SECOND EDITION
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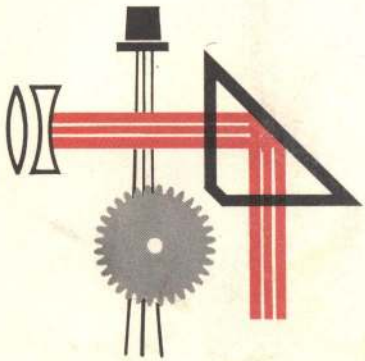

INSTRUCTIONS

ABBE-3L REFRACTOMETER

BAUSCH & LOMB

You have become the owner of a fine quality instrument. There is no similar instrument made anywhere in the world that will give you greater satisfaction or more dependable service. From the raw materials used in making optical glass to the final inspection of finished instruments, Bausch & Lomb products are made under the rigid control of optical, electronic, and mechanical experts. The formulae for the glass, and the design and manufacture of all parts contribute to one purpose—a product which will afford the highest satisfaction.

GUARANTEE: If a product of our manufacture proves defective in material or workmanship, an appropriate adjustment will be made . . . parts not of B&L manufacture, carry the guarantee of their manufacturers. This guarantee does not cover damage in transit; damage caused by carelessness, misuse, or neglect; or unsatisfactory performance as a result of conditions beyond our control.

—Bausch & Lomb Incorporated

BAUSCH & LOMB

ABBE-3L REFRACTOMETER

CAT. NO. 33-45-58-01

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SECOND EDITION
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BAUSCH & LOMB INCORPORATED
ROCHESTER, NEW YORK 14602

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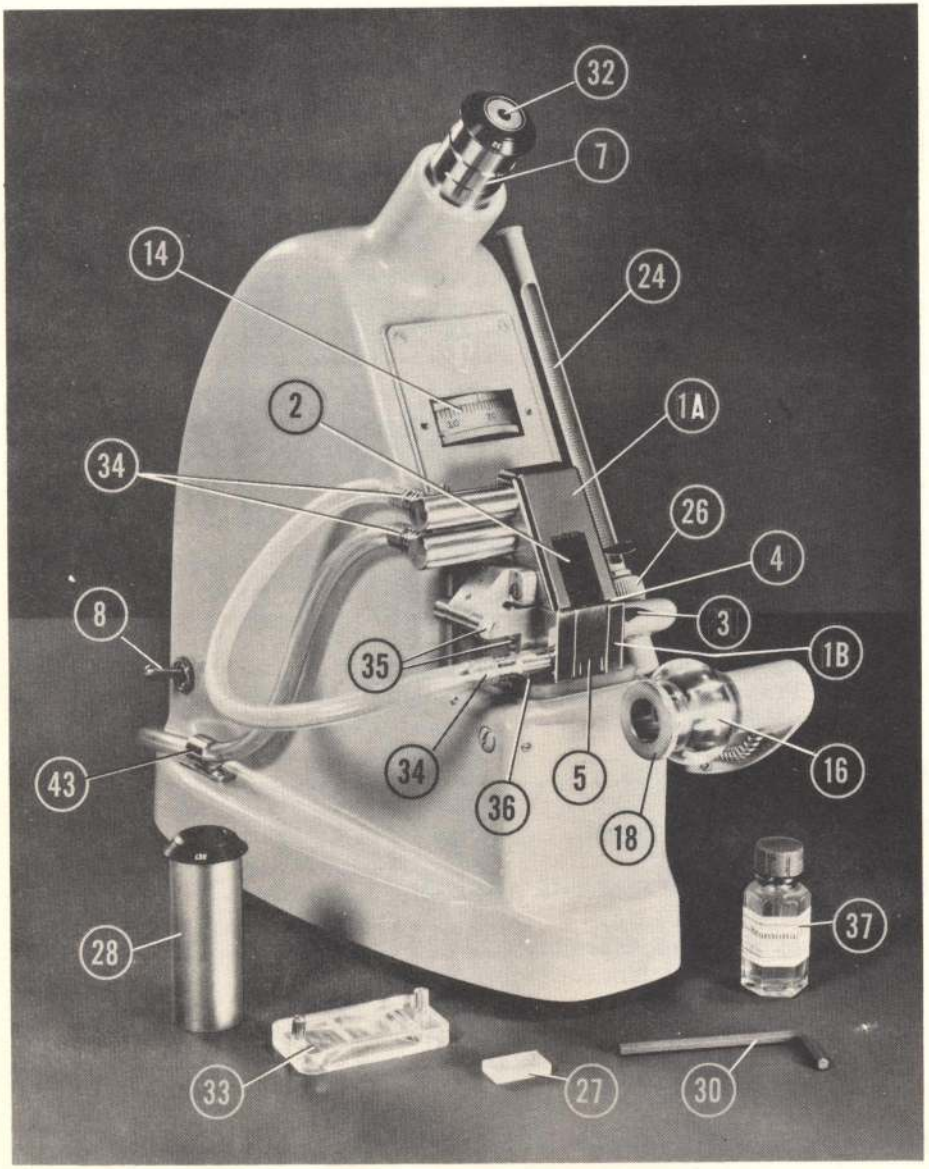


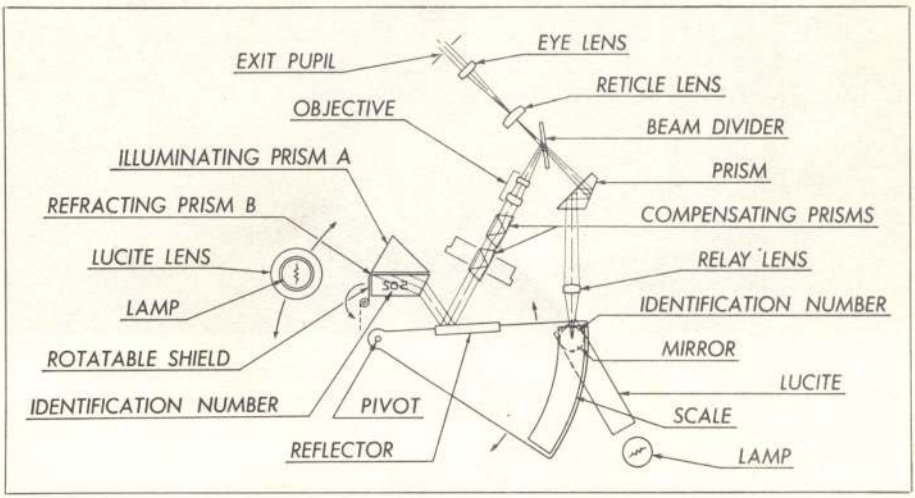
Figure 1

CAUTION

Do not attempt to use this instrument, clean the prisms, or make any adjustments until you have first read this manual completely.

REFRACTOMETER COMPONENTS

1A. Upper prism case
1B. Lower prism case
2. Illuminating prism
2A. Refracting prism
3. Prism housing lever 334558-114
4. Liquid channels
5. Prism shield 334558-164
6. Glass scale plate
7. Eyepiece - Catalog No. 33-45-68
8. Momentary contact switch 533103-598ND
9. Mirror
10. Sector
11. Coarse hand wheel
12. Fine adjustment hand wheel
13. Friction disc drive
14. Compensator Scale dial
15. Field lamp - Catalog No. 33-33-10
16. Toric lens 334558-138
17. Arm 334558-137
18. Shield control 334558-140
19. Transformer 334558-211ND
20. Scale Lamp - Catalog No. 33-33-10
21. Trap door
22. Slotted lever
23 Thermometer - Catalog No. 33-45-22
24. Knurled collar 334558-256
25. Thermometer knurled collar 334558-256
26. Test piece - Catalog No. 33-45-85
27. Extra auxiliary eyepiece - Catalog No. 33-45-69
28. Adjustment cover
29. Hex key 211186-295ND
30. Adjusting screw
31. Exit pupil
32. Compensator cover 334558-314
33. Nipples for hose attachment
34. Lower hinge screws
35. Screws
36. 1 Bromonaphthalene - Catalog No. 33-45-81
37. Tube ring 334558-108



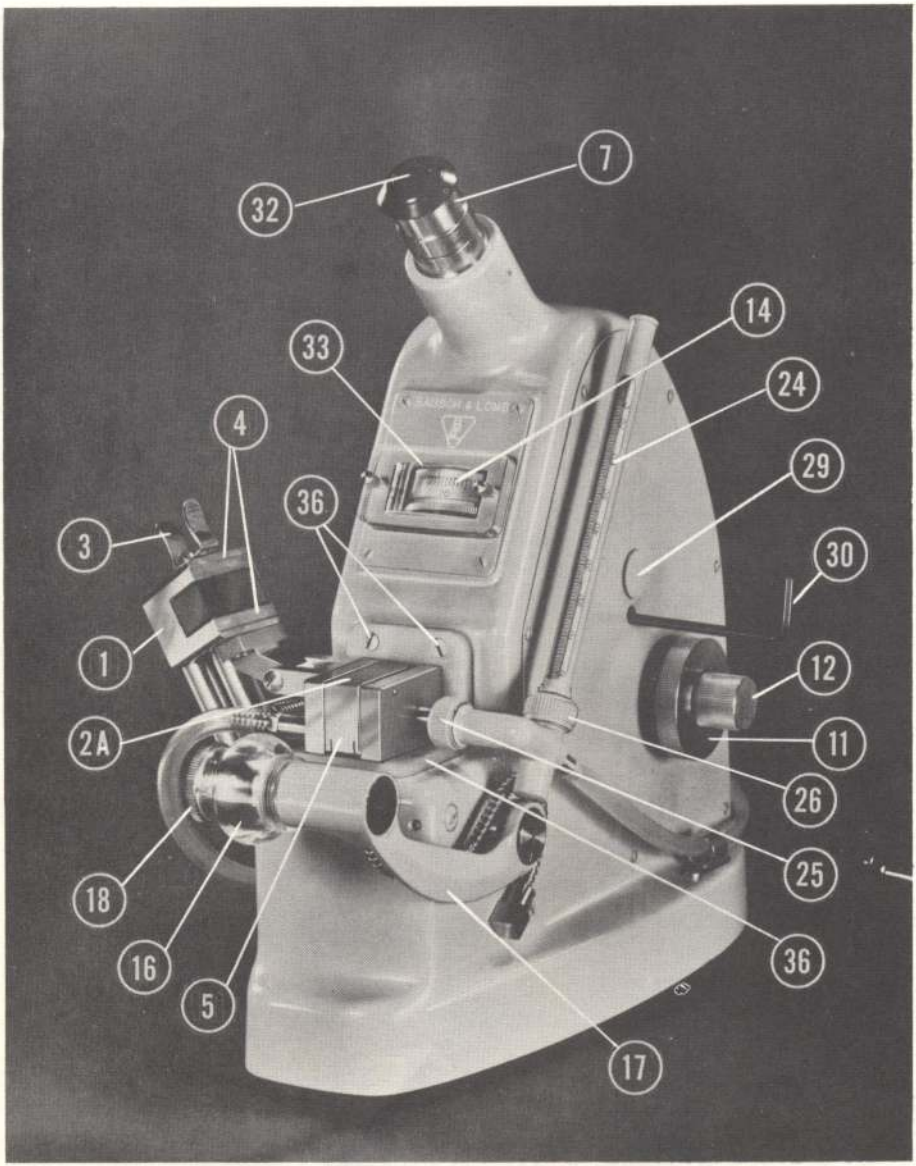


Figure 2

BAUSCH & LOMB
ABBE-3L REFRACTOMETER

Unpacking the Instrument

Prisms and eyepieces are covered with paper, and the whole instrument is protected by a dust cover. Included are the following accessory items.

1. Thermometer with a Metal Guard Tube (2-24)
2. One Hex Socket Screw Key (2-30)
3. Dispensing Bottle with 1-Bromonaphthalene (1-37)
4. Standard Glass Test Piece (2-27)
5. Plastic Cover for Compensator (2-33)
6. Dispersion Tables
7. Reference Manual
8. Plastic Dust Cover

All products of Bausch & Lomb are thoroughly tested and inspected, and carry our unqualified guarantee against defects in material and workmanship.

In the event that this equipment is received in a damaged condition, and the package, box, or crate in which it was shipped shows evidence of rough handling, call in at once a representative of the common carrier responsible and make a claim for damages.

If for any other reason this equipment is found to be damaged, out of adjustment or defective, please advise us promptly. Any legitimate claims arising from defective material or faulty workmanship will receive prompt attention.

Do not make any unnecessary changes in adjustment or take apart optical systems or mechanical assemblies unless you are thoroughly familiar with the construction, and are willing to be responsible for damage or maladjustment which may result.

You can make easy and quick refractometric measurements with your Bausch & Lomb Abbe-3L Refractometer. Here is a rugged and extremely versatile instrument that gives you accurate control and exact determinations. Careful selection of raw materials, highly skilled workmanship, and over 100 year of experience in the optical industry assures you of unending satisfaction with this Bausch & Lomb quality instrument.

For preliminary study of the unit, a sample of distilled water may be used but the operator

SHOULD NOT CLEAN THE PRISMS OR MAKE ANY ADJUSTMENTS UNTIL HE HAS READ THE REFERENCE MANUAL COMPLETELY.

This instrument is designed for use on the 110 or 120 volt AC line, 50 to 60 cycles.

Description of the Instrument

Any instrument of the Abbe type consists essentially of (a) a refracting prism system (b) an appropriate scale, (c) a compensation system consisting of Amici prisms which permit the use of white light, and (d) a telescope with crosshairs which permits the borderline of total reflection to be observed and set precisely. This instrument differs from conventional types in that the refracting prism is fixed and horizontal and that the observing eyepiece is directly above the measuring prism. A pivoted mirror is used to move the total reflection dividing line. The index scale is attached to this moving mirror. A single eyepiece is used to observe both the total reflection field and the scale.

Liquids are measured by introducing a thin film between the upper and lower refracting prisms. Solids are measured by affixing them to the surface of the lower prism by means of a suitable contact liquid which must be higher in index than the sample to be measured.

The Prism System

The upper prism case (1-1A) carrying the illuminating prism (1-2) is opened by exerting upward pressure on the prism housing lever (2-3). When the prisms are closed a liquid sample may be introduced by pipette or dropper through the channel between the prism boxes (2-4). The measuring prism is mounted in the lower housing with its polished surface facing upward. The manner in which this surface is treated will determine in great measure the

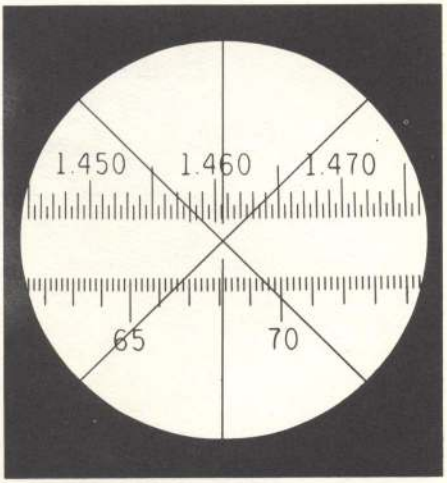


Figure 3

useful life of the instrument. If it becomes scratched and striped through improper cleaning, the sharpness of the dividing line will decrease and the scale settings will become less accurate. In the following text, careful directions are given for cleaning the prisms.

The prism housings are hollow and provide for the flow of liquid to hold the prism at a constant temperature. The liquid from the controller enters the lower prism housing (1-1B) past the thermometer bulb and upper prism housing, (1-1A) through a short "jumper" tubing and out.

A small hinged shield on the end of the lower prism housing (2-5) blocks off the front face of the refractometer prism to prevent the entrance of stray light. When making readings by reflection where the light must enter the front face of the refraction prism, the shutter is rotated out and down toward the base of the instrument. Its polished surface may be used as a reflector to pro-

vide optimum illumination.

The Scales

The index and "total solids" scales are photographed on a transparent glass plate (5-6) which is rigidly attached to the sector arm inside the housing. The scales are read through the eyepiece (2-7) by depressing the momentary contact switch (1-8) on the side of the instrument. Depressing the switch, lights the internal scale lamp while the main outside lamp is turned off simultaneously. The eyepiece should be focused to give the best image of the reticle-scale combination. The index scale is designed to read directly to five units in the fourth place with estimation to one in the fourth. The "total solids" scale is based directly on the 20°C International Sucrose Tables and reads directly to 0.2% with easy estimation to 0.1%. You will note that the 41.5% and 68% lines have been extended on the scale. This has been done to aid the citrus and preservative industries in making end point readings easier. This scale has been cemented in place and cannot be moved without damaging it.

Identification Numbers

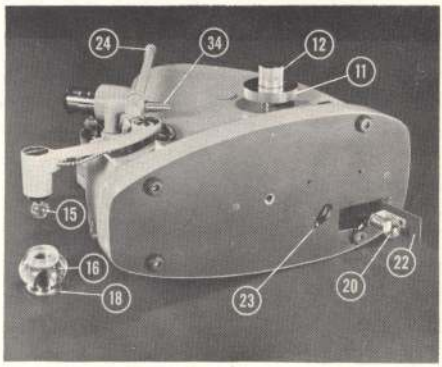
When the scale is rotated to the low end of the range, by means of the hand wheel, a small engraved number will appear in the field. This number identifies the prism glass and should be the same as that appearing on the vertical inside face of the refracting (lower) prism (2A). The number on the prism may be seen by holding a small flashlight near the outer end of the prism. The serial number of the instrument appears on the name plate.

WHEN CORRESPONDING REGARDING THE INSTRUMENT OR A SPARE PRISM OR WHEN ORDERING PARTS, BOTH NUMBERS SHOULD BE GIVEN.

Index Setting Control

As indicated previously, a mirror (5-9) is used to direct the total reflection line from the refracting prism into the viewing system. It is mounted on a pivoted ball bearing sector (5-10). Its position, calibrated in index or "percent solids" is indicated on the scales (5-6) attached to the sector. This sector is moved by turning the concentric hand wheels on the side of the instrument. The larger of the two (4-11) is a fast friction disc drive (5-13) traversing the entire index range in two and a quarter turns. The smaller (4-12) is a slow planetary ball bearing drive requiring eleven turns to traverse the range. Any slight backlash which may exist in the system is of no consequence in the accuracy of setting since the scales and the mirror constitute a rigid member and, hence, remain always in the same alignment. For adjustment purposes the relative position of the scale and mirror is adjustable

Figure 4



but this is a factory adjustment only.

Because of the ball bearing nature of the drive mechanism, lubrication problems have been virtually eliminated.

Compensation System

The compensator unit differs from that in older Abbe instruments in that both prisms of the unit move together in the same direction. The scale dial (1, 2 or 5-14) serves to rotate them. With this system compensation is different than in the older counter rotating forms. When correct compensation has been secured, the borderline will be achromatic at the center of the field with a faint red dispersion showing at one extremity and a faint blue dispersion showing at the other. The system should be set so that the short achromatic section of the borderline is centered on the crosshairs. The standard dispersion charts supplied with the instrument are used for evaluating the (C-F) dispersion. Directions for their use are found on the charts.

A "snap-on" plastic cover (2-33) is provided to cover the compensator scale dial. This is of particular value in production line applications where it is undesirable to change the compensator reading. The cover also prevents samples from running inside the instrument.

Eyepieces

The standard instrument comes equipped with a 2X eyepiece (Cat. No. 33-45-68) which is best suited for the majority of applications. For those fluids producing a line that is blurred, a lower power eyepiece (Cat. No. 33-45-69, 1.3X) will assist in setting the line accurately. This eyepiece should be ordered separately.

Illumination

The field lamp (4-15) is carried in a plastic toric shaped housing (4-16) at the extremity of the rotating arm (5-17). A knurled ring (5-18) at the end of the housing controls an internal shield. The lamp is of the miniature type and is operated from an internally mounted transformer (5-19) which also serves the scale lamp (4-20). A line switch is used to control the power to the transformer while a momentary contact switch (1-8) on the side of the instrument determines which of the two lamps is activated. Normally the field lamp is on while the internal scale lamp is off. Depressing the momentary contact switch lever reverses this condition. This assures an unbiased reading. It eliminates any tendency to set the instrument to a known reading.

If it is necessary to change the field lamp unscrew the toric shaped housing (5-16) from the swinging arm (17). To replace the scale lamp swing open the trap door (4-22) on the bottom of the instrument. This door is released by rotating the slotted lever (4-23). A coin may be inserted in the slot if the lever turns with difficulty.

When ordering replacement lamps use No. 605 General Electric flashlight lamps (6.15 volt—.50 amp.), our Cat. No. 33-33-10.

Thermometer

The thermometer is attached in

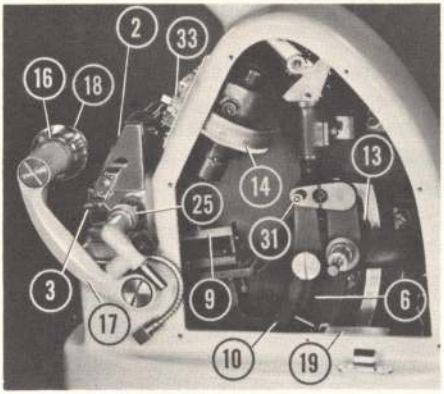


Figure 5

upright position by means of the knurled collar (2-25). By loosening the collar slightly the thermometer may be adjusted to any desired reading position. To loosen the elbow, the collar (2-25) should be turned counterclockwise and then tightened again when the thermometer is in the desired position. At the base of the thermometer guard tube is a second collar (2-26) the loosening of which permits that unit to be rotated to bring the scale toward the operator. The Cat. No. of the complete assembly is 33-45-21.

Care of the Instrument

The Abbe-3L has been designed to provide maximum convenience and precision of reading. All operating parts are protected as far as possible from the sample materials and solvents. In spite of all that a designer can do, however, trouble will ultimately result unless an operator follows certain basic practices in the daily use of the instrument. These are discussed at some length in the following paragraphs and it is strongly urged that an operator train himself along the lines suggested.

1. The refractometer must be kept scrupulously clean at all times. Dust, oil, and solid materials, if allowed to accumulate, on any part of the instrument, will find their way into bearings and hinges causing wear and eventual misalignment. The operator should make it a practice at the close of each day's work to clean all exposed surfaces thoroughly.

2. The prism (2, and 2A) should be thoroughly cleaned after each test and should be kept closed when not in use. In this type of instrument, the glass of which the prisms are made is of high refractive index and is inherently soft. It is therefore easily damaged by surface scratching and corrosion. If a dust film is allowed to accumulate on the polished surface its removal can cause more damage than many hours of actual service. The gradual deterioration of surface quality results in hazy borderlines and, hence, every care should be exercised to protect and preserve the prism surfaces. This is especially to be watched when solid materials are being measured. Special directions are given for the use of the standard test piece and these apply equally well to all solid materials.

3. Prisms should always be cleaned immediately after use. Where possible, wipe first with clean dry lens tissue followed by a tissue or cotton swab dampened

with water, alcohol, or other suitable solvent. A dilute solution (0.1% - 0.5%) of a non-ionic detergent such as Triton X-100 or Tergitol NPX may be used if necessary. Some other soaps and detergents have been known to fog the prisms. Never use a sharp object such as a knife, needle, etc., on either the prism or the seal around the prism. Even a slight crack in the sealer may cause serious damage to the prism mounting which will necessitate considerable repair. Do not dry the surfaces by rubbing with cotton. Lens tissue, if kept in a closed container, may be employed if used lightly. Thoroughly washed linen may also be safely used. Avoid the use of any cleaning means, either linen or tissue which has been lying about on the work table where it can pick up dust and grit.

The sealer around the prisms is a chemically resistant epoxy resin. While it has been found to give generally good protection toward numerous materials, there are a few solvents which are known to attack it. Among these are:

1. N, N – Dimethylformamide
2. Phenols, cresols, and other tar acids
3. Acetic Acid Solutions
4. N, N – Dimethylacetamide

Other materials to which the sealer has been known to have unsatisfactory resistance over long periods of time or at elevated temperatures are:

1. Tetrahydrofuran
2. Mixtures of esters, especially methyl acetate and vinyl acetate
3. Some Lacquer Thinners

In the above instances other sealers have been found to give satisfactory performance for the specific solvents in question. These may be obtained on special order.

Strong mineral acids and bases will quickly fog the prisms and should not be used.

The internal mirror (5-9) is first surface aluminum and should not be touched except with a camel's hair brush. This brush may also be used on the scale (5-6). However, since the instrument is almost completely enclosed except for one or two functional openings it is not anticipated that these elements will need attention except under very unusual circumstances.

If circulating water is used at elevated temperatures, the prism box must be heated and cooled slowly to prevent large thermal differences which might crack the prism.

Bibliography

For a detailed discussion of Refractometry, see Arnold Weissberger, editor, Physical Methods of Organic Analysis, Vol. 1, Part II, Chap. XVIII.

METHODS FOR READING THE INSTRUMENT

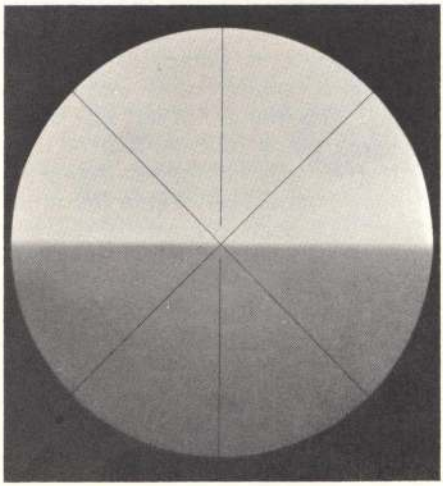
I. General Instructions

The following general directions apply in making any reading with the instrument. Specific directions for various types of material appear below.

1. After the sample is in position on the instrument, set the scale at the approximate value expected. (To see the scale depress the momentary contact switch (1-8) on the side of the instrument.)

2. Release the switch and bring the borderline, which will probably be strongly colored, near the crosshair and compensate the color by adjusting the position of the dial (5-14). The borderline should be faintly blue on one side and faintly red on the other.

Figure 6



3. Observe the crosshairs sharply focusing the eyepiece if necessary and bring the dividing line upon their intersection by means of the coarse or fine hand controls.

4. Read the index by depressing the momentary contact switch (1-8), estimating the fourth place.

5. If working with liquids, record both index and the prism temperature at the time of reading.

II. Transparent and Viscous Liquids

For the measurement of liquids and especially those of an organic nature, hydrocarbons, vegetable oils and the like, excellent temperature control is necessary and thorough cleaning of the prism between samples is equally necessary. The cement used to retain the prisms is a thermo-setting plastic, which is almost completely unaffected by organic solvent, fruit acids, etc.

If the liquid is free flowing or only slightly viscous, it may be introduced by means of a pipette or dropper through one of the channels (1-4) alongside the prism. If it is quite viscous it is best placed upon the prism (1B) spreading it over the face with a wooden applicator. The prisms are then closed slowly allowing the excess to squeeze out into the space between the metal mounts. NEVER USE GLASS OR METAL APPLICATORS AGAINST THE PRISM FACE.

In order to secure the best line with any liquid or semi-liquid material, it is essential that the space between the prism be uniformly filled. To determine whether or not this condition exists, examine the exit pupil (2-32) with a low power magnifier. Nonuniformity of filling will be evidenced by dark areas in the bright disc. It is also possible by this method to detect contamination of the sample which may have arisen from improper cleaning. Contaminating materials entering the measuring space from the metal or cement areas will be indicated by dark tongues or striations, extending into the bright area from top or bottom. Where either bubbles or contaminating materials are detected, it is preferable to clean the prism surfaces again, though bubbles may sometimes be eliminated by opening and closing the prisms slightly two or three times. Bubbles are often caused by the adherence of foreign materials, especially those of an oily nature, to the glass surfaces. These prevent complete wetting of the surfaces as the samples flows in from the channel. This emphasizes again the need for thorough cleaning between samples.

Illumination in this case should be directed through the ground face of the upper prism. After sample is placed on the prisms and the illumination is set, follow the general instructions outlined above.

III-A. Use of the Standard Test Piece

The measured glass test piece (1-27) provided with the instrument is for the purpose of securing precise adjustment of the scale in its relation to the position of the total reflecting dividing line. Proper use of this accessory is of prime importance. The first essential operation is the proper cleaning of the two surfaces (one on the polished face of the lower prism and the second on the test piece) which are to be placed in contact. Before applying the contact liquid (1-bromonaphthalene) these two surfaces should be carefully cleaned as described above with a suitable solvent and ether. Just before applying the contact liquid two surfaces should be brushed with a clean camel's hair brush to remove any grit or loose particles which may have remained after the liquid cleaning. If the surfaces are viewed at almost grazing incidence these residual particles are easily seen. This brush, like the tissues or linen mentioned above should be kept in a closed stoppered container like a test tube. When the operator is sure that both surfaces are properly cleaned, a small drop of 1-bromonaphthalene should be put upon the surface of the test piece and the two surfaces brought together. The size of the liquid drop should be of the order of one cubic millimeter, the aim being to provide just enough to fill the test piece area completely without having a liquid bead around its edge. Too much liquid will cause the test piece to slide and too little will give an incomplete contact and a poor borderline. When the small drop has been placed on the test piece the two surfaces should be brought together gently, the polished end of the test piece being toward the illuminator and engraved side up. If, on contact, there is the least trace of roughness or grittiness, remove the test piece immediately and clean both surfaces again.

When certain that there is no grit or dirt in the liquid space, move the test piece around gently to thin out the liquid film, and spread it evenly over the contact area, keeping the sliding motion at a minimum. If these operations are properly carried out, the test piece will adhere firmly to the prism surface.

Prepare a thin piece of white paper in the form of a small, one layer cylinder which may be inserted in the open end of the lamphouse so that it is between the lamp (4-15) and the plastic lens (4-16). This will give the necessary diffusion of light to properly read a solid sample. (Liquid samples do not require this diffuser.)

With the test piece in position and the illuminating prism (2) swung sideways out of the way depress the momentary contact switch (1-8). Set the scale of the instrument at the index value engraved on the surface of the test piece and swing the illuminant (4-15) to a position directly in line with the prism surface. Release the momentary contact switch (1-8). Adjust the lamp shield (4-18) so that the best contrast is secured between the two halves of the field. Make sure that the line as set does not shift with motion of the lamp. Turn the compensator dial (5-14) until the dividing line is correctly compensated (red at one end and blue at the other).

In passing, it is well to note that any solid specimen to be measured should possess at least one surface that is optically flat, in order that good contact may be achieved. A further requirement for correct reading on a solid specimen is that the edge toward the source be sharp. If this edge is rounded a poor borderline will result. The type of sharpness needed is like that obtained when a piece of glass is broken.

III-B. Checking and Adjusting with Test Piece

When the operator has succeeded in putting the test piece into proper position he can proceed with a check of the scale and compensator positions. To check the scale the borderline should again be carefully compensated so that the achromatic portion lies symmetrically upon the crosshairs and is set so that it crosses the intersection exactly. If, with this setting, the index read on the scale differs from that engraved on the test piece (1-27) some adjustment error is indicated. To correct this rotate the small cover (2-29) near the concentric band wheels (2-11) (2-12) disclosing a small hole. Inserting the hex socket screw key (2-30) into this hole, engage the adjusting screw (5-31) and turn it to move the scale image sideways until the proper reading as marked on the test piece is obtained. This completes the adjustment. Remove the key and close the hole.

While the test piece is in position, the compensator (2-14) may also be checked for two possible errors. As in the older form of instrument the compensation prisms have two positions of rotation, one on each side at either of which an achromatic borderline may be secured. The dividing line should first be set as precisely as possible on the crosshairs in either position of compensation. The compensating dial should then be

rotated to the second position (on the opposite side of the zero point) without disturbing the setting of the dividing line. If the compensators are in good working order the position of the dividing line should not have changed with the reversal. If the reading of index differs by a discernible amount it is an indication that the compensators have developed deviation, and that the instrument should be returned to the factory for repair. These troubles sometimes occur due to deterioration of the cement layers, causing shifting of prism elements, and cannot be corrected by the user. However, should such a defect be found in the course of a series of experiments or during a seasonal run in any industry, the instrument can still be used until it is convenient to return it for repair, provided one condition is observed. All readings of index should be made with the compensators set on the same side of the zero point. As long as the instrument is set for one compensator position by means of the test piece and that position used for all index readings, the results will be correct. This, however, is only a stop gap procedure and if deviation exists the instrument should be returned for repair.

While checking the compensators for deviation the direct and reversed readings of the scale should be noted. If they are not the same, the readings should be averaged. If index only is of interest a difference between the two compensator readings causes no error. If the compensator readings are too different the instrument should be returned to the factory for repair.

When these adjustments have been carefully checked remove the test piece and clean it and the prism surface with a suitable organic solvent.

Other test pieces are available for checking other parts of the scale; see listing at the end of this manual.

III-C. Other Transparent Solids

All readings on transparent solids should be made in accordance with the test piece directions as given under the heading: "Use of the Standard Test Piece." In the case of such materials the character of the dividing line is materially affected by (A) the planeness of the contacting surface; (B) the sharpness of the edge toward the source of light; (C) the inherent homogeniety of the material itself.

As mentioned above, the contracting surface should be flat to a few wavelengths or better and the forward edge should be sharp. Striated materials will usually give poor lines and there is little that can be done to help such a situation.

The liquid used for contacting the material to the prism face must always have a higher index than the material itself. Up to an index value of 1.64, the contacting liquid supplied with the instrument (1-bromonaphthalene) is satisfactory. Above that index, methylene iodine ($n_D = 1.74$) must be used. The latter should be kept in the dark and corked, as exposure to air and light result in darkening due to liberation of free iodine. This darkening can be prevented by adding a strip of copper or a few copper shot to the bottle in which it is kept. Other materials such as anise oil ($n_D = 1.55$)

Figure 7

can be used where the indices of materials are lower. Their only advantage, however, is that they may make the interference fringes used for the positioning somewhat more easily seen.

In general, the temperature coefficient of index change is so small in the case of solids that no temperature control is required. However, with some of the newer plastic materials this may not always be true. Where there is doubt, the temperature coefficient should be checked.

IV. Opaque Materials

This type of material is seldom encountered but when it is necessary to secure such readings, they must be obtained by reflection methods which at best are not too satisfactory. The method of attaching a solid sample is the same as in the case of transparent solids by a suitable liquid. When measuring by reflection the prism shield (2-5) on the lower prism is swung down and the light is directed downward toward this shield from which it is reflected into the front face of the measuring prism. A borderline is formed just as when

measuring by transmission methods. In reflection, however, the line is very indistinct, because of lack of contrast between the two halves of the field. This situation is inherent in the Abbe system and cannot be avoided.

While the borderline, when using transmission methods, is always evident because of field contrast, the line in reflection is very indistinct, reducing almost to the vanishing point. This situation arises because both halves of the field are inherently bright. The contrast is so low that at times the line can be seen only when it is actually in motion across the field. Even under these adverse conditions good results can be obtained by moving the line back and forth over the crosshair with a constantly decreasing amplitude until visibility becomes too low to distinguish motion. In using this method one should take a greater number of readings and should be sure that the crosshair is approached alternately from above and below. Sometimes visibility can be enhanced by altering the illumination until both fields become relatively dark. This can be accomplished by moving the lamp.

If one is compelled to use this technique, he should experiment with reflection readings, using some material like paraffin oil, until there is no question of his familiarity with the appearance of the field and the dividing line. With such a material it is possible to set the dividing line by transmission and then go to reflection with the knowledge that the line will appear at the crosshairs. When once its characteristics have been recognized, the finding is not too difficult.

V. Measurement of Refractive Index and Thickness of Thin Films with an Abbe Refractometer

This method is applicable to films with thicknesses between about .05 and .0001mm (.002 and .00004 inches). The refractive index of the film must be within the range of the instrument; the sample must be flat and uniform in thickness.

When thin films are contacted to the measuring prism, the usual critical angle dividing line disappears and a series of interference bands are seen. The first two bands are used. Films coated on a backing material must be of lower refractive than the backing.

The first two interference bands are designated as n_1 and n_2 respectively, n_1 being the one with apparently the higher refractive index. In the following formulae the thickness is designated as d and the index of the film n_f.

To determine the index of the film the following formula is used:

$$n_f = \left(\frac{4n_1^2 - n_2^2}{3}\right)^{\frac{1}{2}}$$

To determine the thickness of the film the following formula is used:

$$d = 0.000295 \left(\frac{3}{n_1^2 - n_2^2}\right)^{\frac{1}{2}} \text{ mm}$$

$$d = 0.0000116 \left(\frac{3}{n_1^2 - n_2^2}\right)^{\frac{1}{2}} \text{ inches}$$

The filmed side should be contacted to the refractometer prism with a high index liquid which will not dissolve the coating. The read-

ings must be made using the reflected light method. A Polaroid filter such as the 31-57-11 Polaroid Cap Analyzer must be used over the eyepiece to increase the contrast of the interference bands and eliminate any double line effects due to birefringence in the coated films.

The fringes are of low contrast and some difficulty may be experienced, as first, in locating them. Although the interference bands may be seen using white light and the standard compensator, it is very difficult to locate them since the correct position of the compensator is not known. Therefore, a sodium vapor lamp is necessary to locate the fringes and also can be used in making the measurements.

VI. Determination of Refractive Index at other Wavelengths.

While any Abbe type instrument is designed primarily for the reading of index of refraction for the sodium wavelength (589mu), the compensator system is designed so that it can also furnish dispersion values. This system is so computed that it has a known dispersion, that is, a known difference of refraction for the red hydrogen line (656mu) and the blue hydrogen line (486mu). Using these computed values and the computed values for the index scale, tables or graphs may be prepared in which the sodium index value and the rotational position of the compensators, when the borderline is achromatized, can be used to determine the difference of index between the above lines. It should be noted that the difference between the indices for 656mu and 486mu is determined but that neither index is known as an absolute value. This value, the difference of index, is known as dispersion and from it and the value for index (sodium), a third constant known as the nu-value (Greek letter ν) can be obtained. This comes from a solution of the equation:

$$\nu = \frac{n_D - 1}{n_F - n_C}$$

where n_D is the index for sodium n_F light and n_C are the indices for the blue and the red lines respectively. The value $(n_F - n_C)$ is obtained from the charts or graphs, neither of these values being known absolutely.

The operation of the compensators may be briefly explained as follows: When any sample is placed in the instrument, there is always a residual dispersion between sample and prism. This results in a borderline which is colored and so dispersed that settings are not possible. The compensation system is an adjustable unit which can be rotated to a position where it counteracts the residual sample-prism dispersion and reduces the borderline to achromatism. In effect, it is nothing but a carefully computed prism used in reverse to the sample dispersion.

Since only dispersion perpendicular to the dividing line is concerned, the compensator prisms may be regarded as having zero dispersion vertically when their principal planes are horizontal that is, parallel to the dividing line and some maximum dispersion when 90^{o} away from that point. As the system rotates

from one position (0) to the other (90) it provides a variable dispersional component to correct the color on the borderline. The value of the maximum dispersion is originally chosen in computation so that it will be greater than any possible residual which could exist between sample and prism, thus assuring coverage for all materials. The use of the Dispersion Tables which accompany the instrument is explained on the sheets attached to the charts and need not be repeated here.

From the dispersion measurements, it is possible to estimate the refractive index at other wavelengths. To do this, proceed in the following manner:

1) Determine $n_F - n_C$ using the standard dispersion tables as supplied with the instrument.

2) Compute "B" from the equation
$B = 0.52364 \times 10^{-6} (n_F - n_C)$

3) Compute "A" from the equation $A = n_D - 2.8796 \times 10^{-6} B$ where n_D is the refractive index of the sample as measured on the Abbe in the usual manner.

4) Compute the refractive index at the wavelength desired using the equation

$$n_x = A + \frac{B}{\lambda_x^2}$$

where n_x is the refractive index of the sample at the wavelength, λx, in millimicrons, of interest.

In most cases, this will provide an accuracy of plus or minus 0.0005 refractive index units; in a few cases, this value may be exceeded, depending on the sample and the wavelength of interest. In general, the further one goes from the sodium line, the greater the error will be.

It is possible to improve this accuracy by a factor of 10 with the Bausch & Lomb Precision Refractometer, using a light source at the desired wavelength. For more information, consult B&L Inc., or your Dealer.

VII. Temperature Control

Materials differ greatly in their change of index with respect to a change in temperature. How closely the temperature of the sample should be controlled depends entirely on the nature of the material and the accuracy of reading desired. The list below gives several materials together with the change of index per degree Centigrade.

Water	0.0001
Linseed Oil	0.0004
Carbon Disulphide	0.0008
Crown Glass	0.000002
Flint Glass	0.000001
Fluorite	0.0001

From this list it is immediately evident that one can read the indices of flint and crown glass at ordinary room temperatures without temperature control and secure results which are good to the fifth decimal place. In the case of liquids, a change of one degree can cause errors extending well into the fourth place. A change of one degree, for instance, can cause a change of index of 0.0001

for water solutions and a change of 0.0008 for carbon disulphide. In the first case temperature should be controlled to approximately 0.5°C to secure correct readings and in the latter case to approximately 0.05°C. These represent extremes but most of the vegetable or animal oils and fats and the hydrocarbons series have coefficients of the order of 0.0004 to 0.0005 per degree and, hence, must be well controlled with respect to temperature if consistent and accurate results are to be obtained.

In the case of many materials where refractive index is commonly determined, the values have been found for various temperatures and correction tables prepared, so that readings may be made at any temperature in the normal operating range and the value at a standard temperature computed by adding or subtracting factors obtained from the tables. In the case of the International Sucrose Tables, which are discussed on page 9, the values are set up for 28°C normal and 20° normal and the corrections cover an operating range of 15° to 20°. Where such tables are available, temperature control to some normal value is not needed. It is necessary, however, to keep the temperature constant for a reasonable period of time, and to know the temperature of the prisms themselves rather than the ambient temperature, since the prism temperature will always lag behind if the ambient changes suddenly.

The temperature control device described in the following paragraphs of this booklet will serve for almost all ordinary work (see Fig. 8). The Precision Temperature Controller, when properly operated, will hold the measuring system for long periods to a few hundredths of a degree. It is applicable to work with materials when the coefficient of temperature change is large as in the case of hydrocarbons and essential oils.

Since temperature changes can cause wide variations in results and apparent discrepancies among readings, it is well to make a practice of recording temperatures for each reported reading. It is a simple matter to record both values and this may often help to explain unexpected deviations from the normal. The prism temperature should be elevated slowly to prevent its cracking.

The safe limit of temperature control is around 80°C though this may be exceeded somewhat if care is taken to prevent the formation of steam pockets in the flow-lines.

REPAIR AND SERVICE OF THE ABBE-3L

I. Factory Service

Should your instrument become damaged return it to Bausch & Lomb for repair. Indicate whether you would prefer that the work be started immediately. Fastest service can be expected during the fall and winter months.

For a limited time after the purchase of your Abbe-3L, a spare prism assembly is available. Having this spare prism, in many cases, will save you time and money when you have sent your other prism assembly in to be repaired.

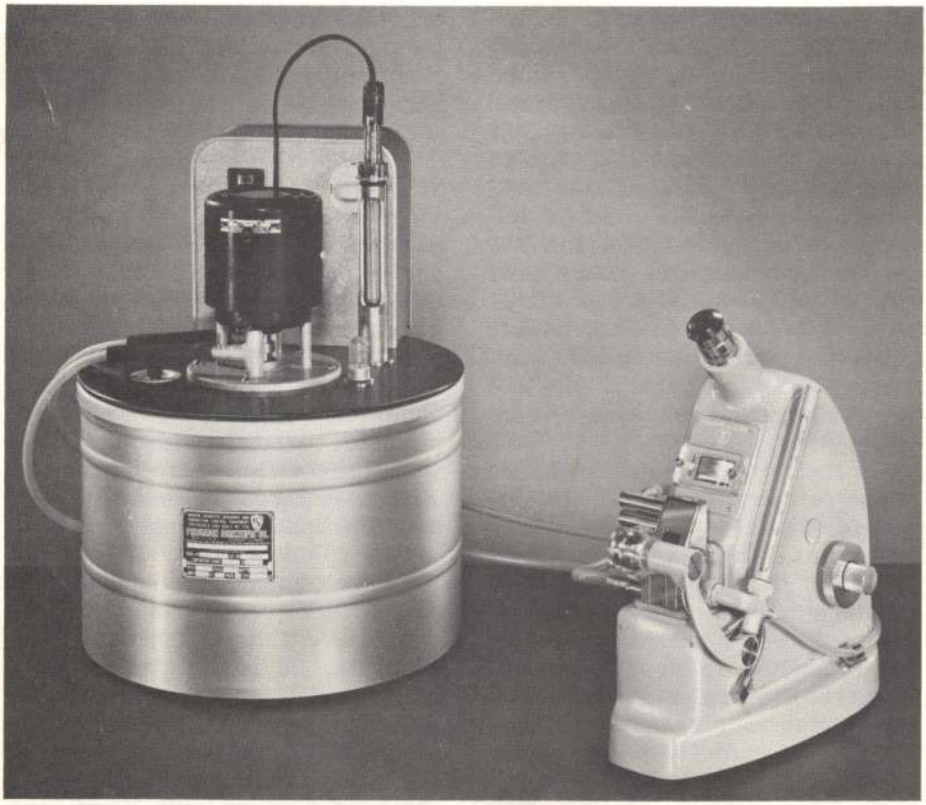


Figure 8

II. Removal of Prism Assembly

If it becomes necessary to return this prism to the factory to have the prism surface repolished, the prism housing may be removed from the instrument by following the steps outlined.

1. Remove the two lower hinge screws (1-35) and separate the hinge assembly from the lower prism mounting.

2. Remove the four screws (2-36) holding the Nylon heat insulator to the body of the instrument, at the same time removing the prism unit.

If a replacement prism assembly No. 33-45-59 is available, HAVING THE SAME PRISM SERIES NUMBERS AS THAT ENGRAVED ON THE SCALE AND ON THE ORIGINAL REFRACTING PRISM, it may be placed in the refractometer.

III. Replacement and Realignment of Prism Assembly

This procedure should be followed whenever a prism assembly is installed or requires realignment.

1. Assemble the prism box (2-5) to the instrument using four screws (2-36).

2. Attach the hinge and upper prism case to the prism box using two screws (1-35). When tightening press downward on the upper prism case (with the illuminating prism in its closed position) to insure that the upper and lower prism mounts are in contact and that parallelism between prisms is maintained.

IV. Service Information

Minor replacement parts should be ordered by catalog number from your regular dealer. See listing at the end of this manual.

*Temperature Controllers

The manufacturer's directions for use for this control unit are included with the instrument and should be followed exactly. The control unit should be placed on the table so that reasonably short hose connections are possible (Fig. 8), and should be so connected that the output of the tank is connected to the prism coupling in which the thermometer is mounted.

Any laboratory type rubber tubing, which will fit the nipples, is suitable to use for the various connections. One should be particular in following minutely the manufacturer's directions for the filling and installation of the thermostatic control in the tank, since this, in itself, can cause quite erratic performance of the system.

International Sucrose Tables

The "Abbe-3L" has engraved on its sector the so-called "total dissolved solids" scale. This scale is based directly on the International Sucrose Tables as agreed upon by the Ninth Session of the International Commission for Uniform Methods of Sugar Analysis at London in 1936. In the International publication some of the index values are given to five decimal places while the remainder are given only to four. In reprinting these tables for use with the Abbe type instrument, all the values have been reduced to four decimal figures in order to be in accord with the reading precision of the instrument.

These tables are based on the index values for pure sucrose solutions. When dissolved substances other than sucrose are present in solution, the refractometer reads the combined index. In such cases, the result should be labeled "per cent total dissolved solids" and not "per cent sucrose". In certain cases direct correctional values have been established for commonly determined materials in which the "total solids" reading on the basis of the International Table differs from the value obtained by ashing or other chemical analysis. Two illustrations of this situation may be cited and there are probably many others which differ to a greater or lesser degree. The National Canners Association in their Bulletin No. 27-L on Tomato Products gives a "Total solids" table for Tomato Catsup by means of the Abbe. In this case the total solids are approximately one per cent higher than would be shown by the Standard Sucrose Scale. Similarly the Chataway Tables for honey

* Mfg. by: Precision Scientific Co., Chicago, Ill. and Labline, Chicago, Ill.

show a difference of approximately 2% from the Sucrose Scale.

For purposes of reference the International Tables for Sucrose, together with the temperature correction factors are given for the two temperatures commonly used, 20° and 28°.

Correction Thermometer

The 33-45-20 Correction Thermometer is supplied as an accessory device to quickly give the correct total solids scale correction when the 20°C solids scale in the instrument is used at other temperatures. The correction is read directly from the thermometer and applied as an addition or subtraction to the scale reading depending on the thermometer reading. It must be noted that this correction thermometer is only approximate, especially at the extreme end of the temperature range and the percentage solids scale. However, at these extreme points errors of only a little more than 0.2% are introduced. For exact temperature correction, reference must be made to be the standard thermometer and the International Temperature Correction Table printed on the following pages.

International Scale (1936) of Refractive Indices of Sucrose Solutions at 20° C.

Index	Per cent	Index	Per cent	Index	Per cent	Index	Per cent
1.3330	0	1.3723	25	1.4200	50	1.4774	75
1.3344	1	1.3740	26	1.4221	51	1.4799	76
1.3359	2	1.3758	27	1.4242	52	1.4825	77
1.3373	3	1.3775	28	1.4264	53	1.4850	78
1.3388	4	1.3793	29	1.4285	54	1.4876	79
1.3403	5	1.3811	30	1.4307	55	1.4901	80
1.3418	6	1.3829	31	1.4329	56	1.4927	81
1.3433	7	1.3847	32	1.4351	57	1.4954	82
1.3448	8	1.3865	33	1.4373	58	1.4980	83
1.3463	9	1.3883	34	1.4396	59	1.5007	84
1.3478	10	1.3902	35	1.4418	60	1.5033	85
1.3494	11	1.3920	36	1.4441	61		
1.3509	12	1.3939	37	1.4464	62		
1.3525	13	1.3958	38	1.4486	63		
1.3541	14	1.3978	39	1.4509	64		
1.3557	15	1.3997	40	1.4532	65		
1.3573	16	1.4016	41	1.4555	66		
1.3589	17	1.4036	42	1.4579	67		
1.3605	18	1.4056	43	1.4603	68		
1.3622	19	1.4076	44	1.4627	69		
1.3638	20	1.4096	45	1.4651	70		
1.3655	21	1.4117	46	1.4676	71		
1.3672	22	1.4137	47	1.4700	72		
1.3689	23	1.4158	48	1.4725	73		
1.3706	24	1.4179	49	1.4749	74		

International Temperature Correction Table (1936) for the Normal Model of Refractometer Above and Below 20° C.

Temp. ° C	Per cent Sucrose														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
	Subtract from the per cent Sucrose														
10	0.50	0.54	0.58	0.61	0.64	0.66	0.68	0.70	0.72	0.73	0.74	0.75	0.76	0.78	0.79
11	0.46	0.49	0.53	0.55	0.58	0.60	0.62	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71
12	0.42	0.45	0.48	0.50	0.52	0.54	0.56	0.57	0.58	0.59	0.60	0.61	0.61	0.63	0.63
13	0.37	0.40	0.42	0.44	0.46	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.54	0.55	0.55
14	0.33	0.35	0.37	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.45	0.46	0.46	0.47	0.48
15	0.27	0.29	0.31	0.33	0.34	0.34	0.35	0.36	0.37	0.37	0.38	0.39	0.39	0.40	0.40
16	0.22	0.24	0.25	0.26	0.27	0.28	0.28	0.29	0.30	0.30	0.30	0.31	0.31	0.32	0.32
17	0.17	0.18	0.19	0.20	0.21	0.21	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.24
18	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16
19	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	Add to the per cent Sucrose														
21	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
22	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16
23	0.19	0.20	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24
24	0.26	0.27	0.28	0.29	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32
25	0.33	0.35	0.36	0.37	0.38	0.38	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
26	0.40	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.48	0.50	0.52	0.53	0.54	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
28	0.56	0.57	0.60	0.61	0.62	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
29	0.64	0.66	0.68	0.69	0.71	0.72	0.72	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
30	0.72	0.74	0.77	0.78	0.79	0.80	0.80	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81

International Scale (1936) of Refractive Indices of Sucrose Solutions at 28° C.

Index	Per cent	Index	Per cent	Index	Per cent	Index	Per cent
1.3322	0	1.3712	25	1.4187	50	1.4758	75
1.3336	1	1.3729	26	1.4207	51	1.4783	76
1.3351	2	1.3747	27	1.4228	52	1.4809	77
1.3365	3	1.3764	28	1.4250	53	1.4834	78
1.3380	4	1.3782	29	1.4271	54	1.4860	79
1.3394	5	1.3800	30	1.4293	55	1.4884	80
1.3409	6	1.3818	31	1.4315	56	1.4910	81
1.3424	7	1.3835	32	1.4337	57	1.4937	82
1.3439	8	1.3853	33	1.4359	58	1.4963	83
1.3454	9	1.3871	34	1.4382	59	1.4990	84
1.3469	10	1.3890	35	1.4403	60	1.5016	85
1.3484	11	1.3908	36	1.4426	61		
1.3500	12	1.3927	37	1.4449	62		
1.3516	13	1.3946	38	1.4471	63		
1.3531	14	1.3966	39	1.4494	64		
1.3547	15	1.3985	40	1.4517	65		
1.3563	16	1.4003	41	1.4540	66		
1.3579	17	1.4023	42	1.4564	67		
1.3595	18	1.4043	43	1.4588	68		
1.3612	19	1.4063	44	1.4612	69		
1.3628	20	1.4083	45	1.4635	70		
1.3645	21	1.4104	46	1.4660	71		
1.3662	22	1.4124	47	1.4684	72		
1.3678	23	1.4145	48	1.4709	73		
1.3695	24	1.4166	49	1.4733	74		

International Temperature Correction Table (1936) for the Tropical Model of Refractometer Above and Below 28° C.

Temp. ° C	Per cent Sucrose														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
	Subtract from the per cent Sucrose														
20	0.57	0.59	0.60	0.61	0.62	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.65	0.65
21	0.51	0.52	0.53	0.53	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.57	0.57
22	0.44	0.46	0.46	0.46	0.47	0.48	0.48	0.49	0.48	0.48	0.48	0.48	0.48	0.49	0.49
23	0.37	0.38	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.41	0.40	0.40	0.40	0.41	0.41
24	0.30	0.31	0.32	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.32	0.32	0.32	0.33	0.33
25	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.24
26	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16
27	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	Add to the per cent Sucrose														
29	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
30	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
31	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
32	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.33	0.33
33	0.44	0.44	0.44	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.42
34	0.54	0.54	0.53	0.53	0.53	0.52	0.52	0.52	0.52	0.51	0.51	0.50	0.50	0.50	0.50
35	0.63	0.63	0.63	0.62	0.62	0.62	0.61	0.61	0.61	0.60	0.60	0.59	0.59	0.59	0.58
36	0.73	0.73	0.73	0.72	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.67	0.67	0.67

Index of refraction of distilled water for various spectral lines

Read initial digits in same column above tabulated values unless asterisk refers to initial digits below. For instance, for 5892.6 sodium line at 20°C, read 1.3329877; for 5015.7 helium line at 14°C, read 1.3368302.

t°C	Wave lengths in angstroms												
	7065.2 Helium	6678.1 Helium	6562.8 Hydrogen	5892.6 Sodium	5875.6 Helium	5769.6 Mercury	5460.7 Mercury	5015.7 Helium	4861.3 Hydrogen	4713.1 Helium	4471.5 Helium	4358.3 Mercury	4046.6 Mercury
	1.330	1.331	1.332	1.333	1.334	1.334	1.335	1.337	1.338	1.338	1.340	1.341	1.343
0	9477	8155	0939	9493	0028	3453	4397	3391	1129	9254	4248	2144	7564
.5	9482	8158	0940	9191	0026	3450	4393	3385	1122	9247	4240	2135	7553
1	9472	8145	0927	9474	0010	3433	4374	3364	1101	9225	4217	2112	7528
.5	9447	8118	0900	9443	*9978	3401	4341	3329	1065	9188	4179	2073	7488
2	9409	8077	0858	9798	*9933	3355	4293	3279	1014	9137	4126	2020	7433
.5	9356	8022	0802	9338	*9873	3295	4231	3215	0950	9071	4059	1953	7364
3	9290	7954	0733	9265	*9800	3221	4156	3137	0871	8992	3978	1871	7281
.5	9210	7872	0650	9178	*9712	3133	4066	3045	0778	8898	3884	1776	7184
4	9117	7776	0554	9078	*9612	3032	3964	2940	0672	8792	3776	1667	7074
.5	9011	7667	0444	8964	*9498	2918	3848	2821	0553	8672	3654	1545	6950
					1.333								
5	8892	7546	0322	8838	9372	2791	3719	2690	0420	8538	3520	1410	6812
.5	8761	7412	0187	8699	9233	2651	3577	2545	0275	8392	3372	1262	6662
6	8617	7265	0040	8547	9081	2499	3422	2388	0117	8233	3212	1100	6499
.5	8461	7106	*9880	8383	8917	2334	3256	2219	*9947	8062	3039	0927	6324
7	8292	6935	*9708	8207	8740	2157	3077	2037	*9764	7878	2854	0741	6136
.5	8112	6752	*9525	8019	8552	1968	2886	1844	*9569	7683	2656	0543	5936
8	7920	6558	*9330	7819	8352	1767	2683	1638	*9363	7475	2447	0333	5724
.5	7717	6352	*9123	7607	8141	1555	2469	1420	*9144	7256	2226	0111	5500
9	7502	6134	*8904	7384	7918	1331	2243	1192	*8914	7025	1994	*9878	5264
.5	7276	5906	*8675	7150	7683	1096	2006	0951	*8673	6782	1750	*9633	5017
			1.331						1.337			1.340	
10	7040	5666	8434	6905	7438	0850	1757	0700	8420	6528	1494	9377	4758
.5	6792	5415	8183	6648	7181	0593	1498	0437	8157	6264	1228	9110	4489
11	6533	5154	7920	6381	6914	0325	1228	0164	7882	5988	0950	8831	4208
.5	6264	4882	7648	6104	6636	0046	0947	*9880	7597	5702	0662	8542	3916
12	5984	4599	7364	5815	6348	*9757	0655	*9585	7301	5404	0363	8242	3614
.5	5694	4306	7071	5517	6049	*9457	0353	*9279	6994	5097	0053	7932	3301
13	5394	4004	6767	5208	5740	*9147	0041	*8964	6677	4779	*9733	7611	2978
.5	5084	3690	6453	4889	5421	*8827	*9719	*8638	6350	4451	*9403	7280	2644
14	4764	3368	6129	4560	5092	*8498	*9386	*8302	6013	4112	*9063	6938	2300
.5	4435	3035	5795	4221	4753	*8158	*9044	*7956	5666	3764	*8713	6587	1946
						1.333	1.334	1.336			1.339		
15	4095	2692	5452	3872	4404	7808	8692	7601	5309	3406	8352	6226	1582
.5	3746	2340	5099	3514	4046	7449	8331	7236	4943	3038	7983	5855	1208
16	3388	1979	4737	3146	3678	7080	7960	6861	4567	2661	7603	5475	0825
.5	3020	1608	4365	2770	3301	6702	7579	6476	4181	2274	7214	5085	0432
17	2643	1228	3984	2383	2915	6315	7189	6083	3786	1878	6816	4685	0029
.5	2257	0839	3594	1988	2519	5919	6790	5680	3382	1472	6408	4276	*9618
18	1862	0441	3196	1584	2114	5513	6382	5268	2969	1057	5991	3858	*9196
.5	1459	0034	2788	1170	1701	5099	5965	4847	2546	0634	5565	3431	*8766
19	1046	*9619	2371	0748	1279	4676	5539	4417	2115	0201	5130	2995	*8327
.5	0625	*9194	1946	0317	0847	4244	5104	3979	1675	*9760	4686	2550	*7879
		1.330		1.332						1.337			1.342
20	0195	8761	1512	9877	0408	3803	4661	3531	1226	9309	4234	2096	7422
.5	*9757	8320	1069	9429	*9959	3354	4209	3075	0769	8850	3772	1634	6956
21	*9310	7870	0618	8973	*9503	2896	3749	2611	0303	8383	3302	1163	6482
.5	*8855	7412	0159	8508	*9038	2430	3280	2138	*9828	7907	2824	0684	5999
22	*8392	6945	*9692	8034	*8564	1956	2803	1656	*9346	7423	2338	0196	5508
.5	*7920	6471	*9216	7553	*8083	1473	2318	1167	*8854	6930	1842	*9699	5008
23	*7441	5988	*8733	7064	*7593	0983	1824	0669	*8355	6430	1339	*9195	4500
.5	*6954	5497	*8241	6566	*7095	0484	1323	0164	*7848	5921	0828	*8682	3983
24	*6458	4999	*7741	6061	*6590	*9978	0813	*9650	*7333	5404	0308	*8162	3459
.5	*5955	4492	*7234	5547	*6076	*9463	0296	*9128	*6809	4879	*9781	*7633	2926
	1.329		1.330		1.332	1.332	1.333	1.335	1.336		1.338	1.339	
25	5445	3978	6719	5026	5555	8941	9771	8599	6278	4347	9246	7096	2386
.5	4926	3456	6196	4497	5026	8411	9238	8061	5739	3806	8703	6552	1838
26	4400	2927	5666	3961	4490	7873	8697	7516	5193	3258	8152	6000	1282
.5	3866	2390	5128	3417	3945	7328	8149	6964	4639	2702	7593	5440	0718
27	3326	1846	4582	2866	3394	6776	7594	6404	4077	2139	7027	4872	0146
.5	2777	1294	4030	2307	2835	6216	7031	5836	3508	1568	6453	4297	*9567
28	2222	0735	3470	1740	2268	5648	6460	5261	2931	0990	5872	3715	*8980
.5	1659	0169	2902	1167	1695	5073	5882	4679	2347	0404	5284	3125	*8386
29	1089	*9595	2328	0586	1114	4492	5298	4089	1756	*9811	4688	2528	*7785
.5	0512	*9015	1746	*9998	0526	3902	4705	3492	1157	*9211	4085	1923	*7176
	1.328	1.329		1.331	1.331					1.336			1.341
30	9927	8427	1157	9403	9930	3308	4106	2888	0551	8603	3474	1311	6561

From Tilton, L. W., and Taylor, J. K.,
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Index of refraction of distilled water for various spectral lines

Read initial digits in same column above tabulated values unless asterisk refers to initial digits below. For instance, for 5892.6 sodium line at 20°C, read 1.3329877; for 5015.7 helium line at 14°C, read 1.3368302.

t°C	Wave lengths in angstroms												
	7065.2	6678.1	6562.8	5892.6	5875.6	5769.6	5460.7	5015.7	4861.3	4713.1	4471.5	4358.3	4046.6
	1.328	1.329	1.330	1.331	1.331	1.332	1.333	1.335	1.336	1.336	1.338	1.339	1.341
30	9927	8427	1157	9403	9930	3306	4106	2888	0551	8603	3474	1311	6561
.5	9336	7832	0562	8801	9328	2703	3500	2277	*9939	7989	2857	0692	5937
31	8738	7231	*9959	8192	8719	2093	2886	1659	*9319	7367	2232	0066	5307
.5	8133	6622	*9350	7576	8103	1476	2266	1034	*8692	6739	1601	*9433	4669
32	7521	6007	*8733	6954	7480	0852	1639	0402	*8058	6103	0962	*8793	4025
.5	6903	5385	*8110	6324	6850	0221	1005	*9763	*7418	5461	0317	*8146	3373
33	6278	4756	*7480	5688	6214	*9583	0364	*9118	*6770	4812	*9664	*7492	2715
.5	5646	4121	*6844	5045	5571	*8939	*9717	*8466	*6116	4156	*9005	*6832	2050
34	5007	3479	*6200	4395	4921	*8288	*9063	*7806	*5455	3493	*8340	*6164	1378
.5	4362	2830	*5551	3739	4264	*7631	*8402	*7141	*4788	2824	*7667	*5490	0699
			1.329			1.331	1.332	1.334	1.335		1.337	1.338	
35	3711	2175	4894	3076	3602	6967	7735	6469	4114	2148	6988	4810	0014
.5	3053	1513	4232	2407	2932	6296	7061	5790	3433	1465	6302	4122	*9322
36	2388	0845	3563	1731	2256	5619	6381	5105	2746	0776	5610	3428	*8623
.5	1718	0171	2887	1049	1574	4936	5694	4413	2052	0081	4911	2728	*7918
37	1041	*9490	2205	0361	0886	4246	5001	3715	1352	*9379	4206	2021	*7206
.5	0357	*8803	1517	*9666	0191	3550	4302	3010	0646	*8671	3495	1308	*6488
38	*9668	*8110	0823	*8965	*9489	2848	3596	2300	*9934	*7956	2777	0588	*5763
.5	*8972	*7411	0122	*8258	*8782	2140	2885	1583	*9215	*7236	2052	*9863	*5032
39	*8270	*6705	*9416	*7544	*8069	1425	2167	0860	*8490	*6508	1322	*9130	*4295
.5	*7563	*5994	*8703	*6825	*7349	0704	1443	0130	*7758	*5775	0585	*8392	*3551
	1.327	1.328	1.328	1.330	1.330	1.330		1.333	1.334	1.335	1.336	1.337	1.340
40	6849	5276	7984	6099	6623	9977	0712	9395	7021	5036	9842	7647	2801
.5	6129	4552	7260	5368	5891	9244	*9976	8653	6277	4290	9094	6897	2045
41	5403	3823	6529	4630	5154	8506	*9234	7906	5528	3539	8338	6140	1283
.5	4671	3087	5792	3887	4410	7761	*8486	7152	4772	2781	7577	5377	0514
42	3934	2346	5050	3137	3660	7010	*7732	6393	4011	2018	6810	4608	*9740
.5	3190	1598	4301	2382	2905	6253	*6971	5627	3243	1248	6037	3833	*8960
43	2441	0845	3547	1621	2143	5491	*6205	4856	2470	0473	5258	3052	*8173
.5	1686	0086	2787	0854	1376	4722	*5434	4079	1691	*9691	4473	2266	*7381
44	0925	*9321	2021	0081	0603	3948	*4656	3296	0906	*8904	3682	1473	*6582
.5	0158	*8551	1249	*9302	*9825	3168	*3873	2507	0115	*8111	2886	0674	*5778
	1.326	1.327		1.329	1.329		1.331		1.333	1.334		1.336	1.339
45	9386	7775	0472	8518	9040	2383	3084	1712	9318	7313	2083	9870	4968
.5	8608	6993	*9689	7728	8250	1592	2289	0912	8516	6508	1275	9060	4152
46	7825	6206	*8900	6933	7454	0795	1489	0106	7708	5698	0461	8244	3330
.5	7036	5413	*8106	6132	6653	*9992	0683	*9295	6894	4882	*9642	7423	2503
47	6241	4614	*7307	5325	5846	*9184	*9871	*8478	6075	4061	*8816	6596	1670
.5	5441	3810	*6501	4512	5034	*8371	*9054	*7655	5250	3234	*7986	5763	0831
48	4636	3001	*5691	3695	4216	*7552	*8231	*6827	4420	2401	*7149	4924	*9986
.5	3824	2186	*4875	2872	3392	*6727	*7403	*5993	3584	1563	*6307	4080	*9136
49	3008	1366	*4053	2043	2564	*5897	*6570	*5154	2742	0720	*5459	3231	*8280
.5	2186	0540	*3226	1209	1729	*5061	*5730	*4309	1896	*9870	*4607	2376	*7419
		1.326	1.327			1.329	1.330	1.332		1.333	1.335		1.338
50	1359	9709	2394	0369	0889	4221	4886	3459	1043	9016	3748	1515	6552
.5	0527	8872	1556	*9524	0044	3374	4036	2603	0186	8156	2884	0649	5680
51	*9689	8030	0713	*8674	*9194	2523	3181	1742	*9322	7291	2015	*9778	4802
.5	*8846	7183	*9865	*7819	*8338	1666	2321	0876	*8454	6420	1140	*8901	3918
52	*7998	6331	*9011	*6958	*7477	0804	1455	0005	*7580	5544	0260	*8019	3030
.5	*7144	5473	*8152	*6092	*6611	*9936	0584	*9128	*6701	4663	*9375	*7131	2135
53	*6286	4610	*7288	*5221	*5740	*9064	*9708	*8246	*5817	3776	*8484	*6238	1236
.5	*5422	3742	*6419	*4344	*4863	*8186	*8826	*7358	*4927	2884	*7588	*5340	0331
54	*4553	2869	*5545	*3463	*3981	*7303	*7939	*6466	*4033	1987	*6687	*4437	*9421
.5	*3678	1991	*4665	*2576	*3094	*6415	*7048	*5568	*3133	1085	*5780	*3528	*8505
	1.325		1.326	1.328	1.328	1.328	1.329	1.331	1.332		1.334	1.335	1.337
55	2799	1108	3781	1684	2202	5521	6151	4665	2227	0177	4868	2614	7584
.5	1915	0219	2891	0787	1305	4623	5248	3757	1317	*9265	3952	1695	6658
56	1026	*9326	1996	*9885	0403	3720	4341	2844	0402	*8347	3030	0771	5727
.5	0131	*8427	1096	*8978	*9496	2811	3429	1926	*9482	*7424	2102	*9842	4791
57	*9232	*7524	0192	*8066	*8583	1898	2512	1003	*8556	*6496	1170	*8907	3849
.5	*8328	*6615	*9282	*7148	*7666	0979	1590	0075	*7625	*5563	0233	*7968	2902
58	*7418	*5702	*8367	*6226	*6743	0055	0662	*9141	*6690	*4625	*9290	*7024	1950
.5	*6504	*4783	*7447	*5299	*5816	*9127	*9730	*8203	*5749	*3682	*8343	*6073	0994
59	*5585	*3860	*6523	*4367	*4884	*8193	*8793	*7260	*4803	*2734	*7390	*5118	0031
.5	*4661	*2931	*5593	*3430	*3947	*7255	*7850	*6312	*3853	*1781	*6433	*4159	*9064
	1.324	1.325	1.325	1.327	1.327	1.327	1.328	1.330	1.331	1.332	1.333	1.334	1.336
60	3732	1998	4859	2488	3005	6312	6904	5358	2837	0823	5471	3194	8092

From Tilton, L. W., and Taylor, J. K.,
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ORDERING NO.	DESCRIPTION
31-57-11	Polaroid Cap Analyzer
33-33-10	GE Number 605 flashlight lamp, 6 volt, 1/2 amp, for 33-45-58-01; used both for sample illumination and for scale illumination.
33-45-04-027	Auxiliary test piece (triangular) with nominal index of 1.4660.
33-45-20	Thermometer calibrated to read directly in "total solids".
33-45-21	Thermometer assembly, complete with 33-45-22 thermometer.
33-45-22	Thermometer, 0 - 100°C. in 1° divisions; unmounted.
33-45-46-023	Synthetic fluorite test piece with index of 1.43383 at 20°C. for sodium D line (589.3mu).
33-45-48-022	Auxiliary test piece (triangular) with nominal index of 1.5060.
33-45-49-022	Auxiliary test piece (triangular) with nominal index of 1.5125.
33-45-57	Replacement prism Assembly for 33-45-56 only.
33-45-58-01	Abbe 3-L Refractometer, complete, for 115 v 50/60 cycle operation only; with index range from 1.30 to 1.71; includes glass test piece (33-45-85), thermometer (33-45-22), bottle of contact liquid (33-45-81), calibration wrench, dust cover, reference manual, and dispersion tables. The instrument is available on special order with an index range from 1.45 to 1.85.
33-45-59	Replacement prism set for 33-45-58-01; series number of prism and serial number of instrument must be specified.
33-45-68	Standard eyepiece, 2x, as supplied with standard instrument (33-45-58-01).
33-45-69	Auxiliary eyepiece, 1.3x; used where the lower power will give an apparent improvement in sharpness of the dividing line.

ORDERING NO.	DESCRIPTION
33-45-77	Case for 33-45-88-01 and 33-99-8431
33-45-79	Discontinued; replace with 33-45-88.
33-45-81	7 ml. bottle of 1-bromonaphthalene, for use as contact liquid for test pieces and other solid samples with indices less than 1.64.
33-45-85	Square test piece supplied with 33-45-58-01, with nominal index of 1.5125.
33-45-88	Temperature control equipment, Precision Scientific model 66600, with 0.03°C. sensitivity, for 115 volt 50/60 cycle operation, with an operating range from room temperature to just below the boiling point of water.
33-99-8431	High index Abbe. Same as 33-45-58-01 except with range from 1.45 to 1.85.
33-99-5485-023	Triangular test piece for 33-99-8431 with nominal index of 1.7200.

– NOTES –

— NOTES —

THESE DIRECTIONS or instructions do not presume to cover all details, variations, or changes in this equipment; nor to provide for all possible contingencies to be met in connection with installation or use. We would be glad to help on any problems not covered in this manual.

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