A new model refractometer for determining the refractive indices of gem-stones, crystals, and liquids.

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THE general outline and weight of the body of the instrument are devised to ensure perfect rigidity and steadiness during use, all necessary adjustments, such as the focusing of the rotating eyepiece, movement of the revolving stage, reflector, or screen, being quite independent of the optical system; which, being contained in the main body in a dust-proof receptacle, entirely prevents any vital part of the refractometer getting out of adjustment, unless deliberately tampered with.

The eyepiece, which by rotation is capable of giving a wide variation of focus, is set at the most convenient angle to ensure easy and comfortable observation.

The forward projecting portion attached to the main body is rectangular in shape, and hollow, the upper surface forming a platform in which revolves a circular plated stage with a milled edge capable of being turned about a vertical axis through 360°, with an engraved scale marked at every 45° to enable the observer to read with accuracy the least and greatest refractive indices of all doubly refracting stones.

Into this circular stage is mounted the soft dense glass hemisphere *B*, and this stage being capable of rotation allows observation of a gem or crystal being made from all directions, thus obviating the frequent necessity of turning the specimen on the dense hemisphere, and consequent risk of scratching by the far harder specimens.

The velvet-lined shield *D*, hinged at the forward end of the platform, serves the dual purpose of acting as a screen to keep out all extraneous light that may enter from above during examination of a gem; and also as a protection to the hemisphere when the instrument is not in use.

The matt opal reflector *A*, hinged below the shield, affords a most suitable means of throwing a beam of diffused light to the under surface of the hemisphere, thereby giving an even illumination to the scale. It is provided with a catch to hold it at about 45° when in use, or vertically when in the case. When it is desired to use monochromatic light, the reflector can be swung downwards out of range.

From the first, I intended the instrument to be essentially a 'stand' instrument, practical, comfortable in use, and stable upon a bench or

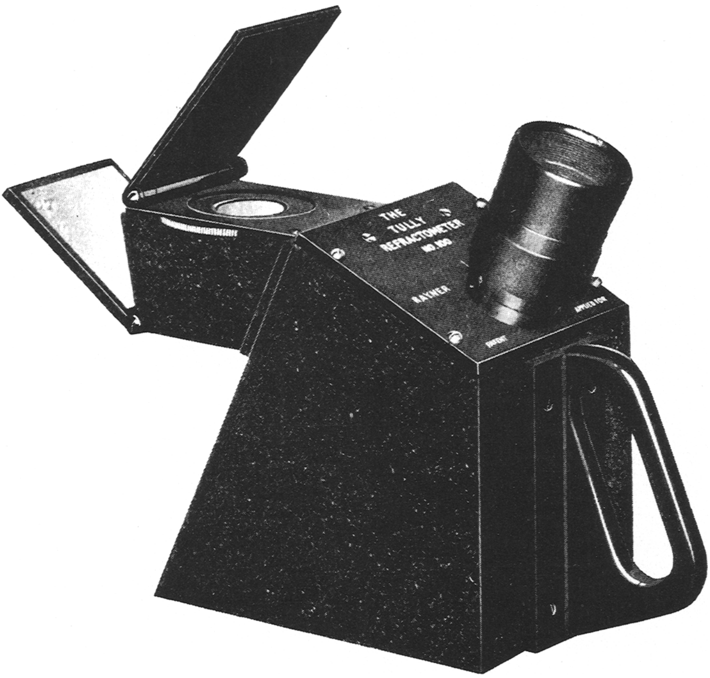

Fig. 1. The 'Tully' Refractometer.

table; means were to be provided for obtaining the refractive indices of doubly refracting substances without having to turn them, as in existing types, upon the comparatively soft glass hemisphere; the scale was to be well magnified and read upwards commensurate with increasing values, with the low numbers commencing at the bottom; and the optical performance had to be clear and definite.

After designing various models, in the final type the fulfilment of a number of these conditions went very conveniently hand in hand. To erect the eyepiece scale, it was necessary to make several reversals of the beam of light, by lenses, mirrors, or by both, and a consequent lengthening of the optical system was inevitable. At the same time, comfortable positions for the head in observing, and for the hand in rotating the hemisphere were required, so that the eyepiece had to be some inches above the base of the instrument, and the hemisphere some inches in front of the eyepiece. This has been done by making the body of the instrument of two antimony-bronze castings—a main body and a projecting portion. The projecting portion carries the hemisphere an inch or so before the front face of the main body, and the eyepiece is adjusted at the back of its top face. The optical system entirely occupies the main body. The accuracy of the surfacing, placing, and form of the lenses give the required degree of optical performance.

Considerable difficulty was experienced in the satisfactory mounting of the hemisphere on a narrow ring of a flat plate so that the rotation took place on an axis through the centre of the hemisphere. This difficulty was overcome by fitting a very shallow ring to the plate, bedding the edge of the hemisphere and the ring in a special plaster, and centring up on a spindle during setting. The plate and hemisphere turn in machined grooves in the small front casting which is rigidly attached to the main body.

Only one external adjustment is necessary, namely, that of focusing the eyepiece upon the scale. The eyepiece and hemisphere are fixed in position with respect to the main body, and the adjustments for position and range of the shadow-edge are made by altering the positions of elements in the optical system during the assembly of the instrument. Three lenses and two prisms are employed. The first lens *F*, very close to the hemisphere, is contained in a sliding framework; immediately behind, mounted in trunions, is the first prism *G*. Movement of the first lens along the optical axis with respect to the hemisphere makes the range of the shadow larger or smaller, e.g. with the 1·4 reading correct, the 1·7 reading might actually be 1·6 or 1·8. Movement of the first lens and prism provides a coarse adjustment for the position of the shadow-edge, e.g. the 1·4 reading might be at 1·3 on the scale, and the reading 1·72 at 1·62; the actual linear difference between 1·4 and 1·3 being about the same as that between 1·72 and 1·62. The first prism is mounted so that a small rotation about the mid-line of its hypotenuse can be made, by means of a screw, and this provides a fine adjustment for the position of the shadow-edge.

The second prism *I* comes between the second and third lenses, *H* and *J*, and reflects the light back along a parallel path. It plays no part in the adjustments, so is fixed in position, and merely makes the optical system compact. The second and third lenses are both adjustable along the optical axis, and, in conjunction with the first lens, bring the shadow-edge clearly to the eyepiece scale. One lens actually would be sufficient to do this, but it would have to be placed opposite the middle of the

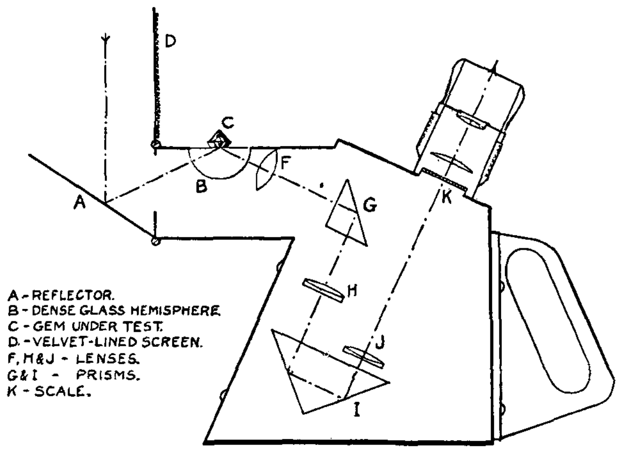

Fig. 2. Diagrammatic section through Refractometer.

second prism, and to be provided with means of adjustment, conditions rather difficult to fulfil.

A specially plotted photographic scale *K* showing the divisions very clearly is fixed under the compound rotating eyepiece.

The instrument is chiefly intended for the determination of the refractive index of gem-stones, and difficulties have arisen owing to the width of the dispersion band that is always met, say, in the case of spinel and sapphire. It becomes necessary either to set the instrument for a certain wave-length and leave the location of it in the spectrum seen to the user, or to cut off some part of the spectrum by a filter. If a filter could be used that allowed only the extreme red to pass through it, to all intents and purposes for every stone there would be a sharp black line, for not much red is seen. But so very little light would be enabled to pass through at all that under any but the best lighting conditions it would be very difficult to say which was the shadow part of the field and which was the light part. A compromise has been effected that seems to meet with approval. A light-orange filter has been fitted over the eyepiece, and the shadow is seen with a green edge. The green edge is not very far from the sodium-yellow position, so that readings taken at the green edge will be found to agree almost exactly with those taken with monochromatic sodium-light, especially if a liquid with little dispersion, such as monobromonaphthalene, is used. If the available light is bad and the orange filter is removed, the first 'dark' part of the dispersion band is the green edge, so that agreement is again obtained.

It must be emphasized that this instrument is not intended for field work or for work of the high order of accuracy of the Abbe instrument. Refractive indices are marked on the scale to the second decimal place and can be read off with ease by estimation to the third place. A gem-stone or crystal on the hemisphere can be turned with comfort while examining the shadow-edge through the eyepiece; and with the solution of the dispersion trouble, a definite addition in the field of mineralogical instruments would seem to have been supplied.

In conclusion, I wish to tender my sincere thanks to Mr. J. Pike, A.R.C.S., and Mr. Hobson, of the firm of Messrs. Rayner of 9 Vere Street, London, W. 1, the makers and co-patentees, for their help and technical suggestions in overcoming several difficulties arising during the evolution and subsequent completion of the model.