The Abbe Refractometer

with water jacketed prisms

INSTRUCTIONS FOR USE

1960

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The Abbe Refractometer

UNPACKING

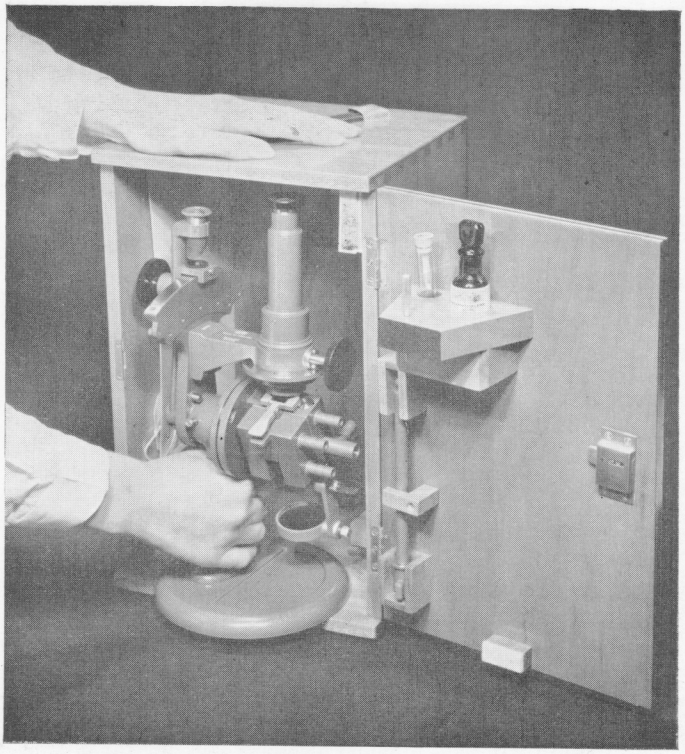

Fig 1. Removing instrument from case

When unpacking the instrument, check that in addition to the refractometer the following items are included:

1. Thermometer 2. Bottle of monobromonaphthalene 3. Camel hair brush in bottle 4. Glass test piece 5. Small screwdriver for scale adjustment. The method of removing the instrument from its case can be seen in Fig. 1.

WORKING PRINCIPLE

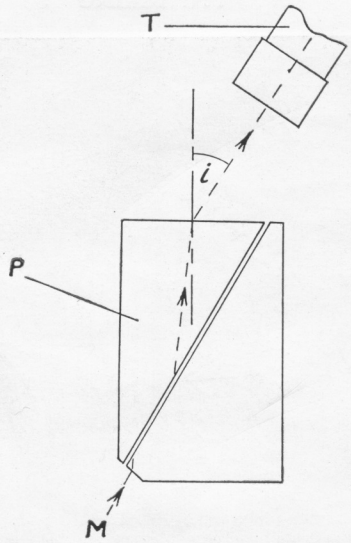

Fig. 2 (a)

Fig. 2 shows cross sectional views of the prism system of the instrument, (*a*) when used for determining the refractive index of a liquid and (*b*) when the sample is a transparent solid; in both cases, P represents the upper prism. In Fig. 2 (*a*) light is reflected into the prism from an adjustable mirror at M; in Fig. 2 (*b*) S represents a source of white light.

All rays of light of equal incidence entering the prism are equally deviated and combine in the focal plane of the telescope T to form a fine line parallel to the top edge of the emergent face of the prism; the total effect of a number of such rays being the formation of a patch of light in the telescope field.

Rays entering the prism at grazing incidence, as shown by the arrowed lines, are sharply delimited and cause the

patch of light to terminate abruptly in a clearly defined straight edge.

If the telescope is adjusted to make this line coincide with the intersection of the eyepiece cross lines, then the inclination of the telescope axis to the normal of the emergent face of the prism is equal to the angle of emergence ' i '.

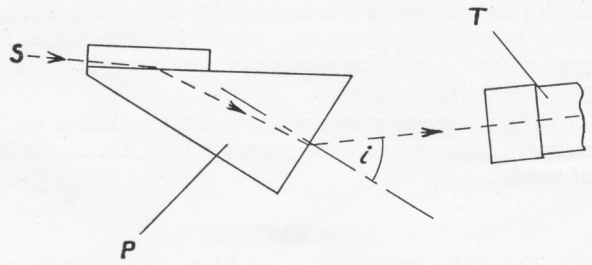

Fig. 2 (b)

The graduated scale is so calibrated that this angle is read off directly as the refractive index.

To counteract the effects of dispersion when white light is used, an Abbe compensator is embodied in the telescope. This consists of two direct vision prisms that can be rotated uniformly in opposite directions about the telescope axis. Together they form a system of variable dispersion that can be adjusted to cancel out dispersion due to the refractometer prism and the substance being investigated.

APPLICATION

REFRACTIVE INDEX OF LIQUIDS

The accuracy obtainable (.0002) is comparable with other methods and is as high as is warranted by ordinary methods of temperature control. The applied film of

liquid is sufficiently thin to permit the investigation of turbid and highly coloured liquids. Substances such as butter may be introduced in the molten state.

A few of the substances that may be investigated are blood serum, butter, edible fats and oils, milk serum, milk sugar, sugar solutions, wax, etc.

REFRACTIVE INDEX OF TRANSPARENT SOLIDS

The same degree of accuracy is obtainable as for liquids and compares favourably with that of any but the most expensive instruments, while the procedure for preparing and assessing specimens is very simple.

DISPERSION

The ability to measure dispersion provides a useful source of information in many applications, e.g. the sorting of glasses.

DESCRIPTION

The Abbe prisms of dense flint glass are mounted inside metal water jackets hinged together at one end and secured at the other by a spring clamp lever (13 Fig. 3). The face of the upper prism (5 Fig. 3) is highly polished while the corresponding face of the lower prism (10 Fig. 3) is left grey to prevent the formation of false images.

The telescope and index scale form an integral unit which can be rotated, together with the prism assembly, on a common shaft located in a plain bearing at the head of the supporting pillar (6 Fig. 4). The scale arm (5 Fig. 4) which rotates the prism assembly independently, is provided with a friction drive for fine setting, operated by a small hand wheel (2 Fig. 3).

A reading lens (3 Fig. 3), having a glass window which can be rotated to give maximum illumination, is mounted on the scale arm; through the lens a magnified image of the scale can be seen.

The scale is calibrated from 1.300 to 1.700 in the case of model M.46, and from 1.46 to 1.86 in the case of model M.450, each scale division being equal to .001; the final digit is obtained by estimation.

A thermometer is provided with the instrument to measure the temperature in the water jacket. The thermometer, which screws into a threaded sleeve in the water outlet Tee connection, is calibrated 0–75°C.

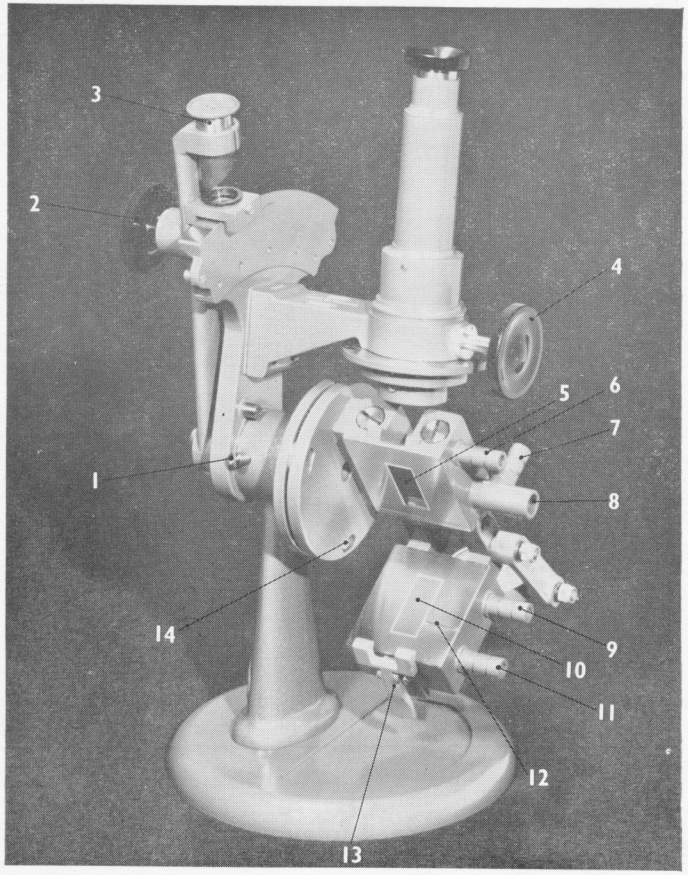

Fig. 3

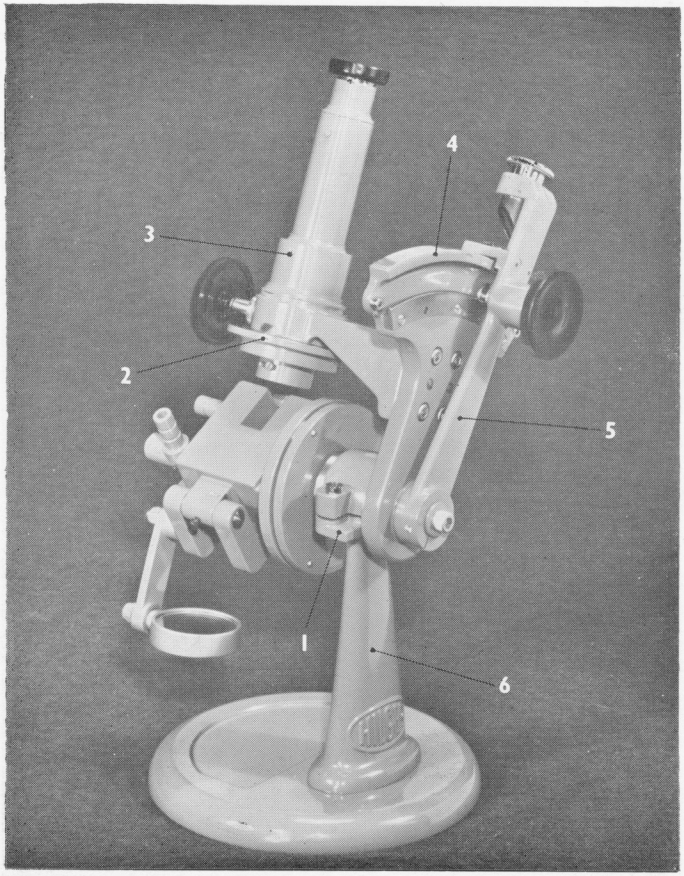

Fig. 4

USING THE INSTRUMENT

MEASUREMENT OF LIQUIDS

Where it is necessary to carry out measurements of refractive index at specific temperatures, e.g. in the case of butter, the temperature of the prisms should be adjusted by passing water at the required temperature through the water jacket surrounding the Abbe prisms before introducing the liquid to be investigated.

Water should be fed into the lower half of the jacket by way of the connection nearest the hinge (9 Fig. 3) and pass out from the upper jacket at the Tee joint in which the thermometer bulb is located (7 Fig. 3). The remaining two connections (6 and 11 Fig. 3) should be joined by a length of rubber tubing.

For temperatures up to 40°C, a conventional type of thermostat, consisting of a mechanically agitated water tank heated by a regulated gas jet, will give temperature control accurate to 0.01°C.

When temperature is less critical, the heating water may be run from a large tank of some 2 to 5 gallons capacity which is raised to the required temperature.

The sample liquid should be introduced when the thermometer has remained steady at the required temperature for a period of 5–10 minutes.

The procedure for applying the sample liquid is as follows, a clean glass rod and a test tube being set ready to hand.

1. Steady the instrument by placing one hand on the base, and with the other hand, rotate the arc casting until it comes to rest against the fixed stop, as in Fig. 5.

2. Hold the instrument in this position and, with the thumb and forefinger, release the spring clamp lever by pressing the grips together and swing the upper prism as far back on its hinge as possible (Fig. 6).

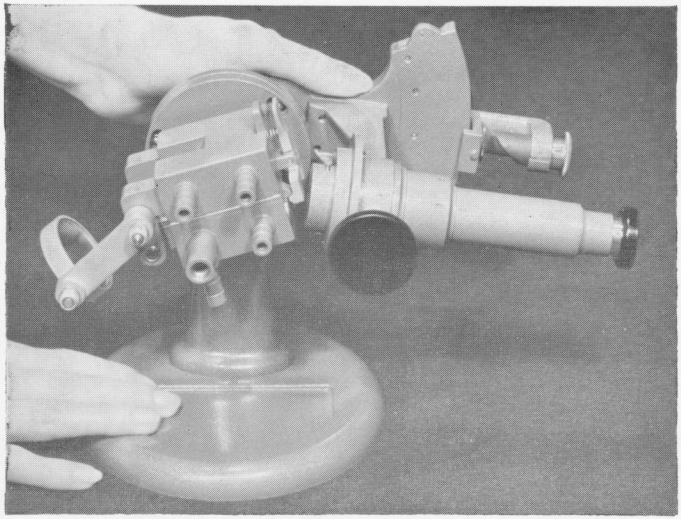

Fig. 5 Rotating the arc casting

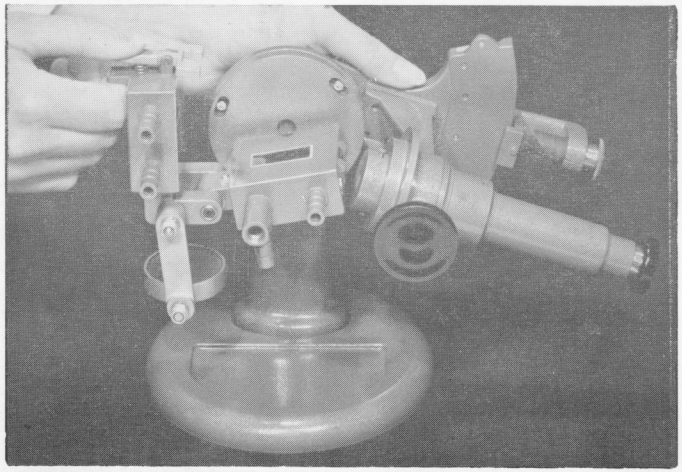

Fig. 6 Opening the prism jacket

3. Retaining the grip on the sector arm, take a drop of the liquid to be measured on the end of the glass rod and transfer it to the polished face of the prism (Fig. 7).
   Place the rod in the test tube and close the water jacket, making quite sure that the catch is securely fastened.
4. Return the sector arm to the upright position.

READING THE REFRACTIVE INDEX

1. Adjust the reading lens to give the best possible scale illumination and focus.
2. Move the scale arm (5 Fig. 4) by means of the hand wheel until a patch of red or blue light is observed in the telescope field. (The mirror should be adjusted to reflect light along the axis of the telescope tube. The best position can be found by trial when the liquid has been introduced, and once set does not need to be altered provided that the light source remains steady.)
3. Adjust the Abbe compensator, using the other hand wheel (4 Fig. 3), until the field is seen to consist of a bright area and a dark area, sharply divided, the colour having disappeared.
4. Move the scale arm again until the dividing line coincides exactly with the point of intersection of the cross lines.
5. Read off the refractive index directly from the scale (4 Fig. 4).

MEASUREMENT OF SOLIDS

A solid sample should be made up in the form of a rectangular block about 20 mm. × 10 mm. and not less than 1 mm. in thickness; one of its faces should be flat and polished and one end approximately perpendicular to this face but not necessarily polished.

Temperature control is less important than for liquids and for most purposes may be neglected.

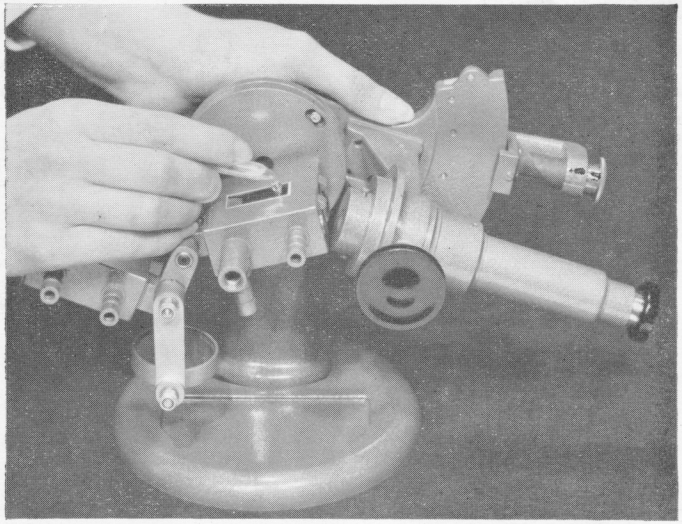

Fig. 7 Applying liquid to face of prism

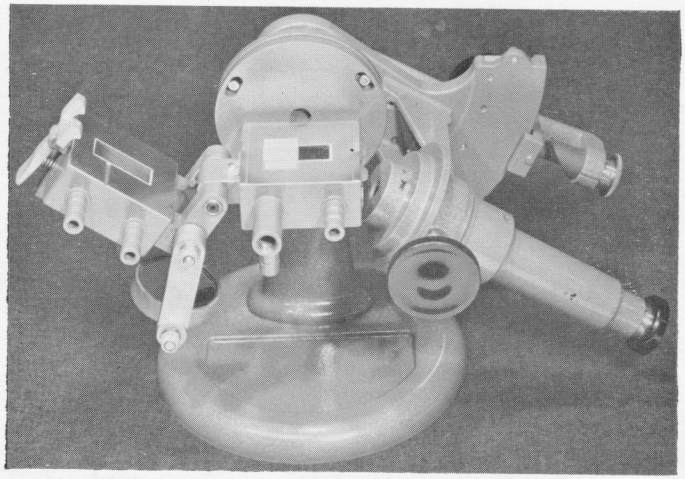

Fig. 8 Solid sample in position on prism

Monobromonaphthalene is recommended for use as a contact liquid for solids having a refractive index of 1.65 or less; for substances of higher refractive index, a solution of methylene iodide or potassium mercury iodide should be used. Care must be exercised if the latter is used, on account of its poisonous nature, and the possibility of damage being caused to the prism surfaces by small crystals contained in it.

To take a reading, proceed as follows:

1. Move the sector arm until it rests against the fixed stop (1 Fig. 4).
2. Position the instrument so that the telescope is pointed directly at the light source.
3. Place the sample centrally upon the face of the upper prism, as close as possible to the edge furthest from the telescope, and make optical contact by using a drop of one of the liquids referred to above. Sufficient liquid should be used to cover the whole surface when the sample is pressed well down, but not so much that an excess of liquid is pressed out along the edges.
   NOTE: It is important that no liquid lies in front of the sample as this may result in a false reading.
4. Leave the sample in position and proceed as described under the sub-section 'Reading the refractive index', para. 2 onwards.
   The position of the sample can be seen in Fig. 8.

GENERAL PRECAUTIONS

1. Liquid samples should be absolutely free from solid particles such as small crystals.
2. When examining solids, care should be taken that the faces of both prism and sample are free of dust before introducing the contact liquid.
3. Solid samples must be removed with great caution after measurement, as they adhere firmly to the face of the prism after having been pressed down.

4. The following method of cleaning and applying a solid sample is recommended:
   First remove any grease—finger marks, etc.—from the prism and from the polished face of the sample, using a very little alcohol if necessary.
   Hold the sample face downward and remove any specks of dust from the surface using the brush provided, before applying a small amount of the contact liquid.
   Brush away any specks of dust adhering to the surface of the prism and immediately place the sample in position.
   The camel hair brush should be kept in a bottle and never laid down on the bench, and should periodically be washed out in alcohol.

CORRECTION FOR AMBIENT TEMPERATURE

The instrument is calibrated to read accurately at a temperature of 20°C. The refractive index of the prisms is however affected by changes in temperature, and corresponding corrections must be made to attain complete accuracy at other temperatures.

The compensator prisms are also affected, and terms for these also appear in the correction tables.

The temperature of the compensator prisms may be found to within 1°C by supporting a thermometer with the bulb in contact with the compensator.

In the following expressions

n = refractive index as indicated on the instrument scale

t_1 = temperature of the Abbe prisms in °C

t_2 = temperature of the compensator prisms in °C

d = reading of the compensator scale

A and B are values taken from the dispersion table

A quantity R (which after dividing by 10^5) is to be added to observed values of refractive index to correct for the effect of temperature is given by the equation

$$R = 29.5\,A\,(t_1 - 20) + 0.094\,\left(\frac{0.04525}{A} - n\right) d\,(t_2 - 20)$$

and may be evaluated with the aid of the dispersion tables for any value of n.

A quicker method is to use the simplified expression

$$R = r_1\,(t_1 - 20) + r_2\,d\,(t_2 - 20)$$

taking values of r_1 and r_2 from Table I below.

TABLE I

n_D	r_1	r_2
1.30	0.71	0.0543
1.40	0.70	0.0476
1.50	0.70	0.0395
1.60	0.70	0.0291
1.70	0.72	0.0139

It will be seen that a correction of .0001 must be made for each rise of 14°C of the Abbe prisms, and the same amount for a rise of 7°–29°C of the compensator prisms, assuming a maximum value of d, viz. 25.

EXAMPLE

The specimen is oil of $n_D = 1.47$ at 40°C.

Assume the temperature of the compensator to be 26°C and the dispersion scale reading −12.5.

From Table I

$r_1 = 0.70$, $r_2 = 0.0419$ approx.

Therefore $R = 0.70\,(40–20) - 0.0419 \times 12.5\,(26–20)$

$= 14.0 - 3.1$

$= 10.9$

Dividing this by 10^5, the correction to be added is .0001.