GenRad

Calibration Certificate

and

OPERATING INSTRUCTIONS

COAXIAL CAPACITANCE STANDARD

Type 1406-	Serial No.
pF NOMINAL CAPACITANCE	± 0.1% at 1 kHz ADJUSTMENT ACCURACY

Measured Capacitance	Frequency
pF	1 kHz
Temperature	**Relative Humidity**
±1°C	%

The effective capacitance at MHz is pF ± %

MEASURED CAPACITANCE: The measured capacitance above is the capacitance at the reference plane of the GR900 connector. It was obtained by comparison with working standards whose absolute values are known to an accuracy of ±0.01%. The comparison was made to a precision better than ±0.01%.

The values of the working standards are determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

EFFECTIVE CAPACITANCE: The effective capacitance was obtained by calculation from the measured low-frequency capacitance and the known inductance of the capacitor.

Type 1406
COAXIAL CAPACITANCE STANDARDS

SPECIFICATIONS

Calibration: See Calibration Certificate.
Stability: The capacitance change is less than 0.05% per year.
Accuracy: Capacitance adjusted to within 0.1% of nominal value.
Residual Parameters: See table. Dissipation factor is given for 40% RH and varies as the 3/2 power of frequency above about 100 kHz.
Insulation Resistance: Greater than 10^{12} ohms at 23 °C and less than 50% RH.
Temperature Coefficient of Capacitance: Typically 10 to 20 ppm/ °C between 20 °C and 70 °C.
Accessories Available: Adaptor Type 1615-P2 for convenience in calibrating with Type 1615-A Capacitance Bridge.
Terminal: GR900 Precision Coaxial Connector.
Mounting: Aluminum panel and cylindrical case.
Dimensions (diameter x height): 3 x 5 1/4 in. (77 x 135 mm).
Weight: Net, 1 3/4 lb (0.8 kg); shipping, (est) 5 lb (2.3 kg).

Figure 1-1. Type 1406-A Coaxial Capacitance Standard.

Catalog Number	Type	Nominal Capacitance	Peak Volts	Typical Dissipation Factor 1 kHz (40% RH)	Typical Dissipation Factor 1 MHz	Typical Inductance
1406-9701	1406-A	1000 pF	700	3×10^{-6}	50×10^{-6}	8.6 nH
1406-9702	1406-B	500 pF	900	5×10^{-6}	30×10^{-6}	8.4 nH
1406-9703	1406-C	200 pF	1200	20×10^{-6}	25×10^{-6}	8.1 nH
1406-9704	1406-D	100 pF	1500	30×10^{-6}	20×10^{-6}	7.6 nH
1406-9705	1406-E	50 pF	1500	50×10^{-6}	15×10^{-6}	6.7 nH
1615-9602	1615-P2 Coaxial Adaptor, GR900 to binding post					

*Discontinued — 1406-B, 1406-C, 1406-E.

CAUTION

Keep the connector clean. Use the protective cap when the standard is not in use.

1 INTRODUCTION

1.1 PURPOSE.

The Type 1406 Coaxial Capacitance Standards are two-terminal, precision air capacitors ideally suited for use as high-frequency capacitance standards. Low inductance, low rf losses, and repeatability of connections of these capacitors permit accurate, traceable calibration of high-frequency bridges and other impedance-measuring instruments.

1.2 DESCRIPTION.

The Type 1406 capacitance standards use GR900 Precision Coaxial Connectors for terminals. These connectors have the stability, repeatability, and the well defined reference plane required for accurate two-terminal measurements at high frequencies. Precision coaxial connectors (such as the GR900) are compatible with the National Bureau of Standards system and recommended for higher calibration accuracy.*

Refer to the table and specifications above for a complete listing of the Type 1406 models available.

Physically, the Type 1406 is a rigid assembly of parallel plates mounted in a shielded enclosure with a coaxial connector used for outside terminals. The plate assembly, with rigid support rods and precision spacers, is attached to a thick mounting plate. All of these parts are aluminum to minimize stresses caused by differences in thermal expansion. The plate assembly is insulated from the mounting plate by cross-linked, thermosetting, polystyrene insulators that are treated to reduce surface effects caused by high humidity. The entire assembly is attached to the inside of the aluminum top plate (part of the case), and also connected to the GR900 connector.

**Paragraph 201.830 Federal Register, Jan 24, 1967, NBS Electricity Test Fee Schedules.

1.3 ACCESSORY EQUIPMENT.

The Type 1615 Capacitance Bridge (part of Type 1620-A Capacitance-Measuring Assembly) and the Type 1615-P2 Coaxial Adaptor are recommended for low-frequency calibration of the Type 1406 capacitors (refer to paragraph 4.3). Refer to the appendix for details and specifications.

2 OPERATING PROCEDURE

2.1 MATING OF GR900 CONNECTORS.

The GR900 Precision Coaxial Connector on the Type 1406 will mate with any other GR900 connector. Since only one locking nut is used per junction, the unused nut is stored at the rear of one of the connec-

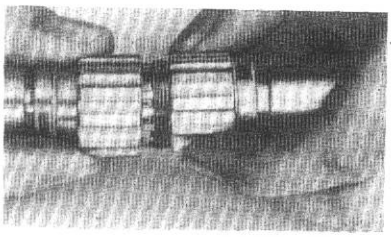


Figure 2-1. Mating of GR900 connectors.

tors. The mating procedure is as follows (see Figure 2-1):

a. To store the locking nut, slide it back until the threads engage. Then thread it back off the centering gear ring and slide it back as far as it will go.

b. Move the locking nut of the other connector back slightly. Align the connectors axially and engage the teeth of the centering gear rings in any convenient orientation.

c. Hold the connectors in the joined position, thread the active locking nut over the centering gear ring of the mating connector, and hand tighten.

2.2 CORRECTION FOR FRINGE CAPACITANCE.

The Type 1406 capacitor is calibrated for the capacitance value at the reference plane of its connector. This value does not include the fringe capacitance that exists outside of its reference plane. (Refer to paragraph 3.2.) Therefore, when the capacitance standard is used with an instrument that measures capacitance at the reference plane of the connector, no special correction for fringe capacitance is necessary.

However, using an instrument that measures the change in capacitance (or impedance) from open terminals is more complicated. This type of measurement involves two readings, one with open terminals (and fringe capacitance), and another reading with the capacitor connected. In this case, the difference between the two readings is the value of the standard minus the value of fringe capacitance (0.155 ±0.008 pF for GR900 connectors).

$$\Delta C = C_s - C_f$$

where C_s = value of standard added
C_f = fringe capacitance

If greater precision is required, the uncertainty (±0.008 pF) of the fringe capacitance can be eliminated by simply substituting a known value of capacitance for the open-connector capacitance when taking the first measurement. This small capacitor must have an accurately known value of capacitance at its reference plane. Thus, the difference between the first and second readings will be the true difference between the two known values with no uncertainty due to fringe capacitance.

3 PRINCIPLES OF OPERATION

3.1 GENERAL.

Refer to the General Radio Catalog for a general discussion of the characteristics of standard capacitors. For specific information on the use of Type 1406 standards using GR900 connectors, refer to the following paragraphs.

3.2 FRINGE CAPACITANCE.

An open coaxial connector, as shown in Figure 3-1, has stray (fringe) capacitance (C_f) extending beyond the reference plane. A reading with the instrument using this connector in the open-circuit state, shown in Figure 3-1, would include the internal capacitance (C_o) plus the fringe capacitance (C_f).

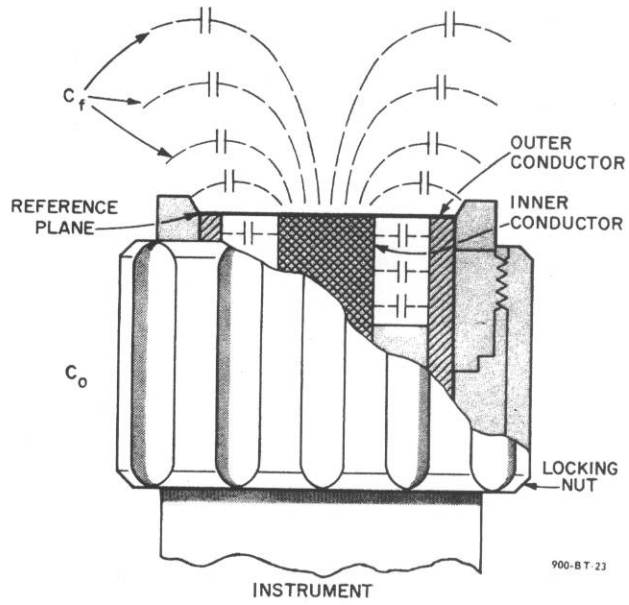


Figure 3-1. Open GR900 Precision Coaxial Connector showing internal capacitance (C_o) and fringe capacitance (C_f).

When two coaxial connectors are properly mated, the fringe capacitance is eliminated as shown in Figure 3-2). The reference planes of the two connectors effectively become a single plane of reference with no stray capacitance existing between them. A second reading would include the internal capacitance (C_o) plus the added capacitance (C_s) of the standard and its connector. Thus, the fringe capacitance must be added to the difference between the two readings to obtain the true value of the standard capacitor.

3.3 FREQUENCY CHARACTERISTIC.

The series inductance of the capacitor causes its effective capacitance to increase with frequency as shown in Figure 3-3. The proportional increase in effective capacitance $\left(\frac{\Delta C}{C_o}\right)$ is given by:

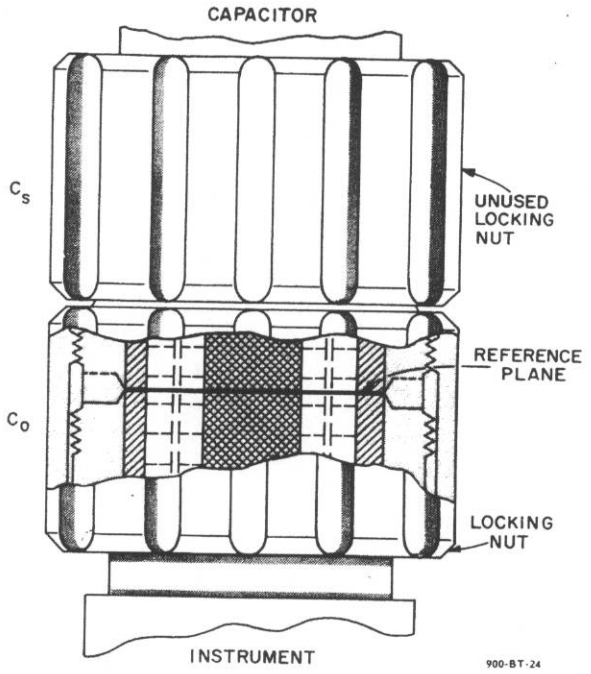


Figure 3-2. Two GR900 Precision Coaxial Connectors indicating elimination of fringe capacitance when connectors are properly mated.

$$\frac{\Delta C}{C_o} = \omega^2 LC_e \approx \omega^2 LC_o$$

where C_e = effective capacitance at the reference plane

C_o = zero-frequency capacitance
L = series inductance
$\omega = 2\pi f$

The low inductance of the Type 1406 capacitors keeps the capacitance change with frequency at a very low value. The change is so small at the lower radio frequencies that correction will be unnecessary, except for the most precise measurements. For example, the capacitance change between 1 kHz and 1 MHz, for Type 1406 capacitors of 200 pF and smaller, is less than the possible uncertainty of the 1-kHz measurements.

3.4 DISSIPATION FACTOR.

At low frequencies (1 kHz, for example), and under conditions of moderate humidity and temperature, the dissipation factor of an air-capacitor standard is largely determined by losses in the insulating supports. With high humidity, losses caused by moisture on the insulators and plate surfaces become significant.

At higher frequencies, the dominant losses result from the resistance of the plates and the plate-connecting structure. Above 100 kHz, the dissipation factor is proportional to the 3/2 power of the frequency.

In the Type 1406 standards, rigid construction, aluminum parts, and special polystyrene insulators are used to minimize losses under all conditions of humidity and temperature.

3.5 EFFECTS OF HUMIDITY.

Changes in humidity affect the value of capacitance in two ways: by changing the dielectric constant of the air (about 2.5 ppm for each percent change in relative humidity), and because of moisture that collects on the insulators and plate surfaces. The change due to moisture becomes particularly important with the smaller values of capacitance, and at lower frequencies. For example, at a frequency of 1 kHz, the change in a 1000-pF air capacitor, due to moisture, will be somewhat greater than the change due to an increase in the dielectric constant of the air, and a similar change in a 50-pF air capacitor will be several times greater. This effect is negligible at high frequencies and should be considered only when preparing to calibrate the capacitor at low frequencies.

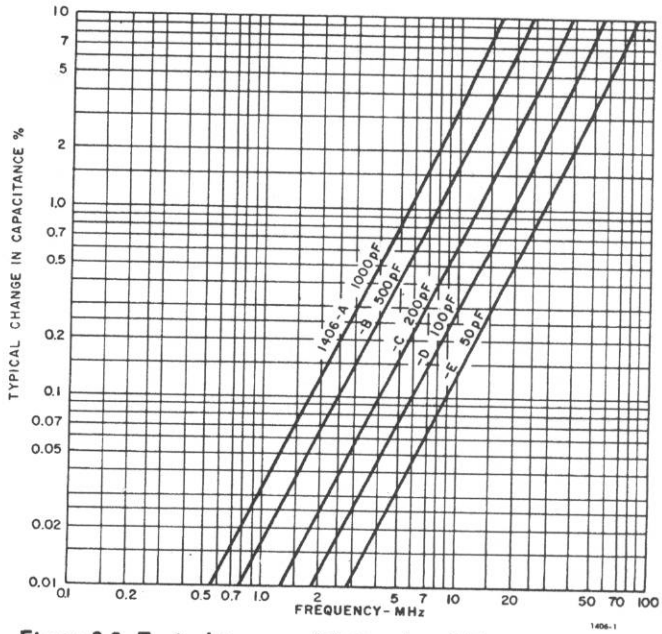


Figure 3-3. Typical increase (%) in value of Type 1406 Coaxial Capacitance Standards with frequency in 0.1 – 100 MHz range.

4 SERVICE AND MAINTENANCE

4.1 WARRANTY.

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable GenRad 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 GenRad, replaced at no charge when returned to a GenRad service facility. Changes in the product not approved by GenRad shall void this warranty. GenRad shall not be liable for any indirect, special, or consequential damages, even if notice has been given of 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 A PARTICULAR PURPOSE.

GenRad policy is to maintain product repair capability for a period of ten years after original shipment and to make this capability available at the then prevailing schedule of charges.

4.2 SERVICE.

The standard warranty stated above attests the quality of materials and workmanship in our products.

When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest Sales Engineering Office, requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

4.3 CALIBRATION.

It is recommended that calibration of the Type 1406 be made at a frequency of 1 kHz using a Type 1620 Capacitance-Measuring Assembly and a Type 1615-P2 Adaptor (refer to appendix), or equivalent. For details on the use of this equipment to calibrate capacitance standards, refer to the individual instructions furnished with the equipment.

The Type 1406 is an extremely stable capacitance standard. It is always possible, however, to subject it accidently to excessive shock which could result in an appreciable change in capacitance. In the case of a capacitance change such as this, the inductance will not change significantly, and 1-kHz measurements can be used to detect capacitance changes that will affect high-frequency calibration. When the capacitance change is small, such as that which might occur with normal aging and handling, the change in capacitance at high frequencies will always be proportional to the change at 1 kHz.

4.4 MAINTENANCE.

4.4.1 GENERAL.

Maintenance and parts replacement should be limited to the external parts of the capacitor

CAUTION

Do not remove the case unless it is necessary. If the case must be removed, avoid handling internal parts and do not attempt to disassemble or make adjustments.

4.4.2 PARTS REPLACEMENT.

The parts that may need replacement at some time are listed as follows:

Catalog No.	*Description*
0900-7190	Protective Cap, white plastic.
0900-2000	Inner Contact Assembly, on GR900 connector.

To replace the Inner Contact Assembly on the connector, remove the old contact assembly using a 1/16 Allen wrench, and thread the replacement assembly in its place. Tighten firmly, but avoid using excessive torque.

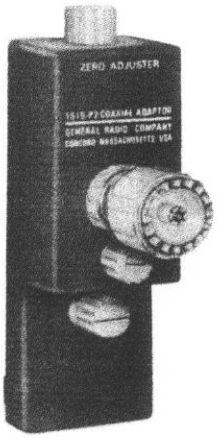
4.4.3. CONTACT CLEANING.

The butt surfaces of the connector must be kept clean, both at the outer-and inner-contact junctions. When there is evidence of dirt on these surfaces, or poor make-break repeatability, cleaning is necessary. Only certain solvents may be used in cleaning; Freon TF, denatured alcohol, synthetic methanol, grain alcohol, and petroleum ether are recommended. Liquid cleaning is generally more effective than dry cleaning; abrasive cleaning can remove the protective plating and is not recommended.

Poor repeatability results also if the inner conductor of the mating connector (with contact removed) protrudes beyond the outer conductor. This should be checked if trouble occurs.

APPENDIX

TYPE 1615-P2 COAXIAL ADAPTOR



SPECIFICATIONS

Capacitance range when mounted on Type 1615
Terminals:
Maximum: ≥5.6 pF
Minimum: ≤5.2 pF

Fringing capacitance
With GR900 Connector: 0.155 pF ±0.008 pF
With GR900-WO: 0.172 pF ±0.008 pF

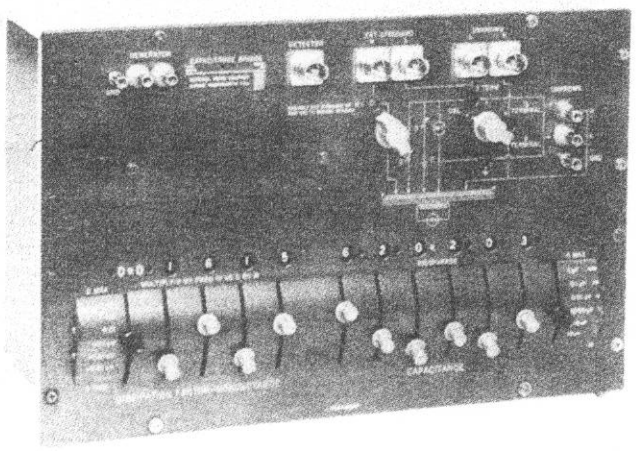
Inductance: 25 nH (typical)

Catalog No.	*Description*
1615-9602	**Type 1615-P2 Coaxial Adaptor**

TYPE 1615-A CAPACITANCE BRIDGE

Features

0.01% direct-reading accuracy; comparison accuracy, one ppm.
6-figure resolution for capacitance; one ppm for dissipation factor.
Wide capacitance range — 10^{-5} pF to 11 μF.
Loss can be measured as either dissipation factor or conductance.
Lever-type balance controls.
In-line readout in C, D, and G with automatically positioned decimal point.
Makes both 2- and 3-terminal measurements.
Low terminal at ground for 2-terminal measurements.



Uses: Accurate and precise measurements of capacitance and dissipation factor.

Measurement of circuit capacitances.

Dielectric measurements.

Intercomparison of capacitance standards differing in magnitude by as much as 1000:1.

Catalog Number	*Description*
1615-9801	**Type 1615-A Capacitance Bridge,** Bench Model
1615-9811	**Type 1615-A Capacitance Bridge,** Rack Model

TYPE 1620-A CAPACITANCE—MEASURING ASSEMBLY

The TYPE 1620-A Capacitance-Measuring Assembly consists of the TYPE 1615-A Capacitance Bridge with the TYPE 1311-A Audio Oscillator and the TYPE 1232-A Tuned Amplifier and Null Detector, thus providing a complete system for the precise measurement of capacitance over the range of 10 aF to 1 μF (10^{-17} to 10^{-6} farad). Frequency range is approximately 50 c/s to 10 kc/s. The sensitivity of the system provides resolution beyond 0.01% except for measurements of capacitors above 0.1 μF and below 100 pF at frequencies below 100 c/s.

Oscillator and detector are mounted side by side as shown in the photograph. The end frames are bolted together to make a rigid assembly without the use of a relay rack. Connection cables are supplied.

The oscillator operates from the power line, the detector from internal batteries.

Catalog No.	*Description*
1620-9701	**Type 1620-A Capacitance-Measuring Assembly**