A new model of Refractometer.

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THE instrument described in this paper is identical in principle with the small refractometer[1] designed by the author more than three years ago, but differs from it in several details which are of considerable practical importance. As in the earlier form, a compensative lens is introduced of such curvature and focal length that the focal surface of the optical combination is a plane within the range for which the instrument is required, and consequently the critical edges are sharply defined in monochromatic light for all positions. It will be more convenient, before entering into the description, to take the features which have been changed.

1. As will be seen from the illustration (fig. 1), the aspect of the refractometer has been completely altered. The awkward corner existing close to the dense glass in the earlier form has been obviated, and now the whole of the parts lie on the same side of the plane of the brass plate carrying the dense glass which forms the constant medium; there is, therefore, practically no limit to the size or to the shape of a stone for which the instrument may be used, and it matters not if it be surrounded by a wide setting. In the case of the earlier instrument the table-facet of a large stone, or of one mounted, for instance, in a brooch, often could not be brought on to the plane surface of the dense glass. Of course, a small facet would answer the purpose equally well; but the author is aware, from experience, of the difficulty of assuring that a small facet of a large stone is pressed evenly against, and not inclined to the surface of the glass. Any such uncertainty might render the observations valueless, and, moreover, there is great risk of scratching the surface of the dense glass. The same kind of difficulty not infrequently arises in the case of jewellery.

2. The instrument is larger in size; indeed, the focal length is precisely double what it is in the smaller form, and delicacy of the readings has been correspondingly increased.

[1] Min. Mag., 1905, vol. xiv, pp. 83–6.

3. The scale (fig. 2) is no longer arbitrary, but gives the refractive indices for sodium-light directly to the second place of decimals, and the intervals are such, particularly in the higher values, that the tenth parts may be estimated with some certainty, and a trustworthy value, therefore, obtained of the indices to the third place of decimals. Previously the scale was quite arbitrary and had to be calibrated by means of observations of substances of known refractive indices, and after an observation had been taken reference had to be made to a card on which was given the equivalents in refractive indices of the divisions on the scale. If the card were lost, the instrument was useless until it had been recalibrated. At the same time the range has been increased by at least a whole unit in the second place of decimals, and extends now to 1·770. The limit varies slightly with the instrument, depending as it does on the amount to which the plane surface of the dense glass projects beyond the brass plate embracing it, and may be as high as 1·775. In the earlier form the higher limit is rarely much above 1·750 and never exceeds 1·760. The extension is of extreme importance, since the range now includes the refractive indices of corundum, a species which occupies such a prominent place among gem-stones that the direct determination of the refractive power greatly increases the utility of the instrument. In the earlier refractometer it was, indeed, possible to see in white light the violet end of the coloured edge

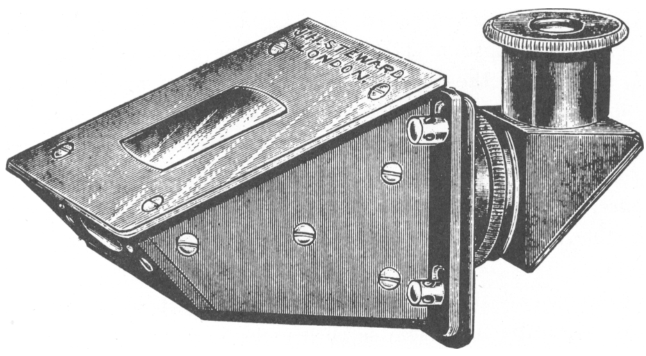

Fig. 1.—Refractometer (actual size).

corresponding to the extraordinary index in the case of all save the deep-red stones; but bright daylight was required for a trustworthy observation, and such a determination cannot be considered so satisfactory as an actual measurement of the refractive indices.

4. A lens, of one inch (25 mm.) focal length, has been substituted for

the ground-glass plate through which light is admitted to the instrument. Owing to the extreme shortness of the focal length of the telescope—as optically considered the instrument really is—the image of the surface of the ground-glass plate is formed so near the focal plane as to be within the accommodating power of the observer's eye, and consequently not only is an exact appreciation of the position of the critical edge rendered difficult, owing to the apparent diffusion of the edge, but a course of observations becomes most fatiguing by reason of the incessant change in the eye's focal adjustment. The lens throws outside objects, such as window-bars, the sodium-flame, &c., sufficiently out of focus that no inconvenience is experienced. If white light be employed, the most satisfactory illumination is obtained by using the diffused light reflected from a sheet of white paper laid on a table.

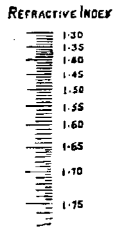

Fig. 2.—Scale of Refractometer.

It will simplify the description of the refractometer as regards the orientation of the various parts, if we suppose that the divisions of the scale are horizontal, whence it results that the optic axis of the combination formed by the dense glass and the compensative lens is also horizontal, and, further, if we suppose that we are viewing the instrument from the end, having the eye-piece towards us.

The constant medium, with which in a total-reflectometer the substance under examination is compared, is a highly refracting glass having an index for sodium-light of 1·7902. A denser glass, of refractive index 1·8924, is used in the type of total-reflectometer of greater precision which possesses rotational parts; but it is unfortunately so soft, fragile, and wanting in durability as to be little adapted to the purposes of a determinative instrument in constant use. Even in the case of the less dense, but more durable glass, great care must be taken not to scratch the surface when observations are made on the far harder gem-stones.

The glass is cut to the shape of a hemisphere, 1 cm. in radius, which is sliced vertically and symmetrically with regard to its centre to a convenient width, slightly exceeding that of the part of the field utilized. If desired, the shape may be a portion of a semi-cylinder, the circular section of which has the same radius, viz. 1 cm. The brass plate surrounding the dense glass is cut away and bevelled so that the plane surface of the latter projects slightly above the plate. The glass is firmly held in position from the two sides, but can be readily removed for repolishing without any risk of injury. In the case of the earlier instrument the dense glass is fitted in from above and burnished into position; i. e. a thin strip of metal is turned over the bevelled edge of the glass. Owing to its brittle nature, it is an operation of extreme delicacy thus to fix the glass in the right position, and, when once fixed, it cannot be removed without almost certain damage.

The brass plate, just mentioned, forms the top of the box, quadrilateral in shape when viewed from the side, which contains in addition to the dense glass the compensative lens. Of the sides of the quadrilateral figure, the base is horizontal; the right-hand side is vertical; and it and the left-hand side make equal angles, viz. 61°, with the upper side, i. e. the brass plate surrounding the dense glass. The left-hand side contains the lens through which light is admitted to the instrument. The right-hand side is the plate which is attached by means of four screws passing through holes in it, slotted vertically, to the corresponding plate which carries the scale and the eye-piece, and the former plate is cut away in the centre to admit the tube carrying at its inner end the scale. The upper plate is attached to the sides of the box, as may be seen from the figure, by means of four countersunk screws, which pass through holes in it slotted lengthwise—a means for varying slightly the distance between the dense glass and the compensative lens. The plate is hollowed out underneath from front to back, i. e. lengthwise, about the width of the dense glass in order to extend the range of the instrument as high as possible.

The compensative lens is carried in a frame, which may be moved up and down in two vertical grooves, fixed to the side plates, the motion being given by a screw, the head of which emerging through the bottom plate is actuated by a key and is covered by a cap to prevent accidental interference with the adjustment. The frame itself is cut away at the top so that the lens may fit into the groove hollowed out of the upper plate, the curvature of which is such as to accommodate the lens.

The tube, which carries at its inner end the scale, may be pushed in or out of the fixed tube surrounding it in order to bring the scale into focus and rotated to bring it upright, i. e. the divisions horizontal, and is held rigidly, when in the correct position, by means of a clamp of the ordinary split-ring type. The top of the tube at the inner end is filed away so that the top of the scale, or the bottom as seen in the eye-piece, may fit into the groove in the upper plate.

The scale, as has been stated above, gives the refractive indices for sodium-light direct to the second place of decimals, and the graduation extends from 1·300 to 1·775. The intervals between the divisions increase in size with the index, and to facilitate the estimation of the tenth parts the intervals from 1·650 upwards have been bisected. All the lines are drawn from the centre of the field towards the left, and every fifth is distinguished by its greater length. The readings are intended to be taken just at the point where the critical edge meets the right-hand edge of the scale, i. e. in the centre of the field; for, when the curved surfaces of the dense glass and the compensative lens are spherical, the critical edges are slightly curved, being circular arcs, and it is, of course, essential to know what part of the curve is to be observed. The difficulty does not arise in the case of cylindrical surfaces, because the edges are straight.

The eye-piece is of the ordinary positive type and magnifies about ten times; for convenience of observation a totally-reflecting prism is inserted between the two lenses. Since the eye-piece cannot be pulled out far without consequent unsteadiness, an adaptor can, if desired, be provided for observers with long sight.

In order to maintain during observation the stone in position upon the plane surface of the dense glass, and especially to minimize the risk of the stone falling off the instrument, light springs of German silver are provided. They are shaped like the Greek letter Ω, so as to grip the sides of the instrument, and vary in length to suit different sizes of stones.

All the instruments are made as closely as possible to the same pattern; but, of course, certain adjustments are necessary, which are as follows:—

1. The scale is fixed into its frame in as nearly as possible the same position in each instrument. To bring it into the correct position in the focal plane, the compensative lens is first screwed up until almost in contact with the upper plate; the screws holding the two parts of the instrument together are then slightly released, and the two parts moved relatively to each other in a vertical direction until the reading of the scale for the critical edge given by some known, preferably in all these preliminary tests singly refractive, substance is within a division of the truth; the final adjustment is effected by means of the screw adjustment to the compensative lens.

2. The focal length of the optical combination must be the same in all cases, because otherwise a troublesome correction to the readings of the scale would be necessary. The curvatures of the surfaces of the dense glass and of the compensative lens are invariable, and the only adjust-

ment required, viz. the distance between the two constituents of the optical combination, is provided for by the slotting of the holes in the upper plate.

Unless there has been some error in the workmanship, the correct adjustment of the refractometer presents little difficulty. The scale is first brought into the focal plane and rotated until the divisions are horizontal, and is then securely clamped ; as a criterion the critical edge given by some known substance is employed. The scale is next adjusted vertically in the manner described above until the reading for the edge is correct. Readings are now taken for two substances which give edges near the opposite ends of the scale. If the readings cannot be made simultaneously correct, the interval between the dense glass and the compensative lens is varied to the extent required. A last glance to see that all the screws are properly tightened, and the refractometer is ready for use.

This refractometer, like the earlier form, is the work of the well-known optician, Mr. J. H. Steward, 457 West Strand, London, W.C. To Mr. John Steward of that firm the author acknowledges an especial debt of thanks for many valuable suggestions for overcoming the various difficulties which almost inevitably arise in the construction of a new form of instrument.