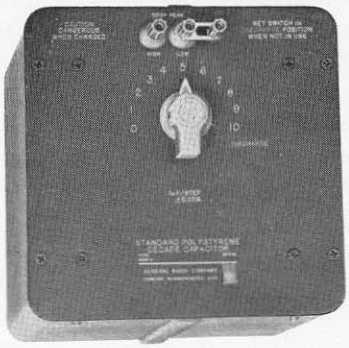
A NEW 10-MICROFARAD CAPACITANCE STANDARD



Type 1424-A
Standard Polystyrene Decade Capacitor.

General Radio fixed capacitance standards are available from stock, in relative magnitudes of 1-2-5, from 0.01 pf to 1 μf. TYPE 1401 and TYPE 1403 Air-Dielectric Models cover the range from 0.01 pf to 1000 pf, while the TYPE 1409, with silvered-mica dielectric, is available in values from 1000 pf to 1 μf. There has for some time been a demand for capacitance standards having values well above 1 μf. Carrying the silvered-mica standards above 1 μf, however, is not very practical, since the resulting capacitor would be heavy, bulky, and very expensive. For these higher capacitance values, polystyrene dielectric offers many advantages.

Since a large polystyrene capacitor must for production reasons be built up of many smaller capacitors paralleled, it is very little extra trouble to switch the capacitors in one by one instead of connecting them all solidly together. In the new TYPE 1424-A Standard Polystyrene Decade Capacitor, ten 1-μf capacitors are switched in this manner to provide not one but ten standards, one at each integral microfarad from 1 to 10. Each of the 1-μf capacitors is accurate to 0.25%. When all ten of these have been switched in parallel to make a 10-μf unit, the laws of probability will make the majority of units as close as 0.1% to the nominal 10 microfarads.

Residual Impedances

The most important problems in the design are not so much those of packaging as of minimizing the unwanted residual impedances. Inductance must be minimized to keep the natural frequency of the shorted capacitor low, in order that the capacitor may be used with accuracy over a broad frequency range. If the capacitor is used at 1/20 of its natural frequency, the frequency error will be 0.25%, equal to the adjustment accuracy of the unit. To appreciate the importance of resistance, consider that the reactance of 10 microfarads at 10 kc is 1.6 ohms. Since the dissipation factor of good polystyrene capacitors rarely exceeds 0.0001, a series resistance of 0.16 milliohm would double the dissipation factor. Naturally it is desirable that both L and R be kept so low that their effects will be small, compared to adjustment accuracy and to dissipation factor, respectively.

In this new polystyrene decade, the range of natural frequencies with the terminals shorted is from 525 kc at 1 μf to 235 kc at 10 μf, corresponding to a series-inductance range of 91 to 46 mμh.

The series resistance, R, difficult to measure directly, is low enough not to affect dissipation factor adversely at 1 kc. The desirable reductions of L and R have been accomplished by generous use of current-sheet conductors, ribbon leads, switch-terminal replication, etc. The residual series inductances will be found to be comparable to those of other GR fixed standard capacitors as well as to those of the air-dielectric precision capacitors, even though the TYPE 1424-A is much larger and the conducting leads consequently longer. The paralleling of paths that helps to reduce the inductance is still more effective in reducing the resistance.

Charge Storage

One of the most important considerations in any application involving dc is the large amount of stored energy. With all capacitors switched in (10 microfarads) and charged up to the rated 500 volts dc, the stored energy is 1.25 watt-seconds. This is not only a great deal of energy at a comparatively high voltage, but it will stay in the capacitor a long, long time, because the leakage resistance is of the order of 100,000 megohms, signifying a time constant of 10^6 seconds, or *12 days*. Caution notices are prominently engraved in red on the panel, and the clockwise position of the switch discharges the capacitor through a 100-kilohm resistor. The switch should be kept at the DISCHARGE position except when the capacitor is actually in use. This will assure that a minimum of residual absorbed energy will remain in the capacitor. Should it, through oversight, be left elsewhere after discharge, the low dielectric absorption of polystyrene assures that the residual voltage later acquired, as the absorbed charge comes out of the dielectric, will be small and not hazardous, although it will not be negligible in a dc storage application such as an analog computer.

Sudden charge or discharge is potentially damaging to the capacitor. In the DISCHARGE switch position, the discharge current is limited, with a nominal time constant of one second. Limitation of charging current is accomplished by the charging of each section through a series resistor of 1000 ohms, which is not in series with the capacitor at any detented switch position. This kind of switching is done through the agency of a second switch wafer which inserts the resistor between the sections already charged (if any) and the section about to be charged, during the time of traverse between switch positions. This resistor limits the peak current to 0.5 ampere at full rated voltage in a circuit having a time constant of 1 millisecond, which is fast enough to control charging current reliably, even with fast rotation of the switch.

Construction

The TYPE 1424-A Standard Polystyrene Decade Capacitor uses twenty 0.5-μf capacitors, paired to get ten 1-μf $\pm 0.25\%$ sections. These are housed in two solder-sealed brass cases with Teflon-insulated high terminals, the case being common. These two cases and the switch are mounted to a subpanel, which is itself insulated from the main panel. Thus the capacitor may be used in either a 2- or a 3-terminal connection, with no significant difference in capacitance values. A calibration chart is provided giving the actual capacitance at each of the ten switch positions. Dissipation factor typically is 0.0002, and insulation resistance 10^6 ohm-farads.

Much care was required in the design

of the instrument to keep series L and R at manageable levels. The excellence of the TYPE 1424-A in these respects can be fully exploited only if in application the inductance and resistance of the connecting means employed by the user are as carefully controlled.

— P. K. McELROY

SPECIFICATIONS

Nominal Value: 0 to 10 microfarads, in steps of 1 microfarad.

Adjustment Accuracy: ±0.25% at 1 kc.

Certificate: A certificate is supplied giving measured values, obtained by comparison to a precision better than ±.01% with working standards maintained to an accuracy of ±.03% in terms of NBS-certified reference standards.

Stability: Change is less than ±.05% per year.

Frequency: Calibrated at 1 kc. Variation with frequency down to 60 cps is typically less than +.02%. At higher frequencies, terminal capacitance rises as resonant frequency is approached (see curves). The increase can be calculated from $\frac{\Delta C}{C} = \left(\frac{f}{f_o}\right)^2$. Typical values of f_o are given in the calibration certificate.

Voltage Recovery: Less than 0.1%, final, of original charging voltage after a charging period of one hour and a 10-second discharge through a resistance equal to one ohm per volt of charging.

Dissipation Factor: Less than .0003 at 1 kc. (See curves for variation with frequency.)

Temperature Coefficient: Approximately −140 ppm per degree C.

Maximum Operating Temperature: 65 C.

Insulation Resistance: Approximately one million ohm-farads.

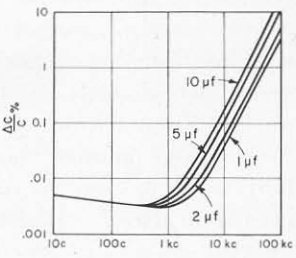
Maximum Voltage: 500 volts peak, up to 10 kc.

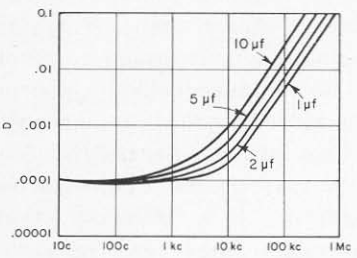
Mounting: Aluminum cabinet and panel, finished in gray.

Terminals: A separate ground terminal is provided, permitting 2- or 3-terminal use.

Dimensions: Width 8, height 7¾, depth 9½ inches (205 by 195 by 240 mm), over-all.

Net Weight: 16½ pounds (7.5 kg).





Typical curves for Type 1424-A Capacitors. (left) Change in capacitance as a function of frequency. These changes are referred to the values which the capacitors would have if there were neither interfacial polarization nor series inductance. The 1-kc value on the plot should be used as a basis of reference in estimating frequency errors. (right) Dissipation factor as a function of frequency.

Type		*Code Word*	*Price*
1424-A	Standard Polystyrene Decade Capacitor.....	BAIRN	$325.00

A NEW FOUR-DIAL PRECISION CAPACITOR

Fixed-value impedance standards are generally used for maximum accuracy and stability, while adjustable standards ordinarily provide convenience and flexibility at some sacrifice in stability and accuracy. The new TYPE 1423-A Precision Decade Capacitor, however, combines the high accuracy normally associated only with fixed, reference-type standards with convenient decade construction, which makes available any desired value within the range of the capacitor. Four individual decade capacitors within the cabinet provide 11,110 discrete values of capacitance, each known to an accuracy of ±.05%. Any value of capacitance be-