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Thermal stress to glass and the application of vinyl graphics

Glass does not *just* break. It breaks for a reason.

The application of vinyl graphics to windows and glass has been staple product for sign and graphics suppliers however over the past few years, the number of installations has increased and the style of graphics and demand has changed considerably.

Glass is a non-crystalline, often transparent amorphous solid, that has widespread practical, technological and decorative use. It is most often formed by rapid cooling (quenching) of the molten form; some glasses such as volcanic glass are naturally occurring.

The most familiar, and historically the oldest, types of manufactured glass are "silicate glasses" based on the chemical compound silica (silicon dioxide, or quartz), the primary constituent of sand. Soda-lime glass, containing around 70% silica, accounts for around 90% of manufactured glass. The term *glass*, in popular usage, is often used to refer only to this type of material, although silica-free glasses often have desirable properties for applications in modern communications technology.

Glass is technically a liquid material and can therefore be subject to:

- Temperature changes which result in volume changes.
- Volume changes which result in compression stress.

In addition to the absolute temperature, different temperatures (temperature gradients) in, for example, a single pane of glass sheet, may cause thermal stress regardless as to whether graphics have been applied or not.

Photo of broken glass. Classic meandering pattern of heat-related stress crack accompanied by evidence of edge damage. In this case, the glass had both: edge damage and underspecified glass. In addition, reflective blinds and a South exposure combined to create a high frequency of this type of breakage.

Sign and graphics companies should be aware of **thermal stress** and that vinyl graphics including solar control films, applied to glass may contribute or can be the cause of fractures appearing in the glass. As these stress fractures can reveal themselves after the application of vinyl graphics, this leads customers to insisting that it must be solely the graphics causing the problem and that the sign/graphics company must be responsible for replacing the damaged glass units - which may wipe out any profit made from the job in the first place. It will be difficult to prove that the glass was already compromised by thermal stress or other factors before the graphics were applied unless there was visible evidence of a fault beforehand.

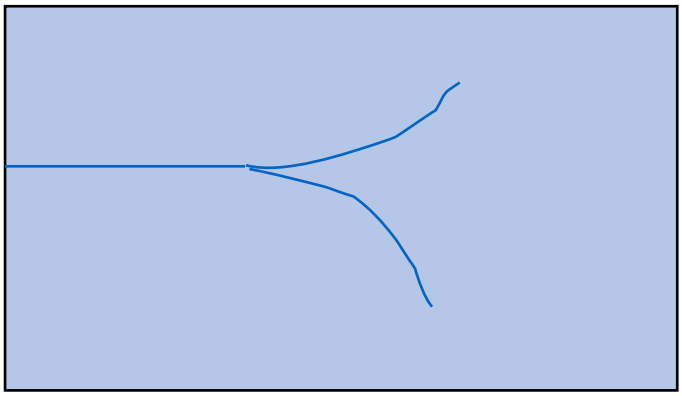
The intention of this guidance note is to help explain the causes and effect of applying vinyl graphics to shop windows and the like. This is not to say that vinyl graphics are the sole cause of damage to glass. We cannot comment on an individual case only in generalities.

Furthermore, this guidance is intended to be more of an awareness campaign and one that should be discussed with the customer before any design, quoting, specification of materials or colours and installation takes place.

Photo of two cracks present in the outside face of a double-glazed unit. Vinyl graphics applied to the lower part of a window.

What to look for

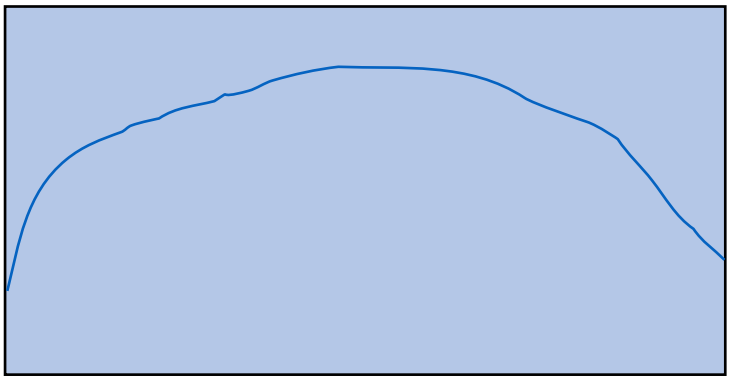
Damage caused by thermal stress



1. Crack is initially perpendicular to the edge of the glass and then branches out into one or more directions. The number of branches or secondary cracks is dependent on the amount of stress in the glass.
2. The crack ends within the pane
3. The breakage can be single or multiple

Possible cause: Temperature difference >37°C with various causes for this effect (including window films).

Damage caused by mechanical means or physical contact



1. Random start to crack
2. Crack path from pane edge to pane edge
   Possible cause: Effect of force against the pane, defective glass e.g. edge damage.

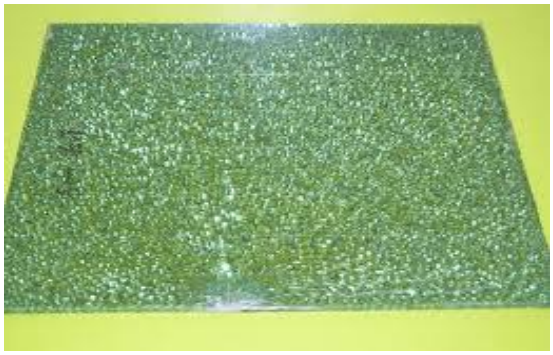
There are usually 5 types of glass that are used in window construction

They are:

1. Single pane annealed/Simple float glass:

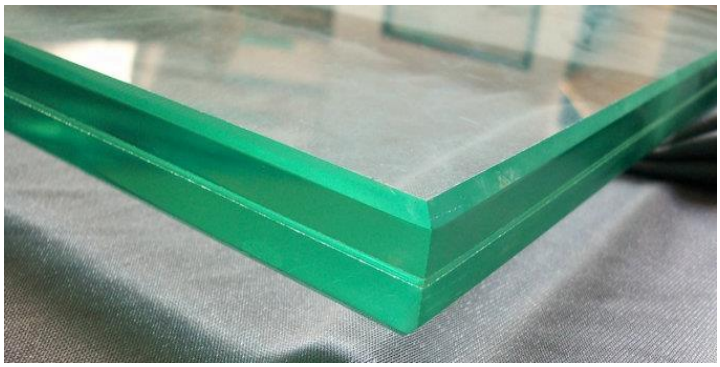
Most common type and least expensive. This glass is most easily broken, fragments are large and most of the broken pieces will remain in the frame. Average sensitivity to thermal stress risk only in the case of extreme pane areas or previous damage to the edges

2. Toughened glass:



Glass is brought to high temperature then rapidly cooled in a tempering oven. Chemical tempering can also be used in the manufacture process. This glass is the most difficult to break however it is more easily broken from the edge and breaks into small pieces. No residual strength, pieces will fall and not stay together in the frame. Spontaneous breakage can occur. Very insensitive to thermal stress as the thermal stress-resistance is massively increased by the hardening of the glass in the manufacturing process.

3. Laminated glass:



Laminated Glass is two or more pieces of glass bonded together with an interlayer adhesive (commonly PVB) that is clear and bonds the glass pieces together. Sensitive to thermal stress as stresses in the panes cannot be compensated by evasive movements between the two sheets of glass.

4. Double/Triple glazing

5. Double/Triple glazing with ‘Low E’ coating

It is important that you know which type of glass you are applying graphics to as they all carry different properties and are affected in separate ways. For example, Low E coatings on some windows can cause higher glass temperatures as they are designed to reduce radiant heat flow to improve energy efficiency. This in turn increases the risk of thermal stress before any graphics are applied.

The material used, the design of graphics being applied and the area covered will also affect how much thermal stress is placed on the glass.

Thermal Stress Risk Guide for vinyl graphics

	White Graphics	Dusted/Frosted	Light/Medium	Medium Colour	Dark Print	Very Dark/Black
Toughened glass						
Single pane annealed						
Double glazing						
Double glazing Low E coating						
Laminated either single or double glazed						

low risk	
low to medium risk	
medium to high risk	
high risk	

The above graph is based on a complete sheet of glass being covered in one colour to the 'exterior' face of the glass. Multiple colours will create differing areas of temperature differences.

How is thermal stress caused?

Thermal stress occurs when a sufficient temperature differential is created within the glass and this is usually when the glass panel comes into contact with direct sunlight or there is a discrepancy in the ambient temperatures to both faces of the glass (outside the building v inside the building).

Solar energy (sunlight) is formed from 52% Infra-red (heat), 43% visible rays and 5% Ultraviolet rays.

As a warmed area expands or a cool area contracts, stress forces develop potentially leading to a fracture if the temperature differences on the surface of the material are great enough.

Factors to consider are:

- Glass type, dimensions and material thickness.
- Thermal radiation e.g. such as solar radiation and/or indoor convection (heaters or air-conditioners).
- Thermal conduction in solid objects such as the heat transfer from glass, frame and seal.
- Heat transmission in gases such as the space between panes.
- Partial shading or application of a film that results in temperature gradients in a single sheet.

Partial shading

Glass that is also in partial shade (shadow of trees, overhangs, canopies etc.), may suffer thermal stress with or without graphics as obviously, part of the glass is receiving full exposure to sunlight and its radiant heat whereas the other part is in the shade and cooler. When this happens, different areas of the glass are expanding and contracting at different rates causing the glass to fracture.

As a guide, windows that are covered by less than 50% of shade are at greater risk of thermal stress than windows that are shaded by more than 50%. Shade that remains in one place is also more likely to cause fractures than shade that is mobile.

Graphic image

If the graphics are partially covering the glass area, this may increase the level of thermal stress and even more so if multi-coloured or dark colours predominate. Full coverage with little variance in colour depth lowers risk but is not absolute. The darker the colours used, the more heat is generated from sunlight which may in turn affect the amount of thermal stress (see chart above).

Other considerations

The overwhelming vast majority of applications do not result in the glass fracturing or shattering which would therefore suggest that each incident or installation will have its own influences as to whether thermal stress takes place or not. Regretfully, there is no ‘one size fits all’ answer to this issue as there may well be other reasons for the glass to fracture.

Applying graphics to the inside of the window or double glazing may not resolve problems. One such potential source is air-conditioning which may create a difference in temperature on the inside surface versus the outside surface making thermal stress more likely. This can be further exacerbated if the glass has a Low E coating.

The integrity of the fixings and construction of the window frame and its installation may create a starting point for thermal stress.

It is not unknown that the glass itself can have internal flaws. The risk of thermal breakage is also influenced by the condition of the glass edge. Glass with clean cut edges has the greatest resistance to thermal breakage. However, annealed glass

edges that have been damaged in handling or during installation have greater risk of thermal breakage and sometimes edge worked glass is advisable. For applications where thermal stress is a concern, heat treated glass should be specified.

Recommendations

Window graphics can and have been applied successfully over many years. You should be prepared and aware of potential pitfalls and take these into consideration before designing and applying graphics.

Discuss any potential problems with your customer so that this matter is bought to their attention before anything may go wrong.

Some window film manufacturers have film-to-glass tables for use by factory-trained dealer installers. If in doubt, request a copy of such guidelines.

Listed are some glass types or conditions where the use of a solar control (not clear safety) type of window film is **not** recommended without extreme caution. It is advisable to take some of these into consideration for the application of day to day vinyl graphics.

- Single pane glass larger than 100 sq. ft
- Double glazing larger than 40 sq. ft
- Clear glass thicker than ⅜ inch or 9.53mm
- Tinted glass thicker than ¼ inch or 6.35mm
- Window framing systems of concrete, solid aluminium or solid steel
- Glass where sealant or glazing compound has hardened.
- Visibly chipped, cracked or otherwise damaged glass
- Reflective, wired, textured or patterned glass
- Triple pane glass
- Laminated glass windows

Make sure that you understand the type of glass that you are applying graphics to and be aware of the high and minimal risk graphics as set out in the chart above.

Consider setting out clearly in your terms and conditions of sale that your liability for the fracturing or shattering of glass after the application of graphics is limited to the cost of the graphics (or a nominal stated sum) as there are too many variables that can contribute to this phenomenon.

In the event of a glass failure, it would be most beneficial if you can be present when the glass is removed in order to inspect and look out for other reasons for the glass to crack e.g. faulty fittings, panel pins holding the frame together coming into contact with the glass, obvious devices causing heat and cold variances.

Before specifying or considering applying vinyl graphics to the surface of the glass, always carry out a test* to ensure that the surface energy of the glass will allow graphics to adhere to. This can normally be achieved by the use of a 'pen test' such as an Acro pen which when used will produce a result similar to the options shown in this image.

Not possible to apply films. Possible to apply film.

*We also recommend using this test when applying graphics to painted surfaces and similar.