ABBE REFRACTOMETER

BAUSCH & LOMB
OPTICAL CO. ROCHESTER, N. Y., U. S. A.

THE BAUSCH & LOMB
ABBE REFRACTOMETER
Cat. No. 33-45-50

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DIRECTIONS FOR USE

BAUSCH & LOMB OPTICAL COMPANY

ROCHESTER, N.Y., U.S.A.

The Bausch & Lomb

ABBE REFRACTOMETER

Directions for Use

The Bausch & Lomb Abbe Refractometer, with prisms and eyepiece covered with paper and the whole instrument covered by a cloth sack, is packed in an individual carrying case. Included in the case are the following items:

1. Thermometer with metal jacket
2. Screw Driver
3. One bottle of Mono-brom-naphthalene
4. Dropping Bottle
5. Glass Test Piece
6. Dispersion Chart

The thermometer, screw driver, mono-brom-naphthalene, dropping bottle, and glass test piece have places fitted for them on the inside of the door of the case. The dispersion chart is at the back of the case.

DESCRIPTION OF THE INSTRUMENT

The Abbe Refractometer, as made by the Bausch & Lomb Optical Co., is designed and constructed so as to combine accuracy with strength and durability. The instrument consists essentially of four parts.

1. The Telescope
2. The Abbe Prisms
3. The Sector
4. The Compensator Prisms.

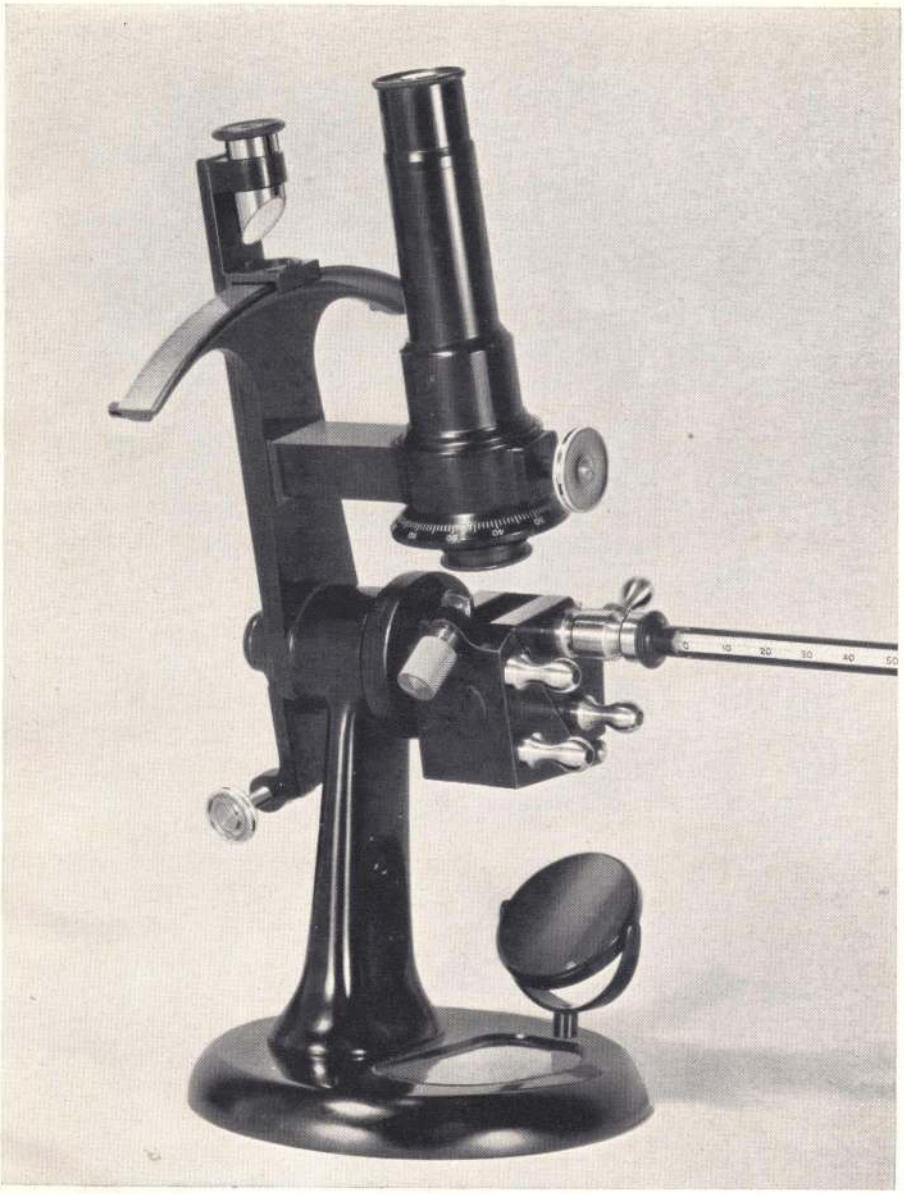

Figure 1

BAUSCH & LOMB ABBE REFRACTOMETER

The telescope consists of an objective "C" (Fig. 2), Eyepiece "A," and a Cross Hair Disc "B" mounted in the focal plane of the Objective. The function of the telescope is to form an image of the border line of the total reflection in the plane of the cross hairs, whose intersection provides a point with which the border line may be brought into coincidence under conditions assuring the greatest possible accuracy of setting.

The Abbe prisms, two flint glass prisms of high refractive index, are cemented in hollow water jacketed mounts so designed that when temperature control is desired, water can be circulated around the prisms. The exposed surfaces of the upper Abbe Prism "E," are highly polished, while the hypotenuse surface of the lower Abbe Prism is finely ground. This surface serves solely for the purpose of illumination. The upper prism mount is rigidly attached to the alidade or index arm. When the lower mount is clamped into position against the upper, the hypotenuse surfaces are separated by a space of 0.1 to 0.15mm thick. It is in this space that the liquid to be measured is held.

The sector "I" is a metal arm to which the telescope is rigidly attached. One end is connected to the upright in the base in such a manner that the whole sector may be rotated about an axis, which coincides with the axis of rotation of the Abbe prisms. This may be considered as the main axis of the instrument. The sector may be rotated between fixed limits to suit the various conditions of illumination at various points on the index scale. On the upper end of the sector is mounted a German silver scale graduated directly in terms of refractive index of the D line

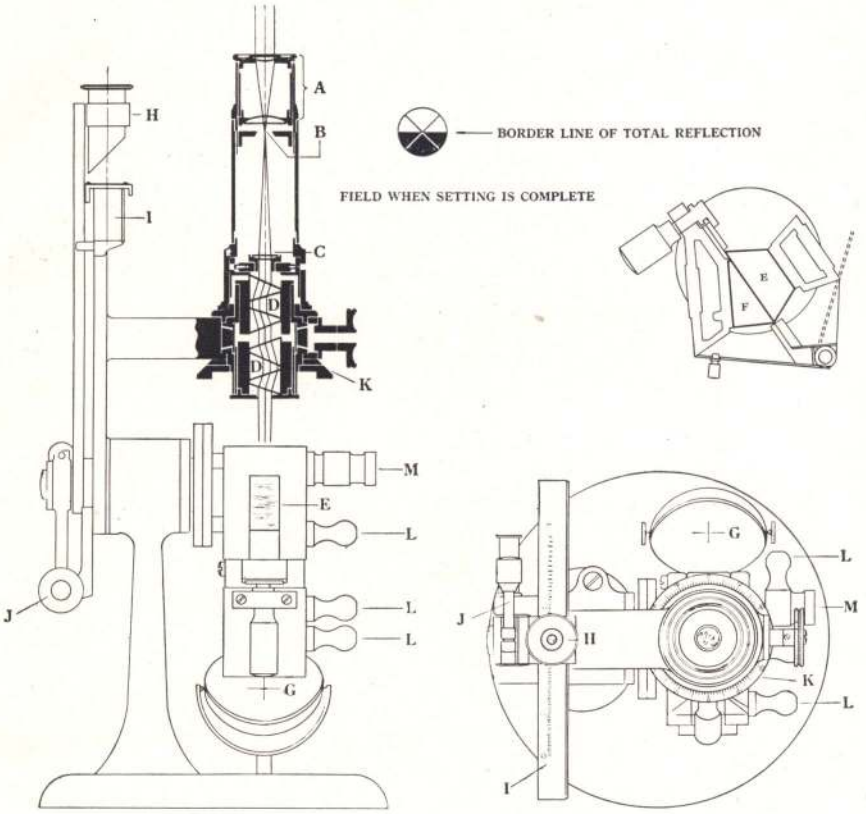

Figure 2

PATH OF LIGHT RAYS THROUGH THE BAUSCH & LOMB ABBE REFRACTOMETER

A—*Eyepiece*
B—*Cross Hair Disc*
C—*Objective*
D—*Compensator Prisms (2)*
F—*Abbe Prism (Upper)*
G—*Mirror*
H—*Magnifier*
I—*Sector*
J—*Fine Adjustment*
K—*Arbitrary Scale*
M—*Opening (for Metal Adapter with Thermometer)*

(Sodium) at a temperature of 20 degrees c.

An alidade or movable arm which may be rotated as a unit with the Abbe prisms around the main axis of the instrument but independently with respect to the Sector "I" (Fig.2) rests against the sector. The upper end of the alidade bears a reference line, which when the arm is rotated moves along the index scale. The Fine Adjustment "J" provides a slow motion and facilitates bringing the border line in exact coincidence with the cross hairs.

The two Compensator Prisms "D-D" are two direct vision Amici prisms that rotate in opposite directions about the optical axis of the telescope. The pinion head rotates the prisms, the amount of rotation being read on an Arbitrary Scale "K." The lower prism can be rotated with reference to the scale for purposes of adjustment, by means of the milled ring, which is clamped by a small screw at the base of the lower Amici prism mount.

MANIPULATION OF THE INSTRUMENT

Experience shows that a short time spent in systematic manipulation of the refractometer is sufficient to establish deftness in its use. Such a habit is a great asset and it is recommended that the beginner carry out the following instructions carefully, before any readings are taken, repeating the whole series of actions until they can be performed without thought.

Space for the instrument should be reserved in front of a well lighted window or other source of white light. To the right of this space is placed a bottle of distilled water and one of alcohol. The operator should

obtain a glass rod, a test tube in which to keep it and a piece of clean, soft cloth - a piece of linen washed in distilled water is the best.

The refractometer is removed from the case by taking hold of it and sliding the instrument from the case. The cloth covering the instrument and the paper covering the prisms and eyepiece are removed. The instrument is placed in the space reserved for it with the Scale Sector "I" (Fig.2) to the left and the mirror "G" to the rear.

The index arm is unclamped by loosening "J" and moved to the rear end of the scale. The refractometer base is held firmly with the right hand and with the left the telescope and sector are rotated until the telescope is horizontal and pointing away from the operator.

The prisms are opened by loosening the prism clamp and the hinged Prism swung out until its surface is horizontal. The surface of this prism is finely ground, while the surface of the fixed prism is highly polished.

The distilled water is placed on the polished surface of the fixed Prism "E," using the glass rod, and only enough distilled water is used to insure filling the spaces between the prisms when they are clamped together. Again the base is held in the right hand and the telescope and scale sector are rotated about the axis until the instrument is in position.

The index arm is unclamped and moved to the other end of the scale. The telescope eyepiece "A" is focused sharply on the cross hairs and the divided field is brought into view by moving the index arm. The field will

have a colored border, which may be achromatized by use of the compensators rotated by the pinion.

The line will be sharpest when the edge is just turning blue. The line is then brought almost into coincidence by moving the index arm. This arm is clamped and exact coincidence with the cross hairs is obtained by means of the slow motion screw.

The refractive index is read throughthe Magnifier, H. This is sharply focused on the cross line and also turned until the scale is well illuminated. The index scale is divided so as to read to three decimals directly, while the fourth is estimated. The lines on the scale are of three different lengths. The line of intermediate length reads one unit in the second decimal place, the longest line reads five in the third decimal place, while the shortest line is one unit in the third decimal place. The index of distilled water will be about 1.3330 depending on the temperature of the liquid.

After reading the index the prisms are opened and cleaned with the soft cloth.

To use transmitted light through the Abbe, swing the prism box shutter into the upright position in order to close the rear ground glass window.

To use reflected light, swing the prism box shutter under the auxiliary prism so that the opening is closed.

CARE OF PRISMS

In order to obtain the best results with the refractometer great care should be taken

of the prisms since they are made of dense glass which tarnishes and scratches easily.

Immediately after use the lower prism should be cleaned with a cloth and traces of substances used removed with a suitable solvent. Greater care should be taken of the upper prism. When cleaning, it should be rubbed very carefully to prevent scratching. Liquids introduced for examination should be free from solid particles. Solid specimens should be cleaned carefully and the surface of specimen and prism should be free from dust before they are placed together. In removing a solid specimen from the surface of the prism the specimen should be lifted directly upward from the prism surface and not allowed to slide over it.

THE EFFECT AND CONTROL OF TEMPERATURE

As the index and dispersion of a substance vary with the temperature it is important to know the temperature and to control it. This is particularly true in the case of liquids, where as a rule the temperature coefficients are large and negative. The temperature coefficients for a few liquids are as follows:

Water	- 0.0001	Linseed Oil	- 0.0004
Benzine	- 0.0006	Carbon Disulphide	-0.0008

Thus it is seen that in order to obtain an accuracy of one or two units in the fourth decimal place it is necessary to know the temperature and control it to a fraction of a degree.

On the other hand in the case of solids, the temperature has very little effect and can generally be neglected. A few examples are as follows:

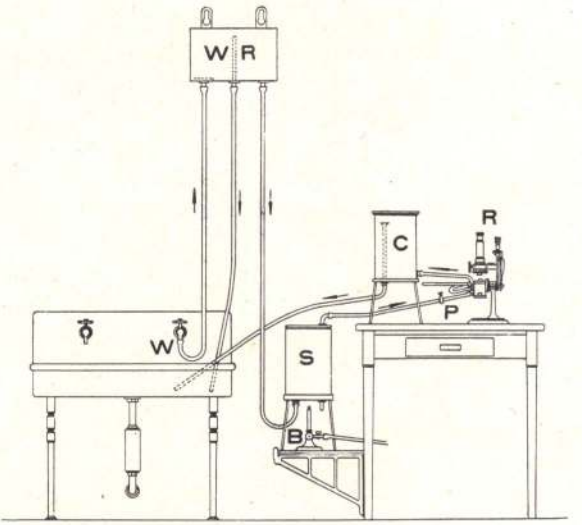

Figure 3

APPARATUS FOR TEMPERATURE REGULATION WITH THE BAUSCH & LOMB ABBE REFRACTOMETER

WR—*Water Pressure Regulator*
W —*Water Supply*
S —*Water Heater*
B —*Bunsen Burner*
C —*Table Pressure Regulator*
P —*Pinchcock*
R —*Refractometer*

Light Crown Glass	-	0.000,002
Heavy Crown Glass	-	0.000,014
Light Flint Glass	-	0.000,001
Fluorite	-	0.000,012

The apparatus furnished for use with the Abbe Refractometer for the purpose of temperature control is illustrated in Fig. 3.

It consists of a water Heater "S" (Fig.3) and two Water Pressure Regulator Tanks "WR" and "C". The Heater is essentially a coil of heavy copper tubing between two cylinders of sheet copper. It is designed so as to provide an even distribution of heat, which may be obtained from a Bunsen Burner "B," or alcohol flame. The water pressure regulating tanks are made of heavy enameled zinc.

Examination of Figure 3 will show the method of connecting the apparatus. All connections are made with rubber tubing. It is well to place a pinch cock at "P" (Fig.3) in case it is necessary to stop work suddenly. The Water Pressure Regulating Tank "WR" should be mounted so that it can be adjusted vertically. An approximate temperature may be obtained most readily by adjusting of the heat source "B," after which the exact temperature desired may be obtained by variation of the height of the Wall Tank "WR." A little experience will soon enable the operator to know how much variation in "WR" will change the temperature one tenth of a degree.

The thermometer supplied with each instrument is mounted in a metal adapter which screws into the opening "M" (Fig.2) of the prism mount in such a manner that the mercury bulb extends into the water jacket where it is surrounded by the circulating water.

Reading of refractive index must not be taken until the temperature has remained constant for five or ten minutes. The liquid to be measured is then introduced between the prisms and its index read.

MEASUREMENT OF REFRACTIVE INDEX - SOLIDS

Solid specimens to be measured should have two polished surfaces at right angles to each other and intersecting in a sharp line. Where an accurate result is not required, it is possible to obtain a suitable image by simply breaking the specimen approximately at right angles to one polished surface.

Practice in the manipulation of the Abbe for solid specimens can be obtained by the use of the glass test piece provided with the instrument.

The important part in measuring solid pieces is to see that the two surfaces which will come in contact are perfectly clean. A surface can be most readily examined for the presence of dirt if it is viewed along an axis almost parallel to itself and so held that a strong diffused illumination, as skylight, is reflected from the surface into the eye.

The instrument is handled in the same way as in the measurements of liquids except that the telescope, when the prisms are opened, points to the right. A drop of mono-bromnaphthalene is placed on the polished surface of the test piece which is then placed on the polished surface of the prism. The two are pressed firmly together without sliding one on the other. The liquid forms a thin film between the prism and the test piece, holding the latter firmly in position. Care should be taken that as little liquid as is possible is used. A single small drop is quite sufficient.

The instrument is rotated into reading position as in the case of liquids except that the scale sector is on the right. Light from a window is reflected from the lower prism case onto the polished end of the test piece. The settings can be made quite easily if a piece of white paper is placed on the surface of the lower prism in order to reflect the light evenly.

For solids whose indices are lower than 1.64 mono-brom-naphthalene can be used; for indices higher than 1.64 methylene-di-iodide is used. The latter liquid should be kept corked as exposure to air causes it to crystallize and turn black.

MEASUREMENT OF DISPERSION

The Abbe Refractometer was designed for use in white light. When white light is used the border line of total reflection, instead of being clean and sharp, appears as a band of colored light. This is due to the unequal refraction of the different wave lengths of which white light is composed.

The compensation for the dispersion of the light is accomplished by placing two similar Amici Prisms "D-D" (Fig.2) between the telescope objective and the Abbe prisms. These prisms transmit sodium light without deviation and are so mounted that they can be rotated simultaneously, but in opposite directions, about the telescope axis. Thus the dispersion of these prisms can be made to vary in value from zero, when the bases are opposite and parallel, to double the amount of the dispersion of each prism, when the bases are parallel and on the same side. In order to get a colorless border it is only necessary to rotate the Amici prisms by means of the milled head until there is obtained an

equal but opposite dispersion to that caused by the Abbe prisms in conjunction with the substance being measured.

When measuring substances having a low dispersion, it is not always possible to obtain a colorless border line due to the secondary spectrum. Under these conditions the compensating prisms should be adjusted so that the bright part of the field appears colorless up to a very definite line, beyond which, toward the dark half of the field, will be a visible fringe of blue. In spite of this color disturbance accurate settings may be made by bringing the edge of the colorless half of the field to the intersection of the cross hairs.

The amount of rotation of the compensator prisms with respect to each other furnishes a means for obtaining the factor $\frac{n_D - 1}{n_F - n_C}$* of a substance. The drum on which is engraved an arbitrary scale rotates in conjunction with the prisms. The index on the front of the telescope provides a means of reading the drum. When the border line has been carefully achromatized, the drum reading with reference to the index on the front of the telescope, is taken.

There are two positions of the compensating prisms at which the border line will be colorless. The two positions are symmetrical with respect to the zero point of the drum and

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* This is a characteristic value for any substance. n_D, n_C and n_F are respectively, the index for λ = 5893 (sodium) for λ = 6563 (red hydrogen) and for λ = 4861 (Blue hydrogen). The fraction $\frac{n_D - 1}{n_F - n_C}$ is known as the ν-value of the substance.

give the same drum readings. If measurements of the highest accuracy are desired, the mean of settings on both sides of the zero point should be taken.

A special chart is provided with each instrument by means of which, when the index and drum readings are known, the factor $\frac{n_D - 1}{n_F - n_C}$ can be read directly. This chart, which was devised by our Scientific Bureau, supercedes the tables usually supplied with this type of instrument and eliminates any computations.

USE OF DISPERSION CHART

The horizontal lines on the chart represent the compensator or drum readings, while the vertical lines represent the index for D. The curves give the factor $\frac{n_D - 1}{n_F - n_C}$ directly. The interesection of the two lines representing the drum reading and index is found. From interpolation of values of these curves on either side of this point the dispersion is read directly.

Example I Calcite (Ordinary Ray)

n_D 1.6585 Drum reading 14.7

The point of intersection of the vertical line, representing 1.6585 and the horizontal line representing 14.7 lies between the curve 48 and 50, interpolation gives 48.7 for the dispersion.

Example II Water 20 degrees C

n_D 1.3330 Drum Reading 17.4

The intersection of these curves is between 54 and 56. Interpolation gives a dispersion value of 55.

Geerligs' Table for Dry Substance in Sugar-House Products

by Abbe Refractometer, at 28° C

Index refraction	Percent dry substance	Index refraction	Percent dry substance	Index refraction	Percent dry substance	Index refraction	Percent dry substance
1.3335	1	1.3695	24	1.4124	47	1.4639	70
1.3349	2	1.3712	25	1.4145	48	1.4663	71
1.3364	3	1.3729	26	1.4166	49	1.4687	72
1.3379	4	1.3746	27	1.4186	50	1.4711	73
1.3394	5	1.3764	28	1.4207	51	1.4736	74
1.3409	6	1.3782	29	1.4228	52	1.4761	75
1.3424	7	1.3800	30	1.4249	53	1.4786	76
1.3439	8	1.3818	31	1.4270	54	1.4811	77
1.3454	9	1.3836	32	1.4292	55	1.4836	78
1.3469	10	1.3854	33	1.4314	56	1.4862	79
1.3484	11	1.3872	34	1.4337	57	1.4880	80
1.3500	12	1.3890	35	1.4359	58	1.4914	81
1.3516	13	1.3909	36	1.4382	59	1.4940	82
1.3530	14	1.3928	37	1.4405	60	1.4966	83
1.3546	15	1.3947	38	1.4428	61	1.4992	84
1.3562	16	1.3966	39	1.4451	62	1.5019	85
1.3578	17	1.3984	40	1.4474	63	1.5046	86
1.3594	18	1.4003	41	1.4497	64	1.4073	87
1.3611	19	1.4023	42	1.4520	65	1.5100	88
1.3627	20	1.4043	43	1.4543	66	1.5127	89
1.3644	21	1.4063	44	1.4567	67	1.5155	90
1.3661	22	1.4083	45	1.4591	68		
1.3678	23	1.4104	46	1.4615	69		

Corrections for the Temperature

Temperature of the prisms in ° C	Dry Substance												
	0	5	10	15	20	25	30	40	50	60	70	80	90
	Subtract—												
20	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.62	0.64	0.62	0.61	0.60	0.58
21	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50
22	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
23	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
24	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
25	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
26	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
27	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
	Add—												
29	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
30	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
31	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
32	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
33	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
34	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
35	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50

ADJUSTMENT OF THE INSTRUMENT

Each instrument is given a thorough inspection and is placed in proper adjustment before leaving the factory. In order, however, that the adjustment may be checked as the occasion demands, a test piece of special glass, whose refractive index is carefully measured and engraved upon it, is supplied.

The test piece is applied to the Prism "E" (Fig.2) as described under measurement of solids. If the mean of several readings does not agree with the index engraved on the test piece, the instrument is corrected by setting the index arm so that it reads correctly and then bringing the dividing line to the cross hairs by moving the objective of the telescope. This is accomplished by turning the small screw in the telescope tube close to the drum index. The screw driver provided with each instrument is for this purpose. The screw itself is at the bottom of a small opening on the lower portion of the telescope tube.

THE BAUSCH & LOMB CONSTANT TEMPERATURE CONTROL EQUIPMENT

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Directions for Use

The Bausch & Lomb Constant Temperature Control Equipment, for purposes of shipment, is broken down into two sections, the base, to which is attached a variable resistance of the water cooled type, and a standpipe. A small piece of heavy walled rubber tubing is supplied for the connection. To assemble,

the volume control valve (Fig.4) (5) is connected to the inlet of the resistance and the base of the standpipe (2) adjusted over the holes in the main base. When the base is securely fastened, the unit is ready for connection into the system where it is to be used.

The standpipe (2) consists of an outer shield and a smaller inner tube extending not quite to the top of the outer shield. A splash cap (1) closes the top of the outer shield. The water from the main, entering by the inlet (3), divides, part passing through the control valve (5) to the resistance and the remainder passing up through the inner tube of the standpipe. The overflow from this inner pipe returns between the tube and the shield and is carried off to the drain through the outlet (4). The top of the inner tube and the overflow may be observed by removing the splash cap (1). The purpose of the inner tube is to maintain a constant head to force water through the system. Under proper working conditions there should be maintained at all times a good overflow.

To connect the equipment for use the following steps should be taken:

1. Connect the inlet (3) to the water main and the outlet (4) to the drain by means of laboratory tubing.

2. Provide proper tubing connections from the equipment (8) to the apparatus to be heated, and from there to the drain.

3. Open control valve (5) to its fullest extent.

4. Open any other convenient faucet in the main to reduce the pressure.

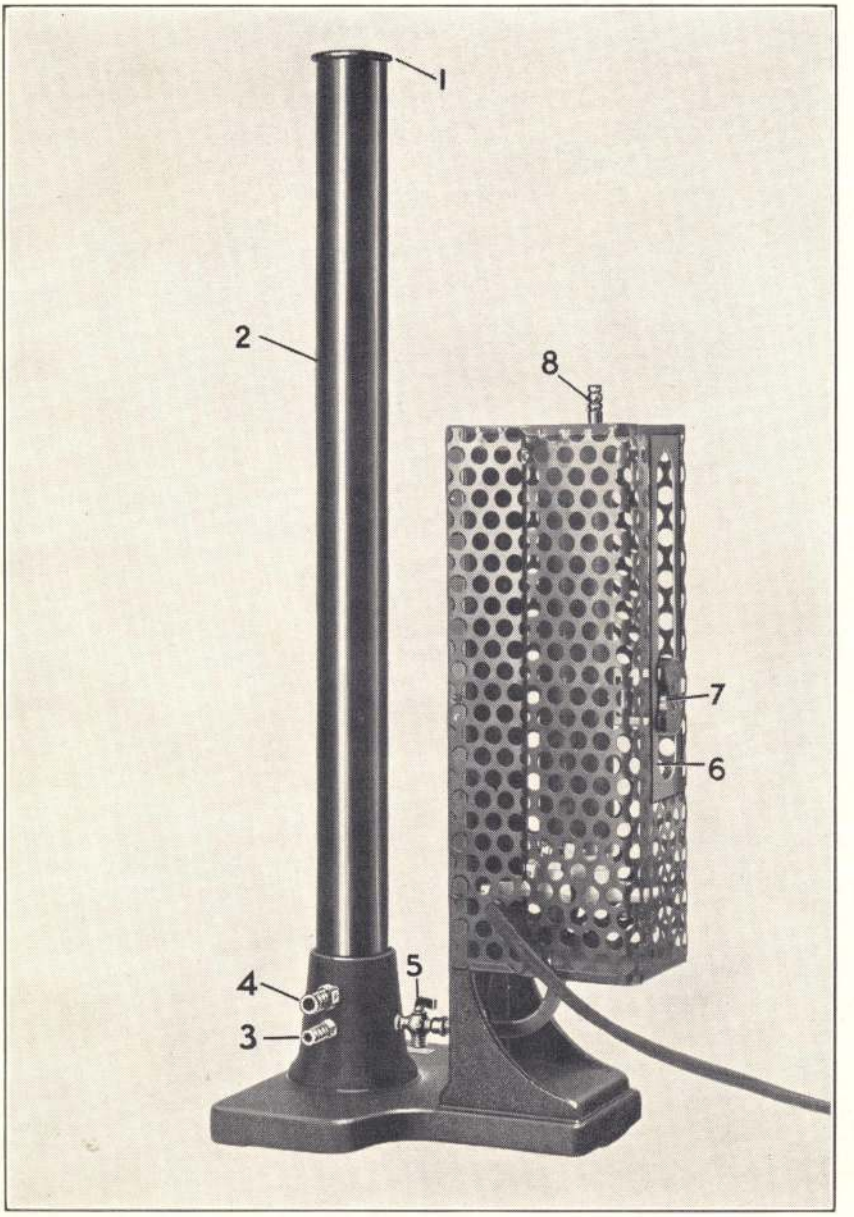

Figure 4

THE BAUSCH & LOMB CONSTANT TEMPERATURE CONTROL EQUIPMENT

1—*Splash Cap*
2—*Standpipe*
3—*Input, direct from main*
4—*Outflow, to drain*
5—*Volume Control Valve*
6—*Slide Stop*
7—*Temperature Control Slide*
8—*Outflow, to instrument*

5. Adjust the volume of water flowing into the equipment, by means of the faucet in the main until the water is just overflowing in the inner tube. The splash cap is removed for observation.

6. Turn off the extra faucet mentioned above. This will increase the overflow.

Under the conditions thus established, the flow through the apparatus will be maintained at constant head and will amount to about a liter a minute.

The heating unit should now be plugged into any 110 A.C. or D.C. line. The slide (7) may be moved from the end of the bar up to a screw stop (6). This stop is provided for the safety of the system, to prevent overheating and consequent damage to the resistance. The stop represents the point of highest temperature. Where the slide will be placed to secure a desired constant temperature depends, of course, on that of the inflowing water. If the desired temperature can be reached only with the slide against the stop (6) the flow may be decreased by readjusting the control valve (5). With a slower flow the temperature will rise and may be reduced again to the desired value by moving the slide. The flow, however, should not be reduced below 500 cc per minute. The total range of temperature available is approximately 35° C, above that of the inflow. Experience will permit control to 0.2° C.

CAUTIONS

1. If the equipment is to be out of use for a considerable period of time, it should be drained to prevent deposition of mineral matter.

2. While the resistance may safely be plugged into any 110-volt line, it is well to have the water flowing before the connection is made.

3. Do not turn off the water flow without turning off the current.