and in accordance with European standards EN 673 and EN 410.
Numerous other tests and glass available.

10.6 Safety glass

Table 16: Safety barrier glass to EN 12 600 – pendulum impact

Type	Design	Safety level EN 12600
LamiGlass 22.1	Float glass 2+2; 0.38 mm PVB	2(B)2
LamiGlass 32.1[1]	Float glass 3+2; 0.38 mm PVB	2(B)2
LamiGlass 33.1	Float glass 3+3; 0.38 mm PVB	2(B)2
LamiGlass 33.2	Float glass 3+3; 0.76 mm PVB	1(B)1
LamiGlass 33.4	Float glass 3+3; 1.52 mm PVB	1(B)1
LamiGlass 43.1[1]	Float glass 4+3; 0.38 mm PVB	2(B)2
LamiGlass 43.2[1]	Float glass 4+3; 0.76 mm PVB	1(B)1
LamiGlass 44.1	Float glass 4+4; 0.38 mm PVB	2(B)2
LamiGlass 44.2	Float glass 4+4; 0.76 mm PVB	1(B)1
LamiGlass 44.4	Float glass 4+4; 1.52 mm PVB	1(B)1
LamiGlass 44.6	Float glass 4+4; 2.28 mm PVB	1(B)1
LamiGlass 55.1	Float glass 5+5; 0.38 mm PVB	2(B)2
LamiGlass 55.2	Float glass 5+5; 0.76 mm PVB	1(B)1
LamiGlass 55.4	Float glass 5+5; 1.52 mm PVB	1(B)1
LamiGlass 66.1	Float glass 6+6; 0.38 mm PVB	2(B)2
LamiGlass 66.2	Float glass 6+6; 0.76 mm PVB	1(B)1
LamiGlass 64.2[1]	Float glass 6+4; 0.76 mm PVB	1(B)1
LamiGlass 66.4	Float glass 6+6; 1.52 mm PVB	1(B)1
LamiGlass 88.1	Float glass 8+8; 0.38 mm PVB	1(B)1
LamiGlass 88.2	Float glass 8+8; 0.76 mm PVB	1(B)1
LamiGlass 88.4	Float glass 8+8; 1.52 mm PVB	1(B)1
LamiGlass Sound Control 44.2 SC	Float glass 4+4; 0.76 mm PVB-SC	1(B)1
LamiGlass Sound Control 33.1 SR	Float glass 3+3; 0.50 mm PVB-SR	1(B)1
LamiGlass Sound Control 33.2 SR	Float glass 3+3; 0.76 mm PVB-SR	1(B)1
LamiGlass Sound Control 44.1 SR	Float glass 4+4; 0.50 mm PVB-SR	1(B)1
LamiGlass Sound Control 44.2 SR	Float glass 4+4; 0.76 mm PVB-SR	1(B)1
LamiGlass Sound Control 44.4 SR	Float glass 4+4; 1.52 mm PVB-SR	1(B)1
LamiGlass Sound Control 44.6 SR	Float glass 4+4; 2.28 mm PVB-SR	1(B)1
LamiGlass Sound Control 55.1 SR	Float glass 5+5; 0.50 mm PVB-SR	1(B)1
LamiGlass Sound Control 55.2 SR	Float glass 5+5; 0.76 mm PVB-SR	1(B)1
LamiGlass Sound Control 66.1 SR	Float glass 6+6; 0.50 mm PVB-SR	1(B)1
LamiGlass Sound Control 66.2 SR	Float glass 6+6; 0.76 mm PVB-SR	1(B)1
LamiGlass Sound Control 66.4 SR	Float glass 6+6; 1.52 mm PVB-SR	1(B)1
LamiGlass Sound Control 88.2 SR	Float glass 8+8; 0.76 mm PVB-SR	1(B)1
LamiGlass Sound Control 88.4 SR	Float glass 8+8; 1.52 mm PVB-SR	1(B)1

GUARDIAN audited designs (As of 07/2012). Products delivered by GUARDIAN are compliant with the building regulations A, part 1, n°11.14 (Edition 2012/1).
[1] asymmetrical designs are examined on both sides.

Table 17: Resistance to manual attack acc. to EN 356

Type	Design	Safety level EN 356
LamiGlass 33.2	Float glass 3+3; 0.76 mm PVB	P2A
LamiGlass 33.4	Float glass 3+3; 1.52 mm PVB	P4A
LamiGlass 44.2	Float glass 4+4; 0.76 mm PVB	P2A
LamiGlass 44.3	Float glass 4+4; 1.14 mm PVB	P3A
LamiGlass 44.4	Float glass 4+4; 1.52 mm PVB	P4A
LamiGlass 44.6	Float glass 4+4; 2.28 mm PVB	P5A
LamiGlass 55.6	Float glass 5+5; 2.28 mm PVB	P5A
LamiGlass 66.6	Float glass 6+6; 2.28 mm PVB	P5A
LamiGlass Sound Control 44.2 SC	Float glass 4+4; 0.76 mm PVB-SR	P1A
LamiGlass Sound Control 33.2 SR	Float glass 3+3; 0.76 mm PVB-SR	P2A
LamiGlass Sound Control 44.1 SR	Float glass 4+4; 0.50 mm PVB-SR	P1A
LamiGlass Sound Control 44.2 SR	Float glass 4+4; 0.76 mm PVB-SR	P2A
LamiGlass Sound Control 44.4 SR	Float glass 4+4; 1.52 mm PVB-SR	P4A
LamiGlass Sound Control 44.6 SR	Float glass 4+4; 2.28 mm PVB-SR	P5A
LamiGlass Sound Control 66.2 SR	Float glass 6+6; 0.76 mm PVB-SR	P2A
LamiGlass Sound Control 66.4 SR	Float glass 6+6; 1.52 mm PVB-SR	P4A

GUARDIAN audited designs (As of 07/2012).

Table 18: Ball resistant glazing – according to DIN 18032-3

Type	Design	Safety level EN 356
LamiGlass 44.2	Float glass 4+4; 0.76 mm PVB	ball resistant

GUARDIAN audited designs (As of 07/2012).

Department of Health Offices, Bilbao
SunGuard® HP Neutral 41/33
Juan Coll-Barreu architect

Burj Khalifa, Dubai
SunGuard® Solar Silver 20
Skidmore, Owings & Merrill LLP architects

Various elements are summarised in this chapter, ranging from searching for particular service offers to finding special technical terms or abbreviations . We do not claim completeness, but merely wish to provide an insight into the different options and conditions available.

11.1 Service offer

GUARDIAN supplements its high-quality products, practical glass solutions and functional distribution with a wide range of services. Highly qualified and motivated GUARDIAN employees are available to answer your questions and assist you the different categories. GUARDIAN is just as focused on rapid response times and providing support in the areas of marketing, technology, construction and logistics.

11.1.1 Electronic support for actual use in the field

GUARDIAN's home page makes it easy to find what you need:

11.1.1.1 Production comparison tool

This is an internet application that, based on various criteria, can locate specific products from our broad range of products, or use it to compare various products. The customer defines parameters such as appearance and/or value specifications, and the software finds and displays the products that fall within these parameters online and within seconds.

→ www.sunguardglass.com

11.1.1.2 GUARDIAN Configurator

The downloadable configurator tool can calculate light and energy values for any type of glass, or a combination of different types and thicknesses for double and triple-glazed units.

Calculation results describe the photometric, energy and thermal characteristics of glazing in accordance with the EN 410 and EN 673 European norms. The results are generated as pdf files for simple distribution and storage.

These calculation methods have been verified by an accredited institute. The calculations are based on spectra the independent institutes defined and established. The calculations are based on spectra which have all been determined by independent institutes. This means that you and your team can have confidence in the accuracy of the calculated results when using this data to design your building and its environmental control systems.

The GUARDIAN configurator can be downloaded from the website or ordered directly from GUARDIAN.

→ www.sunguardglass.com

11.1.2 Glass-relevant calculations

In many cases, various calculations are required as early as the planning and/or quotation phases before a precise further course of action can be determined. These may be static loads which need to be determined for deciding the proper glass dimensions, or isothermal lines defined for façades and windows have to be defined, or solar-relevant values which need to be determined for certain complicated assemblies that the configurator is no longer able to generate. State-of-the-art software that is continually updated and handled by top-notch specialists produces the required values quickly and reliably, providing efficient and effective assistance in working in the everyday commercial glass business.

It must, however, be categorically stated that these value indicators are given without any kind of guarantee, and are only recommendations that should still be confirmed by designated and authorised experts when placing an order.

11.1.3 Technical customer service

In addition to a multitude of varied documents, available to customers to view items such as test certificates, manufacturer statements and other technical documents, we also have employees on our staff who can provide onsite support, if necessary, regardless of whether you are a new customer who needs a professional assessment made of your storage and production facilities, or you would like a personal introduction to new GUARDIAN products with test runs.

GUARDIAN actively promotes high-quality and efficient production processes and operations at the customer's site as this also enhances its own image and professional reputation.

11.1.4 Competence transfer

The more differentiated the knowledge, the more efficient the consulting service and sales. GUARDIAN experts remain true to this motto when providing their customers with all the information they need with regard to our complete product range. Whether inquiries involve new developments, products or application areas, changes to boundary parameters or sales and support, appropriate assistance and advice is always available. Training seminars held regularly throughout Europe cover all the aspects contributing to mutual success, as only highly qualified customer support personnel are capable of producing the variety of glass applications in and on buildings and positioning them effectively and profitably on the market.

11.1.5 The GUARDIAN staff contacts at a glance

We have dispensed with a listing of the numerous contact persons for individual areas and countries in this publication, as it is subject to updating. However, the latest listing of staff contacts and their contact information can be viewed at any time on our website. Please take advantage of this opportunity to contact our staff personally and get to know them.

→ www.guardian-europe.com

11.2 Subject index

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11.3 Common abbreviations

a .... Year
A .... Ampere
abP .... German National test certificate
AbZ .... General approval by a construction supervising body
AGB .... Terms and conditions
ATV .... General technical specifications
AufzV .... Lift ordinance
b .... Factor of mean transition
BauPG .... German Building Products Act
BM .... Ribbon dimension
BPR .... Construction Products Directive
BRL .... Building Regulations List
BW .... Rated value
c .... Specific heat capacity
C .... Spectrum adjustment value
CE .... Conformité Européenne
CEN .... Comité Européen de Normalisation
CENELEC .... Commité Européen de Normalisation Électrotechnique
CiO .... Degree of gas filling
cm .... Centimetre
CO_2 .... Carbon dioxide
C_{tr} .... Spectrum adjustment value
dB .... Decibel
dB(A) .... Weighted sound reduction index
DIBt .... German Institute for Civil Engineering
DIN .... German Institute for Standardization
E .... Emissivity
E .... Young module (Modulus of elasticity)
EN .... European standards
EnEV .... Energy Conservation Regulation
EOTA .... European Organisation for Technical Approvals
EPBD .... Energy Performance of Buildings Directive
ETA .... European Technical Approval
ETAG .... European Technical Approval Guideline
ETZ .... Europäische technische Zulassung
EU .... European Union
F_c .... Reducing coefficient for solar protection equipment
FEM .... Finite-Element Method
F_g .... Coincidence frequencies
$f_{g,h}$ .... Characteristic tensile bending strength
f_R .... Resonance frequency
g .... Total energy transmittance degree
G .... Heating degree days
GBM .... Split ribbon dimensions
GHz .... Gigahertz (109 Hertz)
GPa .... Giga pascals
GWp .... Maximum reachable power (from photovoltaic modules) in Gigawatt (peak)
H .... Hour
H .... Calorific value of oil
hEN .... European harmonised standards
HK .... Knoop hardness test
HSG .... Heat strengthened glass
HVBG .... Federation of the legal professional associations
Hz .... Hertz
Ift .... Institute for Window Technology, Rosenheim
ISO .... International Organization for Standardization
J .... Joule
k .... Kilo
K .... Kelvin
K .... Correction value (at sound insulation)

k_F .... Heat conductivity coefficient window (old)
kg .... Kilogram
kHz .... Kilohertz (10^3 Hertz)
kPa .... Kilopascals
LBO .... Building regulation
LSG .... Laminated safety glass
LTB .... List of acknowledged technical rules for works
m .... Surface mass
m .... Meter
M .... Mega (10^9)
m^2 .... Square meter
m^3 .... cubic meters
mbar .... Millibar
MBO .... Model Building Regulation
MDCA .... Labels for special glasses in the U.S.
MHz .... Megahertz
MIG .... Insulating glass
MLTB .... Model List of Technical Building
mm .... Millimetre
MPA .... Material control authorities
ms .... Millisecond
n .... Nano
N .... Newton
N .... medium light calculation index
nm .... Nanometre (10^{-9} m)
P .... Sound power
Pa .... Pascal
PAR .... Photo-synthetically Active Radiation
prEN .... Draft European standard
PU; PUR .... Polyurethane
PV .... Photovoltaics
PVB .... Polyvinyl butyral
PVC .... Polyvinyl chloride
P1A to P8B .... Resistance categories
q_i; q_a .... Secondary heat dissipation
R .... Sound reduction index
R .... Electrical resistance
R_a; $R_{a,D}$; $R_{a,R}$ .... Colour rendition index
RAL .... German Institute for Quality Assurance and Certification
Re .... Solar energy reflection
RL .... Degree of light reflection
RLT .... Ventilation and air conditioning systems for indoor climate
$R_{w,B}$ .... weighted sound reduction, values measured on the construction
$R_{w,P}$ .... weighted sound reduction, determined on the test station
$R_{w,R}$ .... weighted sound reduction, calculation value
$R'_{w,res}$ .... resulting sound reduction index of the entire structural component
R_w; R'_w .... weighted sound reduction
S .... Selectivity factor
S .... solar input factor
SC .... Shading coefficient
SZR .... Pane interspace
TG .... Single-pane safety glass (tempered glass)
TG-H .... Heat-soak single pane safety glass
TR .... Technical rules
TRAV .... Technical rules for safety barrier glazing
TRLV .... Technical rules for the use of linear supported glazing
TRPV .... Technical rules for the design and specification of point-fixed glazing
TUV .... UV radiation transmission

U .... Heat transmittance coefficient

U_{CW} .... Heat transmittance coefficient, facade

U_f; U_m; U_t........ Heat transmittance coefficient of frames, post-and-beam profiles

$U_{g, BW}$ .... Heat transmittance coefficient, glass, measured value

U_g; U_p............ Heat transmittance coefficient of gas and filling

ÜH .... Declaration of conformity of the manufacturer

ÜHP .... Declaration of conformity of the manufacturer after test

ÜHZ .... Certificate of conformity

UV................. Ultraviolet

U_W................. Heat transmittance coefficient, window

VDI................ Association of German Engineers

VdS............... Association of Property Insurers, damage prevention

VG .... Laminated glass

VOB.............. Procurement and construction contract procedures

W.................. Watt

W.................. Window (Fenster)

WPK.............. Factory production control

ZiE .... Approval on a case-by-case basis

11.4 Greek symbols

α	Drop height of the pendulum impact
α	Average linear thermal expansion coefficient
α	Angle
α_e	Energy absorption
β	Fracture behaviour in pendulum impact
γ	global safety factor
Δ	Difference
Δ_υ	Temperature difference
ε	Emissivity
θ	Temperature
λ	Wavelength of sound and light
λ	Thermal conductivity
μ	Micro
μ	Poisson number
μ	Poisson´s ratio
μm	Micrometre (= 10^{-6} m)
ρ	Density
ρ_e	Solar energy reflection
Σ	Sum
σ	Tensile bending strength
τ_e	Solar energy transmission
τ_L	Degree of light transmittance
τ_V	Degree of light transmittance
$\tau_{V,BW}$	Degree of light transmittance, measured value
φ	Drop height in pendulum impact
ψ	Heat transfer coefficient, related to length
Ω	Ohm

NOTES