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GLASS FRAGMENTS AS EVIDENCE

A Comparative Study of Physical Properties*

Lucy Gamble, David Q. Burd, and Paul L. Kirk†

Bits of broken glass are so commonly encountered in the investigation of crime as to be considered of major importance as evidence. Not only is this true in traffic accidents, hit-run offenses and so forth, in which headlight and spectacles lenses and perhaps windshields or windows may be broken, but also in a large proportion of burglaries and other similar offenses in which entry may be gained by the breaking of windows. Due to the almost invariable widespread distribution of minute fragments formed at the moment of breaking, it is usually unavoidable that the person breaking a window will collect and retain in his clothing a considerable number of these fragments. Less common, but still important, is the collection of glass on shoes and pants cuffs from walking over areas where considerable glass is lying.

Some investigators prefer to subject bits of glass to spectrographic examination for comparison purposes. This is undoubtedly an effective procedure for determining qualitative and approximate quantitative similarities or differences in glass samples, in the hands of a properly skilled spectrographer. However, it requires a considerable amount of expensive equipment, and is subject to greater uncertainty than is the examination of many other types of evidence, due to the inherent difficulties of generating a proper and reproducible light emission from a small glass fragment. In contrast to the spectrographic examination, the comparison of physical properties is not materially slower; requires much less experience; no elaborate or particularly costly equipment; and is, we believe, of equal validity. This follows from the examination of tables of constants of silicates in such publications as that of Winchell (1) and Wright (2) who have shown exact correlation between composition of the glass and certain of its physical properties.

The excellent discussion of glass fragments by Tryhorn (3) considers the physical properties of glass as well as the effects of weathering, color, hardness, form, fractures, and other properties which may be examined. As he points out, only an exact fit of two pieces of glass is conclusive proof of a common origin. He does not stress the fact that identity of physical properties is virtual proof of chemical identity, which follows from the data compiled by Winchell, showing unequivocably that glasses of qualitatively different composition usually fall in completely different ranges of refractive index, specific gravity, and dispersion, and that within a series of glasses of the same qualitative type, variations in the

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ratios of the constituents give rise to corresponding variations in these properties. Composition changes can be balanced in such a way as to reproduce any particular physical property, but in so doing, other properties must be thrown out of balance, and complete identity is not found.

Tryhorn correctly states that identity of glass as based on its properties is inherently a matter of probability rather than conclusive proof, but he does not present actual data to establish the magnitude of the probability factors concerned with any of the specific types of examination. Morris (4) has reported that of 65 samples of glass examined, all were distinguishable on the basis of refractive index, specific gravity, and appearance under polarized light. He also presented no data in the publication, nor did Donovan (5) who published limited studies on identification of glass splinters.

Without collecting very extensive or complete data on manufacturing practices, batch variations, and distributions of the glass manufactured to each specific formula, it cannot be decided from available figures what is the probability of two glasses from different sources being identical with respect to any or all of these physical properties (and corresponding chemical composition).

In this paper is reported a study of a simpler type designed to yield an approximate answer to this question, and to give some quantitative idea of the value of evidence based on the determination of physical properties of a sample of glass involved as evidence in a criminal trial. At the present time it is not practical to attempt the absolute determination of dispersion of small and irregular fragments of glass. For this reason, this study is confined to determination and comparison of the refractive index and specific gravity of 100 samples of glass, collected at random, taking care that none of them are accidentally duplicated in the collection. The type of source is known in most cases, e.g., window, bottle, etc., but not the absolute source, the manufacturer, or the formula. This procedure is valid because the similar collection by a burglar, or from street accidents would have exactly the same degree of randomness.

The data of this paper are designed to supplement the otherwise excellent studies of Tryhorn and of Morris, and to determine approximately the significance of the refractive index and specific gravity comparisons in establishing identity of glass fragments. Similar studies on a larger scale might profitably be made on these properties and on others listed by Tryhorn.

EXPERIMENTAL

Refractive index. The well known immersion method (Becke line) described by Winchell (1), Chamot and Mason (6), and others was followed with certain variations. The immersion media were made from selected quantities of methylene iodide, α-chlornaphthalene, "cellosolve", and nitrobenzene. A large number of standards was prepared, each of which varied from the adjoining members of the series by as small an amount as was practical, i.e., about 0.001. Each standard was then carefully calibrated with an Abbé type refractometer which measured to 4 significant decimals.

All glass samples were immersed in appropriate media and the refractive indices determined with respect to the closest immersion medium. It was thus possible to determine a relative index to about $\pm$ 0.0005, it being understood that variations in temperature, evaporation during measurement, and similar factors prevent an absolute accuracy to this value. Some of the measurements were made with a sodium vapor lamp and some in white light. It was found that comparative results were as accurate in the one case as in the other, though it is recognized that the expression of absolute values would require a definition of the wave length used, due to dispersion effects.

Having arranged all glasses in a series with respect to their refractive indices, it remained to check comparatively all of those pairs or groups of glass samples which were close together and therefore either identical or subject to confusion. Comparisons were carried out by immersing one of the questioned fragments in the closest standard medium, observing its shape and appearance carefully, then adding to the same drop a fragment of the other glass being compared. The pieces were manipulated so that their edges actually overlapped at some one point. Thus, the movement of the Becke lines could be compared up to the actual point of overlapping, ensuring against any effect from local variations in the medium. The refractive index of the immersion drop was then varied up and down with respect to that of the fragment by adding small amounts of media of slightly lower or higher index. After each such addition the comparative behavior of the Becke lines was observed. If any detectable differences existed between the two samples, it could be ascertained with a degree of certainty at least ten times as great as an absolute index value could be determined.

Specific gravity. The determination of absolute and relative specific gravity of the various glass samples was made by the technique described by Kirk and Russel. (7) Methylene iodide and chloroform were mixed in a small test tube or shell vial to give a medium in which a glass sample would neither settle nor rise to the top. The specific gravity of the liquid was then determined by weighing a sample of it in a micropycnometer. After grading all glass samples in a similar manner to that employed for absolute refractive index values, all of the samples which had values close to each other were carefully compared by immersing two fragments from different sources in a larger quantity of the same liquid

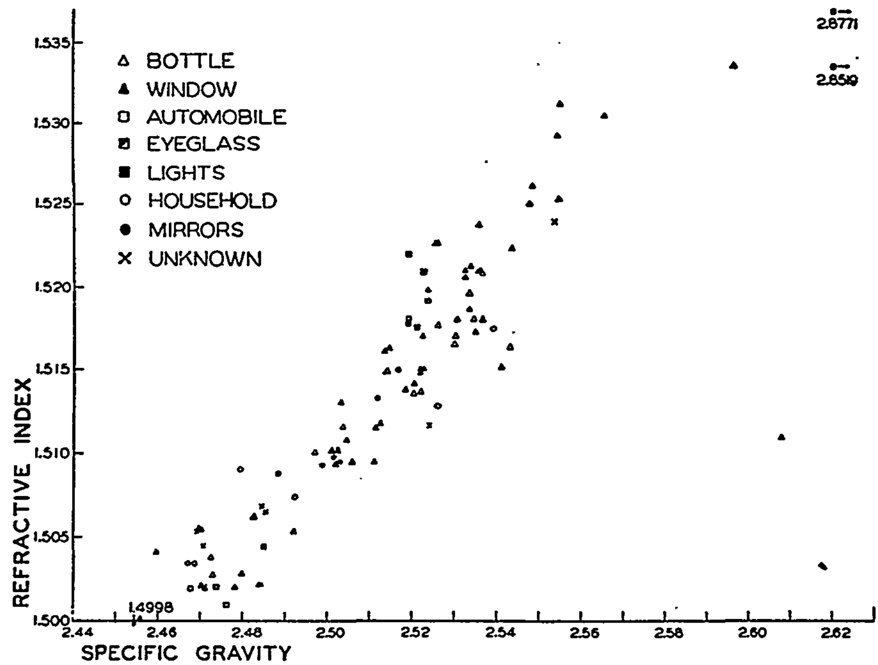

Figure 1

and ascertaining whether any possible mixture would allow one to rise while the other one sank. Use of larger volumes ensured smaller changes after a small addition. Thus, the relative specific gravities could be determined with far greater accuracy than the absolute value could be measured.

RESULTS

The results of the study of the refractive index and specific gravity of the 100 samples of glass are shown as a chart in Fig. 1. This chart is made in a manner similar to a graph, not in order to relate the properties listed along the coordinates, but rather to show the differences between the glasses studied. Each point gives the values for refractive index and specific gravity of a single glass sample. If any two glasses were identical, the two points would coincide. It is immediately apparent that each glass studied was distinguishable from all others, even though there is a definite parallelism between the two properties. Thus, two glasses having different values of refractive index would be expected on the average, to show differences of the same sign in specific gravity. This is only true in the statistical sense, since the sign of the change may be reversed, and there is no proportionality between the values in any instance.

The refractive index values found ranged from a minimum of 1.469 to a maximum of 1.566. This range is decidedly more narrow than the over-all range given by Winchell, as would be expected because of the omission of unusual types of glass, such as the high index optical glasses and the natural glasses. The lower limit of the range was somewhat under that of Winchell, presumably because of alterations in methods of manufacture and composition since the data there compiled were determined. The difference between maximum and minimum values was 0.097, but 88 of the glass samples fell within the narrow range of only 0.0265. It is an interesting and unexpected fact that refractive index comparison alone was sufficient to distinguish every single glass sample studied from every other one. In ten instances, pairs of samples were so close that only the most careful observations were sufficient to distinguish them. One set of three and one set of four glasses were likewise very difficult to distinguish.

Values for the specific gravity ranged from 2.2447 to 3.1278, a difference of 0.8831. This range was also much narrower than that of Winchell, for the same reasons that apply to the refractive index. In spite of the rather broad over-all range, 96 samples fell in the much narrower range of 0.4877. Specific gravity was not as valuable in distinguishing glass samples as was the refractive index. In all, five pairs of samples and the members of one set of three samples could not be distinguished while the samples in two additional pairs, three sets of three and two sets of four were only distinguishable with difficulty. All of these glasses had different refractive indices, some of the differences being quite large (up to 0.028). The combination of properties gave very clean-cut and definite distinctions between all of the 100 glass samples, even in those cases in which one or the other property was close or identical.

It is a well known fact among those who are familiar with glass manufacture, that not only do successive batches made to the same formula show variations due to imperfect measurements and other variations, but also, different parts of the same batch may vary in composition and physical properties. These effects arise from a variety of causes:

(a) Solution of material from the crucible by the melt. This factor is a function of the age and previous history of the crucible and its construction material.

(b) Volatility of constituents of the melt. This tends to affect the surface portion of the melt disproportionately.

(c) Inadequacy of stirring and mixing of the melt due to its high temperature and viscocity.

(d) Local variations in the crucible due to inadequate original mixing of the constituents of the furnace charge.

(e) Variations in heating or other conditions due to inadequate factory control.

Consideration of these factors, which are so important in precise manufacture, such as that of optical glass, inevitably lead to the conclusion that not only different batches would be expected to show different physical properties, but that different portions of the same batch might show such variations, and indeed that different portions of the same glass object might show variations from point to point. In order to test this possibility, widely different portions of twenty large pieces of glass (windows, large bottles, etc.) were compared. In one case only, there was found a slight but detectable difference in refractive index. This was of the same order as shown by the few very close samples quoted earlier. It is tentatively concluded from this observation, that minute differences in refractive index may not always mean that the glass is from a different source. Comparison should then be made with other portions of the standard, and other physical properties checked whenever such small differences are observed. It is desirable to determine as many physical properties as possible before drawing final conclusions about any two samples of glass which are very similar, as was pointed out by Tryhorn. The implications of his statements, however, would tend to underrate the value of physical properties as a means of establishing chemical identity or non-identity of glass fragments, as shown in this paper and that of Morris. It is not possible as yet to establish an absolute probability factor in the use of either refractive index or specific gravity, or for that matter, any other physical property. The indications are, however, that these two factors alone are nearly always sufficient to establish lack of identity of different samples, and that identity can be established with a high degree of probability, but not absolute certainty.

SUMMARY

One hundred samples of glass, collected at random were compared as to their refractive index and specific gravity. All of them were definitely distinguishable on the basis of these properties alone.

All of the samples could be distinguished on the basis of refractive index alone, but in a few cases the differences were not larger than might occur at times as local variations due to manufacturing imperfections.

Most, but not all samples could be distinguished from the others on the basis of specific gravity comparisons. In no case were both the refractive index and specific gravity of two samples so close as to lead to possible confusion.

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