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Standard Practice for Interpreting Glass Fracture Surface Features[1]

This standard is issued under the fixed designation C 1256; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Fracture features on the surface of a crack reflect the nature and course of the fracture event associated with the breakage of a glass object. This practice is a guide to the identification and interpretation of these fracture surface features.

1.2 The practice describes the various fracture surface features as to their appearance, the process of formation and their significance.

1.3 The practice does not provide the procedural information necessary for a complete fractographic analysis. Such information is available in the general literature. (See Glossary for suggested literature).

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 162 ~~Standard~~ Terminology of Glass and Glass Products

3. Terminology

3.1 *Definitions:*

3.1.1 *bending stress*—a continuously and linearly changing stress across the thickness of a glass body, varying from compression on one surface to tension on the opposite surface.

3.1.2 *forking*—a mechanism whereby a propagating fracture branches into two fractures, separated from each other by an acute angle.

3.1.3 *forking angle*—the angle subtended by two immediately adjacent fractures which have just branched or forked.

3.1.4 *fracture mirror constant*—a constant, characteristic of a given glass composition, which, when divided by the square root of the fracture mirror radius, will yield the fracture stress.

3.1.5 *fracture mirror radius*—a dimension of the fracture mirror as measured along the original specimen surface. It is defined as the distance from the origin to the first detectable mist.

3.1.6 *fracture surface markings*—features of the fracture surface produced during the fracture event which are useful in determining the origin and the nature of the local stresses that produced the fracture.

3.1.7 *fracture system*—the fracture surfaces that have a common cause or origin.

3.1.8 *terminal velocity*—the uppermost limiting velocity at which a crack can propagate in a material, the approach to which is marked on the fracture generated surface by the presence of mist. The terminal velocity is approximately one half the velocity of sound in the material.

3.1.9 *uniform stress*—a state of stress that does not change within the region of concern.

4. Summary

4.1 This practice is intended to aid in the identification of fracture surface markings as well as to assist in the understanding of their formation and significance.

5. Significance and Use

5.1 Fractography is often used to help identify the events that have resulted in the fracture of a glass object. This practice defines the appearance of various fracture surface features, as well as their method of formation. Thus, there can be a common

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* ~~, Vol 15.02.~~ volume information, refer to the standard's Document Summary page on the ASTM website.

understanding of their relationship to the fracture process as well as a common terminology.

6. Fracture Surface Markings

6.1 *Origin*:

6.1.1 *Identification*—The origin is almost always found at the junction where the fracture-generated surface meets a free surface or a dissimilar material. Commonly, the origin is symmetrically located near the apex of the mirror and it is usually small compared to the mirror. Fig. 1 shows typical origins and mirrors bounded by mist.

6.1.2 *Formation*—The origin represents the single, unique location at which every fracture system begins to form.

6.1.3 *Significance*—The origin defines the location where the fracture began. It may contain the stress concentrator or it may be the stress concentrator.

6.2 *Mist Region*:

6.2.1 *Identification*—Under low power (5 – 50 ×) magnification, it has a misty appearance. Proceeding away from the origin, it becomes more fibrous in appearance and elongated in the direction of crack spread. (See Fig. 2.)

6.2.2 *Formation*—It is produced as the crack front breaks into numerous segments, which then round into one another. Their propagation aborts as the crack front approaches terminal velocity.

6.2.3 *Significance*—It defines the limit of the mirror region and indicates that the crack has nearly reached terminal velocity, or both.

6.3 *Mirror*:

6.3.1 *Identification*—The mirror is a smooth portion of the fracture surface surrounding the origin (see Fig. 2). It is commonly bounded by mist, but mist may not form when the local stress at the fracture front diminishes as the crack extends.

6.3.2 *Formation*—It represents the initial portion of the propagating crack where the velocity is accelerating from the origin to a value sufficient to induce turbulence at the crack front, that is, approaching terminal velocity, where mist and forking may appear.

6.3.3 *Significance*—It is often helpful in locating the origin. The shape defined by the mist boundary is indicative of the uniformity of the stress field at the time of failure, for example; an open mirror, defined by mist only along the original surface, implies bending; a semicircular mirror implies uniform tension: (See Fig. 1) The mirror dimensions may be used to calculate the stress at breakage, because the mirror radius is inversely proportional to the square of the stress at the time the mirror was formed. If the mirror is symmetrical, then use the radius to the mist boundary. To calculate the stress at breakage when the mirror is not symmetrical, the mirror radius is best determined by dividing the mirror diameter by two. A more detailed description of the relationship between the mirror and the breaking strength for various glasses is found on p. 364 of **(1)** and in **(2)** and **(3)**. Further discussion on quantitative fracture analysis techniques is well summarized in **(4)**.

6.4 *Wallner Lines*:

6.4.1 *Identification*—Wallner lines, also called ripple marks, are rib-shaped marks, frequently appearing as a series of curved lines resembling ripples created when an object is dropped into still water. (See Figs. 3-8.)

6.4.2 *Formation*—They are produced when the plane of the propagating crack front is temporarily altered by an elastic pulse.

6.4.3 *Significance*—The direction of local propagation is perpendicular to the Wallner lines; it proceeds from the concave to the convex side of the line. The shape of the line indicates the direction of stresses at various points on the crack front. The more advanced portions of the line generally correspond to regions of higher tension.

6.5 *Wallner Lines, Primary*:

6.5.1 *Identification*—Primary Wallner lines are usually quite distinct and always have their source associated with some discontinuity which was present before fracture. Examples would include bubbles or other inclusions, surface damage or an abrupt

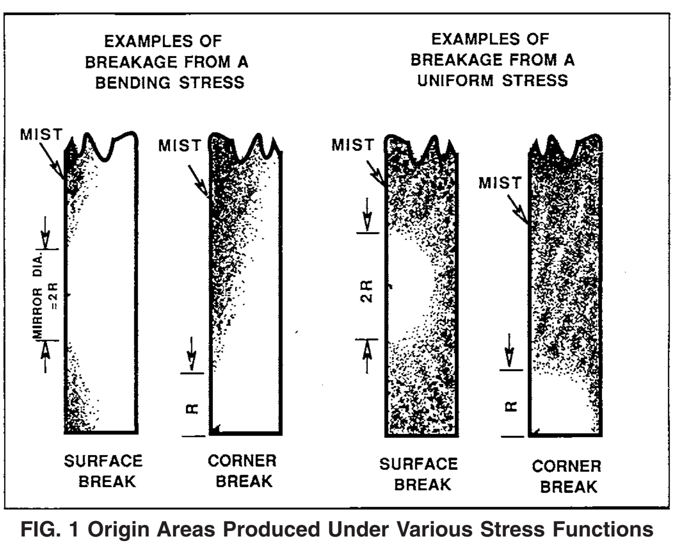


FIG. 1 Origin Areas Produced Under Various Stress Functions and Their Typical Fracture Features

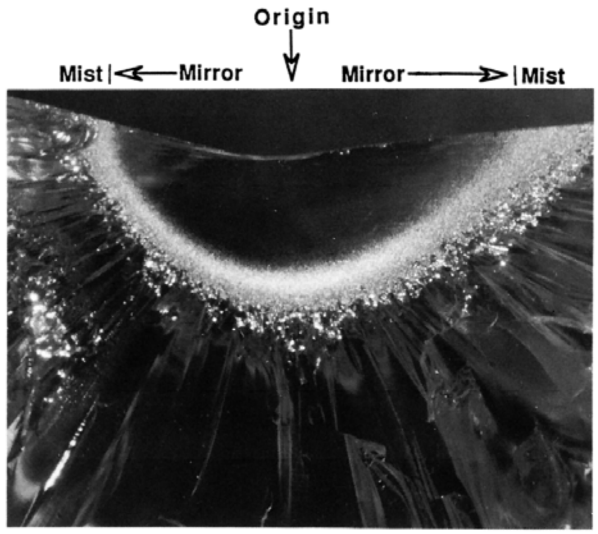


FIG. 2 An Origin Area, with Mirror and Mist

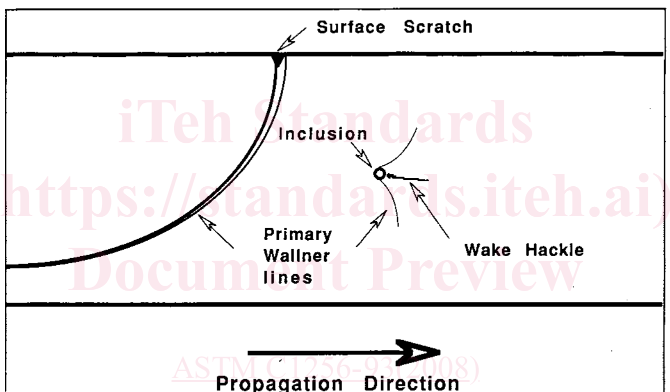


FIG. 3 Primary Wallner Lines Generated From a Surface Nonconformity and an Inclusion

change in surface contour. (See Fig. 3 and Fig. 4.)

6.5.2 *Formation*—They result from the interaction of a propagating crack with an elastic pulse coming from the encounter of the crack front with a preexisting discontinuity.

6.5.3 *Significance*—The convex side is toward the direction of crack propagation. Primary Wallner lines can be used to determine whether a discontinuity was present before or after the breakage occured. In thin glassware, the crack breaking through to the opposite surface will generate a primary Wallner line which indicates the stress distribution at the time of failure.

6.6 *Wallner Lines, Secondary*:

6.6.1 *Identification*—Secondary Wallner lines are fish-hook shaped, numerous and closely spaced. (See Fig. 5 and Fig. 6.)

6.6.2 *Formation*—They result from perturbations of the crack front as it passes through the mist hackle that is produced when the crack approaches terminal velocity.

6.6.3 *Significance*—The convex side points toward the direction of crack propagation. They are indicative of the stress profile at the crack front. In instances where the mist hackle band is quite narrow, they verify its presence.

6.7 *Wallner Lines, Tertiary*:

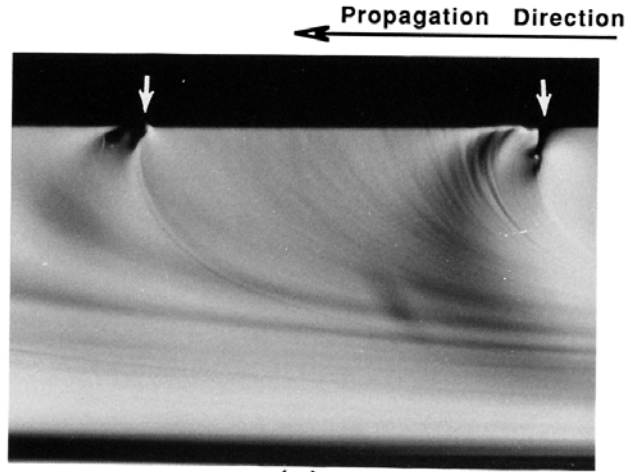
6.7.1 *Identification*—These are a complex set of lines, exhibiting a periodicity and an intensity which may diminish within the pattern. They are neither hook-shaped nor trace to a discontinuity as the source of an elastic pulse. (See Fig. 7 and Fig. 8.)

6.7.2 *Formation*—They result from an interaction at the crack front with sonic waves from an external shock or from stress release at the onset of cracking.

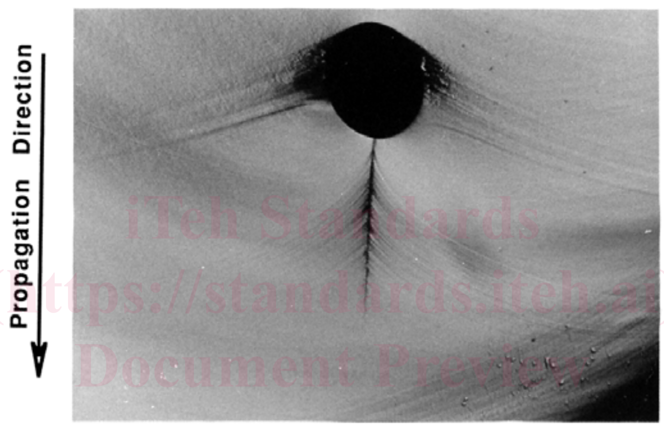
6.7.3 *Significance*—They indicate that the failure resulted from a mechanical shock, where an elastic pulse was generated outside the plane of crack propagation.

6.8 *Dwell Mark*:

6.8.1 *Identification*—Dwell marks, also called arrest lines, have a similar rib-shaped contour to that of Wallner lines but are



(a)



(b)

FIG. 4 Primary Wallner Lines Generated; (a) From Surface Scratches, (b) A Bubble Generating Gull Wings

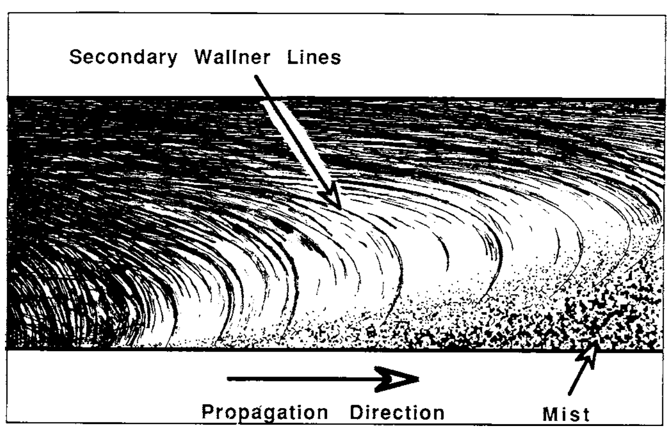


FIG. 5 Secondary Wallner Lines Generated From Mist Formation

distinctly sharper, often exhibiting a noticeable change in fracture plane after the mark and may have twist hackle associated. (See Fig. 9 and Fig. 10.)

6.8.2 *Formation*—They are formed when there is an abrupt change in the direction of the stress field such as when the crack stops and then is restarted by a different stress field.

6.8.3 *Significance*—They indicate that the crack stopped propagation along a given plane and was restarted by a different stress