Brookhaven
Instruments Corporation

Instruction Manual for BI-870 Dielectric Constant Meter

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Please Read

This is the instruction manual for your Brookhaven BI-870 dielectric constant meter. Please read it carefully before making measurements. If you have any questions or suggestions, please contact Brookhaven Instruments.

Remember the old saying: “When in doubt, read the instruction manual.” Sometimes the solution to your problem has already been addressed. You just need to find it. Thanks for purchasing a Brookhaven product.

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Specifications

Full Scale Sensitivity:	Dielectric constants of 1-20 and 1-200
Maximum Conductivity of Sample:	Range 1-20: 1 µS/cm Range 1-200: 10 µS/cm (<0.05 mM 1:1 electrolyte)
Accuracy:	2% Absolute: Repeatability and Linearity 0.2%
Probe Materials:	Stainless Steel, Teflon®, and Nylon
Minimum Liquid Required:	~23 mL standard probe
Power Requirements:	100/115 and 220/240 VAC; 50/60 Hz; 10 Watts
Dimensions:	190 mm x 240 mm x 70 mm
Operating Temperature:	22° - 58°C
Measurement Signal:	Low-distortion, 10 kHz sine wave
Display:	Backlit LCD
Output:	Analog Recorder, Full Scale Reading 1.999 volts
Calibration:	Back Panel Adjustment with Reference Liquid

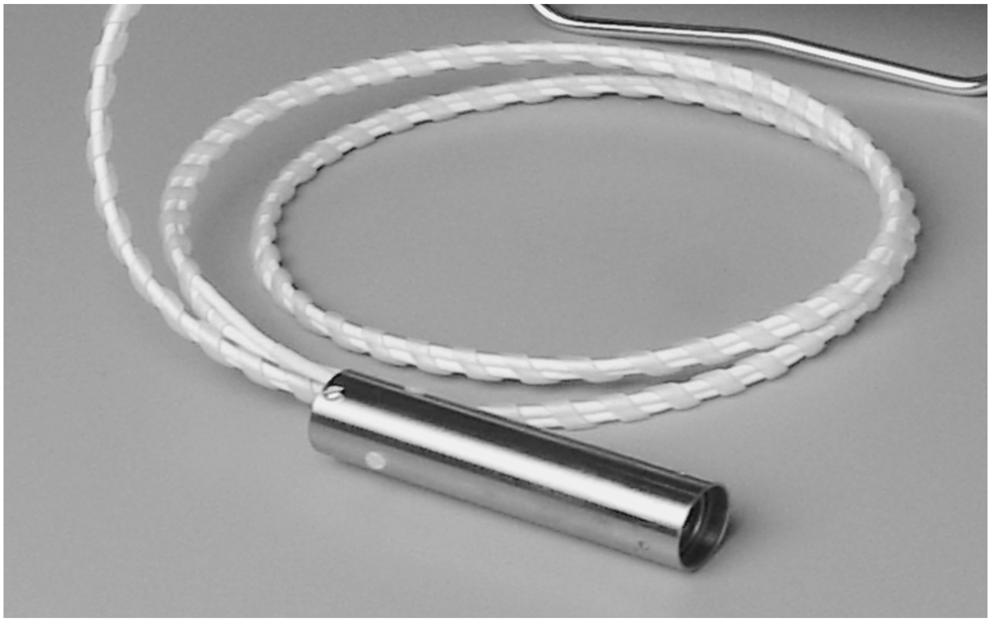
Introduction

Literature values of dielectric constants of pure liquids are fairly easily obtained. The difficulties arise when determining dielectric constants of mixed liquids. Although it is very tempting to try to apply simple mixing rules to approximate a new dielectric constant, there is no simple equation that will adequately characterize the interaction of fluids to calculate dielectric constants of mixed liquids. Thus direct measurement is the only recourse.

For *ZetaPALS* and *ZetaPlus* users, accurate dielectric constant values become especially important because in the calculation of zeta potential from electrophoretic mobility, the dielectric constant is needed.

Probe Construction

The probe is constructed from two precision cylinders, machined from type 316 stainless steel. Six 2-56, 6.4 mm nylon screws maintain the cylinder spacing. The cable consists of two, bundled type 187, low-capacitance, *Teflon*®-insulated coaxial cables. The outer braid of each cable is grounded. The inner conductors are electrically connected to the two concentric cylinders, which comprise the sensor. The outer cylinder is connected to the measurement signal source: a 7-volt rms, 10 kHz, very low distortion sine wave. The inner cylinder is connected to the detection circuitry.



Probe Cleaning

The probe has an open structure and is easy to clean. If the probe is used primarily with low-dielectric constant hydrocarbon fluids, we recommend cleaning by agitation in acetone or ethyl alcohol, followed by gentle drying with clean compressed air. Any residue of the liquid left in the probe will affect measurement accuracy, so it is important that it be cleaned before any residue dries on the cylinder. It is suggested that the highest-grade acetone or alcohol be used to minimize the residue left on the probe from the rinse fluid after drying. In the event that a residue is left on the probe, do not attempt to clean the probe by inserting a swab between the cylinders or inside the inner cylinder. This may change the geometry and, therefore, the probe calibration. We've found that the most efficient way to remove residual matter is to immerse the probe in an ultrasonic cleaner with an appropriate solvent.

It is important that the probe not be disassembled for cleaning. The accuracy of measurement is strongly dependents upon maintaining the geometry of the probe, which will unavoidably change with disassembly and reassembly.

Principles of Operation

The measurement signal applied to the outer cylinder of the probe is a low-distortion sine wave at a frequency of 10 kHz. The amplitude is approximately 7-volts rms on the 1-20 range, and 0.7-volts on the 1-200 range. The frequency is crystal-controlled, and is therefore stable to approximately 1 part in 10^5. The amplitude is stable to approximately 1 part in 10^3. The dielectric constant of the liquid sample is determined by measuring the current between the outer cylinder and the inner cylinder of the probe. With a stable voltage source and precisely known probe parameters, it is possible to display the dielectric constant directly.

The inner cylinder of the probe is connected to the input of a low-noise current-to-voltage converter with input at virtual ground. The current into the input consists of two components: an in-phase component representing the conductivity of the liquid, and a component that is shifted by 90°, representing the capacitive component.

From the internal signal generator, two reference signals are derived: an in-phase component, and a component that is shifted by precisely 90°. The real part of the current is determined by synchronous detection using the in-phase reference. The output of the in-phase current detector goes to a set of comparators. A third reference voltage is also generated; one that has precise amplitude, and is shifted exactly 180° from the probe signal. This signal is used to compensate the conductive current. When the sum of the compensating current and the conductive component is less than a predetermined fraction of the capacitive current, neither of the front-panel LEDs is illuminated, indicating that the conductive current is compensated accurately. The capacitive current is then determined by synchronous detection using the reference that has been shifted 90°.

The power supply of the **BI-870** is of conventional design producing outputs of ±5 volts and ±15 volts. The power supply is designed so that it will operate from 90 to 125 volts and 50/60 Hz, with the back panel voltage selector switch in the 115-volt position, and from 180 to 250 volts with the switch in the 230-volt position. The meter is fully protected against transients. If the instrument is plugged into a 220-volt line with the switch in the 115-volt position, no damage will occur; it will simply blow the fuse. The fuse appropriate for the 115-volt setting is a 3AG ¼ amp fast-acting.

Common liquids used as standards of dielectric constant include cyclohexane, methanol, and de-ionized water, demonstrating the broad range of values of different liquids.

The following table summarizes the values for these common liquids and their temperature coefficients. The published values listed in the table were obtained from the National Institute of Science and Technology (formerly known as National Bureau of Standards) Circular 514 and CRC Handbook of Chemistry and Physics (73rd Edition, Boca Raton, 1992).

Dielectric Constant Values for Common Liquids (from CRC Handbook)

Material	ε_{20}	ε_{25}	**dε/dt (°C^{-1})**
Cyclohexane	2.023	2.015	-0.0016
Chlorobenzene	5.708	5.621	-0.0174
1,2-Dichloroethane	10.65	10.36	-0.058
Methanol	33.62	32.63	-0.198
De-ionized Water	80.37	78.54	-0.366

For nonpolar liquids, dε/dt is on the order of -2×10^{-3}/(°C). For polar liquids dε/dt can be much larger. For example, it is -3.6×10^{-1}/(°C) for water, a very polar liquid.

Liquid Dielectric Constant Measurement

While the use of the **BI-870** dielectric constant meter is quite straight forward, there are a few guidelines that will assure trouble-free operation of the unit. The best geometrical configuration for measurement of dielectric constant is with the probe suspended from the cable, *completely immersed*, and the outer cylinder in contact with nothing but the liquid. It is important that the liquid level be at least to the top of the outer cylinder of the probe. The probe may also be used with either the side or the bottom of the probe resting on an insulating surface in the liquid.

On the front panel of the instrument, there are two knobs labeled “coarse” and “fine.” The “coarse” control is a six-position switch and the “fine” control is a single turn potentiometer. There are also two LEDs labeled “high” and “low.” These controls are used to compensate for the conductivity of the sample. Even in organic liquids, it is not uncommon for the conductive component of the current to be *much* larger than the capacitive component. This must be compensated in the instrument. In order to measure very low conductivity liquids, simply turn both controls to the extreme counter-clockwise position. Adjust the “fine” control until neither LED is on. For conductive liquids, set the “fine” control fully counter-clockwise. Adjust the “coarse” control switch to a position in which the “low” LED is on, but switching to the next position causes the “high” LED to become illuminated. Adjust the “fine” control until neither LED is on. The display will then show the dielectric constant.

As an added precaution users may want to keep in mind that the dielectric constant is slightly dependent on temperature. When determining the dielectric constant of a liquid, it may be useful to monitor temperature. As the temperature increases, the dielectric constant will decrease.