DISPERSION

When the refractive index alone is of interest, the reading of the compensator may be ignored.

Dispersion is assessed by applying the scale reading to the dispersion tables (Appendices II and III). The circular scale is so divided that only one table is needed; the reading may be positive or negative as indicated on the scale.

It is advisable to take the mean of several compensator readings, each estimated to the nearest tenth of a scale division.

The following examples illustrate the use of the dispersion scale.

EXAMPLE 1 The ordinary ray of quartz

The observed readings are:

Refractive index (n_D) = 1.5442

Compensator scale (d) = − 17.1

Reference to the dispersion table produces the following values:

A = .02341, B = .0009216 (approx.), C = .00000041.

To calculate the dispersion, substitute these values in the expression

$$A + Bd + Cd^2$$

$$\text{Dispersion then} = .02341 + (.0009216 \times -17.1) + (.00000041 \times -17.1^2)$$
$$= .02341 - .01576 + .00011$$
$$= .00776$$

EXAMPLE 2 α-monobromonaphthalene at 17.5°C

The observed readings are:

$n_D = 1.6584$

$d = 14.2$

From the dispersion table,

A=.02389 (approx.), B=.00060 (approx.), C=.00000045

Substituting these values as before,

$$\text{Dispersion} = .02389 + (.00060 \times 14.2) + (.00000045 \times 14.2^2)$$
$$= .02389 + .00852 + .00010$$
$$= .03251$$

TEMPERATURE CORRECTION FOR DISPERSION

A quantity S (which after dividing by 10^5) is to be added to calculated values of dispersion is found from the equation

$$S = (13.41\,A + \sigma\,d)(t_1 - 20) + 32.13\,Bd\,(t_2 - 20)$$

where 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

σ is a value taken from Table II below

TABLE II

n	σ	s_1	s_2
1.30	0.0008	0.32	0.0402
1.40	0.0008	0.32	0.0374
1.50	0.0012	0.32	0.0327
1.60	0.0020	0.32	0.0256
1.70	0.0036	0.33	0.0143

This may also be reduced to a simpler form, namely

$$S = (s_1 + \sigma\,d)(t_1 - 20) + s_2\,d\,(t_2 - 20)$$

Again taking the case of oil of refractive index n_D = 1.47 at 40°C, the reading of the compensator scale being —12.5 at 26°C.

From the dispersion table

$$\text{Dispersion } (n_F - n_C) = A + Bd + Cd^2$$
$$= .02343 + (.0010618 \times -12.5) + (.00000037 \times -12.5^2)$$
$$= .02343 - .01327 + .0000578$$
$$= .01022$$

From Table II

$$\sigma = 0.0011,\ s_1 = 0.32,\ s_2 = .0339$$

$$\text{Therefore } S = (0.32 - .014)(40\text{–}20) - .0339 \times 12.5 \times (26\text{–}20)$$

$$= .0306 \times 20 - 0.424 \times 6$$

$$= 6.12 - 2.544$$

$$= 3.576$$

Dividing by 10^5, this gives a correction of .00004, hence the corrected dispersion = .01022 + .00004 = .01026

CHECKING THE SCALE SETTING

USING THE TEST PIECE

The glass test piece supplied with the instrument consists of a rectangular block having two mutually perpendicular polished faces. The refractive index is engraved on the unpolished top face.

To check the instrument, using the test piece, proceed as for measuring any other transparent solid sample (page 8), using a drop of monobromonaphthalene to make optical contact.

The corrected refractometer reading of refractive index should agree with the value engraved on the test piece. If this is not so, the instrument should be adjusted by means of the small screw to bring the intersection of the cross lines into coincidence with the edge of the dividing field at the required scale setting.

Fig. 9 shows this adjustment being made.

USING A LIQUID

The above method using the test piece can be made with accuracy at any temperature, the change of refractive index of the test piece being less than that of the instrument prisms.

It is sometimes more convenient to check the scale setting by means of a liquid, especially where the instrument is set up for continuous working with liquids. Distilled water is recommended for this purpose on account of its

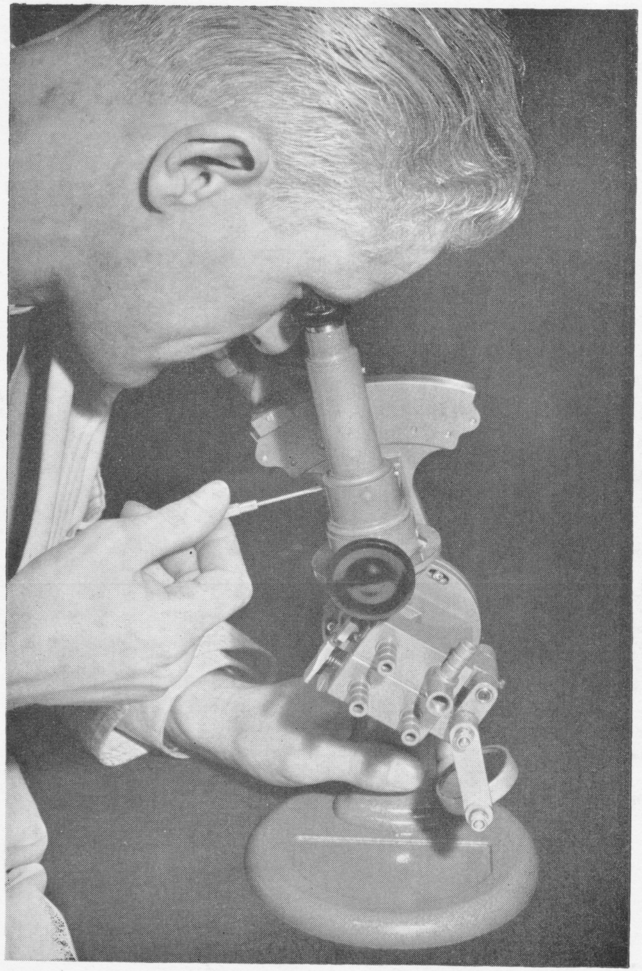

Fig. 9 Adjusting the scale setting

low temperature coefficient of refraction and its general availability.

Table III gives the refractive index of distilled water for a nominal range of temperature (10° to 40°C).

TABLE III

Temp. °C	Ref. Index	Temp. °C	Ref. Index
10	1.3337	21	1.3329
11	1.3337	22	1.3328
12	1.3336	23	1.3327
13	1.3335	24	1.3326
14	1.3335	25	1.3325
15	1.3334	26	1.3324
16	1.3333	27	1.3323
17	1.3332	28	1.3322
18	1.3332	29	1.3321
19	1.3331	30	1.3320
20	1.3330	40	1.3307

ACHROMATISM IN THE TELESCOPE FIELD

The degree of achromatism obtained by the use of the Abbe compensator with a source of white light varies with the substance examined. In practice, achromatism would be complete if only the C and F lines of hydrogen (6563 A—4861 A) were used, but light outside this range influences achromatism to a greater or lesser degree.

The extreme red end of the spectrum is comparatively unimportant as dispersion in this region is small and the sensitivity of the human eye not too critical. At the violet end however, dispersion is greater than throughout the remainder of the visible spectrum and the eye is still sensitive. Consequently, there is in most cases, some violet light that suffers greater dispersion and causes a purplish border to form at the dividing line in the telescope

field; this need not be prejudicial to accuracy when its cause is known, and due allowance made, as in example 2 above.

The refractive index of a substance, as well as its dispersion, influences the appearance of the dividing line. For liquids in general, the dispersion causes a reddish border, the residual violet being thrown into the dark area of the field when the edge is achromatised for red and blue.

In the case of glasses, the lack of achromatism is much less pronounced, and here the effect of refractive index is greater. Glasses of low refractive index, e.g. crowns of about $n_D = 1.51$, exhibit a similar field to liquids, while with dense flint glass, the residual violet is thrown into the bright area of the field and a faint violet border is seen.

It is possible to obtain a glass of intermediate refractive index that will give an almost perfectly achromatic field.

CARE OF PRISMS

The Abbe prisms are made of dense flint glass that is particularly susceptible to damage by scratching and to tarnishing, consequently great care must be taken to keep them perfectly clean and free from adherent solid particles.

After using the instrument the prisms should be wiped with a soft clean cloth after removing all trace of the sample by the use of a suitable solvent.

CHANGING THE WATER JACKET ASSEMBLY

When a replacement water jacket assembly is to be fitted, the following procedure should be adopted.

1. Remove the three socket headed screws (14 Fig. 3) that secure the assembly to the support pillar and detach the complete water jacket assembly.
2. Fit the new assembly, replace the three screws and tighten them until the assembly can just be rotated on the pin.
3. Place a little distilled water between the prisms and close the jacket box.

4. Place the eye to the telescope, and after adjusting the mirror until light is reflected along the telescope tube, rotate the jacket until the dividing line in the field is coincident with the intersection of the cross wires.
   Check that the refractive index scale reads 1.3330.

5. Fill the jacket with ordinary tap water. Insert the thermometer and allow a few minutes for it to stabilise at about 20°C, then again rotate the jacket until the scale reading is 1.3330.
   Final adjustment is made by means of the screw at the base of the telescope tube, as seen in Fig. 9.

ASSESSMENT OF PERCENTAGE OF 'DRY SUBSTANCE'

During the processing of sugar and preserves, it is necessary to determine the percentage of 'dry substance'—sucrose, inorganic salts, protein, etc.—that are present.

One method of doing this is by measuring the refractive index of the sugar solution; only a small volume of the liquid is required to make this measurement using the refractometer, and the full range is obtainable on the instrument.

When specially ordered, the refractometer M.46, can be supplied with an additional engraved scale from which the percentage of sucrose (the whole of the soluble solid in solution being reckoned as sucrose) present in a sample solution can be read with an average accuracy of 0.05 per cent.; the scale being calibrated for accuracy at either 20°C or 28°C, depending upon requirement.

NOTE: Conversion tables showing the refractive index of sugar solutions of various concentrations, for use with instruments not fitted with the subsidiary sugar scale, can be obtained from the manufacturers, Messrs. Hilger & Watts.

The 'apparent purity' of sugar juice is given by the expression

$$\frac{S \times 100}{R}$$

where S is the amount of sucrose present together with other solids which would increase the refractive index by an amount corresponding to the addition to the solution of S^1 per cent. sucrose, S^1 being equal to R–S.

This does not take into account any insoluble matter that may be present in a sample. Such matter should be filtered off before an attempt is made to measure the refractive index, as it may cause clouding of the dividing line in the telescope field.

The total amount of insoluble solid matter may be estimated to within about 0.5 per cent. by the following method.

Take a refractometer reading in the ordinary way and note the percentage of sugar corresponding to the refractive index value, calling it R_1. Dilute the sample by adding an equal amount of distilled water, mix thoroughly, and again read off the sugar percentage, this time calling it R_2.

The percentage of insoluble solids present can then be calculated from the equation:

$$I = \frac{100 R_1 - 200 R_2}{R_1 - R_2}$$

A more accurate measurement of the 'apparent purity' can be calculated using the expression

$$\frac{S \times 100}{X}$$

where X, the true percentage of soluble solids reckoned as sugar is derived from

$$X = \frac{R_1 (100 - I)}{100} = \frac{R_2 (200 - I)}{100}$$

The method is illustrated by the following example of a sample of jam.

1. The refractive index of the sample at 25.9°C is 1.4696 corresponding to 72.3 per cent. sugar (R_1).
2. The refractive index of the sample with an equal amount of distilled water added at 26.5°C is 1.3892 corresponding to 34.95 per cent. sugar (R_2).

From these values it is calculated that I = 6.4 per cent. and X = 67.6 per cent.; and hence the percentage of water W_1 = 26 per cent.

APPENDIX I

SPECIFICATION

SIZE	7 in. × 6 in. × 13.5 in. high. (18 cm. × 15 cm. × 34 cm.)	
WEIGHT	18 lb. (8 kg.)	
REFRACTIVE	M.46	M.450
INDEX SCALES	1.30×.001−1.70 calibrated at 20°C	1.46×.001−1.86 calibrated at 20°C
ACCURACY	.0002	
DISPERSION	$n_F - n_C$ assessed from compensator scale reading and dispersion table	
LIGHT SOURCE	Daylight or white light	
SUGAR SCALE (Optional extra M.46 only)	0 × .05 − 85 per cent. calibrated at either 20°C *or* 28°C	
TEMPERATURE CONTROL	Prisms surrounded by water jackets	
THERMOMETER	Calibrated 0–75°C	

APPENDIX II

DISPERSION TABLE FOR THE ABBE REFRACTOMETER M.46

$$\text{Dispersion } (n_F - n_C) = A + Bd + Cd^2$$

Values of A and B corresponding to refractive index values n_D as read from the refractometer scale, are given in the following table; d is the compensator scale reading. Difference columns $\triangle A$ and $\triangle B$ for interpolation are given for tabulated differences of 0.001 in n_D.

The term Cd^2 in the above expression should be included in calculations when high values of d are obtained and maximum accuracy id desired, but for other cases it may be neglected.

Appendix II - Table

n_D	A	ΔA	B	ΔB	C	n_D
1·300	0·02392	− 4	125·06	0·67	0·016	1·300
1·310	0·02388	− 4	124·39	0·72	0·018	1·310
1·320	0·02384	− 4	123·67	0·78	0·019	1·320
1·330	0·02380	− 4	123·89	0·83	0·020	1·330
1·340	0·02376	− 4	122·06	0·88	0·022	1·340
1·350	0·02372	− 3	122·18	0·94	0·023	1·350
1·360	0·02369	− 3	120·24	1·00	0·024	1·360
1·370	0·02366	− 3	119·24	1·05	0·025	1·370
1·380	0·02363	− 3	118·19	1·11	0·026	1·380
1·390	0·02360	− 3	117·08	1·15	0·027	1·390
1·400	0·02357	− 3	115·93	1·21	0·029	1·400
1·410	0·02354	− 2	114·72	1·27	0·030	1·410
1·420	0·02352	− 2	113·45	1·32	0·031	1·420
1·430	0·02350	− 2	112·13	1·38	0·032	1·430
1·440	0·02348	− 2	110·75	1·46	0·034	1·440
1·450	0·02346	− 2	109·29	1·52	0·035	1·450
1·460	0·02344	− 1	107·77	1·59	0·036	1·460
1·470	0·02343	− 1	106·18	1·64	0·037	1·470
1·480	0·02342	− 1	104·54	1·71	0·037	1·480
1·490	0·02341	− 1	102·83	1·78	0·037	1·490
1·500	0·02340	− 1	101·05	1·84	0·038	1·500
1·510	0·02339	0	99·21	1·93	0·039	1·510
1·520	0·02339	1	97·28	2·03	0·040	1·520
1·530	0·02340	1	95·25	2·09	0·041	1·530
1·540	0·02341	1	93·16	2·18	0·041	1·540
1·550	0·02342	1	90·98	2·27	0·042	1·550
1·560	0·02343	2	88·71	2·36	0·043	1·560
1·570	0·02345	3	86·35	2·47	0·043	1·570
1·580	0·02348	3	83·88	2·57	0·043	1·580
1·590	0·02351	3	80·31	2·69	0·044	1·590
1·600	0·02354	4	78·62	2·83	0·045	1·600
1·610	0·02358	5	75·79	2·97	0·046	1·610
1·620	0·02363	6	72·82	3·09	0·046	1·620
1·630	0·02369	6	69·73	3·25	0·046	1·630
1·640	0·02375	7	66·48	3·41	0·046	1·640
1·650	0·02382	9	63·07	3·62	0·046	1·650
1·660	0·02391	10	59·45	3·84	0·045	1·660
1·670	0·02401	11	55·61	4·12	0·045	1·670
1·680	0·02412	13	51·49	4·44	0·045	1·680
1·690	0·02425	15	47·05	4·93	0·044	1·690
1·700	0·02440		42·12		0·044	1·700

Makers Reference data: M38742 $\theta = 60°$ $n_{OD} = 1.74869$ $n_{OF} - n_{OC} = 0.02702$ $2K = 2° \, 49' \, 10''$.

APPENDIX III

DISPERSION TABLE FOR THE HIGH INDEX ABBE REFRACTOMETER M.450

Dispersion $(n_F - n_C) = A + Bd + Cd^2$

Values of A and B corresponding to refractive index values n_D as read from the refractometer scale, are given in the following table; d is the compensator scale reading. Differences △A and △B for interpolation are given for tabulated differences of 0.01 in n_D.

The values of A, B, and C vary with the proportional partial dispersions of the samples being measured. This variation, which is present with all Abbe type refractometers used with compensating prisms, is enhanced with this instrument by reason of the type of glass used for the prisms.

The proportional partial dispersion of the test sample may be conveniently expressed by the ratio

$$p = \frac{n_C - n_D}{n_D - n_F}$$

For most substances, p lies in the range 0.20 to 0.60, and in the table, the values A, B, and C are given for $p = 0.40$. For other values of p, if they are known, corrections to A, B, and C may be taken from the accompanying curves.

Appendix III - Table

n_D	A	ΔA	B	ΔB	C	n_D
1·46	·03899	− 6	162·8	− ·8	− ·012	1·46
7	·03893	− 6	162·0	− ·9	− ·015	7
8	·03887	− 5	161·1	− ·9	− ·018	8
9	·03882	− 5	160·2	−1·0	− ·020	9
1·50	·03877	− 5	159·2	−1·1	− ·023	1·50
1	·03872	− 4	158·1	−1·1	− ·026	1
2	·03868	− 4	157·0	−1·2	− ·029	2
3	·03864	− 4	155·8	−1·2	− ·031	3
4	·03860	− 4	154·6	−1·3	− ·033	4
5	·03856	− 4	153·3	−1·4	− ·035	5
6	·03852	− 4	151·9	−1·5	− ·038	6
7	·03848	− 3	150·4	−1·5	− ·041	7
8	·03845	− 3	148·9	−1·6	− ·043	8
9	·03842	− 3	147·3	−1·7	− ·045	9
1·60	·03839	− 2	145·6	−1·7	− ·047	1 60
1	·03837	− 2	143·9	−1·8	− ·050	1
2	·03835	− 2	142·1	−1·9	− ·052	2
3	·03833	− 1	140·2	−2·0	− ·055	3
4	·03832	− 1	138·2	−2·1	− ·057	4
5	·03831	0	136·1	−2·2	− ·059	5
6	·03831	− 1	133·9	−2·3	− ·061	6
7	·03830	0	131·6	−2·3	− ·063	7
8	·03830	1	129·3	−2·4	− ·066	8
9	·03831	0	126·9	−2·5	− ·068	9
1·70	·03831	1	124·4	−2·6	− ·070	1·70
1	·03832	1	121·8	−2·8	− ·072	1
2	·03833	2	119·0	−2·9	− ·073	2
3	·03835	3	116·1	−3·0	− ·075	3
4	·03838	4	113·1	−3·1	− ·076	4
5	·03842	5	110·0	−3·3	− ·078	5
6	·03847	6	106·7	−3·4	− ·080	6
7	·03853	6	103·3	−3·5	− ·081	7
8	·03859	7	99·8	−3·6	− ·082	8
9	·03866	8	96·2	−3·9	− ·083	9
1·80	·03874	10	92·3	−4·1	− ·084	1 80
1	·03884	11	88·2	−4·4	− ·085	1
2	·03895	13	83·8	−4·6	− ·084	2
3	·03908	15	79·2	−4·9	− ·083	3
4	·03923	17	74·3	−5·2	− ·082	4
5	·03940	20	69·1	−5·6	− ·081	5
1·86	·03960		63·5		− ·080	1·86

Maker's Reference data: M.37350 A=60° n_{OD}= 1.92855 $n_{OF}-n_{OC}$=0.04424 2K=3° 45′ 56″.