

1403 Series

Capacitance Standard Operation Manual



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1403 im/May 2022

◆ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ◆



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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

Safety Symbols

General definitions of safety symbols used on the instrument or in manuals are listed below.



Caution symbol: the product is marked with this symbol when it is necessary for the user to refer to the instruction manual.



Hazardous voltage symbol: the product is marked with this symbol when high voltage maybe present on the product and an electrical shock hazard can exist.



Indicates the grounding protect terminal, which is used to prevent electric shock from the leakage on chassis. The ground terminal must connect to earth before using the product



Direct current.



Alternating current.



Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.



On supply.



Off supply.



Hot surface. Avoid contact. Surfaces are hot and may cause personal injury if touched.

Disposal



Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC

This product complies with the WEEE Directive (2002/96/EC) marking requirements.

The affixed label indicates that you must not discard this electrical/ electronic product in domestic household waste.

Product Category: With reference to the equipment types in the WEEE directive Annex 1, this product is classified as a “Monitoring and Control instrumentation” product.

Do not dispose of electrical appliances as unsorted municipal waste, use separate collection facilities.

Contact your local government for information regarding the collection systems available. If electrical appliances are disposed of in landfills or dumps, hazardous substances can leak into the groundwater and get into the food chain, damaging your health and well-being.

When replacing old appliances with new one, the retailer is legally obligated to take back your old appliances for disposal.

Proposition 65 Warning for California Residents



WARNING: Cancer and Reproductive Harm - www.P65Warnings.ca.gov.

This product may contain chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm

SAFETY PRECAUTIONS

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific WARNINGS elsewhere in this manual may impair the protection provided by the equipment. Such noncompliance would also violate safety standards of design, manufacture, and intended use of the instrument.

IET Labs assumes no liability for the customer's failure to comply with these precautions.

If an instrument is marked CAT I (IEC Measurement Category I), or it is not marked with a measurement category, its measurement terminals must not be connected to line-voltage mains.

The 1403 is an indoor use product.



Comply with all WARNINGS - Procedures throughout in this manual and instructions on the instrument prevent you from potential hazard. These instructions contained in the warnings must be followed.



- DO NOT Operate in an Explosive Atmosphere
- Do not operate the instrument in the presence of inflammable gasses or fumes
- Operation of any electrical instrument in such an environment clearly constitutes a safety hazard
- Use Caution around live circuits and whenever hazardous voltages > 45 V are present
- Operators must not remove instrument covers
- Component replacement and internal adjustments must be made by qualified maintenance personnel only
- DO NOT substitute parts or modify the instrument
- When working with high voltages; post warning signs, train personnel and keep unauthorized personnel away.

Do not apply any voltage or currents to the terminals of the instrument in excess of the maximum limits indicated in the specifications section of this manual.

To avoid the danger of introducing additional hazards, do not install substitute parts or perform unauthorized modifications to the instrument.

Return the instrument to an IET Labs for service and repair to ensure that safety features are maintained in operational condition.



WARNING



OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

**Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qualified personnel**

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO
AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE
CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND
KEEP UNREQUIRED PERSONNEL SAFELY AWAY.



CAUTION



DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS
INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON
THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

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Chapter 1

INTRODUCTION

1.1 Description of the 1403 Series

The 1403 Series (Figure 1-1) are stable, laboratory capacitance standards. They are working and laboratory standards grade. The 1403 units are available in values ranging from 0.001 pF to 1000 pF.

The 1403 Standard Air Capacitors have a low dielectric constant and excellent frequency response making them ideal for testing LCR meters at various frequencies.

Connections are made to the 1403 via two GenRad 874 connectors.

The new 1403-1pF-bnc Standard Capacitor has 2 bnc connectors to minimize lead stray capacitance.



Figure 1-1: 1403-D Capacitance Standard



Figure 1-2: 1403-1pF-bnc Capacitance Standard

Chapter 2

SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in a label, shown in Figure 2-1 affixed to the case of the instrument.

SPECIFICATIONS

Calibration: An certificate of calibration is supplied with each capacitor traceable to the SI, giving the measured direct capacitance and Df at 1 kHz, 15 Vac and 23° ±1°C.

Model	Nominal Capacitance	Adjustment Accuracy	Maximum Voltage	Dissipation Factor
1403-A	1000 pF	±0.1%	700 V peak	< 20 x10 ⁻⁶
1403-D	100 pF		1500 V peak	< 20 x10 ⁻⁶
1403-G	10 pF			< 30 x10 ⁻⁶
1403-K	1 pF		< 20 x10 ⁻⁶	
1403-1pF-BNC	1 pF		500 V peak	< 20 x10 ⁻⁶
1403-N	0.1pF	±0.3%	1500 V peak	< 20 x10 ⁻⁶
1403-R	0.01 pF			< 20 x10 ⁻⁶
1403-V	0.001 pF	±1%	500 V peak	< 20 x10 ⁻⁶
1403-0.001pF-BNC	0.001 pF			< 20 x10 ⁻⁶

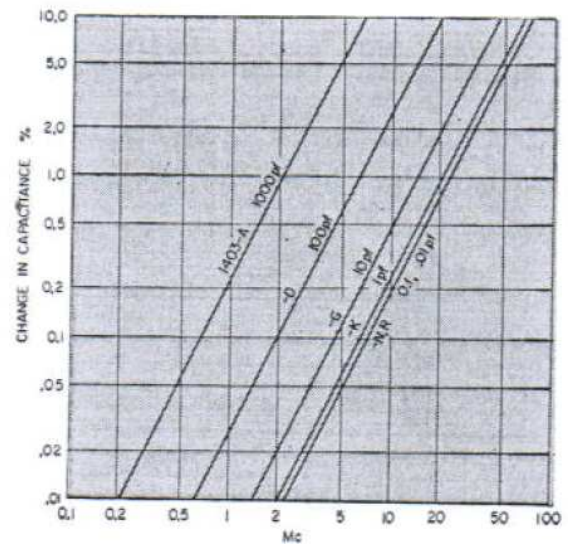


Figure 2

Percentage change in effective capacitance, with frequency produced by residual inductance.
 (1403-1pF-BNC has the same change as 1403-K)
 (1403-0.001pF-BNC has the same change as 1403-V)

Temperature Coefficient of Capacitance:

Typically ±(20 to 40) ppm/°C, between 20°C and 70°C

Stability: Capacitance change is less than 0.05% per year.

Residual impedance: See equivalent circuit and plot on page 1

Terminals: Two GR874 coaxial connectors

Two bnc-f connectors for 1403-1pF-BNC and 1403-0.001 pF-BNC

Outer shell of connectors are connected to case ground to provide complete shielding of the leads.

Mechanical:

Diameter 3.0625 in (78 mm), height 4.875 in (125 mm), over-all.

Net weight: 1 lbs (0.5 kg)

Shipping weight: 4 lbs (1.9 kg)

ORDERING INFORMATION

- 1403-9701 1403-A, 1000 pF
- 1403-9704 1403-D, 100 pF
- 1403-9707 1403-G, 10 pF
- 1403-9711 1403-K, 1 pF
- 1403-1pF-BNC 1 pF

- 1403-9714 1403-N, 0.1 pF
- 1403-9718 1403-R, 0.01 pF
- 1403-9722 1403-V, 0.001 pF
- 1403-0.001pF-BNC 0.001 pF


0.1 pF STANDARD REFERENCE CAPACITOR
Model 1403-N

Calibration: The measured value is obtained by a comparison to a precision better than ± 3 ppm with standards traceable to SI.
Stability: Capacitance change is less than 0.05% per year.
Dissipation Factor: $< 20 \times 10^{-6}$ max at 1 kHz and 50% or less relative humidity.


Temperature Coefficient of Capacitance: Typically 30 ppm/°C between 20 °C and 70 °C.
Max Voltage: 1500 V
Terminals: GR874 coaxial connectors, which provide complete shielding of the leads.


Date	18-Feb-2022				
Capacitance (pF)	0.100 049 0				
Dissipation	0.000 011				
Recommended Due					
By	CN				

SN: A2-2204154



Observe all safety rules when working with high voltages or line voltages. Connect the shield to earth ground in order to maintain the case at a safe voltage. Whenever hazardous voltages (>45 V) are used, take all measures to avoid accidental contact with any live components: a) Use maximum insulation and minimize the use of bare conductors. b) Remove power when adjusting the capacitor. c) Post warning signs and keep personnel safely away.





Formerly manufactured by
GenRad

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1403 lbl/p4/1403-K/02-05-19

Figure 2-1: Sample label attached to an 1403 unit

Chapter 3

OPERATION

3.1 Initial Inspection and Setup

This instrument was carefully inspected before shipment. It should be in proper electrical and mechanical order upon receipt.

To provide ready reference to specifications, a label, shown in Figure 2-1, is attached to the case of the instrument.

3.2 Connections to Capacitor

All 1403 capacitors have 2 GR 874 or 2 bnc connectors labeled **HI** and **LO**, as shown in figure 3-1.



Figure 3-1: 1403 capacitor standard with bnc connectors

Equivalent circuit showing direct capacitance, C_d , and average values of residual inductance, L , and terminal capacitances, C_a and C_b .

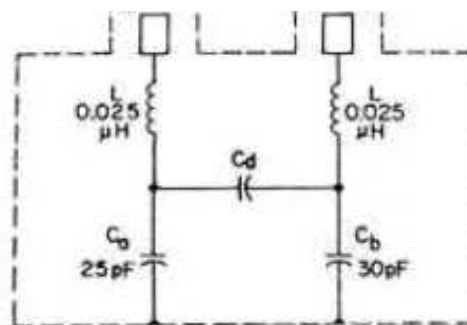


Figure 3-2: Capacitance shunted by leakage to case

3.3 Temperature Coefficient

Temperature coefficients are typically $\pm(20$ to $40)$ ppm/ $^{\circ}\text{C}$.

It is important to consider the TC of the 1403 when measuring at temperatures other than 23°C .

3.4 Permittivity Errors

The 1403 series can be used over a wide temperature range and barometric pressures however it is important to understand that both affect the permittivity and therefore the capacitance.

The change of humidity from dry air to 50% RH results in a around a 1 ppm change in permittivity and therefore a negligible change in capacitance.

A change in atmospheric pressure from sea level to 1600 meters, results in a change of around 100 ppm in permittivity and therefore a significant change in capacitance.

The paper *The Measurement and Uncertainty of Air Dielectric Capacitors from 1 kHz to 10 MHz* provides extremely useful information on the change of capacitance vs barometric pressure, relative humidity and temperature for the 1403 Series Air Capacitors.

<https://www.osti.gov/servlets/purl/1504063>

IET Labs calibrates the 1403 in it's facility in West Roxbury, MA. The approximate elevation is 115 feet (35 meters) above sea level. Given this elevation the approximate air pressure is 101000 Pa.

3.5 Design of the 1403

The 1403 is a three-terminal standard air capacitor. The 1403 with capacitance values < 2 pF use three plates to make up the capacitor element. A high and low plate which are separated by guard plate. The guard plate has an aperture of a specific diameter for the capacitance required.

Higher capacitance values use a stack of plates to make up the capacitor element.

All plates are separated by ceramic shoulder washers which minimize dissipation factor.

Additional information on the design of the 1403 can be found at;

https://www.ietlabs.com/pdf/GR_Experimenters/1959/GenRad_Experimenter_Aug-Sept_1959.pdf



3.6 Environmental Conditions

3.6.1 Operating Temperature

For optimal accuracy, 1403 models should be used in an environment of $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$. They should be allowed to stabilize at those temperatures after any significant temperature variation.

3.6.2 Storage Temperature

The 1403 units should be maintained within the storage temperature range of 0°C to 40°C to retain its accuracy within the specified limits.

3.7 Shipping and Handling

The 1403 Series should not be exposed to any excessive shock or temperature extremes.

3.8 Cleaning and Maintenance

A soft cloth and denatured alcohol can be used for cleaning.

A Q-tip and denatured alcohol can be used to clean the connectors.

No other maintenance is required.

Chapter 4

MAINTENANCE

4.1 Preventive Maintenance

Keep the unit in a clean environment. This will help prevent possible contamination.

1403's are packaged in a closed case, which limits the entry of contaminants and dust into the instruments. If they are maintained in a clean or air-conditioned environment, cleaning will seldom be required. In a contaminated atmosphere, cleaning may be required.

4.2 Calibration

The 1403 units may be employed as stand-alone instruments or as integral components of a system. If used as part of a system, they should be calibrated as part of the overall system to provide an optimum system calibration.

4.2.1 Calibration Interval

The recommended 1403 Series calibration interval is twelve (12) months.

The calibration procedure may be carried out by the user if a calibration capability is available, by IET Labs, or by a certified calibration laboratory.

If the user should choose to perform this procedure, then the considerations below should be observed.

4.2.2 General Considerations

It is important, whenever calibrating an 1403 unit, to be very aware of the capabilities and limitations of the test instruments used.

Recommended Instruments:

- **Andeen and Hagerling AH2500A**
or
- **IET Model 1620 or 1621 Precision Capacitance Measurement System** (bridge)

It is important to allow both the testing instrument and the 1403 to stabilize for a number of hours at the nominal operating temperature of 23°C, and at nominal laboratory conditions of humidity. There should be no temperature gradients across the unit under test.

4.3 Calibration Procedure with GenRad 1620 or AH2500A/ AH2700A Capacitance Bridge

To calibrate an 1403 unit, proceed as follows:

1. 1403 capacitors with bnc connectors should have the shield disconnected at the **HI** terminal to minimize stray capacitance. The shield on the LO terminal should be maintained.

This connection mimics the connection on the IET/GenRad 1403 Standard Capacitor.

2. Determine and employ proper metrological practices.

Allow a confidence band for the uncertainty of the measuring instrument and setup.

3. Determine the allowable drift limits for the capacitance reading.

<20 ppm/year

4. Confirm that the readings fall within these drift limits, allowing for the uncertainty band.

If the reading falls outside the limits, it has to be repaired by IET or another qualified facility

4.4 Replaceable Parts List

There are no replaceable parts on the 1403 Series.

Contact IET Labs at for an RMA should service be required at:

<https://www.ietlabs.com/>