

TECHNICAL NOTE

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Behavior of Glass at Elevated Temperatures

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ABSTRACT: The author conducted a series of tests to examine the usefulness of crazed glass as an indicator of abnormal fire behavior. Despite widely held beliefs and widely published statements that crazing of glass is a result of exposure to rapidly increasing temperature, the test results show that glass will not craze, except when its temperature is rapidly decreased. A finding of crazed glass in a fire scene has no special meaning regarding the temperatures to which the glass was exposed.

KEYWORDS: forensic science accelerants, crazing, fire investigation, glass

Crazed glass is defined as glass with numerous, tightly spaced random cracks, and crazing is sometimes referred to as checkering or spidering. The left pane in Fig. 1 is a classic example of crazed glass. It is a widely held belief among fire investigators that crazed glass indicates an abnormally rapid increase in temperature. Crazed glass, as physical evidence, can play an important role in fire investigations, especially when other indicators are absent, usually due to the extent of the burning. The presence of clear crazed glass was a major element in the State's case in a recently overturned homicide conviction in Arizona [1]. Discussions of the significance of crazed glass may be found in widely respected fire investigation texts [2,3], and some authors have suggested that, not only does crazing represent a rapid heat build-up, it also suggests that the glass may have been located at or close to the point of origin [4]. One handbook even goes so far as to state that crazing is usually indicative of an accelerated fire or fire that was started with flammable liquids [5].

During a recent study of the multiple fire losses that occurred as a result of the October 20, 1991 fire in Oakland, California, the author noted the presence of crazed glass in 12 of 50 residences examined, even though these residences were known to have been ignited by accidental means. There appeared to have been more crazing of glass found around the edges of fire damaged neighborhoods than in the centers, suggesting that fire suppression efforts may have had a role in causing crazing.

This study was undertaken in order to determine whether crazing could be induced by rapid heating or by rapid cooling.

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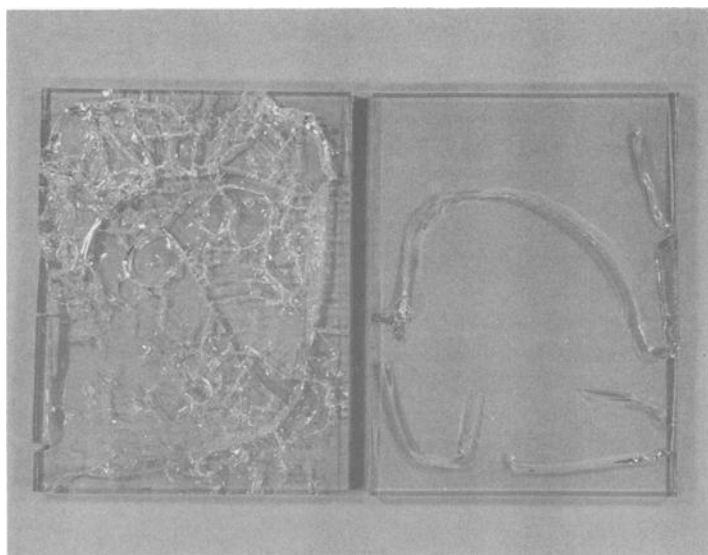


FIG. 1—Panels of 9.27 mm plate glass heated in a propane flame for 5 min. The glass on the left was sprayed with water; the glass on the right cooled naturally.

Experimental Procedure

Four different testing regimes were used. Slow heating in a furnace to 800°C, rapid heating in a furnace to 800°C, exposure to a propane flame at 800 to 1000°C, and rapid heating to 450°C. Various thicknesses of ordinary window glass were used for each test, ranging from 2.16 mm single strength to 9.27 mm ($\frac{3}{8}$ " nominal) plate glass.

Test 1—Slow Heating to 800°C

Four rectangular pieces of glass, measuring approximately 15 by 20 cm, were placed in a Lucifer electric muffle furnace, having a volume of approximately .025 m³, at room temperature. The heating elements were turned on, and the temperature was gradually increased over a period of 2 h to 800°C. The glass panels were positioned between fire bricks, standing on edge at an angle of approximately 80°. After 2 h, all of the test panels had softened and folded over the fire bricks, but no crazing had occurred. The panels on the fire bricks were removed from the furnace, and were observed as they cooled. Several random, irregular cracks appeared in each panel as it cooled, but nothing that could be defined as crazing appeared. A fine mist of water was applied to each panel after approximately 2 min of cooling. Wherever the water hit the glass, crazing was observed to occur. No crazing was observed where water did not hit the glass. The panels were allowed to continue cooling, but no additional crazing occurred.

Test 2—Rapid Heating to 800°C

With the furnace at 800°C, four test panels were placed inside, and allowed to stand for 10 min. Again, the panels softened and began to fold, although the 9.27 mm plate glass bent only slightly. These panels were removed from the furnace and allowed to cool normally. Random, irregular cracking occurred, but no crazing occurred. Selected areas of each panel were sprayed with water, and localized crazing occurred only in those areas where water came into contact with the hot glass.

Test 3—Heating in a Propane Flame

A 40 000 btu/h (168 kcal/min) propane fired burner was used for this test. A stainless steel grid was placed 7.5 cm above the burner, so that the flame caused the steel grid to glow bright cherry red. The flame temperature at the steel grid varied between 800 and 1000°C.

The glass test panels were placed on the steel mesh, and then the propane flame was ignited. This was intended to simulate exposure to an accelerated fire. (The temperature of a well adjusted propane flame has been shown [6] to exceed that of free burning liquid gasoline.) In the first test, a 9.27 mm piece of plate glass was heated for 5 min. No crazing occurred during the heating process. Random cracks appeared upon cooling, but no crazing occurred. When water was applied to the surface of the glass, crazing occurred in exactly those areas that were sprayed with water and those areas only.

The test was repeated using another piece of 9.27 mm plate glass. After heating for 5 min and being allowed to cool, random irregular cracks, but no crazing, appeared. The results of these two tests are shown in Fig. 1.

When 4.70 mm (nominal $\frac{3}{16}$ ") glass was used for this test, explosive cracking of the glass occurred while the glass was being heated. The shards of glass gave the appearance of having been cracked radially due to a mechanical force applied to the center of the panel. Figure 2 shows a broken panel of 4.70 mm glass, which was heated more slowly (grid temperature approximately 550°C) for 5 min, and the pieces were not projected with as much force when the glass fractured. One of the broken pieces of this glass was sprayed with water, and it crazed when it was sprayed.

The 800 to 1000°C test procedure was repeated with 3.18 mm ($\frac{1}{8}$ " nominal or "double strength") glass. After 5 min, the first 3.18 mm test panel was observed to crack on normal cooling, and to craze when exposed to a water spray. Explosive cracking occurred in the next two tests conducted with the 3.18 mm glass. Smaller pieces from one of the exploded panels were heated for five minutes, and crazed when water was sprayed on them. In this test, some of the smaller pieces had started to melt and adhere to the metal grid.

A final flame-exposure test was conducted using single strength (2.16 mm) window

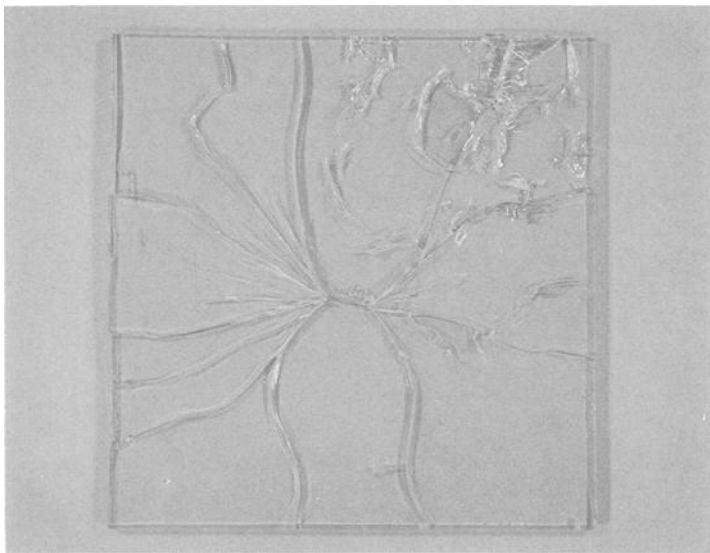


FIG. 2—4.70 mm test panel heated in a cooler (approximately 550°C) propane flame for 5 min prior to exploding weakly. Water was sprayed on the upper right hand corner, causing some crazing.

glass. After 5 min of heating, the first 2.16 mm test panel cracked on cooling, and crazed when sprayed with water. The results of this test are shown in Fig. 3. The second piece of 2.16 mm glass underwent explosive cracking upon heating, in the same manner as the 4.70 mm and 3.18 mm glass. Small broken pieces crazed when sprayed with water. The third test panel of single strength glass gave exactly the same results as the first test panel did, cracking on cooling, and crazing when it was sprayed with water.

Test 4—Heating to Low Fire Temperatures

The furnace was preheated to 450°C². Three test panels, having thicknesses of 2.16 mm (single strength), 3.18 mm ($\frac{1}{8}$ " double strength), and 9.27 mm ($\frac{3}{8}$ " nominal plate glass), were placed in the furnace at an approximately 80° angle. The single-strength glass was removed after 20 min. There was no softening or bending of the glass noted. Contact with the tongs caused localized cracking, and random irregular cracking proceeded as the glass cooled. Crazing was observed to occur when water was sprayed on one section of heated glass. The 3.18 mm glass was removed after 25 min of heating. The same results were noted as those that occurred with the single strength glass. The same results were obtained with the plate glass, which was kept in the furnace for 30 min. The results of this test are shown in Fig. 4.

Discussion

As the temperature of glass is increased, the only type of breaking that is likely to be observed is the explosive cracking, which gives an appearance similar to that of a mechanical fracture with radial cracks. Neither rapid heating nor slow heating in a furnace or with a flame were found to induce crazing under any circumstances.

Crazing could be induced in both rapidly heated glass and slowly heated glass simply

²Although 450°C is well within the normal range for an unaccelerated fire, a final test was conducted to determine the lowest temperature to which the single strength (2.16 mm) glass could be heated, and then craze upon exposure to water. This temperature was determined to be between 250 and 300°C.

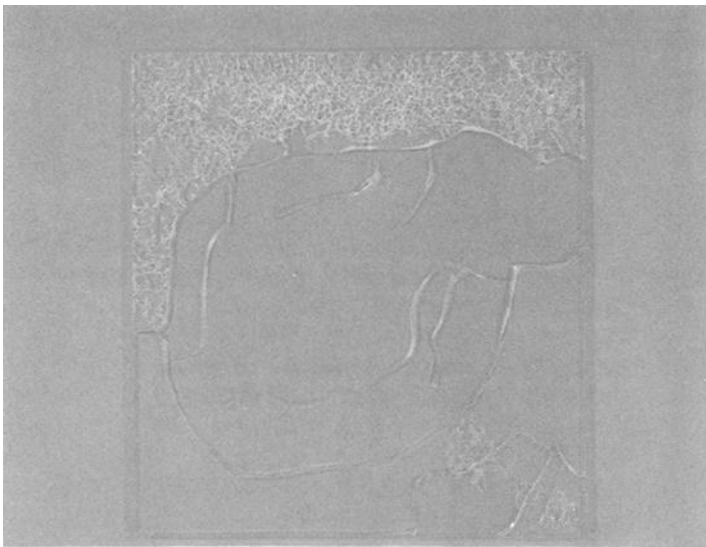


FIG. 3—Single strength (2.16 mm) glass heated in a propane flame for 5 min. The cracks at the bottom are a result of normal cooling. Water was sprayed on the top piece, causing crazing.



FIG. 4—9.27 mm plate glass heated to 450°C for 30 min prior to removal from the furnace. Crazed area was sprayed with water.

by placing water on the surface of the glass. This result was reproducible in 100% of the experiments. The crazing effect was localized with respect to the water, and it was possible for the author to write his initials in crazed glass by applying the water with a cotton swab. In actual fire situations, a piece of hot glass is much more likely to be exposed to a rather uniform mist from a fog nozzle. Nonuniform crazing would still be expected, however, when glass falls into wet grass or snow, or when the suppression water comes from a straight stream or is bounced off surrounding surfaces.

It appears that, despite the numerous references to a rapid heat build-up in the literature, crazing of glass is actually caused by rapid cooling, rather than by rapid heating. Crazing can occur even when the temperature of the glass prior to cooling is well within the "normal" expected range of temperatures for an unaccelerated structure fire.

Because crazing is actually a result of rapid cooling, rather than rapid heating, it is likely to be a much less significant indicator of a fire's behavior than previously thought.

References

- [1] *State of Arizona v. Ray Girdler*, Yavapai County, Case #9809, April 23, 1982 Trial Testimony of David Dale, pp. 1110-1114.
- [2] DeHaan, J. D., *Kirk's Fire Investigation, 3rd Edition*, Brady/Prentice Hall, Englewood Cliffs, NJ, 1991, p. 129.
- [3] Brannigan, Bright & Jason, *Fire Investigation Handbook*, National Bureau of Standards Handbook #134, 1980, p. 5.
- [4] O'Connor, J. J., *Practical Fire and Arson Investigation*, Elsevier Publishing, New York, 1987, p. 94.
- [5] Barracato, J., *Burning, A Guide to Fire Investigation*, Aetna Casualty and Surety Company, Hartford, Connecticut, 1986, p. 4.
- [6] Henderson, R. and Lightsey, G., "Theoretical Combustion Temperature," *National Fire & Arson Report*, Vol. 3, No. 5, 1985, p. 7.

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