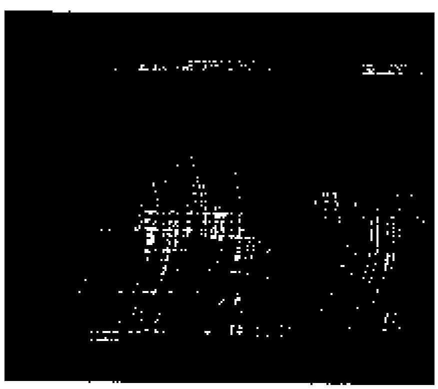
Glass Breakage Analysis II

In "Glass Breakage Analysis I", (TD-110), determining the location of the origin of the break was discussed using concave break wave markings and tracing point-to-tail of arrows back to the origin. In this TD, we discuss thermal stress breakage characteristics, and the relationship of mirror radius to breaking stress.

FIGURE 1 illustrates the fracture face break wave markings produced by temperature difference, e.g., thermal stress breakage, characterized by the parabolic shape of the break waves. The break moved from left to right into the concave face of the waves. Lower stress thermal breaks will cause less distinct parabolic shapes with wider spacing between waves.

Figure 1 Break Wave Markings - Thermal Stress Breakage



Break direction is into the concave face of the parabolic break waves.

With the aid of a good light source, the actual break origin, in many cases, can be located using these illustrations and techniques. Once the break origin is located, if the breaking stress is higher than 1500 psi (10.4 M Pa), a mirror radius fracture face may be evident.

Analyzing the mirror radius of the break origin can provide an estimate of the stress level at breakage in addition to possible causes of the breakage. Examination of the origin can reveal scratches, digs, crush, chips, or weak edges due to poor cutting demonstrated by deep shark teeth or serration hackle at the edge, which caused the breakage.

A powerful point source of light along with a 7 to 10 power jeweler's loupe (e.g., Bausch & Lomb Measuring Magnifier, Catalog No. 81-34-35) will be required for the following definitive break origin analysis techniques.

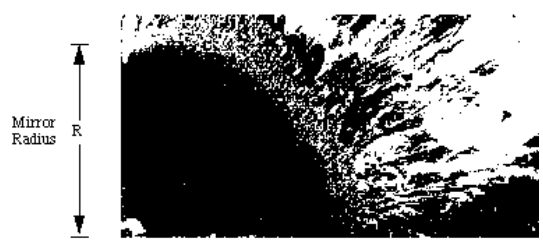


Figure 2

FIGURE 2 shows the break origin and the mirror radius of the break origin at the corner of a 1/4-inch (6 mm) plate. This break occurred at a high breaking stress of 4,100 psi (28.3 M Pa). This is an example of a tension break possible with high thermal stress and also indicates a relatively strong edge.

As the breakage energy increases, crack propagation velocity increases. This is illustrated in the appearance of the fracture face. Near the origin, the fracture face is

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smooth (crack velocity low), but as the propagation velocity increases with higher stress, the fracture face appearance becomes frosted (in a band), then ragged or hackled. Branches develop in the ragged area and the sequence starts again. The mirror radius of the fracture origin is defined as the radius of the smooth portion of the fracture face.

A relationship has been established between the radius of the mirror surface of the origin and the tensile stress that caused the breakage as shown graphically in FIGURE 3. For Vitro float glass, the relationship between breaking stress and the mirror radius can also be expressed using the following equation:

$$\text{Stress} = 1950 / \sqrt{R}$$

As illustrated in the graph and the equation, the radius of the mirror surface increases as the stress causing breakage decreases.

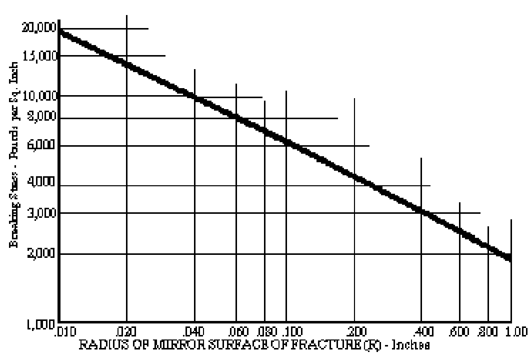
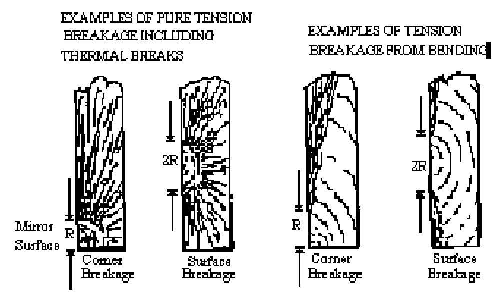


Figure 3 - Relation Between Radius of Mirror Surface of Fracture and Tension Stress Causing Breakage

Figure 4



The two left sketches of FIGURE 4 show break origins from high tensile stresses, e.g., thermal stress breakage. When high tension breaks originate on a surface, the smooth area includes a double quadrant (second sketch from left). The mirror radius is one-half the smooth fracture face which is shown as 2R in the sketch.

The two right sketches of FIGURE 4 illustrate break origins caused by bending. Fracture face appearance may be entirely different, because in bending, the stress varies across the thickness of the plate approaching zero at the neutral axis. For thick plates or high stresses causing breakage, the smooth area mirror radius is small.

For thinner plates or as the breaking stress becomes lower, the smooth area of the mirror radius extends deeply into a lower tensile zone. The smooth area is elliptical and the mirror radius is larger. The two right sketches of FIGURE 4 represent the break origins of thin plates breaking at low bending stresses. A smooth fracture face forms across the entire side of the break origin. For edge breakage, a single frosted

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wedge is formed, for surface breakage, a double frosted wedge is evident.

Fracture origin breakage analysis is a definitive methodology to take the "mystery" out of glass breakage. Much of the information presented here relates to distinctive features associated with higher breaking stresses, i.e., greater than 1500 psi (10.4 M Pa). With high breaking stresses, fracture face markings, break direction, location of the origin, and mirror radius analysis are more evident permitting accurate, detailed information.

Low stress (less than 1500 psi - 10.4 M Pa) bending breaks are typical of breakage experienced in fabrication operations such as insulating glass and laminated glass manufacturing. Breakage in I.G. unit stacking and sashing operations are most often low stress bending breaks associated with damaged surfaces or edges. Crush, dig, scratches, chips and glass-to-metal contact are typical causes.

This type of low stress breakage features much less distinct fracture face markings. The fracture face may be perfectly smooth over the entire length of the broken section. Mirror radii at the break origins may not be present, or cannot be measured. However, careful analysis of fracture face marking and point-to-tail mapping can lead to the break origin. Usually some type of damage at the edge or surface is detectable and observable as the origin and cause of the breakage.

REFERENCES:

1. Vitro Technical Service Report #130 - Installation Recommendations Tinted and Reflective Glass.
2. Leighton Orr - Practical Analysis of Fractures in Glass Windows - Materials Research and Standards, Volume 12, No. 1, American Society for Testing and Materials.
3. Vitro Thermal Stress Update, 1998.
4. Vitro Poster - Guidelines For Cut Edge Quality

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HISTORY TABLE		
ITEM	DATE	DESCRIPTION
Original Publication	January 1996	
Revision #1	1/14/2001	Added refs. 3 & 4 and transferred to TD-111
Revision #2	2016-10-04	Updated to Vitro Logo and format