J Forensic Sci, Jan. 1975, Vol. 20, No. 1

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Shadowgraphs of Bulbs, Bottles, and Panes

The technique of physical comparison of fragments of glass by the characteristics of their edges or cross sections is well established. As successful as this technique can be, one is still occasionally faced with fragments, the edges of which cannot be fitted. Even though these fragments may have the same physical characteristics, identifications and exclusions are both impossible.

This paper describes a technique for the matching of noncontiguous glass fragments by invisible heterogeneities within them (see Fig. 1). Ream or cord are glassy inclusions whose

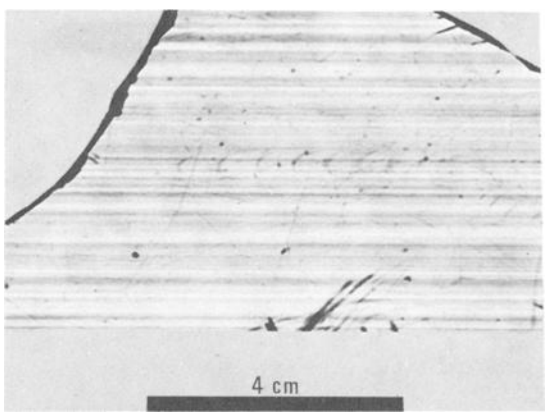

FIG. 1—*A shadowgraph of drawn window glass reveals a variety of ream marks. They may also be present in plate glass and float glass.*

physical and chemical properties differ from those of the surrounding glass. Whenever they are encountered in sheet glass, they are referred to as ream. In the container industry they are called cord.

The production of glass is a complex process filled with many variables. These variables are random in nature and result in ream production. Knight [*1*] made a thorough survey of the various causes of heterogeneities in glass. He states, for instance, that a variation of as little as 1% in silica content would probably cause a serious difficulty with ream. Further, ream may form in the furnace because of poor melting and segregation of the batch. Knight states that silica-rich, low density glass may remain on the surface of the melt and the heavier fractions, rich in soda and lime, may settle toward the bottom. The attack by the melt and vapors on furnace refractories is another source of ream.

Received for publication 1 April 1974; accepted for publication 11 July 1974.

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Apparently ream is always present in drawn window glass, which is produced mile after mile. It is only when ream reaches a certain unacceptable level that production countermeasures are taken. But, despite a wealth of information on the production of ream, it appears that no background information is available on the nature of the change or on the rate of change of these heterogeneities.

The demonstration of ream and cord is accomplished by means of shadowgraphs. These are produced by a point light source that casts a shadow of the sample on photographic film. The basic prinicples of shadowgraph photography have been well explained by Shaftan and Hawley [2].

Experimental

A fiber optics unit was converted to serve as a light source. It has a standard, 250-W projector lamp. A pinhole of 0.8-mm diameter was drilled in a peice of 0.7-mm sheet aluminum. This was attached with double-sided tape to the end of a 16-gauge shotgun cartridge case, as in Fig. 2. The primer had been removed. The cartridge case was slipped

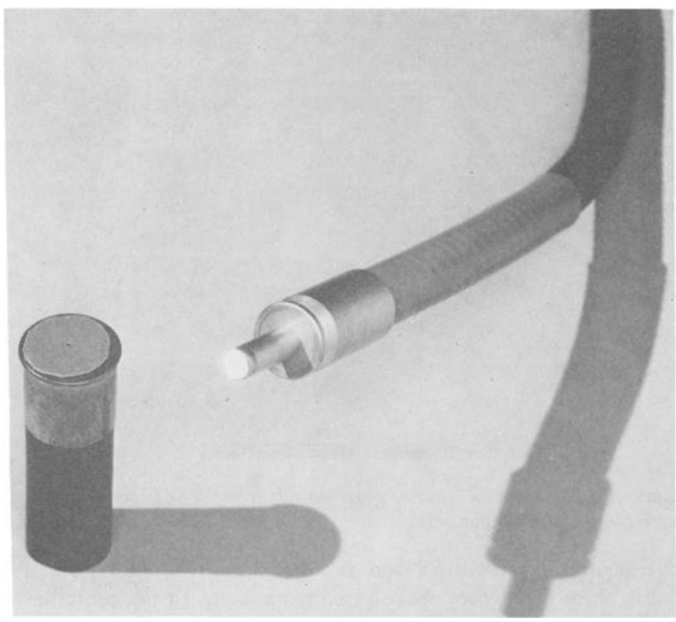

FIG. 2—*The light source consisted of a fiber optics unit with a flexible probe. Attached to the probe was a shotgun cartridge case with a pinhole.*

over the end of the fiber optics probe. A lens shade of black cardboard was attached to the case to narrow the beam of illumination.

A 1.2-m probe was supported from the ceiling and pointed toward the floor (see Fig. 3). The samples were supported by laboratory stands that allowed the sample-to-floor distance to vary between 8 and 90 cm. As the ream in some materials cannot be seen by the human eye, arbitrary distances had to be chosen at first. Only after the film was developed and evaluated could a more satisfactory distance be selected which would result in the ream

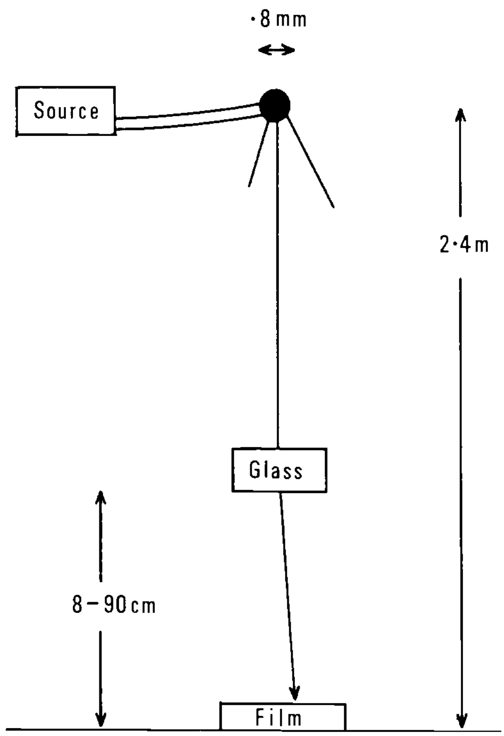

FIG. 3—*The shadowgraphs are produced by projecting a glass onto film with a point light source.*

being well defined. The advantage of the vertical arrangement was that it permitted the examination of many small fragments of glass at the same time by supporting them on a larger sheet of glass. The support sheet had to be free of any ream. A number of float glasses were tried but all showed many heterogeneities. A sheet of glass of unknown origin, which was found to be ream free, was eventually used. Custom melting a support glass would be an alternative. The film was placed in an enlarging easel on the floor.

Preliminary experiments showed that it was possible and desirable to increase the sensitivity for fine detail far beyond that of the human eye by using a high contrast recording media. The whole system was therefore designed to extend contrast to its limit. The film used was 8 by 10-in. Kodalith Ortho®. The exposures ranged from 5 to 20 s. The film was developed in DK-50®, a continuous tone developer. This permitted the recording of many gray tones while still retaining most of the inherent contrast of the film.

To obtain even development, the film had to be developed in a tray with continuous brush agitation. The brush was a 3.7-cm artist brush, Grumbacher Series 6661. Tank or continuous tray development resulted in uneven densities in the film, many of which did not reveal themselves until the films had been contact printed. These distortions may interfere with the heterogeneities in the material. To increase the contrast even further, the films were contact printed on Afga Brovira enlarging paper Nos. 5 and 6.

Initially, a fiber optics unit was not available so an alternative was designed. It consisted of a vertical setup that was somewhat more convenient. Unfortunately, it was not as sensitive and required more space. The setup was a Mona Lamp from Leitz; the condenser lens was removed and the diaphragm reattached. Therefore, the point light source was the approximately 2-mm-square filament, the beam of which had been restricted by a small diaphragm opening. The source-to-film distance was 6.2 m. All sheets of glass larger than 40 by 40 cm were examined with this source.

Results and Discussion

A series of exploratory shadowgraphs was obtained with sheet glass samples from our collection. They varied in size from a few square centimetres to 63 by 66 cm. Drawn glass, float glass, and plate glass were all sampled. The glass of spectroscopic plates and microscope slide cover glasses were also tested. They all showed ream in considerable variety. The individual ream marks varied from a fraction of a millimetre to several millimetres in width.

To use ream for the comparison of noncontiguous fragments, it is necessary to know what types of individual ream marks can be encountered in glass and how much they change over a given distance. To answer these questions, four sheets of 48 cm by 70 cm by 6.2 mm of drawn window glass were obtained from one kiln from a Canadian Pittsburgh plant. Each sheet was separated from the next by 1.4 m during the manufacturing process. Shadowgraphs were prepared from these sheets and cut into strips and lettered. Each strip represented an approximately 1.8-cm-wide piece of glass. The changes in the ream marks over four distances were then observed. These changes were in width, length, direction, division, and darkness. Comparisons were made between strips representing glass at the following four distances: 1.8, 13, 70, and 140 cm.

At the 1.8-cm distance (Fig. 4), 21 strips were compared. It was found that the most frequent change was a change in length of ream mark. This meant that either a new ream mark had been "born" or an existing one had faded away. The least frequent change was the division of one ream mark into two or the combining of two into one. Approximately 90% of the ream marks remained stable over the 1.8-cm distance.

Twelve strips were compared at the 13-cm distance (Fig. 5). It was found that the majority of ream marks had changed. Only approximately 33% remained stable.

The comparison of ream marks at 70 cm (Fig. 6) shows the two extreme edges of one sheet of glass. This was done for all four sheets and it was found that only approximately 10% of the ream marks had survived over that distance. Their intensity or width or both may also have changed in the process. It was not possible to match any ream at the 140-cm distance. Figure 7 illustrates the percent change over the four distances.

Three simulated cases were examined blind. Each consisted of one unknown piece of broken glass that was to be compared with a number of controls. In two of the cases no match was found. This, of course, did not mean that the samples were necessarily from different sources. They could have come from either side of the unknown and therefore would not share some of the same ream marks. In fact, the standards did come from different sheets of the unknowns. In the third case, a correct positive match was found (Fig. 8). The two fragments that were matched by their ream marks were approximately 2.5 cm by 3.7 cm by 3 mm each. Both had more than 15 ream marks. Five ream marks on the unknown could not be matched to the marks on the control. The separation between the fragments was suggested as being less than 30 cm, which proved to be correct.

To determine whether or not refractive index measurements would differentiate between areas in the glass that had dark and light ream marks, three samples of each were removed from the surface of one sheet of glass. The refractive index was measured with the Mettler hot stage and oil immersion. The results for the dark lines were 1.51694, 1.51697, and

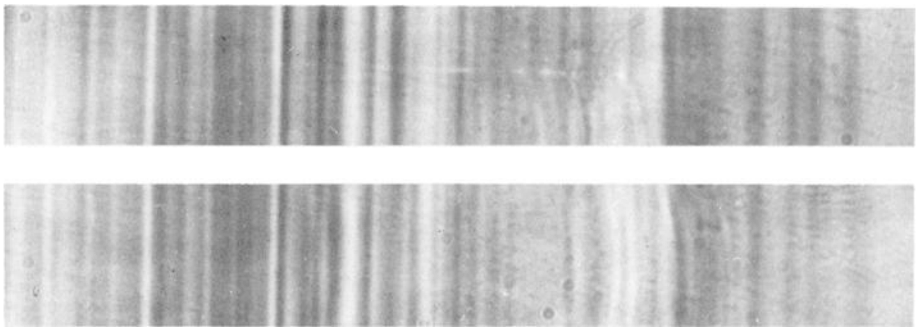

FIG. 4—*Comparison of ream marks that are separated by 1.8 cm.*

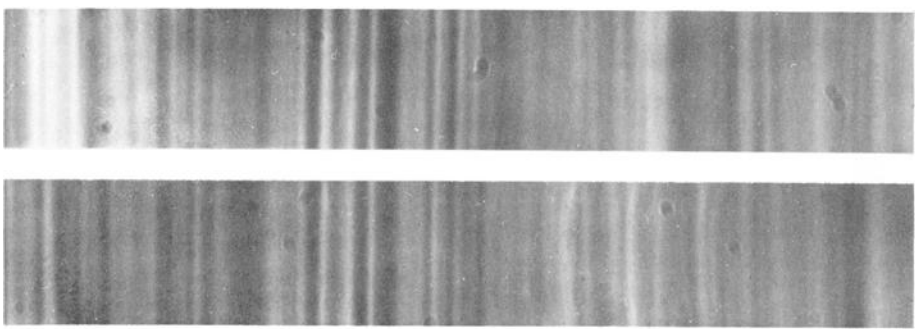

FIG. 5—*Comparison of ream marks that are separated by 13 cm.*

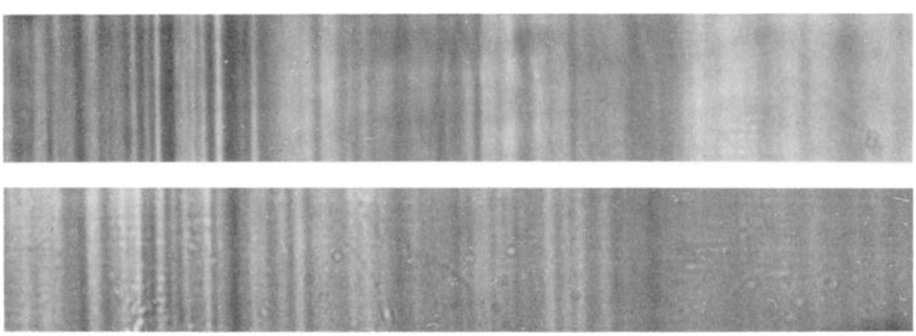

FIG. 6—*Comparison of ream marks that are separated by 70 cm.*

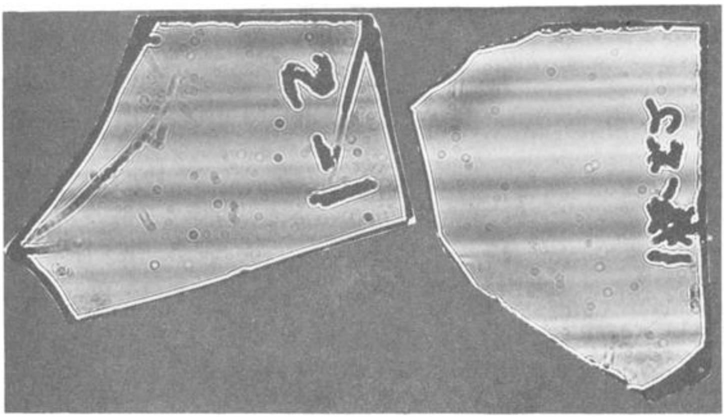

FIG. 8—*Two noncontiguous glass fragments. A high proportion of their ream marks correspond.*

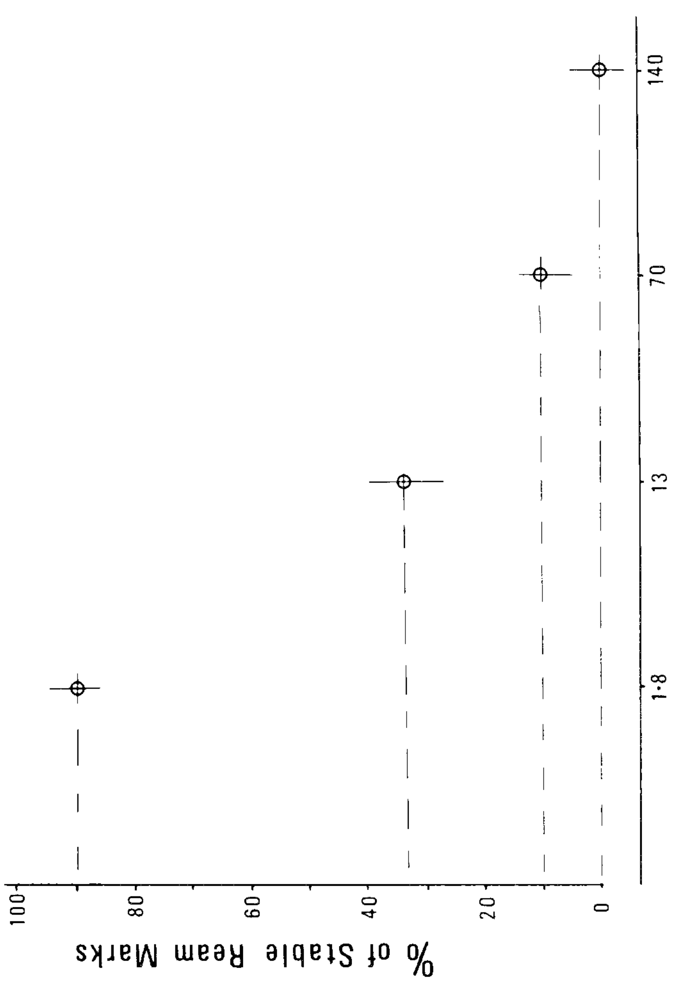

FIG. 7—*Percent change of ream marks over 1.8, 13, 70, and 140 cm.*

1.51699, and for the light lines were 1.51699, 1.51699, and 1.51694. The dark ream marks therefore could not be differentiated from the light.

Exploratory work was also done with some other materials.

Bottles

Fourteen glass bottles were examined for cord. These included beer, wine, and liquor bottles from North America and Europe. Cord was present in all of them. The shadowgraph in Fig. 9 shows the cord pattern in a Portuguese port bottle. Variations of these patterns were found in the other bottles.

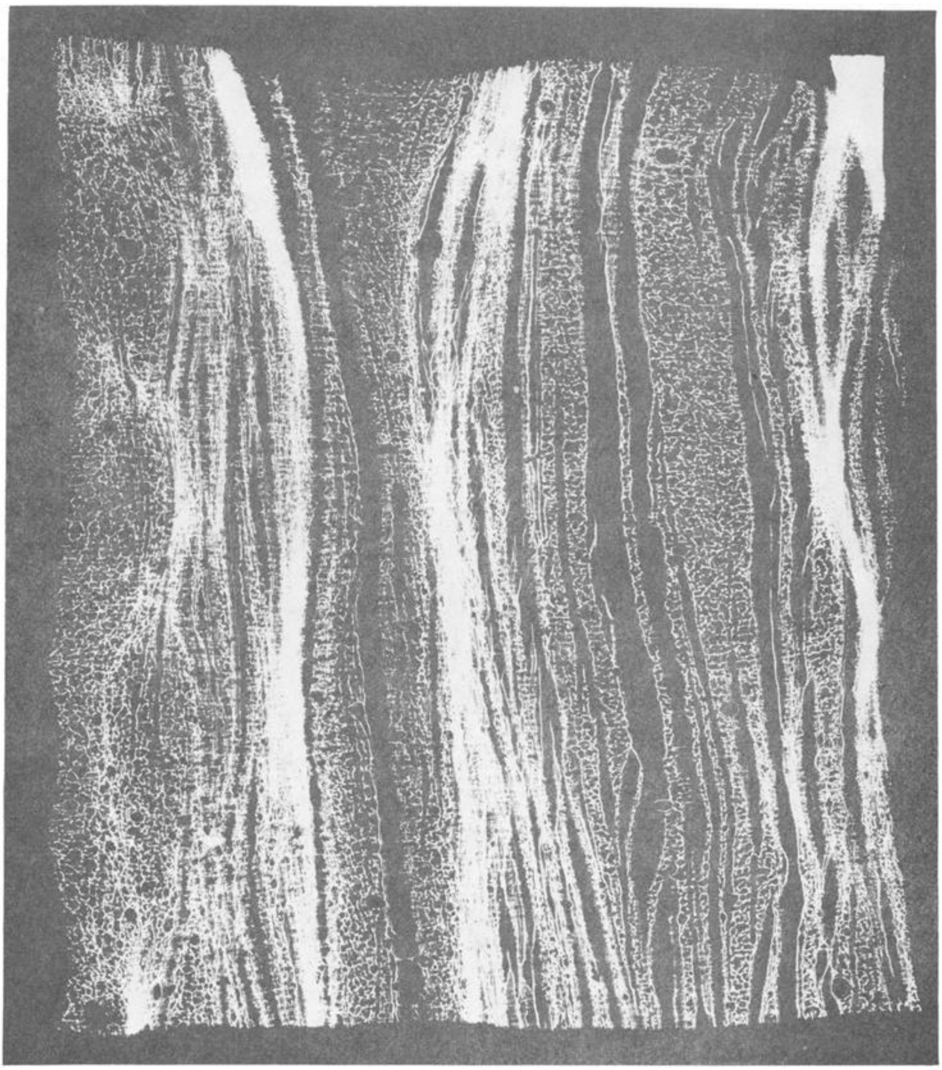

FIG. 9—*The cord pattern in the side of a port bottle.*

Plastics

Six transparent samples that were freely available were shadowgraphed. Saran Wrap® had no marks at all. The other five samples had a variety of marks. Two samples of clear cellulose tape had distinctly different patterns. A yellow Wratten filter, No. 6, had a profusion of fine marks, as shown in Fig. 10. A clear cellulose acetate container had well-defined directional marks. One bag of a roll of Quikki® sandwich bags (Fig. 11) showed many fine lines, the origin and variation of which may well be worth investigating.

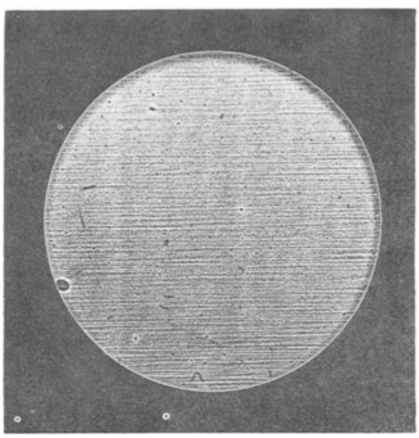

FIG. 10—*The marks in a Wratten No. 6 gelatin filter.*

FIG. 11—*The marks in a plastic sandwich bag run parallel to the edge of the roll.*

Automotive Bulbs

Five replacement bulbs, each of a different shape and size, were obtained from the General Electric Co. Figure 12 shows the side of one of them. Figure 13 shows three fragments of another bulb. It reveals a pattern that is common to all three fragments.

Conclusion

It has been shown with a limited number of tests that shadowgraphs of drawn sheet glass may reveal a sufficient number of ream marks to permit a physical comparison. It has also been shown that the width and intensity of these marks vary greatly. Further, individual marks appear to persist in a sheet for only 50 to 100 cm. In addition, taking all the variables during glassmaking into consideration, common sense would suggest that the formation of a single ream mark is left to chance. Finally, it would appear that the position of a ream mark in a group of other ream marks is left to chance.

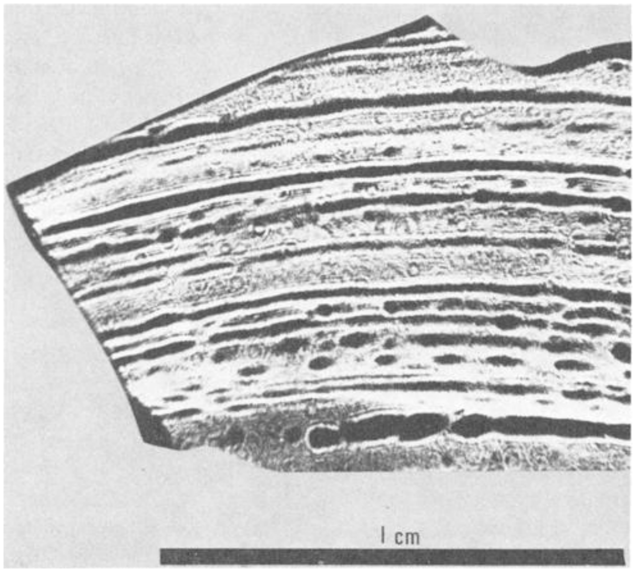

FIG. 12—*The marks in a glass fragment from an automotive light bulb, enlarged by inserting a double-convex lens between the light source and the fragment.*

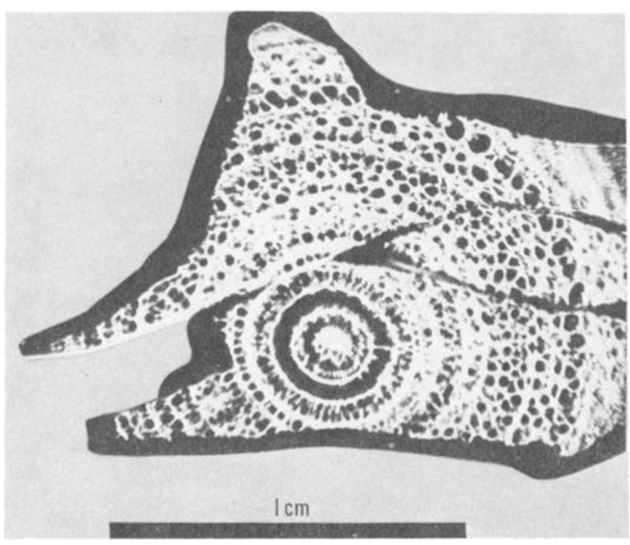

FIG. 13—*Three glass fragments from one automotive light bulb are related to each other by a pattern common to all three.*

It is therefore suggested that ream can be used for an identification in forensic science. Glass fragments can be related by their heterogeneous inclusions, even when they are separated by several centimetres, as shown in Fig. 14. There are, of course, limitations to this technique. The small fragment in the center of Fig. 14 could not be compared with the two large fragments if the ream ran in a vertical direction.

The minimum size for a fragment to be compared is governed by the number of ream marks. In ideal circumstances, the minimum size is about 1 cm square. The small fragment shown in Fig. 14 is approximately 2.5 cm long.

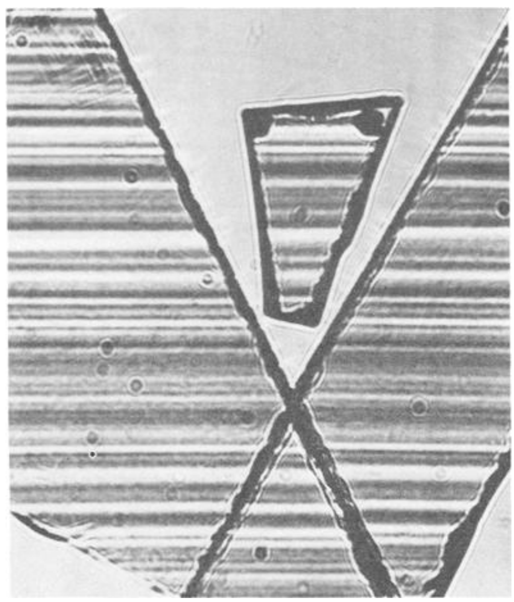

FIG. 14—*Ream marks establish a relationship between noncontiguous glass fragments.*

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