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Correlation of Glass Density and Refractive Index—Implications to Density Gradient Construction

REFERENCE: Thornton, J. I., Langhauser, C., and Kahane, D., **"Correlation of Glass Density and Refractive Index—Implications to Density Gradient Construction,"** *Journal of Forensic Sciences*, JFSCA, Vol. 29, No. 3, July 1984, pp. 711-713.

ABSTRACT: Regression analysis and analysis of covariance demonstrates (1) a high correlation between glass density and refractive index and (2) continuity in the regression line throughout the entire range of glass density values. Once a refractive index value is obtained, reference to the regression line will provide an approximate density value, knowledge of which will assist the analyst in preparing a particularly discriminating density gradient system.

KEYWORDS: engineering, glass, density (mass/volume)

Some workers using a bromoform/bromobenzene density gradient for glass comparisons prefer to construct a gradient that is far more sensitive than can be achieved with bromoform (density 2.90) as the bottom layer and bromoform (density 1.50) as the top layer. These expanded gradients are generally constructed by means of an initial sink-float procedure. The glass in question (either evidence or exemplar) is placed in a tube of bromobenzene and, while stirring, bromoform is added dropwise until the glass barely floats. This resulting liquid then becomes the stock heavy liquid for the construction of the gradient. In a similar manner, the glass is placed in a tube of bromoform and, while stirring, bromobenzene is added until the sample barely sinks. This liquid then becomes the stock light liquid which is used in various proportions with the heavy liquid to construct the gradient.

Murphy's Law is often at play in this procedure, however. It is difficult to estimate the final volume needed because one cannot determine a priori how much of the second component of the two mixtures will eventually be required. Consequently, one frequently ends up with too little of one or both of the liquids to construct as many cuts as desired. Alternatively, one may be left with costly, unused stock liquids.

If the approximate density of the glass was known, however, the optimum amount of stock liquids could be made up by direct mixing of bromoform and bromobenzene. One may start with a mixture of 25 parts of bromobenzene to 75 parts of bromoform. This will give a mixture of density 2.55, which is heavier than any glass likely to be encountered in any actual case situation. Other mixtures may be made, as each additional part of bromobenzene (with a corresponding one part decrease of bromoform) will decrease the density by 0.014. As will be de-

Received for publication 19 Sept. 1983; accepted for publication 3 Nov. 1983.

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scribed below, the approximate density of the glass can be determined without recourse to the tedious and frequently frustrating sink-float method.

This is achieved by means of recourse to a regression line after density is plotted against refractive index. The FBI computer printout of glass data[2] was found to be particularly useful for this purpose. The data set of 8 Aug. 1978 lists the density and refractive index of 1131 samples, coded as to glass type (1-plate; 2-window; 3-laminated; 4-tempered; 5-mirror). For the present work, 74 samples missing density values were culled. Also culled were three outliers that may represent keypunch errors or specialty glasses. A data set of 1054 samples remained.

Standard regression analysis and analysis of covariance were used; the results are depicted in Table 1.

The coefficients of determination (R^2) demonstrate significantly high linear association between refractive index and density. What was being sought here was a regression line that given the more easily determined absolute value of refractive index, could be used to estimate the density of a glass sample. However, as is apparent upon inspection of any scattergram of glass density versus refractive index [*1*], there is an obvious gap in the data at about refractive index 1.5206. Analysis of covariance was therefore conducted below 1.5206, and above 1.5206. No significant differences were found for regressions (slopes) for the two levels of refractive index ($P > 0.05$). This holds true for each of the five types of glass. Thus continuity in the regression line through the entire range may be assumed.

It is possible to plot the regression lines for each of the five types of glass separately, but no statistically differences were found for the regression parameters between the five groups (analysis of covariance, $P > 0.05$). Since the regression lines are virtually superimposed, little purpose would be served by a presentation of such plots here. For the reader who wishes to do so, however, Table 2 indicates the estimated values of density for refractive indices 1.51, 1.52, and 1.53.

TABLE 1—*Regression analysis and analysis of covariance; values of* $\hat{a}_t$, $\hat{b}_t$, *and* R^2 *for 1054 samples of glass.*

Glass	N	Intercept $\hat{a}_t$	Slope $\hat{b}_t$	Coefficient of Determination,[a] R^2
Total	1054	−3.602 081	4.014 355	0.948 027
1-plate	153	−3.510 416	3.510 416	0.948 922
2-window	575	−3.586 890	4.004 518	0.945 280
3-laminated	123	−3.481 639	3.935 044	0.963 634
4-tempered	185	−3.677 917	4.063 418	0.948 566
5-mirror	18	−3.685 970	4.069 680	0.923 074

[a] All coefficients were significant at $P < 0.01$.

TABLE 2—*Estimated values of density for refractive indices 1.51, 1.52, and 1.53.*

Glass	n_D 1.51	1.52	1.53
1-plate	$\hat{y}_1 = 2.4611$	2.5006	2.5402
2-window	$\hat{y}_2 = 2.4599$	2.4999	2.5400
3-laminated	$\hat{y}_3 = 2.4603$	2.4997	2.5389
4-tempered	$\hat{y}_4 = 2.4578$	2.4984	2.5391
5-mirror	$\hat{y}_5 = 2.4592$	2.4999	2.5406

[2] E. T. Miller, FBI Laboratory, Washington, DC, personal communication, 1979.

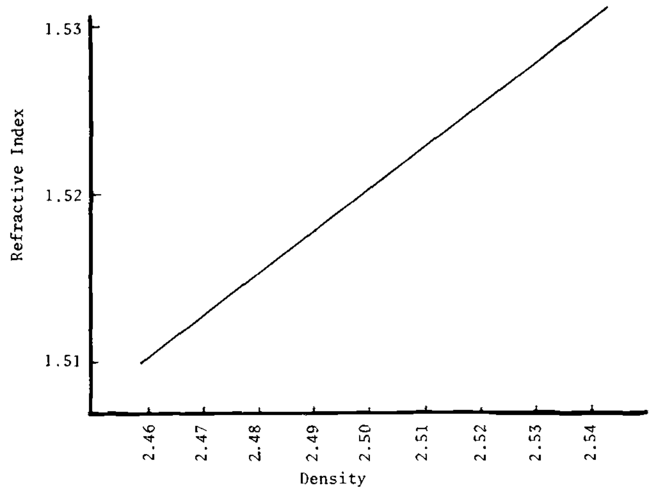

FIG. 1—*Regression line for 1054 pooled samples, without regard to glass type.*

Figure 1 illustrates the total regression of the pooled samples, without regard to glass type. Thus it is possible to find a good approximation of the density of the glass, regardless of type, and without resorting to the frustrations of the sink-float method.

Reference

[*1*] Miller, E. T., "Forensic Glass Comparisons," in *Forensic Science Handbook*, R. Saferstein, Ed., Prentice-Hall, Englewood Cliffs, NJ, 1982.

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