New refractometers employing diamond and other minerals.

By B. W. ANDERSON, B.Sc., F.C.S., C. J. PAYNE, B.Sc.
Laboratory of the Diamond, Pearl, and Precious Stone Trade Section of the London Chamber of Commerce,
and J. PIKE, A.R.C.S.
of Messrs. Rayner & Keeler, Ltd., Instrument Makers, London.

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DIRECT-READING refractometers depend upon observation of the boundary between transmission and total internal reflection, when a flat surface of a specimen is placed in optical contact with the flat surface of the isotropic medium employed in the instrument. This medium is usually a heavy lead glass in the form of a hemisphere or prism. The upper limit to the range of indices which can be measured is determined by two factors: the refractive index of the medium employed in the instrument, and the refractive index of the liquid used to make optical contact between the two surfaces.

Liquids of high refractive index are essential to such instruments, and some reference to them may be conveniently made at this stage. Various pure liquids, mixtures, and melts of high refractivity have been proposed from time to time, chiefly as immersion media. These include:

	n_D.
Methylene iodide saturated with sulphur, further saturated with tetra-iodo-ethylene[1]	1·81
Phenyl-di-iodoarsine[2]	1·85
Methylene iodide, sulphur, and iodides[3]	1·868
Piperine and iodides[3]	1·68–2·10
Phosphorus, sulphur, and methylene iodide[4]	2·06
Selenium bromide and selenium[1]	2·06

The first-mentioned liquid seems quite stable, has no objectionable properties, and no appreciable chemical action on the surface of the usual high-refractive index glass. All the remainder, amongst other

[1] B. W. Anderson and C. J. Payne, Nature, London, 1934, vol. 133, p. 66. [M.A. 5–503.]
[2] B. W. Anderson and C. Payne, loc. cit., and ibid., 1936, vol. 138, p. 168.
[3] H. E. Merwin, Journ. Washington Acad. Sci., 1913, vol. 3, p. 35.
[4] C. D. West, Amer. Min., 1936, vol. 21, p. 245. [M.A. 6–460.]

disadvantages, have a damaging effect on the glass surface of refractometers and are therefore undesirable for use with these instruments. Thus, though in some models of the Tully refractometer[1] the scale extended to 1·9, the upper regions were in practice not available without some risk of damaging the glass surface with a reactive liquid.

It may be useful to mention briefly some of the other disadvantages of these liquids for the information of those who intend to use them. Phenyl-di-iodoarsine has a blistering action on the skin. The iodides in Merwin's liquid make a very dark mixture, and tend to crystallize out as a precipitate. Piperine and iodide melts need careful preparation and solidify at room-temperatures. West's phosphorus melt must be kept under water and handled with care owing to the spontaneous inflammability of the yellow phosphorus present; and finally, selenium bromide is so deep a red as to be practically opaque, is unpleasant to handle, and does not make good optical contacts unless diluted with a little of the 1·81 methylene iodide mixture. In short, it may be said that all these liquids having $n_D > 1{\cdot}81$ are only suitable for laboratory use.

Failing the discovery of a harmless and very refractive liquid, further progress could only be made by substituting for the glass used in the hemisphere some transparent isotropic mineral of even higher refractive index which would be less liable to chemical attack by the special liquids.

Zinc-blende suggested itself as an obvious possibility and experiments were carried out six or seven years ago, when attempts were made to construct a Tully refractometer with a hemisphere of blende. A piece of blende at once sufficiently large and clear for the purpose was hard to find, and the experiment was not successful. It was, however, apparent that there was reasonable expectation of being able to make up small pieces of the required degree of clarity, and the problem of constructing an instrument to utilize small pieces was undertaken. If successful, it was realized that the use of diamond as the refracting mineral might be a practical possibility.

Hitherto gemmological refractometers have almost invariably employed a hemisphere or segment of highly refracting glass, and it was apparent that departure from this convention was almost essential if a diamond was to be used on account of cutting difficulties. Prisms or blocks of glass are well-known in such instruments as the Abbe and Pulfrich refractometers, which are too elaborate for routine use with gemstones, sacrificing the advantage of rotation of the testing surface.

[1] B. J. Tully, Min. Mag., 1927, vol. 21, p. 324.

The first experimental model of the new type utilized a prism of zinc-blende and, by using West's liquid, satisfactory readings to just over 2·00 were obtainable for the first time. This original instrument was used for obtaining a range of values for zircons of all kinds.[1] When a glass prism was used in place of the blende, the design proved so satisfactory and inexpensive to make that it was marketed as the Rayner refractometer.

Diamond Refractometer.

Owing to the generosity of the Diamond Corporation it was now possible to utilize diamond as the material for the prism. Though its

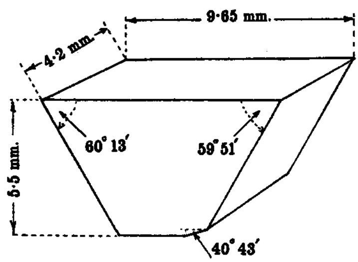

FIG. 1. Diamond prism of refractometer.

refractive index is slightly higher than that of blende (2·42 against 2·37) its real advantages over the latter lie not in this fact, but in its greater optical purity and in its great hardness, which enables it to take a high polish which will not suffer abrasion from any of the specimens tested.

The diamond given us for experimental use in the refractometer had the following properties. Original weight 6·632 carats, density $d_4^{15°}$ 3·519. Cut into prism, weight 2·505 cts. Quality 'silver cape'. Refractive indices (determined with prism of angle 40° 43′):

λ	6708	5893	5461	5350	4358	4227
n	2·4104	2·4190	2·4257	2·4275	2·4504	2·4554

Dispersion: 2·4558 − 2·4104 = 0·0454.

The cutting of the stone was entrusted to Mr. Kaner, who was asked to cut a truncated prism (fig. 1) with angles as nearly 60° as possible. The actual angles were found to be 60° 13′ and 59° 51′—remarkably accurate work when one considers that only the crudest form of goniometrical aid was employed as a check during cutting.

[1] B. W. Anderson and C. J. Payne, Gemmologist, London, December 1937. [M.A. 7–131.]

In its present form (fig. 2), the diamond refractometer enables readings to be taken from 1·52 to 2·03. The scale for this range is three times as long as for the early blende instrument and therefore beyond the scope of a fixed eyepiece. The eyepiece is made to slide over the

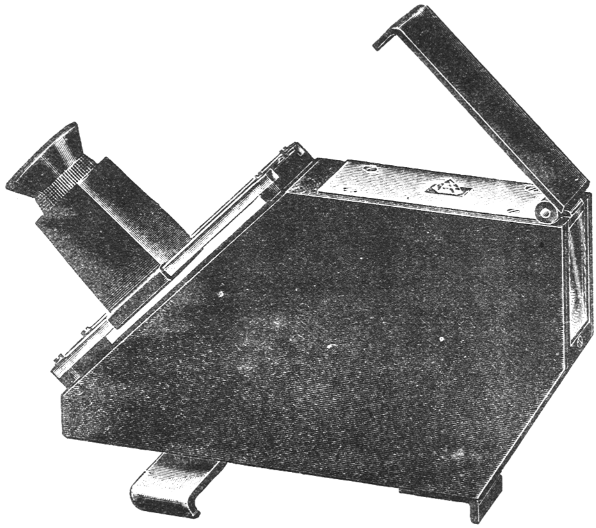

FIG. 2. Diamond refractometer.

scale on parallel rails and can be moved to a position quite clear of the scale. The approximate position of the shadow-edge is first noted, observing the scale at a normal reading distance without the eyepiece; the eyepiece is then moved into position for the scale to be observed. The open scale enables estimation of indices to the third decimal place to be made with comparative ease.

The diamond refractometer having proved a satisfactory pattern, the same model can equally well be made with a blende prism, covering the same range of indices.

One can only hope that a stable liquid having a refractive index of over 2·0 and no unpleasant properties will eventually be discovered for use with the diamond and blende refractometers.

Spinel Refractometer.

By the substitution of a prism of colourless synthetic spinel for the prism of high-refractive index glass usually employed, an instrument having certain great advantages over the normal refractometer is obtained, albeit with a restricted range. The synthetic spinel ($d_4^{15°}$ 3·625) used for the prisms gave the following values for refractive index by the minimum deviation method, the prism angle being 60° 20¾′.

λ	6870	6708	5893	5350	4308	4227
n	1·7222	1·7225	1·7266	1·7304	1·7417	1·7431

The dispersion for the B—G interval is 0·0195, and for C—F approximately 0·0110, which is only a little higher than that for the species which fall within the range of the instrument. The dispersion of the 'extra dense flint' glasses commonly used in refractometers is enormously greater. For two samples of Chance-Parsons glass, for instance, the makers supplied the following figures: n_D 1·8012, dispersion (C—F) 0·0313; n_D 1·9203, C—F, 0·0436.

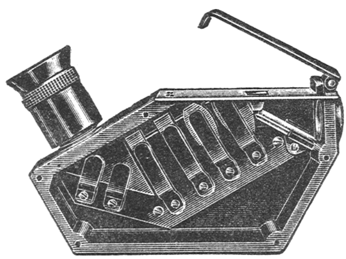

Fig. 3. Spinel refractometer.

Bearing these figures in mind, it will be understood that the critical angle for light passing from the spinel prism into the specimen tested varies hardly at all for different wave-lengths, with the result that a sharp, uncoloured shadow-edge is obtained when using ordinary white light, while with the normal dense glass prism the shadow-edge consists of a fringe of spectrum colours, and monochromatic light must be employed where accurate readings are required.

The short range covered by the spinel refractometer enables a more open scale to be used, with consequent increase in the accuracy of the readings. The spinel surface is, of course, practically unabraded by any of the gem minerals tested. For all readings below 1·65 monobromonaphthalene is an ideal contact liquid, on account of its oily nonvolatile nature.