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Value of Glass as Evidence

Comparison of glass by the forensic scientist is commonly effected through the study of physical properties. Of the methods available, those involving direct comparison of density, refractive index, and dispersion are the most widely used because of their convenience and applicability to small sample sizes.

If the comparison result shows a significant difference in one of the physical properties studied, it can be safely concluded that the two glasses could not have had a common origin. However, when the glasses are not distinguishable through the properties studied, the criminalist is confronted with the problem of assessing his results in relation to their value as evidence. In this assessment he is at a great disadvantage if he does not know the probability of chance occurrence of the kind of glass involved as reflected by the properties studied.

The subject of this paper is to discuss the generation of frequency of occurrence data using a modified version of a thermal gradient described by Fong [*1*] and the application of this data toward interpreting glass density in relation to its value as evidence.

Method and Apparatus

A two-step approach was used. The first step involved classifying each of the glasses selected for study into a well defined density range within a series of incrementally increasing density ranges. The second step involved the further differentiation of glasses falling within each range in the series of ranges by flotation in a thermally generated density gradient.

A series of eight liquids was prepared, each in a volume in excess of 100 ml and ranging in density from 2.4570 to 2.5550 in uniformly increasing steps of 0.010.

The method for preparation is illustrated by the following example in which the liquids dibromomethane (D = 2.4921) and tetrabromoethane (D = 2.9672) are used as components to achieve a desired liquid density of 2.5500.

Assuming the use of 100 ml of dibromomethane, the approximate volume of tetrabromoethane (V_2) necessary to add is calculated from:

$$2.5500 = \frac{100 \times 2.4921 + V_2 \times 2.9672}{100 + V_2}$$

$$V_2 = 14 \text{ ml}$$

The density relative to water of the liquid mixture is determined pycnometrically. A tared pycnometer is used and its weight when filled with water determined at a known

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temperature. The desired weight of the liquid mixture for any desired density can then be calculated. For the pycnometer used in this study the weight of water at 22°C was found to be 24.0070 g. The weight of a liquid mixed to achieve a density of 2.5500 would then be 61.2178 g. If the weight determined departs from this value, adjustments are made based on the pervious considerations. When it is desired to lower the density, bromobenzene (D = 1.4960) can be used.

Rapid classification of glass into specified ranges can now be accomplished with a set of pre-prepared liquids. The liquids in separate containers are arranged in order of increasing density. A fragment of glass approximately ¼-in. in its largest dimension is placed into a Pasteur pipet and the pipet fitted with a rubber bulb. The pipet is inserted into the bottle containing the lowest density liquid, the liquid drawn up, and an observation as to whether the glass sinks or floats is made. If it sinks the liquid is expelled into its original container and the procedure performed repetitively and in progression until a liquid is found that floats the glass. The sink-float range of the glass is then recorded.

Fifty-two glasses acquired as comparison window glass from case work were classified into class intervals in the manner described in less than 1½ h. This rapid determination took place at ambient temperature which was 21.5°C. The greatest number of the glasses were from business establishments. Tinted glass was excluded. The density frequency distribution of the glasses studied is represented geometrically by Fig. 1. The distribution is approximately bimodal.

Glasses falling into the same class interval were then submitted to further differentiation utilizing a thermal apparatus for developing a linear density gradient.

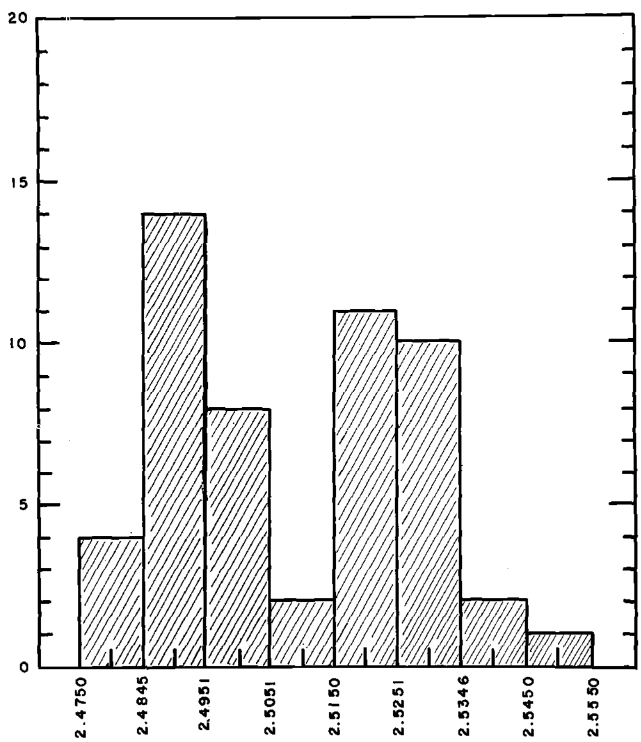

FIG. 1—*Distribution of 52 glasses by class interval.*

The apparatus is illustrated in Fig. 2. The article previously cited [1] should be read for details. The temperature conditions under which maximum sensitivity occurs were determined by using three standards which differed successively in equal increments of 0.0049. Figure 3 shows compression caused by a temperature setting which was too high. Adjustment of the thermal regulator to achieve a temperature difference of 2°C resulted in the range of density difference as shown in Fig. 4. The bottom end of the tube was immersed through a cork stopper into a small vessel containing methyl alcohol. A ⅛-in. slit was cut into the stopper to allow evaporation of the alcohol. This arrangement assures that the temperature at the lower end of the tube is very close to 20°C if ambient temperature happens to be higher than approximately 22°C. All tube portions of the apparatus were insulated with a styrofoam jacket. The jacket surrounding the gradient tube was removed when level readings were made.

The density distribution of glasses falling in the same range was determined by filling the gradient tube with the high density liquid of the range being studied. The thermal apparatus, preset to achieve the desired sensitivity, was then turned on and the gradient tube allowed to come to equilibrium. This takes place in approximately 20 min. The glasses, identified by number, are then dropped one at a time into the tube and their final levels of descent are recorded on a scale.

The distribution of all glasses by groups in each class interval is given in Table 1. The density values listed are calculated from levels of final descent relative to each other for all glasses in each class interval. Thus, the values have high relative validity, but low absolute validity.

Groups within a class are indicated in Table 1 by single space for those glasses falling within a group, while a double space indicates group separation. A group is counted when it is distinguished from another group by a density variance of 0.0003. This threshold level for distinction was arrived at by determining the variation of fragments from a single

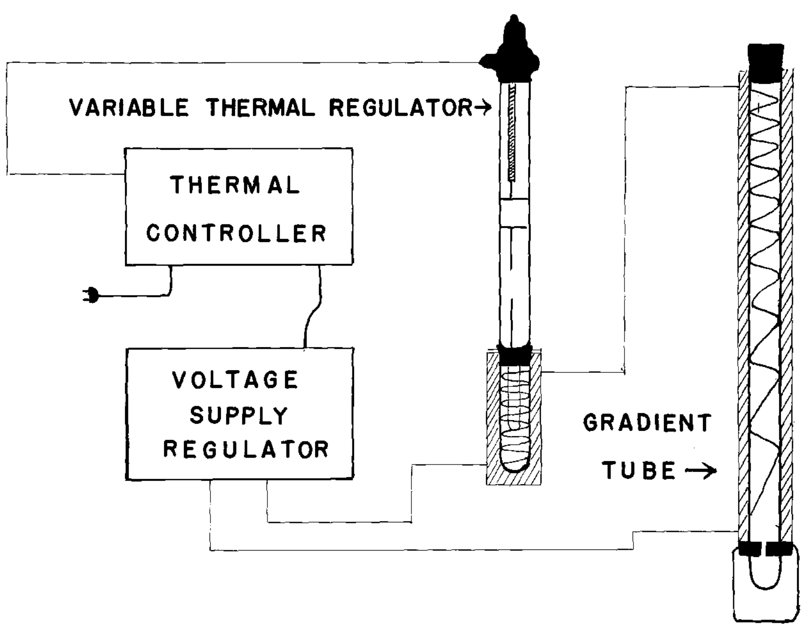

FIG. 2—*Schematic diagram of thermal gradient apparatus.*

FIG. 3 (*left*)—*Compression caused by 5° temperature difference.*

FIG. 4 (*right*)—*Maximum sensitivity resulting from temperature 2° temperature difference; gradient characteristics:* $\Delta 0.1'' = \Delta 0.02°C = \Delta 0.0001$ *D.*

source. This variation was never found to exceed a linear distance of 0.3 in., equivalent to 0.0003 density, for three glass sources selected from three different classes. Eight glasses, each approximately ⅛-in. in its largest dimension, were examined from each selected source.

Discussion

Table 1 shows that 23 of 52 glasses (44 percent) were in groups of one and could be distinguished from all others. The other 29 samples were in ten groups. The largest had five members. As the number of glasses is increased, the fraction of glasses in groups of one would be expected to decrease.

A chi square test of the null hypothesis that the average number of glass samples per group in each class is the same as the average number of samples per group of 52/33 = 1.575 found in this study was performed. A chi square of 3.9158 was obtained for seven

TABLE 1—*Density distribution of 52 glasses studied by groups in each class interval.*

Class Interval in Density	Glass No.	Relative Density By Group
2.4750–2.4845	1	2.4821
	2	2.4830
	3	2.4831
	4	2.4832
2.4845–2.4951	5	2.4882
	6	2.4883
	7	2.4883
	8	2.4885
	9	2.4885
	10	2.4899
	11	2.4902
	12	2.4903
	13	2.4942
	14	2.4943
	15	2.4944
	16	2.4947
	17	2.4948
	18	2.4949
2.4951–2.5051	19	2.4972
	20	2.4985
	21	2.4990
	22	2.4995
	23	2.4996
	24	2.5002
	25	2.5016
	26	2.5019
2.5051–2.5150	27	2.5088
	28	2.5115
2.5150–2.5251	29	2.5151
	30	2.5184
	31	2.5200
	32	2.5206
	33	2.5213
	34	2.5215
	35	2.5236
	36	2.5249
	37	2.5250
	38	2.5251
	39	2.5254
2.5251–2.5346	40	2.5259
	41	2.5288
	42	2.5294
	43	2.5294
	44	2.5296
	45	2.5301
	46	2.5301
	47	2.5303
	48	2.5310
	49	2.5342
2.5346–2.5450	50	2.5358
	51	2.5409
2.5450–2.5550	52	2.5450(+)

degrees of freedom. The value is equivalent to a 79 percent confidence level that the hypothesis stated is true.

An estimation of the probability that two glass samples chosen at random from the total of 52 studied would be indistinguishable was performed based upon the following:

$$\text{There are } \begin{Bmatrix} 23 \\ 3 \\ 6 \\ 0 \\ 1 \end{Bmatrix} \text{ groups of } \begin{Bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{Bmatrix} \text{ having } \begin{Bmatrix} 23 \\ 6 \\ 18 \\ 0 \\ \underline{5} \end{Bmatrix} \text{ members}$$
$$52$$

If the first sample is taken at random, there is:

a. a probability of 23/52 that it will belong to a group of 1, in which case the probability that the next sample belongs to the same group is 0.

b. a probability of 6/52 that it belongs to a group of 2, in which case the probability that the next sample (from 51 possibilities) is the other member is 1/51.

c. a probability of 18/52 that it belongs to a group of 3, in which case the probability that the next sample belongs to the same group is 2/51.

d. a probability of 5/52 that it belongs to the group of 5, in which case the probability that the next sample belongs to the same group is 4/51.

Thus, the total probability that the two samples are indistinguishable is

$$\frac{6}{52} \times \frac{1}{51} + \frac{18}{52} \times \frac{2}{51} + \frac{5}{52} \times \frac{4}{51} = 2.34 \text{ percent.}$$

An estimate of the probability that two glasses taken at random from the total of 52 studied would be eliminated on the basis of class alone was performed based on similar considerations, which can be summarized as follows:

$$\frac{4}{52} \times \frac{48}{51} + \frac{14}{52} \times \frac{38}{51} + \frac{8}{52} \times \frac{44}{51} + \frac{2}{52} \times \frac{50}{51} +$$
$$\frac{11}{52} \times \frac{41}{51} + \frac{10}{52} \times \frac{42}{51} + \frac{2}{52} \times \frac{50}{51} + \frac{1}{52} \times \frac{51}{51} = .829$$

Thus, of all unrelated sample pairs, 83 percent are eliminated by the preliminary sink-float determination and a further 15 percent by density gradient.

The two-step method for differentiation described has applicability in routine examination of glass density in that it lends itself to rapid screening, as well as detection of small differences on a comparative scale. This rapidity is especially important if many glasses need to be examined. It is by necessity the method of first choice as compared with refractive index measurements when the sample size is approximately ⅛-in. in its largest dimension because accurate measurements of refractive index are best performed when the sample glass is reduced to minute particles. Such particles are examined with difficulty by the thermal gradient method.

Dabbs and Pearson [2] have calculated the coefficient of correlation between density and refractive index as being 0.93 for 338 specimens in which both physical properties were measured. This high correlation infers that only limited additional differentiation occurs if both properties, instead of one property, are studied. Applying this correlation coefficient to the data developed in this study, the chance occurrence of indistinguishability when both properties are studied is conservatively estimated to be no greater than 2 percent.

References

[1] Fong, W., "A Thermal Apparatus for Developing a Sensitive, Stable and Linear Density Gradient," *Journal of the Forensic Science Society*, Vol. 11, 1971, pp. 267–272.

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