sedak

sedak fact sheet

Lamination

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Glass can achieve its broad range of applications only by lamination. Interlayers bond individual panes to form laminates, which then serve as a load-bearing component, bullet-resistant panorama pane or exceptionally well-designed element. For perfect structural and optical results, the lamination process must be precisely planned and executed with a high degree of accuracy.

18 panes laminated to a 30 cm thick, highly pressure-stable underwater yacht viewing window with a diameter of four meters: What is unimaginable with a single pane of glass is made possible by lamination. This ranges from special solutions such as this offshore application to support structures for all-glass structures.
This fact sheet explains what lamination is, how it works and what additional applications it opens up for glass.

1 Why glass is laminated

Lamination of glass panes with interlayers gives glass additional safety properties. Laminated safety glass is formed from two or more panes of glass in a solid bond with an interlayer. In case of breakage, the glass fragments adhere to the interlayer. This significantly reduces the risk of cuts and puncture wounds. Depending on the application, either heat-strengthened glass or single-pane safety glass is used for laminated safety glass. Laminated safety glass made of single-pane safety glass is used, for example, in car windshields. The glass breaks into small pieces that adhere to the interlayer and protect the driver against injuries from cuts. Laminated safety glass made of heat-strengthened glass is used for overhead glazing, for example. Due to the residual load-bearing capacity of the interlayer, the glass breaks into larger fragments, so that the glass does not come crashing down in the event of breakage.

Figure 1: Under cleanroom conditions, sedak glass is layered using interlayers to make a single package.

Laminated safety glass is as reliable as it is common. But different types of lamination open up a significantly wider field. Sophisticated optical and structural functions can be realized using glass laminates. This is done by selecting the types of glass and interlayers that are tailored to the desired properties. The interlayers are especially important for specific properties in terms of load-bearing capacity, appearance, soundproofing and thermal insulation.

Laminates enable:

... integration of functional elements
The lamination of metal profiles creates structural connections of the glass elements. Laminates can be used as building components for bridges, staircases, roofs/floors/horizontal glazing or as a supporting structure for a full glass facade.

... decorative and functional facades
Lamination opens up a fascinating creative spectrum – particularly by combining it with other materials. Examples are real wood, natural stone, metal mesh or perforated sheet metal. The advantage: the lifelike appearance of the weather-sensitive materials is retained and does not need to be imitated (e.g., using digital printing). Protected against environmental factors, these materials have a long service life without maintenance. Another advantage: Upkeep is also simpler, as glass can be cleaned more easily. Creativity can develop freely, while the physical building properties remain finely adjustable (shading, thermal insulation, etc.).

... new possibilities for bent glass
Even the design language gains more space: Curved laminates give glass a third dimension. In the process of so-called cold bending, glass can be bent not only in one or two dimensions but also spherically. In this case, individual panes of a bonded package are molded before processing in the autoclave in order to laminate them in their geometrical shape. After cooling, the finished laminated glass retains this curvature without having to rely on a shaping substructure. The main advantage over other bending processes is the extremely good optical quality with little distortion and reflection.

During lamination bending, the minimum bending radius is approximately 1500 times the glass thickness (10mm: bending radius 15m). The sedak "Glass Bending" fact sheet explains more about bent glass; publication: winter 2021.

... bullet-resistant glass
Interlayers in laminates can also protect against penetration of projectiles. sedak offers bulletproof glass as insulating and safety glass up to the highest bullet classification (BR7 NS, test according to DIN EN 1063). Due to the special glass structure, the usual polycarbonate system can be dispensed with.

Special interlayers for additional functions
There does not always have to be a PVB or SentryGlass interlayer. With projection, thermal or colored interlayers, laminates acquire specific properties (see Excursus).

2 The Lamination Process

Special furnaces, known as autoclaves, are required for the bonding process between glass and interlayer to make laminated safety glass. A prerequisite for production: absolute cleanliness. The process starts in the cleanroom. Here, the lamination interlayers are placed between the panes, that is, layered alternating between glass and interlayer. Both must be completely dust- and lint-free. Foreign bodies cannot be removed afterward and represent a defect or in the worst case, scrap.

The package enters the autoclave in a vacuum bag (vaccum sack process) and is heated up to 140 degrees under pressure similar to a pressure cooker. The process usually takes one to six hours. The opaque interlayer permanently bonds to the glass and becomes transparent. This results in very high adhesion and bond strength.

The process parameters of duration, pressure and temperature change according to the size, thickness and shape of the glass package and are extremely important for the quality of the laminates. The human factor plays a central role here: Specialists require experience to optimally adjust the machines. Depending on the installation situation, it is not only the lamination quality in the glass that is very important, but also the edge quality. This is the case if the glass edge is visible, e.g., on glass parapets or all-glass staircases. Here, sedak achieves excellent edge quality, exceptionally smooth and precise thanks to a special process developed in-house.

Figure 2: The vacuum process ensures process reliability for thicker glass and especially for multiple laminates.

sedak has perfected lamination over the course of its company history. Cold bending (lamination bending) of glass and innovative products such as sedak clear-edge and sedak isosecure are developments by sedak. They have been created with a great deal of pioneering and research spirit and with the desire to open up new applications for glass over and over again. These developments were nurtured in part by customer requests, which has led to constantly rethinking and rediscovering glass.

3 Quality determinants

sedak's production facility in Gersthofen manufactures the world's largest premium quality glass. The machines for this glass were developed jointly with the machine manufacturers using many years of know-how in the finishing of oversized glass formats. Although the machine manufacturers are a prerequisite for finishing high-quality glass, the human factor plays a decisive role in glass processing – a feel for glass and experience in dealing with extremely large and heavy formats and special solutions. Under what conditions does a laminate achieve the necessary load-bearing capacity? How can lamination interlayers be uniformly melted in an 18-fold laminate so that maximum transparency is possible despite the immense glass thickness? How can an organic substance such as wood be treated in an autoclave in such a way that it does not burn, shrink or stray from its position in the laminate? These productions require in-depth knowledge of the material as well as a deft touch. Specialists must also take into account factors such as the format (e.g., free forms), recesses and drill holes in the glass. Here it is important to run temperature curves precisely in the autoclave and, if necessary, to readjust them during baking.

Tolerances

Here, sedak often goes far beyond the normatively specified tolerances. Depending on the project, tolerances of just a few millimeters may be required for 20 meter glass.
The sedak quality manual defines how precisely sedak has to manufacture – a commitment that goes far beyond standard specifications.
(see sedak.com -> downloads -> Quality Manual)

Outlook
Lamination opens up new environments for glass construction – functionally and architecturally. Technology shows how glass can take over structural functions – and which design solutions can be achieved beyond ceramic printing. Imagination, not technology, sets the limits.
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4 Lamination processes: Roller pre-bonding and vacuum pre-bonding

Two processes can be used for lamination: depending on the properties of the final product, either roller pre-bonding or vacuum pre-bonding. This table shows the technical differences.

	Roller pre-bonding	**Vacuum pre-bonding**
Application	Standard process	Special process, multiple bonds, lamination bending
Location of process preparation	Lamination room	Cleanroom
Multistage process preparation	1.) Layers of glass and interlayer 2.) Heating the lamination package to approx. 35 degrees Celsius: First press roller presses air out of the layer structure 3.) Reheating of the composite package to 60 to 70 degrees Celsius: renewed rolling process until full-surface bonding of interlayer/glass	1.) Layers of glass and interlayer 2.) Packaging the glass-interlayer sandwich in a vacuum bag. The remaining air is then evacuated at - 0.8 to - 0.9 bar.
Main lamination process	The interlayer-glass package is bonded to the final lamination in an autoclave at 12 to 14 bar and > 130 degrees Celsius	

Comparison
The processes differ in terms of effort and result. The type of production selected depends primarily on the quality of the laminate or whether the desired product can be produced using the particular process. The vacuum process in the cleanroom is more complex. But it is also the process that makes more things possible.

Roller pre-bonding is ideal for single laminates with comparatively thin panes. For thicker panes and especially for multiple laminates, the vacuum process ensures process reliability. This also makes embedding material such as wood, metal or natural stone possible; the theoretical limit for size is set by the autoclave. Holes, recesses, etc., that are difficult for production in the standard process can be easily laminated in the vacuum process. Furthermore, only production in a vacuum sack virtually eliminates delamination, especially for more complex structures. Production in the cleanroom also results in visually higher-quality panes.
When it comes to the third dimension – in other words, curved laminates – there is no alternative to the vacuum process.

5 Excursus: interlayers

The type of interlayer has a great influence on the properties of the glass laminate. That's why interlayers are chosen for specific purposes.

SentryGlass interlayer	Interlayer with high inherent rigidity, residual load-bearing capacity and high transparency. Thanks to its high strength, it is particularly suitable for structural demands on the glass. SentryGlass interlayer is mostly used for glass as a facade element, overhead glazing and safety glass with high safety requirements or in special constructions (bridges, stairs, roofs/floors). It is also used for lamination bending.
PVB (polyvinyl butral)	Elastic, tear-resistant polymer interlayer; easy handling; used for splinter adhesion and when glass is not exposed to major environmental factors
EVA	For glasses with special surfaces
XIR	Coated interlayers for (additional) sun and heat protection
Thermal interlayer	For heating up windows to prevent icing and condensation on the window.
Sound insulation interlayers	Reduces interior noise levels
Projection interlayer	For projection screens