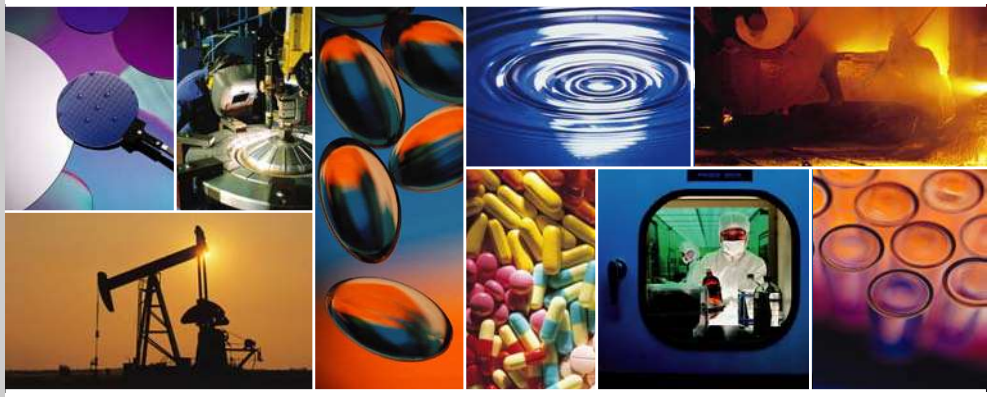
ABBE-3L™ Refractometer
User Guide



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Introduction

The ABBE-3L refractometer is a precision instrument which provides the index of refraction (n_D) on a wide variety of liquid or solid samples. It has a standard working range of 1.30-1.71 n_D and can be operated at ambient temperature or with temperature control via an external recirculator. The instrument also furnishes direct readings in Brix from 0-85%. It is supplied with the following parts:

- Thermometer assembly, 0 – 100°C, with guard tube attached to the refractometer
- 1-Bromonaphthalene contact liquid
- NIST traceable certified calibration test piece (glass) 1.5125 n_D nominal
- Calibration hex wrench
- Compensator dial cover, magnetic
- Dispersion table
- Plastic dust cover
- 2 pieces ¼-in clear vinyl tubing

Conventions used in this manual

This manual includes safety precautions and other important information presented in the following format:

Note Notes contain helpful supplementary information. ▲

Notice Follow instructions labeled "Notice" to avoid damaging the system hardware or losing data. ▲

⚠ Caution Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury. ▲

⚠ Warning Indicates a hazardous situation which, if not avoided, could result in death or serious injury. ▲

⚠ Danger Indicates a hazardous situation which, if not avoided, will result in death or serious injury. ▲

The following safety symbols may be used on this product:

Symbol	Description	Indication
	Black graphical symbol inside a yellow triangle with a black triangular band	This is a warning symbol. The graphic in this symbol is used to alert the user to potential hazards.
	Black graphical symbol inside a red circular band with a red diagonal bar	This is a prohibition symbol. The graphic in this symbol is used to alert the user to actions that shall not be taken or shall be stopped.
	White graphical symbol inside a blue circle	This is a mandatory action symbol. It is used to indicate that an action shall be taken to avoid a hazard.
	Black graphical symbol inside a yellow triangle with a black triangular band	This is the general warning sign. Failure to heed the safety precautions could result in personal injury.
	White graphical symbol inside a blue circle	This is the general data loss or property damage symbol and is not related to personal injury. Failure to heed these precautions can result in irreparable damage to property or permanent data loss.

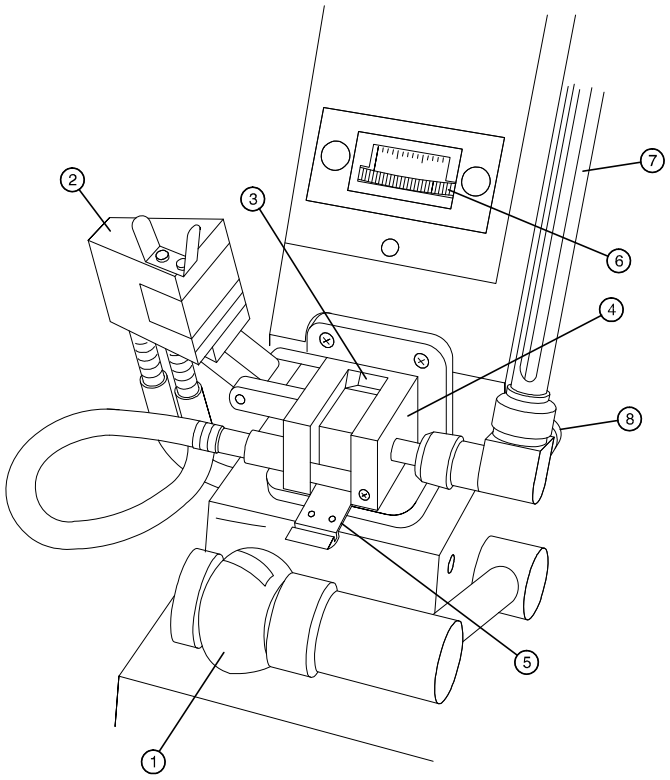
Questions or concerns

In case of emergency, follow the procedures established by your facility. If you have questions or concerns about safety or need assistance with operation, repairs or replacement parts, you can contact our sales or service representative in your area or use the information at the beginning of this document to contact us.

Refractometer Basics

The ABBE-3L consists of a refracting prism assembly (with illuminator), an internal measurement scale, and a compensating prism system.

Figure 1 – Prism area



Key:

① Sample illuminator lamp
② Upper prism case
③ Measuring prism
④ Lower prism case
⑤ Hinged light shield
⑥ Compensator dial
⑦ Thermometer assembly
⑧ Water inlet fitting

Refracting prism assembly

The prism assembly consist of an upper and lower prism case (②and ④ Figure 1), each containing a separate prism. The upper case contains the illuminating prism and the lower case contains the measuring prism (③). The upper case is opened with the handle on the right-hand side.

The n_D of liquid samples is measured by introducing a thin layer of sample between the upper and lower prisms; the n_D of solid samples is measured by opening the upper prism case and placing them in optical contact with the surface of the measuring (lower) prism with a suitable contact liquid.

In both cases, the sample/prism interface generates a borderline which is visually observed through the instrument eyepiece. This borderline is used to determine the n_D of the sample.

The prism cases are hollow to allow for the optional circulation of constant temperature liquid. A thermometer (⑦,Figure 1) in the input line provides an accurate indication of the liquid temperature. A short, external jumper hose carries the liquid to the upper prism case. The lower prism case has a small, hinged shield (⑤,Figure 1) which prevents stray light from entering the front of the measuring prism. This shield can be swung down for measuring opaque samples.

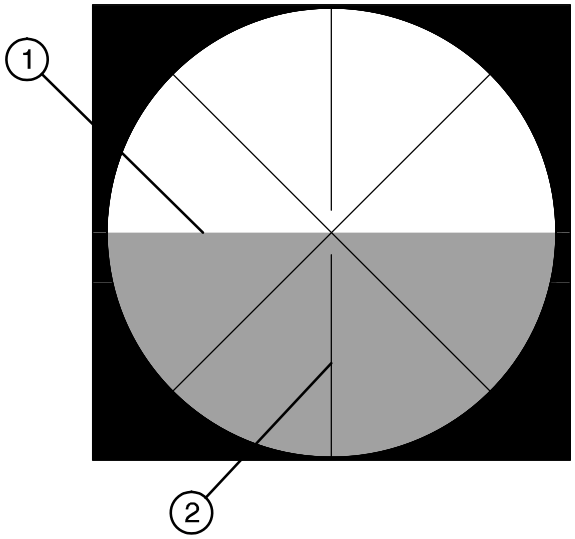
Prism identification number

The particular series of prism glass used in your ABBE-3L is identified by a number found on the right-hand side of the measuring prism. This number can be seen by opening the upper prism case and shining a light down into the lower prism from above. This number MUST match the scale series number (see Measurement Scales) and must be given along with the instrument serial number in all correspondence or parts orders for your instrument.

Prism illumination

The required illumination (tungsten lamp) is given by the sample illuminator (①,Figure 1) located at the end of the adjustable arm. The lamp is housed inside the rotating lens assembly which also contains a lamp shield and diffuser. The arm assembly can be moved up or down and the lens rotated for optimum illumination of the prism. The sample illuminator lamp is turned on when the combined 3-position power/lamp selector switch (③,Figure 5) on the left panel is in the center position.

Figure 2 – View of total reflection

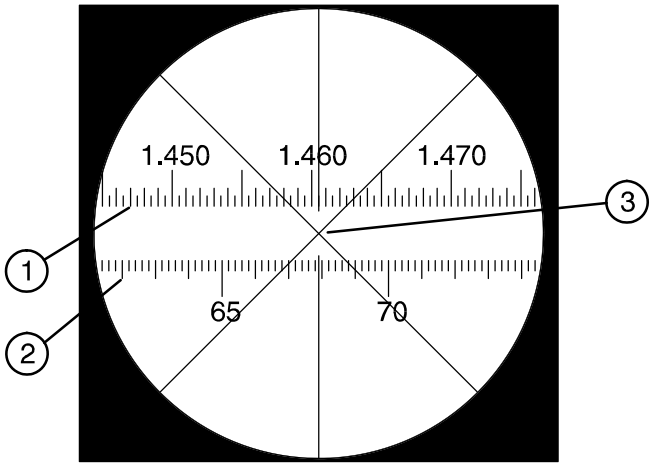


Key:

① Total reflection borderline

② Total reticle

Figure 3 – View of internal scale



① Refractive Index (n_D) scale

② Total dissolved solids scale

③ Dual reticle

Eyepiece

The borderline (①, Figure 2), as seen in the instrument eyepiece, is the dividing line between a light and a dark sector. The eyepiece provides a 2X magnification and is used to observe both the borderline (when the power/lamp selector switch on the left panel is in the middle position) and the instrument's measurement scales (when the power/lamp selector switch is in the low position). For best visibility of the scale or borderline the eyepiece should be focused by moving it in or out of its holder.

Compensator system

The compensator corrects for the dispersion inherent in the refractometer optics and the sample, and is adjusted using the large dial (⑥,Figure 1) on the front of the instrument located just above the prism assembly. When properly set, the borderline seen through the eyepiece will be achromatic in the center (at the cross-hair), with a faint red color at one end, and a faint blue color at the other end.

Note that the dial circumference has two sets of markings with a common zero (0) point. If the compensator is in proper working order, the borderline can be achromatized at two positions of rotation with near identical dial settings. The dial numbers themselves are NOT significant in routine n_D or % total dissolved solids determinations. They are, however, used in the calculation of dispersion with the tables provided with the instrument (see Determination of Dispersion, below).

A removable plastic dial cover prevents the entry of foreign material into the inside of the instrument. Keep the cover in place except when adjusting the Compensator Dial.

Measurement scales

The instrument contains two coincident scales which read from 1.30 to 1.7l n_D and from 0-85% Brix (also called Total Dissolved Solids). The scales (Figure 3) are visible through the instrument eyepiece when the power/lamp selector switch is depressed to its lowest position.

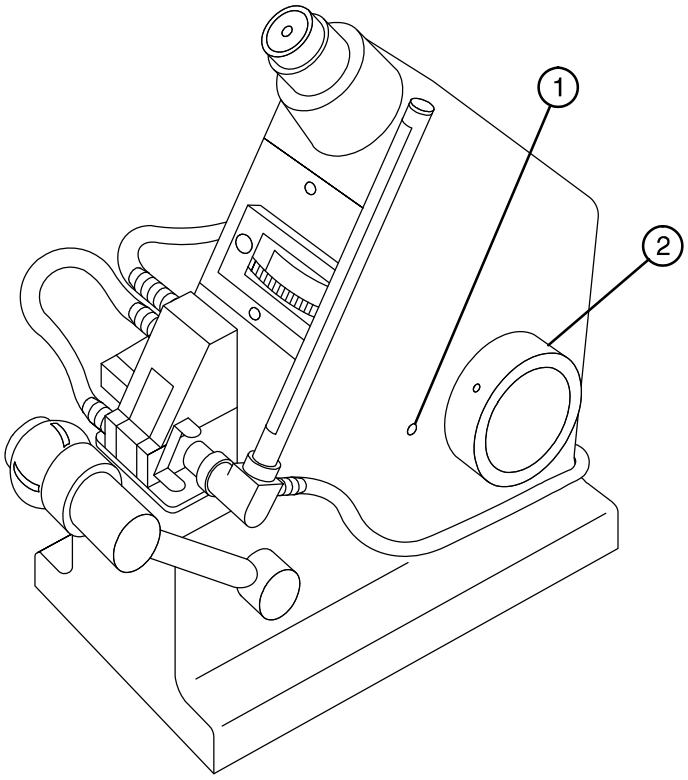
The "Total Dissolved Solids" scale is based directly on the 20°C ICUMSA Tables of 1966 for % by weight of sucrose in water (Brix).

Turning the handwheel on the right-hand side of the instrument moves the scales across the reticle. When the scales are set to their extreme low end, a small 3-digit number will be seen. This number MUST match that found on the side of the measurement prism.

Operating Procedures

This chapter provides important information about using your instrument to analyze samples.

Figure 4 – Right side



Key:

① Calibration screw

② Handwheel

Setting up the instrument

⚠ Caution If the equipment is not used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. ▲

1. **Place the instrument on a flat, even surface that is:**

   - As far as possible from any strong electric or magnetic fields and from any electrical device that may generate high frequency fields.
   - Free of dust, corrosive gases and strong vibrations.

2. **Remove any obstructions or materials that could hinder the flow of air under, behind and around the instrument.**

⚠ Warning If the voltage shown on the label is not the same as the voltage of your power sources, DO NOT PLUG IN THE INSTRUMENT. Contact your distributor. ▲

3. **Plug the power cord into a grounded outlet with the appropriate voltage.**

Instrument calibration

Each instrument is supplied with a NIST traceable certified calibration test piece used to check and adjust the accuracy of the index scale reading. To calibrate the instrument:

1. **Connect the power cord with external transformer to the appropriate outlet and press the power/lamp switch (③, Figure 5) so that it is in the middle position.**

2. **Open the top prism and thoroughly clean the measurement prism and the test piece (see Cleaning in the Maintenance section).**

Notice Use care not to scratch the glass surface. ▲

3. **Apply a small drop of 1-bromonaphthalene contact liquid to the prism.**

Note Refer to the Material Safety Data Sheet, located on the documentation CD, for the correct use and handling of 1-bromonaphthalene. ▲

4. **Drop the calibration test piece from a height of 0.25 cm or so, onto the contact liquid, with the polished end toward the illuminator**

   The 1-bromonaphthalene should spread out to fill the space between the test piece and the prism. Do not allow any excess 1-bromonaphthalene to "bead" at the edges (if so, too much 1-bromonaphthalene has been used).

5. **Press the power/lamp switch to its lowest position and use the handwheel (②, Figure 4) to set the index scale (visible through the eyepiece) to the value engraved on the test piece.**

   Focus the eyepiece for the best definition of the reticle and scale.

6. **Release the switch and position the field lamp arm and shield for the best contrast and definition at the borderline.**

Note It may help to rotate the lamp lens to the diffused position. ▲

7. **Rotate the compensator dial (⑥, Figure 1) until the borderline is achromatic on the spot where the reticle marks cross.**

8. **Use the handwheel to center the achromatic section of the borderline.**

9. **Depress the switch and note the index value.**

   The value must coincide with the value engraved on the test piece.

10. **Repeat the measurement several times, centering the borderline from above and below the crosshair intersection.**

    If the index displayed does not coincide with the test piece, insert the calibration hex wrench (included with the instrument) into the calibration screw (①, Figure 4) on the right-hand side near the handwheel, and adjust the scale to the calibration test piece value.

Liquid samples

1. **Ensure that the prisms are absolutely clean and refer to the Temperature Control section.**

2. **Turn on the instrument.**

3. **Open the top prism case and apply the sample directly to the measurement prism with a dropper.**

Notice Use care not to touch the prism surface with the dropper. ▲

If the sample is very viscous, use a wooden or plastic applicator. Ensure that sufficient sample has been loaded to completely fill the space between prisms.

4. **Close the prism case.**

Note If bubbles form in the sample, they may sometimes be eliminated by slightly opening and closing the prism case. If this is not effective, re-clean the prism surface. ▲

5. **Adjust both the height and rotation of the illuminator for the best contrast in the reflection borderline.**

6. **Using the handwheel, set the borderline on the crosshair intersection, and achromatize it with the compensator dial.**

7. **Depress the contact switch and read the sample value in index of refraction (n_D) or % total dissolved solids.**

Solid samples (clear)

To accurately measure the index of a solid by transmission of light through the sample, it must meet the following requirements:

- The contacting surface must be flat to a few wavelengths (approximately 0.0002 in).
- It must have a sharp right angle edge.
- The material must be homogeneous (no haze or light scattering properties).
- It must not react chemically with the contact liquid. If so, find another contact liquid.

➡ *How to* ➡ Measure the index of refraction.

1. **Open the top prism case and ensure that the measurement prism is absolutely clean.**
2. **Using a suitable contact liquid, place the sample on the measurement prism with the sharp edge toward the illuminator and flat side down.**

Note 1-Bromonaphthalene is suitable for samples with an index up to 1.64 n_D. For samples with a higher index, use methylene iodide. ▲

3. **Adjust both the height and the rotation of the illuminator for the best contrast in the reflection borderline.**
4. **Using the handwheel, set the borderline on the crosshair intersection and achromatize it with the compensator dial.**
5. **Depress the contact switch and read the sample value in index of refraction (n_D).**

   In general, the change in refractive index due to temperature change is so small in solid materials that temperature control is not required. However, with some plastics, this may not be true, and if in doubt, the temperature coefficient should be checked.

Opaque samples

Refractive index measurements are seldom required on opaque materials, but when it is necessary to obtain such a reading the 'reflection' method must be used. When measuring by reflection, the sample is attached to the prism with the usual contact liquid, the light shield on the measuring prism is swung down, and the light from the illuminator is directed toward the opening. The illuminator arm and shield are then adjusted for the most favorable reflection borderline. In the reflection method, the borderline is not as distinct as in the transmission method because of the lack of contrast between the two halves of the field. This is inherent in any ABBE-type instrument and cannot be avoided. Sometimes the line can be seen only when it is in motion across the field. Then it may help to move the borderline past the crosshairs with a constantly decreasing motion until it can no longer be distinguished. In using this method, take a number of readings, approaching the crosshairs from above and below. The reflection borderline will be the reverse of a liquid sample. The dark field will be on top when viewed.

If one is forced to use the reflection method, experimental readings may be made using paraffin oil. With it, the borderline may be set by the usual transmission method and then observed in reflection. This will aid in recognizing the characteristics of a reflection borderline.

Temperature control

Various materials differ greatly in the effect of temperature on their refractive index. The degree of temperature control required depends on the nature of the sample and the desired accuracy of the reading. Most of the vegetable and mineral oils and fats, for example, have temperature coefficients in the order of 0.0004 to 0.0005 n_D per degree centigrade and must have close temperature control for accurate and consistent results.

Correction tables can be prepared for many materials whose refractive index is commonly determined. If so, readings may be made at any normal ambient temperature, and the values at a standard temperature can be computed using the correction factor obtained from the table.

The International Sucrose Tables in this manual are published with correction factors related to the 20°C standard temperature. When a correction table is available, instrument temperature control to a predetermined value is not needed. However, the room ambient temperature would have to remain constant for a reasonable period of time to allow the prism temperature to stabilize to that temperature.

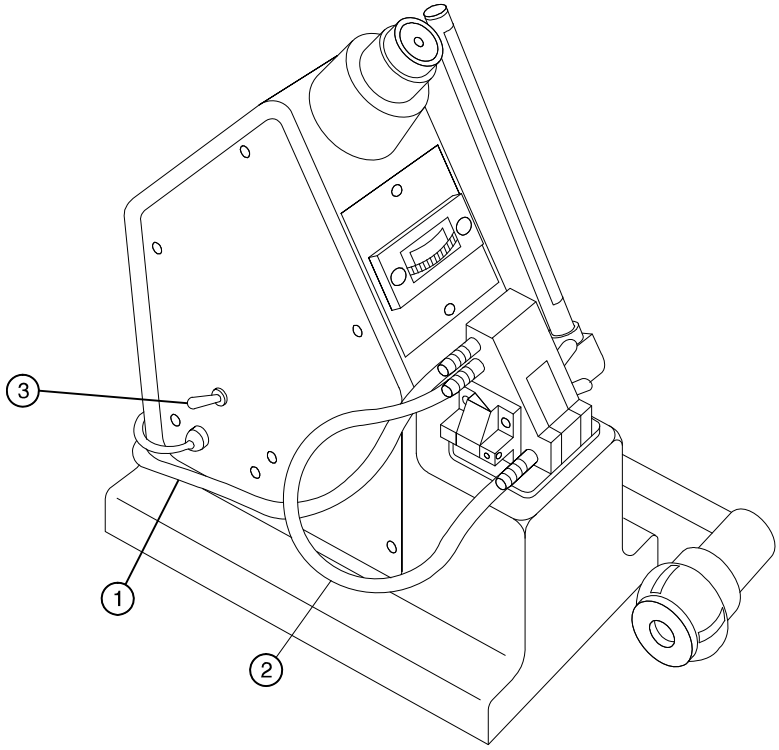
Note The sucrose correction tables are the only tables furnished. Since water is 0% sucrose, this table includes a temperature correction table for water. Using a water sample, the known Brix value at a specific temperature from the table allows you to check the setting on your water circulator. ▲

Note The built-in thermometer may not agree exactly with the thermometer supplied with an external water circulator. This is because the thermometers are in two different locations. Neither of these will be exactly the same as the sample location. For greatest accuracy, the user may wish to make a correlation between one of these thermometers and the actual temperature at the sample location as measured by use of a small, accurately calibrated thermistor placed directly between the closed prisms. ▲

Water bath control

For those applications which require very close temperature control, an external water/heater circulator is recommended. Models are available which provide heating only, or a combination of heating/cooling.

Figure 5 – Hose connections



Key:

① Outlet hose
② Jumper hose
③ 3-position power/lamp selector switch

How to Use an external circulator.

1. **Follow the instructions supplied with the unit.**

2. **Connect the circulator water outlet to the connector on the ABBE-3L thermometer elbow using ¼ in. I.D. tubing.**

   Refer to Figure 5 for the jumper hose and outlet hose connections. Allow time for the prisms to stabilize at the water temperature.

   Use caution when operating at elevated temperatures. At extreme temperatures, the water temperature must be raised and lowered slowly to prevent cracking the prism.

   The ABBE-3L refractometer is designed only for use up to 80°C. Instrument operation cannot be guaranteed at temperatures above 80°C.

Note In high-humidity environments where the prism temperature is lower than the ambient temperature, condensation may appear underneath the lower prism. This may make measurements difficult to determine, until prisms are brought closer to the ambient temperature. ▲

Thin film measurements

The ABBE-3L refractometer can be used to determine both the thickness and refractive index of a thin film coating if it meets the following criteria:

1. A thickness of 0.0001 mm to 0.05 mm, nominal.
2. The refractive index must be within the range of the instrument.
3. The coating must be flat and uniform in thickness.
4. The coating must have a lower refractive index than the backing.

Determination of dispersion

The ABBE-3L can be used to determine the dispersion and v (nu value or ABBE number).

In these applications, it is essential that the compensator be in good working order; i.e., the two positions of the compensator dial which produce an achromatic reflection borderline must occur at identical dial settings on each side of the dial zero mark.

Dispersion

Dispersion is measured as $n_F - n_C$ using the instructions and values given in the Dispersion Table furnished with the instrument.

Note The series number of the Dispersion Table MUST match the series number of the instrument prism and scale. ▲

Nu (v) value

The nu (v) value is determined from the equation:

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

Due to the use of compensator prisms, dispersion measurements are relative to the Sodium D line (589.3 nm).

Maintenance

The ABBE-3L is a rugged, trouble-free instrument that needs a minimum of routine maintenance. Customer repairs are limited to lamp and thermometer replacements and prism assembly replacements ONLY. Do not attempt to make any repairs or adjustments on the internal components of the instrument.

Cleaning instrument exterior

The exterior and sample compartment of the instrument can be cleaned periodically as follows:

⚠ Caution Do not allow moisture to leak into the instrument. ▲

1. **Switch off the instrument and disconnect from AC power source.**
2. **Using a lint free cloth dampened with a weak solution of detergent and water, wipe the exterior surface of the instrument as necessary.**
3. **Wipe over with a cloth dampened with plain water.**
4. **Dry the surface with another cloth.**

Cleaning the measuring prism

To maintain its performance, the ABBE-3L refractometer must be kept clean at all times. The care of the measuring prism is as follows:

Use a non-ionic detergent (e.g., Alconox, Alcojet or Detergent 8) to clean the top and bottom prisms after each sample, then rinse with water and dry. You may use a lint-free non-abrasive cloth to dry prism; however, we recommend to air dry.

Notice Keep the upper prism closed when not in use. The prism glass is quite soft and easily scratched. ▲

Clean the upper and lower prism with non-ionic solution after each use to maintain its performance.

The sealer around the prism is not resistant to most chemicals. Solvents which are known to attack the sealer and must not be used with the instrument are:

- Ethers
- Chromic acid
- Strong mineral acids (e.g., nitric sulphuric, etc.)
- Strong basic solutions (e.g., sodium hydroxide)

All organic and inorganic liquids will, over time, have an effect on the sealer. Therefore, we suggest that, to increase the longevity of your system, place only one drop of the sample in the middle of the prism to reduce contact with the sealer. Also clean the prism immediately after every sample. This will reduce the effect of the chemicals on the sealer.

Notice Strong mineral acids and bases will quickly fog the prisms and must not be used. ▲

Lamp Replacement

The lamp gets very hot during operation. Before removing the lamp, turn off the instrument and allow the lamp to cool down for 10 minutes.

Turn off and unplug the instrument before opening the lamp door.

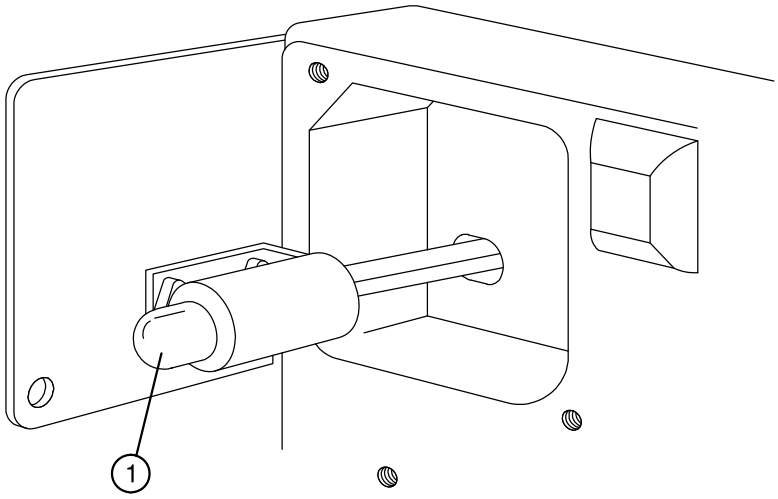
Prism field lamp

To replace the prism field lamp, pull off the plastic lens assembly from the arm and unlock the old lamp.

Scale illumination lamp

To replace the scale illumination lamp, open the access door on the bottom of the instrument by removing the two screws in the door corners ONLY.

Figure 6 – Bottom view



Key:
① Scale illumination lamp

International Sucrose Tables

The Brix or the "Total Dissolved Solids" scale, visible in the instrument eyepiece along with the refractive index scale, is based directly on the International Sucrose Tables as agreed upon the Fourteenth Session of the International Commission for Uniform methods of Sugar Analysis (ICUMSA), held in Copenhagen in 1966.

These tables are based on the index values of pure sucrose solutions. When substances other than sucrose are in the solution, the refractometer reads the combined index as "% total dissolved solids" and not as % (by weight) of the sucrose (or Brix).

The instrument scale is based on the 20°C tables. This manual contains the 20°C tables along with correction factors for other temperatures.

Note ABBE-3L refractometers manufactured prior to August 1980 were calibrated to the 1936 ICUMSA scale. These instruments will read 1.5033 on the n_D scale when the "Total Dissolved Solids" scale is at 85%. Instruments with 1966 ICUMSA scales will read 1.5041 at the 85% setting. ▲

International Scale (1966) of Refractive Indices of Sucrose Solutions at 20°C

Index	Percent	Index	Percent	Index	Percent	Index	Percent
1.3330	0	1.3723	25	1.4200	50	1.4778	75
1.3344	1	1.3740	26	1.4221	51	1.4803	76
1.3359	2	1.3758	27	1.4243	52	1.4829	77
1.3373	3	1.3775	28	1.4264	53	1.4855	78
1.3388	4	1.3793	29	1.4286	54	1.4881	79
1.3403	5	1.3811	30	1.4308	55	1.4907	80
1.3418	6	1.3829	31	1.4329	56	1.4933	81
1.3433	7	1.3847	32	1.4351	57	1.4960	82
1.3448	8	1.3866	33	1.4374	58	1.4987	83
1.3463	9	1.3884	34	1.4396	59	1.5013	84
1.3478	10	1.3903	35	1.4419	60	1.5041	85
1.3494	11	1.3922	36	1.4441	61		
1.3509	12	1.3941	37	1.4464	62		
1.3525	13	1.3960	38	1.4487	63		
1.3541	14	1.3979	39	1.4511	64		
1.3557	15	1.3998	40	1.4534	65		
1.3573	16	1.4018	41	1.4558	66		
1.3589	17	1.4037	42	1.4582	67		
1.3605	18	1.4057	43	1.4605	68		
1.3621	19	1.4077	44	14630	69		
1.3638	20	1.4097	45	1.4654	70		
1.3655	21	1.4118	46	1.4678	71		
1.3672	22	1.4138	47	1.4703	72		
1.3689	23	1.4159	48	1.4728	73		
1.3706	24	1.4179	49	1.4753	74		

International Temperature Correction Table for the normal model of refractometer above and below 20°C

Temp °C	Percent Sucrose														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
	Subtract from the 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 percent 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

Bibliography

For a detailed discussion of refractometry, refer to Physical Methods of Organic Analysis, Vol. 1, Part 2, Chapter 18 by A. Weissberger.

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