

# 1404 Series

## Primary Capacitance Standard Operation Manual



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◆ 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](http://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 1404 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 1404 Series

The 1404 Series (Figure 1-1) are stable, primary laboratory capacitance standards. They are working and laboratory standards grade. The 1404 units are available in values ranging from 10 pF to 10 nF with custom values available.

All critical parts of the plate assembly are made of invar for stability and low temperature coefficient.

After heat cycling and adjustment the assembly is mounted in a heavy brass container, which after evacuation, is filled with dry nitrogen under pressure slightly above atmospheric and sealed. The container is mounted on an aluminum panel and protected by an outer aluminum case. Each capacitor is subjected to a series of temperature cycles to determine hysteresis and temperature coefficients and to stabilize the capacitance.

Connections are made to the 1404 via two bnc connectors to minimize lead stray capacitance. Traditional GenRad 874 connectors are also available upon request.



**Figure 1-1: 1404-A Primary Capacitance Standard**



**Figure 1-2: 1404-10nF shown next to standard 1404-A**

## 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 A2LA certificate of calibration is supplied with each capacitor, giving the measured direct capacitance at 1 kHz, 30 Vac and 23° ±1°C.

Model	Calibration Uncertainty	Adjustment Accuracy	Short Term Drift	Long Term Drift	Max Change with Orientation	Maximum Voltage	Dissipation Factor
1404-A 1404-B 1404-C	< ±6 ppm	±5 ppm to a capacitance about 5 ppm above the nominal value	less than 2 ppm	less than 20 ppm per year	10 ppm and completely reversible	750 V peak	< 10 <sup>-5</sup> at 1 kHz
1404-5 nF 1404-10 nF	±100 ppm	±500 ppm	less than 12 ppm	less than 40 ppm per year	15 ppm and completely reversible	100V peak	< 10 <sup>-5</sup> at 1 kHz

**Temperature Coefficient of Capacitance:** A measured value with and accuracy of ±1 ppm/°C is given on the certificate.

Model	Temperature Coefficient
1404-A 1404-B	2 ±2 ppm/°C from -20°C to +65°C
1404-C	5 ±2 ppm/°C from -20°C to +65°C
1404-5 nF 1404-10 nF	4 ±6 ppm/°C from -20°C to +65°C

**Temperature Cycling:** For temperature cycling over range from -20°C to +65°C, hysteresis (retraceable) is less than 20 ppm at 23°C.

**Residual Impedance:**

Model	C <sub>H</sub>	C <sub>L</sub>	L
1404-A 1404-B 1404-C	30 pF	28 pF	0.05 μH

Model	C <sub>H</sub>	C <sub>L</sub>	L
1404-5 nF 1404-10 nF	130 pF	127 pF	0.1 μH

**Terminals:** Two BNC coaxial connectors (legacy locking G874 coaxial connectors are available). Outer shell of one connector is ungrounded to permit capacitor to be used with external resistor as a dissipation factor standard.

**Mechanical:**

Model	Dimensions	Weight
1404-A 1404-B 1404-C	(16.9 cm H x 17.2 cm W x 20.4 cm D) (6.63" x 6.75" x 8")	3.9 kg 8.5 lb 6.4 kg 14 lb Shipping
1404-5 nF 1404-10 nF	(23 cm W x 23 cm H x 22 cm D) 9" x 9" x 8.5"	16 kg 35 lb 18 kg 40 lb Shipping

### ORDERING INFORMATION

1404-9701 1404-A, 1000 pF  
1404-9702 1404-B, 100 pF  
1404-9703 1404-C, 10 pF

1404-5nF 1404-A, 5 nF  
1404-10nF 1404-A, 10 nF

## STANDARD REFERENCE CAPACITOR Model 1404-A 1000 pF

**Calibration:** At 1 kHz, 1.5 Vac, at 23°C

**Stability:** Long term drift is less than 20 ppm per year, typically much smaller. Maximum change with orientation is 10 ppm and is completely reversible.

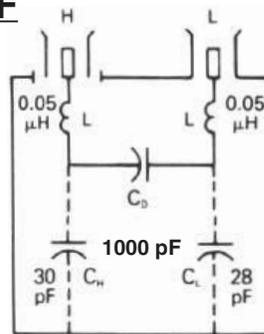
**Temperature Coefficient of Capacitance:**  $2 \pm 2$  ppm/°C, from -20°C to +65°C.

**Dissipation Factor:**  $< 10^{-5}$  at 1 kHz.

**Residual Impedances:** See the figure for typical values of internal series inductances and terminal capacitances.

**Max Voltage:** 750 V.

**Terminals:** Two BNC (standard) or GR 874 connectors; easily convertible to other types of connectors by attachment of locking adaptors. Outer shell of one connector is ungrounded to permit capacitor to be used with external resistor as a dissipation factor standard.



Equivalent circuit showing direct capacitance  $C_0$ , and typical values of residual inductance,  $L$ , and terminal capacitances,  $C_H$ , and  $C_L$ .

Date	5/11/2022				
Frequency	1 kHz				
Capacitance (pF)	1000.0044				
Meas. Uncertainty	5.5 ppm				
Dissipation	0.000002				
Tempco (ppm/C)	-0.160 ppm/C				
Test Conditions	23.2 C				
	33% RH				
Recommended Due					
By	CN				

**SN: D7-21401487**



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.



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1404 Ibl/1000 pF/p1/02-20-19

Figure 2-1: Sample label attached to an 1404 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.

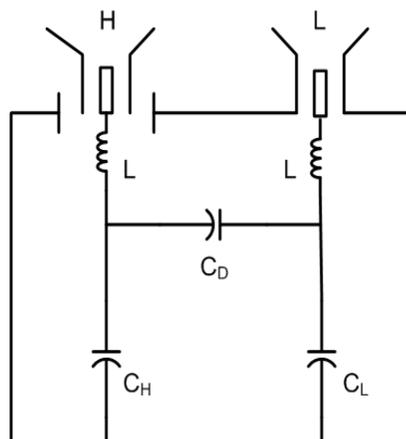
### 3.2 Connections to Capacitor

All 1404 capacitors have 2 bnc connectors labeled **HI** and **LO**, as shown in figure 3-1.



**Figure 3-1: 1404 capacitor standard with bnc connectors**

Equivalent circuit showing direct capacitance,  $C_D$ , and average values of residual inductance,  $L$ , and terminal capacitances,  $C_H$  and  $C_L$ . See specifications for values of residuals



**Figure 3-2: Capacitance shunted by leakage to case**

### 3.3 Temperature Coefficient

Temperature coefficients are given on the certificate of calibration and the label attached to the standards.

It is important to consider the TC of the 1404 when measuring at temperatures other than 23°C.

### 3.4 Temperature Cycling

The 1404 series can be used over a wide temperature range however it is important to understand that hysteresis (retrace) can cause errors of up to 20 ppm.

When a standard is subjected to relatively large temperature changes, such as shipment, the calibrated capacitance value may come back to a different calibrated value at the same temperature after it has been exposed to hot or cold conditions, this is called hysteresis or retrace.

The 1404 Standard Capacitor utilizes invar plates and spacers to minimize the effects of thermal expansion.

The standard should be kept in temperature conditions close to  $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$  to minimize the error due to hysteresis.

### 3.5 Design of the 1404

The 1404 is a three-terminal standard air capacitor. The invar plates that make up the capacitor are hermetically sealed in a can, filled with dry nitrogen to minimize effects of both humidity and barometric pressure.

The 1404 capacitors show very small changes with orientation however this can be minimized by keeping the 1404 in the upright orientation which is how it is calibrated at IET Labs.



Additional information on the design of the 1404 can be found at;

[https://www.ietlabs.com/pdf/GR\\_Experimenters/1963/GenRad\\_Experimenters\\_Aug\\_1963.pdf](https://www.ietlabs.com/pdf/GR_Experimenters/1963/GenRad_Experimenters_Aug_1963.pdf)

### 3.6 Environmental Conditions

#### 3.6.1 Operating Temperature

For optimal accuracy, 1404 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 1404 units should be maintained within the storage temperature range of  $0^{\circ}\text{C}$  to  $40^{\circ}\text{C}$  to retain its accuracy within the specified limits.

### 3.7 Shipping and Handling

The 1404 Series should not be exposed to any excessive shock or temperature extremes.

# Chapter 4

## MAINTENANCE

### 4.1 Preventive Maintenance

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

1404'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 1404 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 1404 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 1404 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 1404 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 1404 unit, proceed as follows:

1. 1404 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 1404 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 1404 Series.

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

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