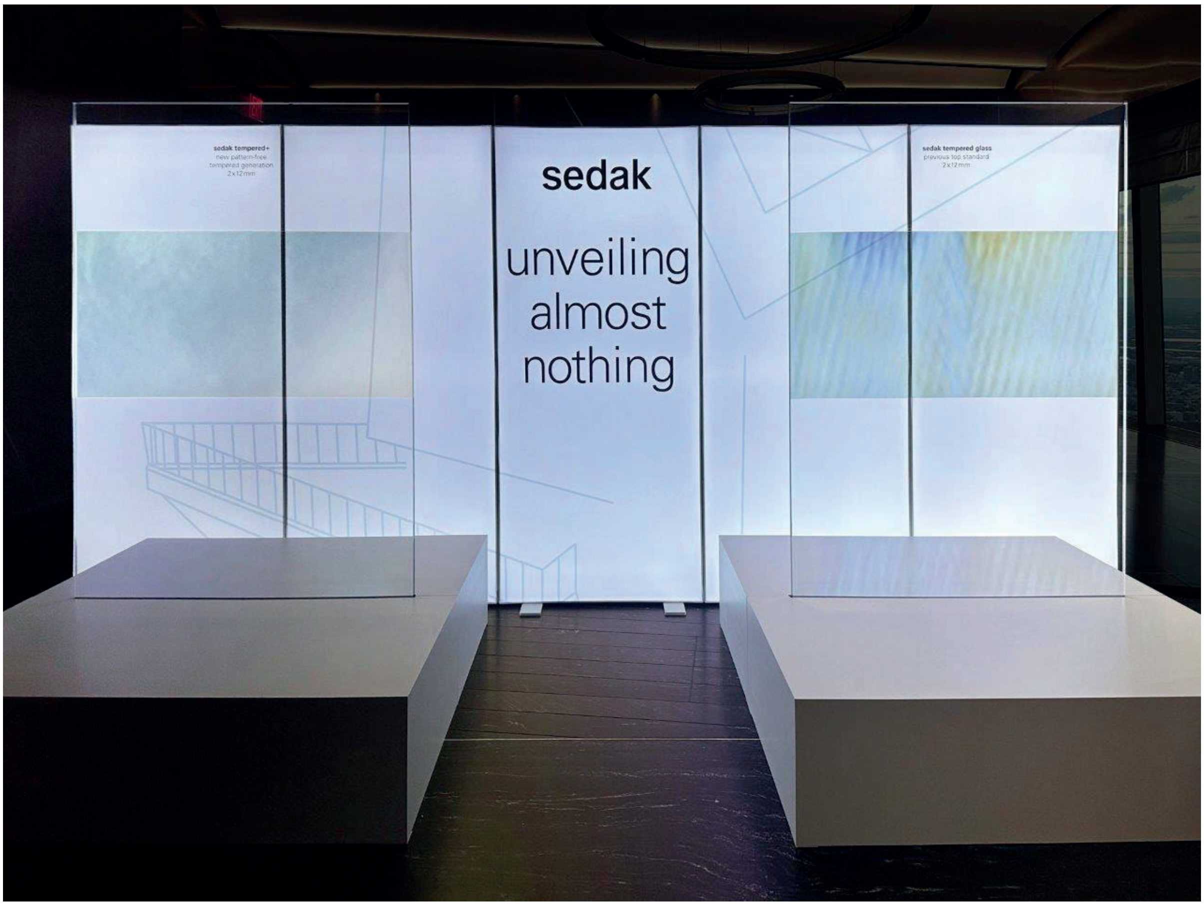
sedak factsheet

Anisotropies and sedak tempered+



The picture displays typical anisotropies (right) and the nearly anisotropic-free **sedak tempered+** (left).

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anisotropies in architectural glass is still a relevant topic

Because of its transparent appearance, glass is often used as a material in the architecture. In addition, the use of glass is becoming more complex and the structural requirements are increasing. As a result, glass is increasingly being toughened and laminated into thicker units. As a result, irregularities in the glass, which become visible under certain lighting conditions, are increasingly common. These irregularities, known as anisotropies, occur during the tempering process. The intensity of the anisotropy is not significantly affected by whether the glass is fully tempered or heat-strengthened. Combining the glass into multi-layer units multiplies anisotropy effect.

1 what actually are anisotropies

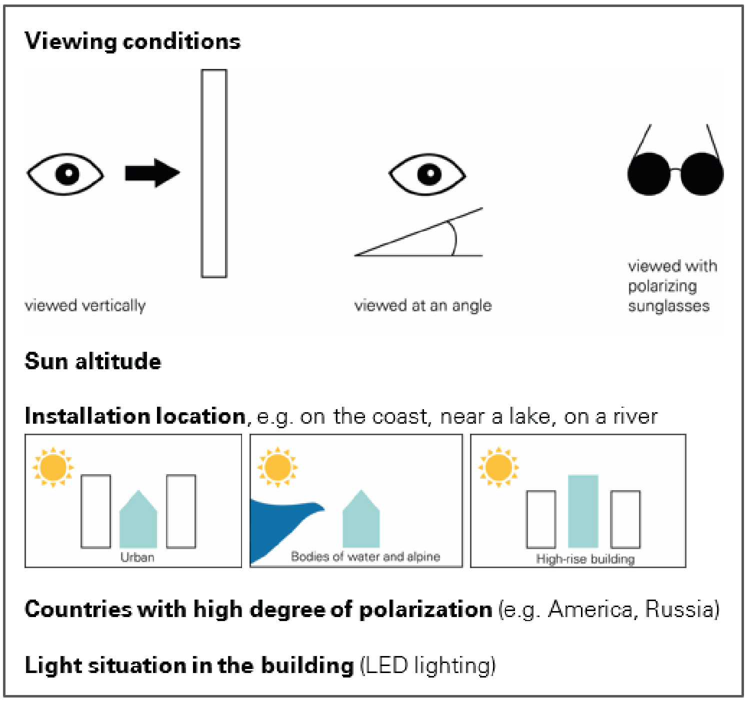
Glass is optically isotropic (Greek isos = equal, tropos = direction), meaning that light is transmitted uniformly and the refractive index of light rays is identical in every direction. However, if stresses are introduced into the glass, the incident light is refracted twice, depending on the state of stress (the glass becomes "anisotropic"). When polarized light hits the glass, it refracts unequally and spreads out at different speeds, causing the light waves to no longer emerge from the glass at the same time. This effect is recognized by the eye as interference color.

1.1 how do anisotropies arise

To temper glass, it is heated to approximately 640°C, which is 1184°F above its glass transition temperature Tg. However, due to its poor thermal conductivity, achieving complete homogeneity in the heating process is not possible. Varied roller contacts in the furnace , as well as boreholes, corners, and edges, result in uneven heat distribution throughout the glass. The tempering process involves controlled cooling with a high air flow rate, which leaves additional traces of the system in the glass. The resulting iridescence is caused by slightly inhomogeneous stresses after the process. Despite using modern furnace technology to heat and cool the glass, it is impossible to completely eliminate these stresses. The stress state differences are 'frozen' inside the glass and will remain unchanged throughout its service life. Environmental influences, storage conditions and transport issues do not affect them.

1.2 optical perception of anisotropies

The visibility of anisotropies is influenced by lighting conditions and viewing angle. Anisotropies appear more visible at a flat viewing angle than when viewed perpendicular. The use of polarized sunglasses enhances the probability of the appearance of anisotropies. Reflective surfaces, such as bodies of water or snow-covered areas, can increase the perception of anisotropies. High-rise buildings, due to their exposed location, also have a higher risk of visible anisotropies. The weather and position of the sun also play a crucial role. When the sky is bright blue and the sun is low, the proportion of polarized light is highest, making anisotropies more detectable.



Overview of visual perception conditions known so far.

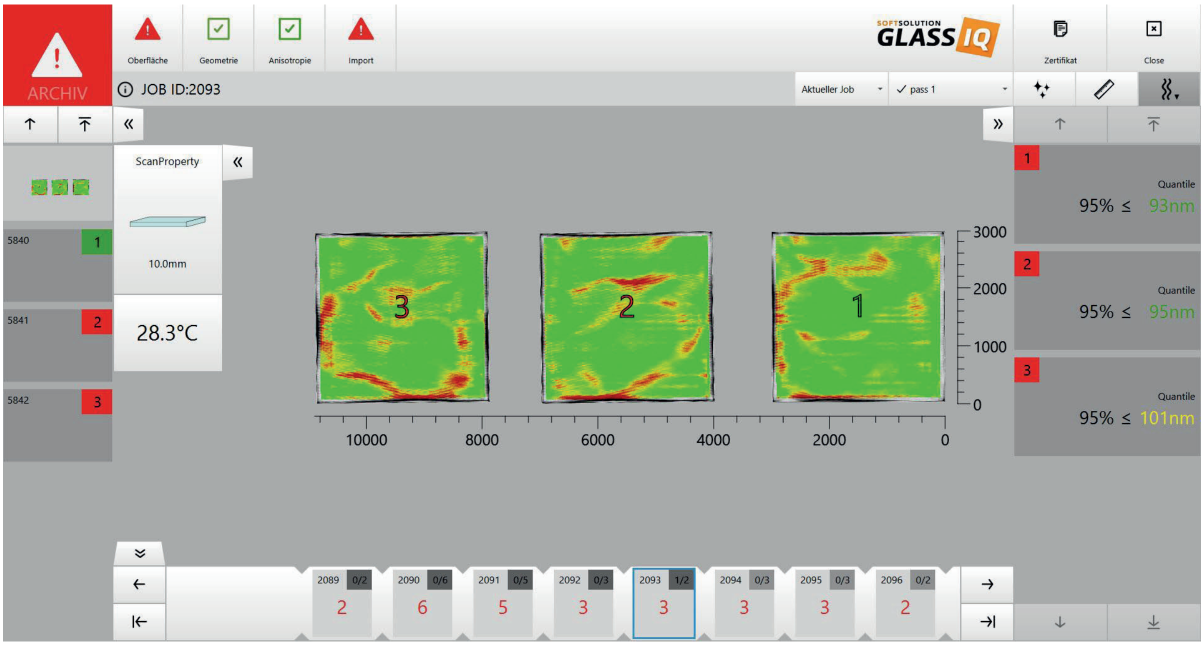
1.3 the glass layout as influencing factor

The overall intensity of the anisotropies is highly influenced by the thickness of the individual glass pane and the number of glass layers. Additionally, glasses with anomalies in their geometry, such as acute angles, holes or machined cut-outs, etc., increase the intensity of the iridescence phenomena. This is due to the more complexity in uniform heating and cooling. This means that larger and more irregularly shaped glasses, with a higher ratio of corners, edges, and openings to surface area, are more difficult to temper and avoid anisotropies. An further exception is made for glasses with more square dimensions because, contrary to other theories, the square is the most unfavorable shape for tempering. The square tends to form a rigid shell shape very quickly in the tempering furnace and tends to settle only very slowly. This behavior has an unfavorable effect on the formation of anisotropies and the flatness. The interlayer material, in particular SGP, have less influence on the anisotropies than previously assumed.

2 sedak anisotropy scanner in use

The **sedak** Softsolution Scanner was installed and commissioned on the ESG II (16.5 m) furnace in April 2020. Since then, all tempering programs for the furnace have been optimized through targeted evaluation of the anisotropy images. The correspondingly optimized program in terms of thickness, size and shape is saved and used again for the next comparable kiln run. This is how we achieve the best possible optical result from our tempering furnace today.

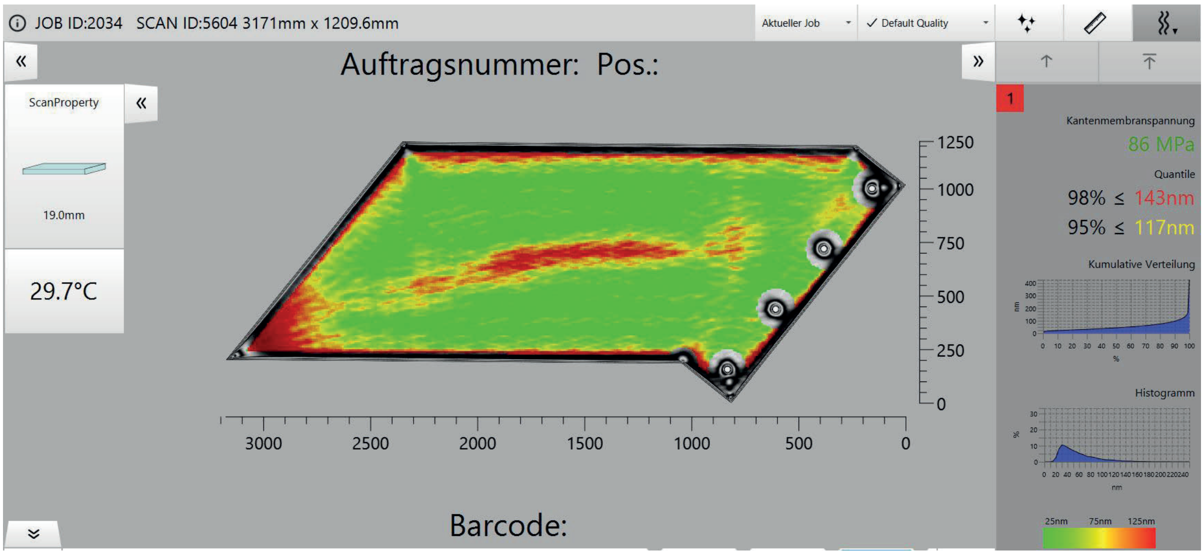
This **sedak** scanner inspects and documents all glasses that are tempered on our furnace.



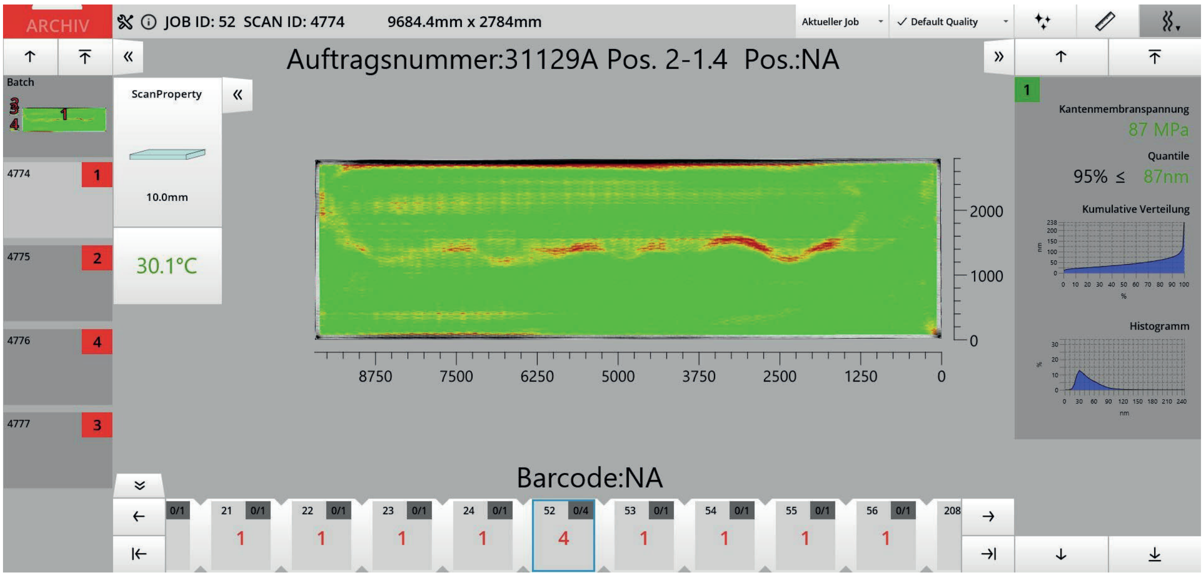
Exemplary anisotropy images of our **sedak** scanner with 3 glasses in one batch rated by the corresponding 95% quantile value.

3 evaluation range of the scanner recordings

The scan excludes the border areas along all edges, corners, and holes. Due to the specified stress state, stress concentrations occur in this location.



Exemplary anisotropy image from a 19mm ESG with excluded holes and corners.



A rectangular shaped glass shows usually a better quality in terms of anisotropy.

So far, coatings and printings have not been evaluated due to the lack of comparability.

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4 anisotropy: standards and regulations

In national and international product standards and regulations for assessing the visual quality of glass, anisotropies are not considered as defects, but as visible effects or characteristics of tempered glass. They are excluded from the assessment of visual quality.

The American ANSI C1901-21 standard provides only basic frame values and no additional features.

X2. SUGGESTED MEASURING RANGE, PRECISION AND BIAS

TABLE X2.1 Suggested Measuring Range of Retardation Apparatus

NOTE 1—There are several ways to quantify the optical retardation of an area. Automated acquisition with cameras or line scan bars offer advantages in online operation. Depending on apparatus type and glass application, the technical capabilities of the polarimeter or polariscope can vary.

Usage	Minimum Retardation Range		Precision	Retardation Azimuth	Bias (repeatability)
	Lower	Upper			
Tempering furnace process control, glass <10 mm	0 nm	120 nm	±10 nm	optional	±5 %
Tempering furnace process control, glass 10–19 mm	0 nm	250 nm	±10 nm	optional	±5 %
Computer modeling of anisotropy in building facades	0 nm	according to modeling needs	±5 nm	±4°	±5 %

Relevant cutout from ANSI C1901 – 21

The recently published German DIN SPEC 18198 provides more detailed information and divides anisotropy results into simple quality levels at hand of 95% quantile values of the retardation measurement.

6.2 Qualitätsklassen

Den Grenzwerten aus Tabelle 2 und Tabelle 3 liegen Referenzversuche an unbeschichtetem Flachglas zugrunde.

Tabelle 2 — Qualitätsklassen auf Basis der Methode A ($x_{0,95}$)

Glasdicke	Qualtitätsklasse		
	A	B	C[a]
≤ 6 mm	≤ 70 nm	> 70 nm und ≤ 95 nm	> 95 nm
8 mm	≤ 80 nm	> 80 nm und ≤ 120 nm	> 120 nm
10 mm	≤ 95 nm	> 95 nm und ≤ 140 nm	> 140 nm
12 mm	≤ 115 nm	> 115 nm und ≤ 165 nm	> 165 nm
15 mm	b	b	b

[a] Für Grenzwerte, die höher als die angegebenen Werte sind, und für Gläser ohne Messung.

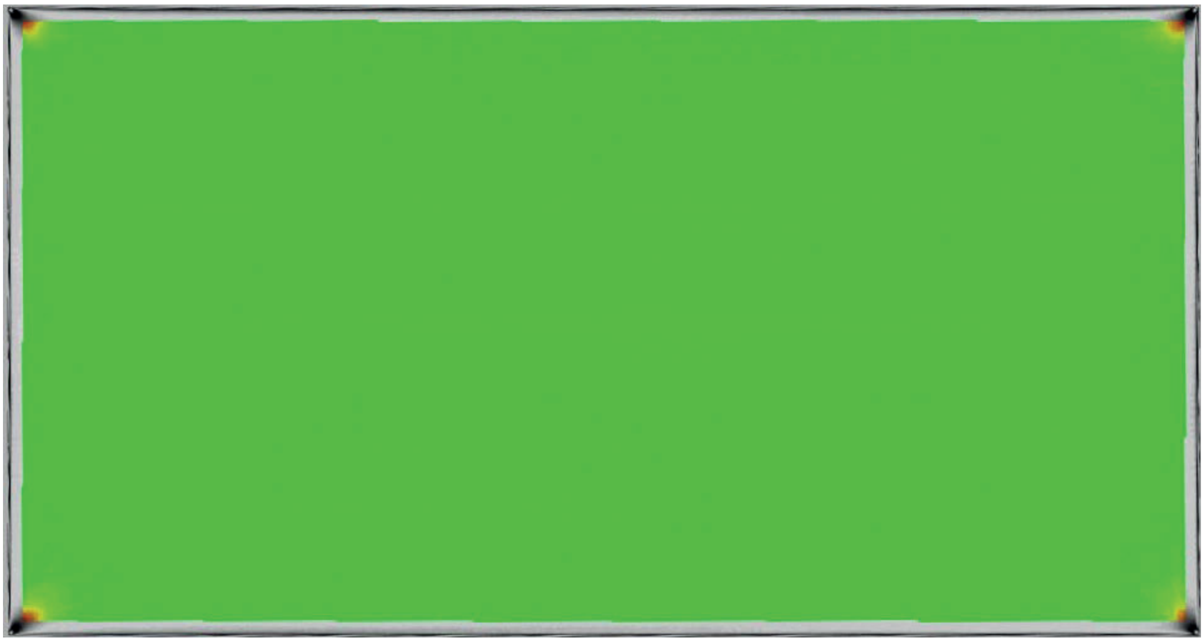
[b] Keine Referenzwerte vorhanden; Grenzwerte sind mit Glashersteller abzustimmen.

Table from the DIN SPEC 18198 defining different quality levels of anisotropy at hand of the 95% quantile value.

5 hard facts of sedak tempered+

sedak tempered+ is the first tempered glass without visible anisotropies.

With the new product **sedak** provides a new generation of fully tempered and heat-strengthened glass offering pattern-free vision with no anisotropies visible to the human eye. Customers receive tempered glass with optimal optical properties from any angle and under any lighting condition thanks to our revolutionary optimized, advanced tempering process.



Anisotropy scan of a 6m x 3,2m 10mm **sedak tempered+** with a 95% quantile value of ≤60nm.

After extensive research, testing, and furnace optimizations, **sedak** achieved a significantly low level of light wave retardation in our tempering process. This delay value, measured in 'nm', corresponds to the value measured per pixel by anisotropy scanners (**sedak** scanner). This indicates that 95% of all measured pixels of the glass pane were below the specified delay value.

We will achieve the 95% quantile values as listed: The tolerance will be ± 15nm

Glass thickness of 6mm	40nm
Glass thickness of 8mm	50nm
Glass thickness of 10mm	60nm
Glass thickness of 12mm	80nm

Additionally, there will be no red zones in the middle area of the glass. The scans on page 4 and 5 of the previous report show red zones that were present before development of **sedak tempered+.**

The colors on this scale explain the delay values of our scans: