
Solutions for Measuring Permittivity and Permeability

Application Note 1297

Meeting Tomorrow's
Material Test Challenges



Solutions For Your Application

Selecting the Best Solution

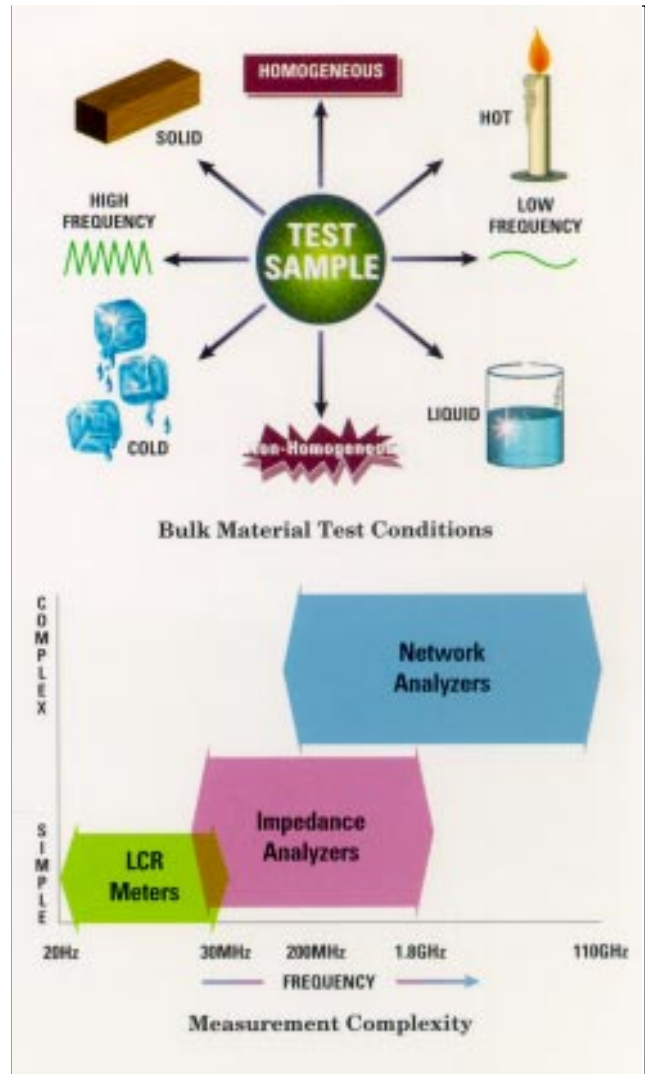
Performance of base materials has a fundamental impact on the success of your end-product

Whether you are looking for simple measurement hardware for QA, or need a sophisticated package with fixtures, instrumentation, and software to improve your design, HP has the right tools for you. For testing bulk materials you need fixtures, precise instrumentation, and perhaps software to analyze and output your test data in an user-definable format.

Fixtures are a vital link that allow an instrument to connect from the front panel to the material under test. Fixturing is never easy; your sample may be freezing cold or boiling hot, liquid or solid, thick or thin. Your testing could be at low frequencies, at millimeterwave, or somewhere in between. And so, you have to pick the right fixture for the right physical and electrical test conditions.

Instruments perform the actual material measurements using a number of techniques. LCR meters are an excellent choice when your application requires a low frequency test at discrete points. Impedance analyzers have the benefits of extended frequency range, a synthesized source, and swept measurement capability. Network analyzers are the best solution for swept high frequency measurements.

The information on this page will assist you in understanding HP's wide range of test fixtures, instrumentation, and software. The figure depicts test complexity



Application/Test Requirement

| | DC Resistivity Cell (HP1600BB) Page 3 | Dielectric Test Fixture (HP16451B) Page 3 | Liquid Dielectric Test Fixture (HP16452A) Page 4 | Dielectric & Magnetic Test Fixtures (HP16453A) (HP16454A) Page 4 | Dielectric Probe System (HP95070M) Page 5 | HP Material Measurement Software (HP95071B) Page 5 | Other Solutions and Software Page 5 |
|---------------------------|---------------------------------------|---|--|--|---|--|-------------------------------------|
| Absorber | | | | | | | |
| Ceramic | • | • | | • | • | | • |
| Fermentation | | | • | | • | | |
| Film (thin) | | • | | • | | | |
| Food | | | • | | • | | |
| Gel, semi-solid | | | | | • | | |
| Liquid | | | • | | • | | |
| Loss | | • | • | • | • | | |
| Permeability | | | | | | • | • |
| Permittivity (dielectric) | | • | • | • | • | • | • |
| Plastic | • | • | • | • | • | | |
| Powder | | | | | • | | |
| Printed Circuit Board | | • | | • | | | |
| Resistivity | • | | | | | | |
| Rubber | • | • | | • | • | | |
| Solid | • | • | | • | • | | |
| Substrate | • | • | | • | • | | • |

versus frequency. The chart is a quick reference application guide to HP solutions.

**DC Resistivity Cell—
HP 16008B**

The HP 16008B DC resistivity cell and the HP 4339B high resistance meter will make sheet material measurements of resistance, surface resistivity, and volume resistivity.



The HP 4339B outputs a dc voltage to the HP 16008B which applies it across electrodes to the material under test. The shielded test enclosure reduces ambient noise and protects the user from high voltage test conditions. Different electrode sizes are available to meet various sample flat sheet requirements. The material under test can be square or circular in shape. The HP 16008B can only be used with HP 4339B high resistance meter.

Key Specifications:

DC voltage: 0.1 to 1000V

Resistance range: 1 k Ω –1.6 x 10¹⁶ Ω

Electrode size: 26, 50, and 76 mm

Parameters: I, R, volume resistivity, surface resistivity

Sample: flat sheet

Thickness range: 10 μ m to 10 mm

**Dielectric Test Fixture—
HP 16451B**

The dielectric test fixture and any HP four terminal pair LCR meter/impedance analyzer will make capacitance and dissipation factor measurements. Using a guarded parallel plate technique, the HP 16451B is ideal for making fast and routine measurements of solid flat dielectric materials. It is also well adapted for small low-loss measurements, and air-gap measurements. For the highest measurement accuracy at low frequencies the best solution is the HP 4284A precision LCR meter. For swept analysis and direct dielectric display, the HP 4194A impedance analyzer is the ideal choice. At high frequencies up to 30 MHz, the HP 4285A is highly recommended. Different electrode sizes and types are available to meet various sample requirements.



Key Specifications:

Frequency: 20 Hz to 30 MHz

Sample: uniformly flat sheet

Sample thickness: 10 μ m to 10 mm

Electrode size: 5 mm to 56 mm

Electrode types: direct contact, guarded

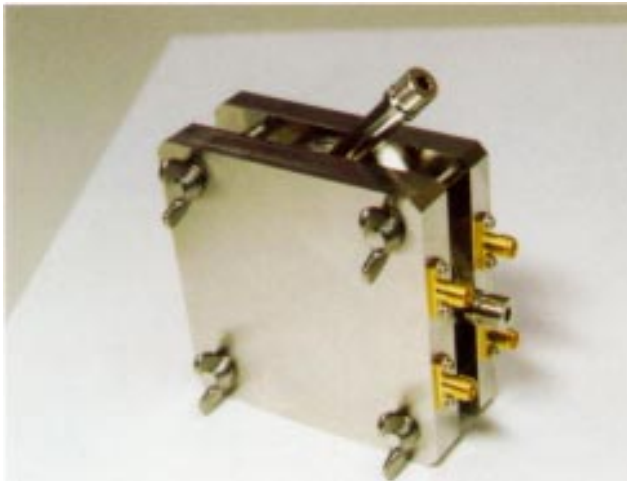
Temperature range: 0–55°C

Parameters: capacitance or | ϵ |, loss tangent

Liquid Dielectric Test Fixture— HP 16452A

Using the liquid dielectric test fixture with any HP four-terminal pair LCR meter or impedance analyzer allows convenient testing of liquids. With the HP 16452A you will be able to measure the permittivity and impedance characteristics of liquid materials like plastic resins, biological fluids, and petrochemical products. The fixture has inlet/outlet ports which allow continuous measurements of liquids flowing in a process monitoring environment. The internal cell allows accurate measurements to be performed on small amounts of liquid samples.

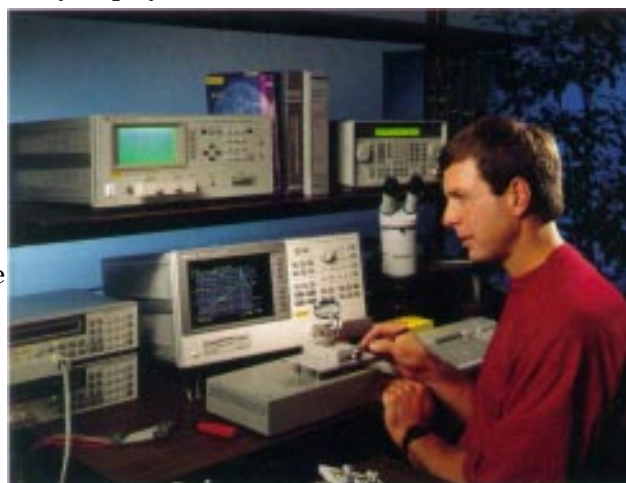
- Frequency range:** 20 Hz to 10 MHz
- Sample size:** 1 ml–4 ml
- Parameters:** capacitance or $|\epsilon|$, loss tangent
- Temperature range:** 0–150°C
- Electric interface:** Four terminal pair



**Dielectric Test Fixture— HP 16453A
Magnetic Test Fixture for— HP 16454A
Impedance/Material Analyzer— HP 4291A**

The HP 16453A dielectric test fixture and the HP 16454A magnetic test fixture are designed to be operated with the HP 4291A RF impedance/ material analyzer. Selectively using the proper test fixture, you will be able to measure permittivity or permeability and directly display accurate results as a function of frequency, time, humidity, temperature, test signal level, or DC bias. Automatic Cole-Cole plotting and relaxation time measurements are available without special effort or programming.

- Frequency range:** 1 MHz to 1.8 GHz
- Compatible instrument:** HP 4291A
- Permittivity parameters:** $|\epsilon|$, ϵ' , ϵ''
- Permeability parameters:** $|\mu|$, μ' , μ''
- DC bias:** $\pm 40\text{VDC}$, $\pm 100\text{mA}$
- Permittivity sample:** flat sheet
- Permeability sample:** toroidal-shaped



Dielectric High-Temperature Probe—HP 85070B
Dielectric Probe System—HP 85070M

The HP 85070B high-temperature dielectric probe kit allows you to quickly measure a variety of homogeneous liquid and semi-solid materials when using the proper HP network analyzer. The probe is designed to resist corrosive and hostile test environments with wide temperature variations. Software is included for instrument control, calibration and data analysis.



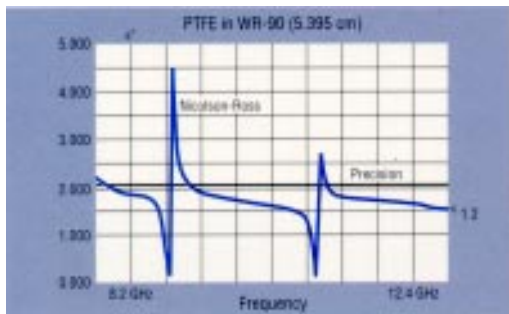
The HP 85070M is a fully configured system that includes an HP 85070B high-temperature dielectric probe, RF, or microwave analyzer, computer, software, and all necessary accessories to measure the complex dielectric constant (including loss tangent) of liquids and semi-solids. The HP 85070M can display the dielectric properties over a 3 (or 20) GHz bandwidth.

Frequency range:
200 MHz–20 GHz

Parameters: ϵ' , ϵ'' , ϵ''' , loss tangent

Sample: liquid, flat solid, semi-solid

Temperature: -40 to +200°C



Software and Other Solutions

Materials Measurement Software—HP 85071B

The HP 85071B materials measurement software can determine the electromagnetic properties of dielectric and magnetic materials. Small samples are machined to fill the cross-section of transmission lines and measured within the fixture. Large flat samples are placed between antennas and measured under free space conditions. The software controls a network analyzer and calculates the permittivity and permeability. Results are displayed as a function of

frequency. Depending on the HP analyzer and fixture used, frequencies can extend from 100 MHz to 110 GHz.

With the HP 85071B you get accurate data at all frequencies

Frequency range: 100 MHz to 110 GHz

Parameters: ϵ' , ϵ'' , loss tangent, μ' , μ'' , cole-cole

Sample: small flat-faced torus (coaxial transmission line) small flat-faced brick (waveguide) large flat parallel-faced (free space)

Damaskos, Inc.

Damaskos offers a broad range of advanced designs for electromagnetic material measurements. This includes stripline cavities, coaxial lines, waveguide platforms, coaxial compactors, high temperature waveguide systems, free-space arch systems, and software. Contact Damaskos at (215) 358-0200 or your local HP representative for more information.

Innovative Measurement Solutions (IMS)

IMS develops material test software for HP LCR meters and impedance analyzers. The software performs easy instrument control, calibration, measurements, data porting, and analysis. Contact IMS at (404) 578-8695 or your local HP representative for more information.

Inter-Continental Microwave, Corp. (ICM)

ICM specializes in the design of precision test fixtures and calibration standards for standard and custom applications. They have expertise with probes for microstrip, stripline, and CPW circuits up to 50 GHz. ICM has fixtures that interface with LCR meters, impedance analyzers, and network analyzers. Contact ICM at (408) 727-1596 or your local HP representative for more information.

Literature Reference

| | |
|--|--------------|
| HP 4194A Impedance Analyzer/Universal Test Platform | 5091-0772E |
| HP 4194A 100 Hz–40 MHz Impedance Analyzer | 5952-7802 |
| HP 4284A 20 Hz–1 MHz Precision LCR Meter | 5952-1431 |
| HP 4285A 75 kHz–30 MHz Precision LCR Meter | 5952-1431 |
| HP 4291A 1 MHz–1.8 GHz Impedance/Material Analyzer | 5091-8596E |
| HP 4339B High Resistance Meter | 5964-6182E |
| HP 8510C 5 MHz–110 GHz Network Analyzer | 5952-3187 |
| | 5952-3188 |
| HP 8720C Network Analyzer | 5091-1939E |
| HP 8752A 300 kHz–3 GHz Network Analyzer | 5952-3528 |
| HP 8753C 300 kHz–6 GHz Network Analyzer | 5952-3193 |
| HP 16008B DC Resistivity Cell | 5091-2145E |
| HP 16451B Dielectric Test Fixture | 5950-2368 |
| HP 1645B Liquid Dielectric Test Fixture | 5091-9228E |
| HP 16453A Dielectric Material Test Fixture | 5091-8596E |
| HP 1645A Magnetic Material Test Fixture | 5091-8596E |
| HP 85070M Dielectric Probe Measurement System/HP 85070B High-Temperature Dielectric Probe Kit | 5091-6274EUS |
| HP 85071B Materials Measurement Software | 5091-6248EUS |
| Application Note 339-13 Measuring the Dielectric Constant of Solid Materials | 5950-2935 |
| Application Note 380-1 Dielectric Constant Measurement of Solid Materials | 5950-2390 |
| Application Note 1210-1 Universal Test Platform-3000 | 5091-1799E |
| Application Note 1217-1 Basics of Measuring the Dielectric Properties of Materials | 5091-3300E |
| Measuring the Dielectric Properties of Food Products at Microwave Frequencies | 5091-2830E |
| Standard Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electric Insulating Materials | ASTM D150-87 |
| Standard Test Method for Rubber Property-Volume Resistivity of Electrically Conductive and Antistatic Products | ASTM D991-85 |
| Standard Test Methods for D-C Resistance of Conductance of Insulating Materials | ASTM D257-78 |

Compatibility Matrix

| Test Fixtures | Instruments |
|--|---|
| HP 16008B Resistivity Cell | HP 4339B High Resistance Meter |
| HP 16451B Dielectric Test Fixture HP 16452A Liquid Dielectric Test Fixture | HP 4284A LCR Meter HP 4285A LCR Meter HP 4194A Impedance Analyzer |
| HP 16453A Dielectric Material Test Fixture HP 16454A Magnetic Material Test Fixture | HP 4291A Impedance Analyzer |
| HP 85070B Dielectric High-Temperature Probe HP 85070M Dielectric Probe Measurement System HP 85071B Materials Measurement Software | HP 8752A Network Analyzer HP 8753A/B/C Network Analyzer HP 8753A/B/C Network Analyzer HP 8719A/B/C Network Analyzer HP 8720A/B/C Network Analyzer HP 8722A/B/C Network Analyzer HP 8510B/C Network Analyzer |

For more information about Hewlett-Packard test & measurement products, applications, services, and for a current sales office listing, visit our web site, <http://www.hp.com/go/tmdir>. You can also contact one of the following centers and ask for a test and measurement sales representative.

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P.O. Box 4026
Englewood, CO 80155-4026
1 800 452 4844

Canada:

Hewlett-Packard Canada Ltd.
5150 Spectrum Way
Mississauga, Ontario
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(905) 206 4725

Europe:

Hewlett-Packard
European Marketing Centre
P.O. Box 999
1180 AZ Amstelveen
The Netherlands
(31 20) 547 9900

Japan:

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