An improved form of Refractometer.

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THE first form of refractometer, in which a reference-scale was substituted for the rotational parts and graduated circles of the more complex instruments, was designed in 1885 by Professor E. Bertrand[1], who at the same time was the first to suggest the employment of a hemisphere of dense glass in place of the prism and cylinder previously used. The original instrument and others on the same principle which have hitherto been constructed do not give satisfactory results, because no attempt has been made to compensate for the curvature of the focal surface of the hemisphere, and the determinations obtained are, therefore, far from trustworthy. In the refractometer described in this paper a corrective lens is placed in the path of the rays emerging from the hemisphere, and the field thus produced is rendered very nearly plane.

For a particular substance in contact with the plane surface of the hemisphere the angle of total-reflection is $\sin^{-1}\frac{\mu}{\mu_0}$, where μ and μ_0 are the refractive indices of the substance and the glass respectively. At any point on the plane the limiting rays of total-reflection form a cone, the axis of which is normal to the plane and the vertical angle double of that of total-reflection. If the effects of spherical and chromatic aberrations be neglected, the rays parallel to any particular ray of the cone come to focus at a point which lies on the ray passing through the centre of the spherical surface at a distance $\frac{\mu}{\mu-1}.r$ from the centre, where r is the radius of the hemisphere. The focal surface, therefore, for all angles of total-reflection is part of a sphere concentric with the glass hemisphere and of radius $\frac{\mu}{\mu-1}.r$. The rays for any particular angle of total-reflection come to focus on a small circle, forming the intersection of the sphere with the cone mentioned above. Since it is impossible for

[1] Bull. Soc. Min. France, 1885, vol. viii, pp. 375–377.

a plane to coincide with a spherical surface, accurate readings are out of the question owing to the bad definition of the edge of the shadow and the uncertainty of its true position owing to the effects of parallax.

It is necessary, therefore, to compensate in some way for the curvature of the focal field. After a few experiments the author found that adequate compensation was obtained by the interposition of a convex lens of suitable focal length in the path of the rays emerging from the hemisphere. The problem is, indeed, to bring light which is parallel within the glass to focus in a flat field, and is the same as the construction of a telescope in which the field-lens of the objective is a hemisphere of dense glass, the plane surface being turned outwards, and in which the angular width of the field is about 30°. The simplest and

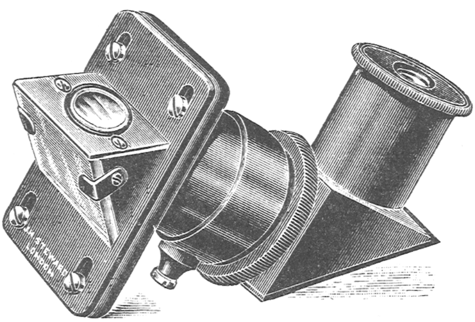

Fig. 1.—Refractometer (actual size).

most convenient method of testing the efficiency of any corrective lens is to employ it in conjunction with the hemisphere as the objective of such a telescope. The author found that, if the hemisphere, 10 mm. in diameter, be composed of glass, the refractive index of which for the D lines is 1·7938, a convex lens of crown glass and focal length 13 mm., placed with the surface of greater curvature almost in contact with the hemisphere, gave satisfactory results, and that, when this combination is employed as a total-reflectometer, the edges separating the light and dark fields are sharply defined throughout the whole of the effective range of the instrument. For reasons stated above the edges appear as circular arcs. If, however, the hemisphere and convex lens be replaced by a semi-cylinder and a cylindrical lens respectively, the sections of the latter pair perpendicular to their geometrical axes being identical with the central sections of the former pair, the edges become straight lines; it is important that the axes of the cylinders should be truly parallel.

The illustration (fig. 1) shows the construction of the instrument. The hemisphere of dense glass, the refractive index of which is 1·7938, is firmly embedded in a thin, brass plate, which is attached by screws to two shoulders rigidly connected to a vertical brass plate. The hemisphere is inclined in such a position that the angle between the perpendicular to its plane surface and the axis of the tube of the instrument is about 64°, and thus the centre of the field corresponds to a refractive index of 1·61. The plate of ground-glass is equally inclined to the vertical plate, but in the converse sense. Four screws passing through slots in the vertical plate connect it with a similar plate terminating the tube, and thus an adjustment of the centre of the plane surface of the hemisphere is provided with regard to the axis of the tube. At the end of this tube is placed the corrective lens, the surface of greater curvature being almost in contact with the hemisphere and its optic axis coinciding with the axis of the tube. The clamp at the other end grips an inner tube carrying at its inner extremity a thin, glass plate on which a scale, figured at every tenth division (fig. 2), has been photographed. Inside the inner tube slides a positive eye-piece, in which a totally-reflecting prism is interposed between the two lenses for greater convenience in taking observations.

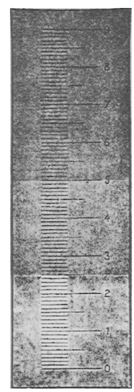

Fig. 2.—Scale with shadow-edges.

The effective range of the instrument is from about 1·40 to 1·76. Each interval on the scale corresponds to a difference of refractive index varying from 0·007 in the higher to 0·015 in the lower indices. If sodium-light be the source of illumination the edge separating the light and dark fields appears as a delicately traced line and is so well defined that a practised eye can estimate the tenths of divisions, and thus measurements may be carried to one or two units in the third place of decimals. The scale is calibrated for this light by means of observations made on a few substances of known refractive power. If white light be used the edge is no longer a line but a spectrum, in which case the position corresponding to the yellow portion should be noted. The value thus obtained will be accurate to units in the second place of decimals at least, and will be sufficient for most determinative purposes. The width of the spectrum measures the amount of chromatic dispersion displayed by the substance under examination. With this instrument accurate measurements may be made of the refractive power of fragments so small as 1 mm. in diameter.

The refractometer has been constructed by Mr. J. H. Steward, the well-known optician of London, whose keen interest in the development of the instrument and zealous assistance in the preliminary experimental work it affords the author much pleasure to acknowledge.