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RADIO AND ELECTRICAL ENGINEERING DIVISION

THE VARIATION WITH VOLTAGE OF THE CAPACITANCE AND DISSIPATION FACTOR OF SOLID - DIELECTRIC CAPACITORS

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OTTAWA

FEBRUARY 1961

ABSTRACT

A method of measuring variations with voltage in the characteristics of precision, solid-dielectric capacitors, using a current comparator, is presented. Results of measurements on capacitors of various sizes and of different manufacture are given.

The capacitance of most capacitors tested did not vary by more than a few parts in 10^5 for voltage changes between 20 and 200 volts rms. However, the variation in some capacitors was found to be as large as 0.06%. The variations in the dissipation factor were smaller than the corresponding capacitance changes.

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Limited

THE VARIATION WITH VOLTAGE OF THE CAPACITANCE AND DISSIPATION FACTOR OF SOLID-DIELECTRIC CAPACITORS

- O. Petersons -

INTRODUCTION

The capacitive voltage divider has been used for many years as the standard of ratio in the precise calibration of potential transformers. In such a divider, the capacitor in the high voltage arm is usually of the air- or gas-dielectric type, while in the low arm, because of the size of capacitance required, the capacitor must, of necessity, be of the solid-dielectric type. In recent tests on a capacitive divider of this type, the capacitance and dissipation factor of the solid-dielectric capacitors were observed to vary with the applied voltage. A special circuit was, therefore, devised to investigate this effect, and this report presents the results of measurements on capacitors of various sizes and of different manufacture. The capacitors which were tested are listed in Table I. These were supplied by Dr. A. F. Dunn of the Division of Applied Physics.

All of the capacitors were tested for this effect at a frequency of 60 cps, with voltages between 20 and 200 volts rms. A few were also subjected to the same test at frequencies of 400 cps and 1000 cps. During these measurements, the characteristics of some of the capacitors under test were observed to vary with time after voltage was applied, and specific tests of this effect were also made.

The tests were made at room temperature (approximately 23°C), and the relative humidity was approximately 20%. Three-terminal connections to the capacitors were used throughout.

TEST METHOD

The capacitors were tested by comparison with an air-dielectric capacitor whose characteristics were found to be invariant with applied voltage. The circuit is shown in Fig. 1.

The capacitor under test, C_x, and the standard capacitor, C_s, are connected in parallel to an a-c source, and the two currents are compared with a current comparator [1]. The current comparator is a device in which two currents are each passed through separate windings on a magnetic toroidal core, in such a way that their magnetizing forces tend to cancel one another. When the currents are such that the two magnetizing forces do cancel one another, the flux in the core is zero, and the current ratio is the inverse of the turns ratio.

TABLE I

CAPACITORS TESTED

Manufacturer	Nominal Capacitance	Type No.	Serial No.	
Sullivan	0.1μf		56,618/1958 56,619/1958 56,620/1958 56,621/1958 56,622/1958	mica
Sullivan	0.01μf		56,458/1958 56,459/1958 56,460/1958 56,461/1958 56,462/1958	mica
Sullivan	0.001μf		56,502/1958 56,503/1958 56,504/1958 56,505/1958 56,506/1958	mica
General Radio	999.5$\mu\mu$f	1409-FSI	6913 6914 6915 6916 6917	silvered mica
Leeds and Northrup	999$\mu\mu$f	1091	A* B* C* D* E*	silvered mica
Sullivan	Decade Box		54,731/1955	mica
Leeds and Northrup	Decade Box	1091	1,162,794	silvered mica
General Radio	Decade Unit 0.01μf per step	980-B		polystyrene

* These capacitors have no serial numbers ; the letters represent identification assigned during the test.

The particular comparator used in the test has five windings. The flux condition in the core is detected by the winding W_d, to which an electronic null detector is connected. The turns ratio of the windings to which the standard and test capacitors were connected $\left(\frac{N_s}{N_x}\right)$ is the inverse of the capacitance ratio of the corresponding capacitors. Small in-phase adjustments are made by adjusting the trimming capacitor, C_t, connected to an auxiliary winding, W_{a1}. The quadrature component is balanced by supplying another auxiliary winding, W_{a2} with current, through a purely resistive impedance. The magnitude of the quadrature current is varied by adjusting the voltage on the resistor, R, with a voltage divider of the Kelvin-Varley type.

RESULTS

Tests at 60 cps consisted of measurement of capacitance variation, taking the capacitance at 20 volts rms as reference, and of measurement of dissipation factors. These results are plotted in Figs. 2 to 9. Tests at 400 and 1000 cps consisted of measurement of capacitance variation, as before, and of the variation in the dissipation factor, taking the dissipation factor at 20 volts as reference. Results are shown in Figs. 10 and 11.

In those capacitors whose properties varied extensively with voltage, it was observed that both capacitance and dissipation factor varied with time when a constant voltage was applied. These variations, as observed in one capacitor in which they were most pronounced, are plotted in Figs. 12 and 13.

The accuracy of most of the relative measurements is estimated to be better than ±0.001%. The exceptions are those measurements concerned with the General Radio silvered mica capacitors and the Leeds and Northrup decade box No. 1,162,794, each of which lacked sufficient short-term stability when the voltage was applied. The accuracy of the absolute measurements (dissipation factors at 60 cps) is estimated at ±0.003%, with the exception of the measurements on the aforementioned capacitors. For these, the tolerances in the quoted values is estimated to be ±0.006%.

REFERENCE

N.L. Kusters and W.J.M. Moore, "The Current Comparator and Its Application to the Absolute Calibration of Current Transformers", AIEE Trans. Paper 61-58

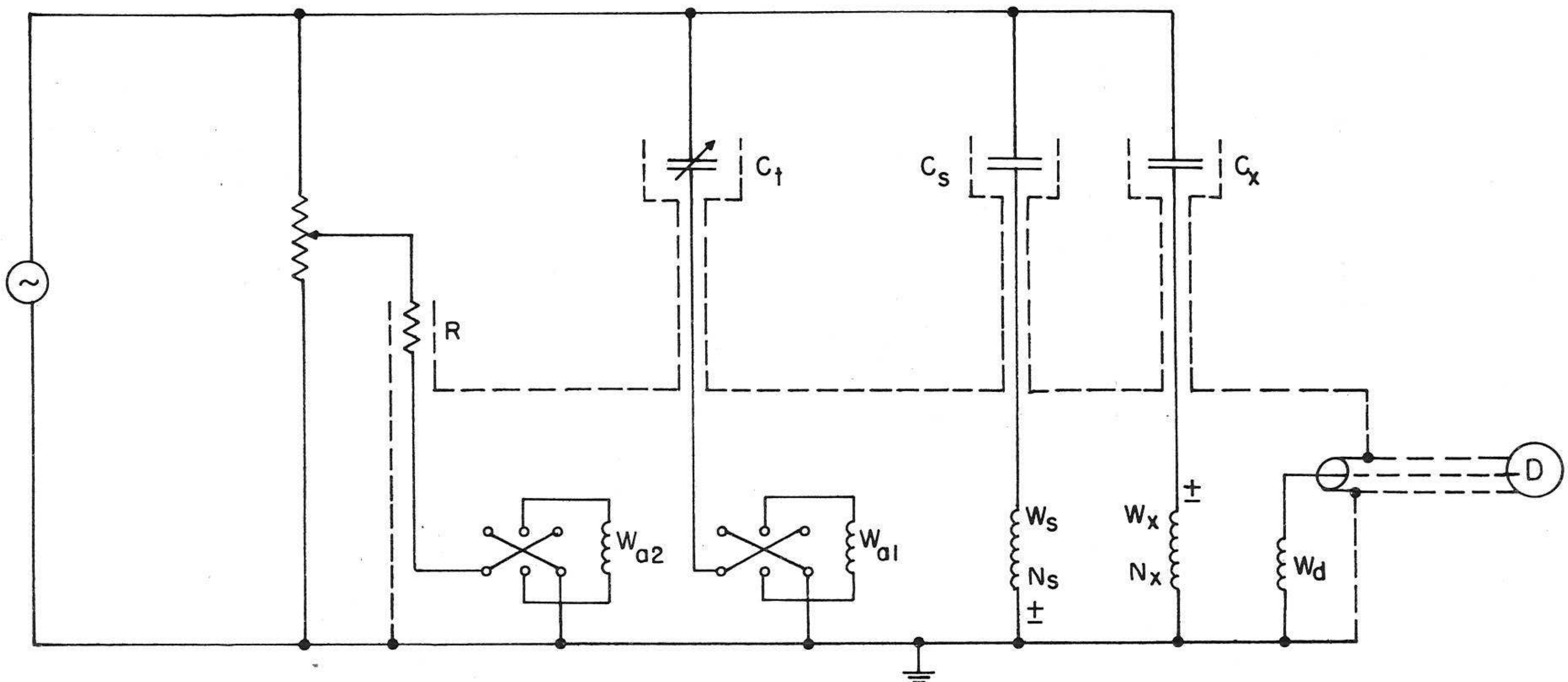
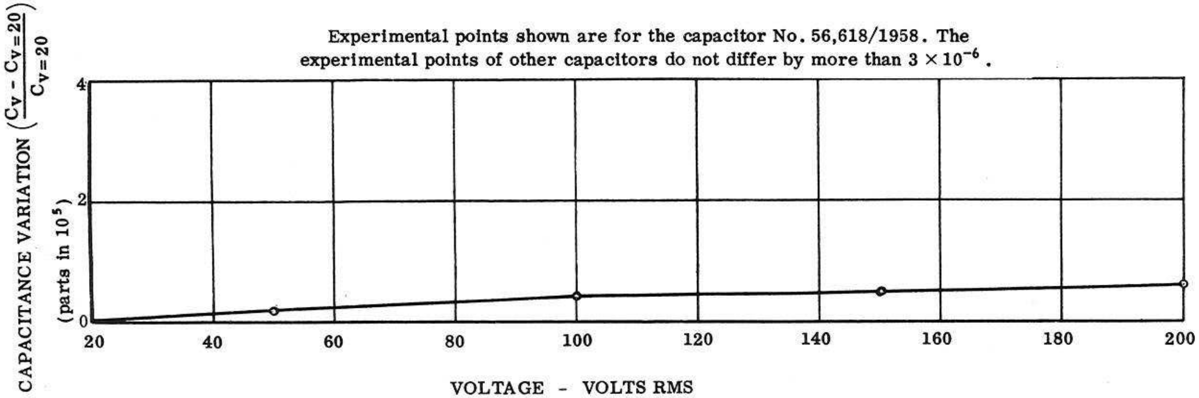


FIG. I TEST CIRCUIT

Fig. 2 Capacitance Variation with Voltage and Dissipation Factor
of Sullivan 0.1μf Capacitors
Serial Nos. 56,618/1958, 56,619/1958, 56,620/1958, 56,621/1958, 56,622/1958
Frequency 60 Cycles per Second

Experimental points shown are for the capacitor No. 56,618/1958. The experimental points of other capacitors do not differ by more than 3×10^{-6}.



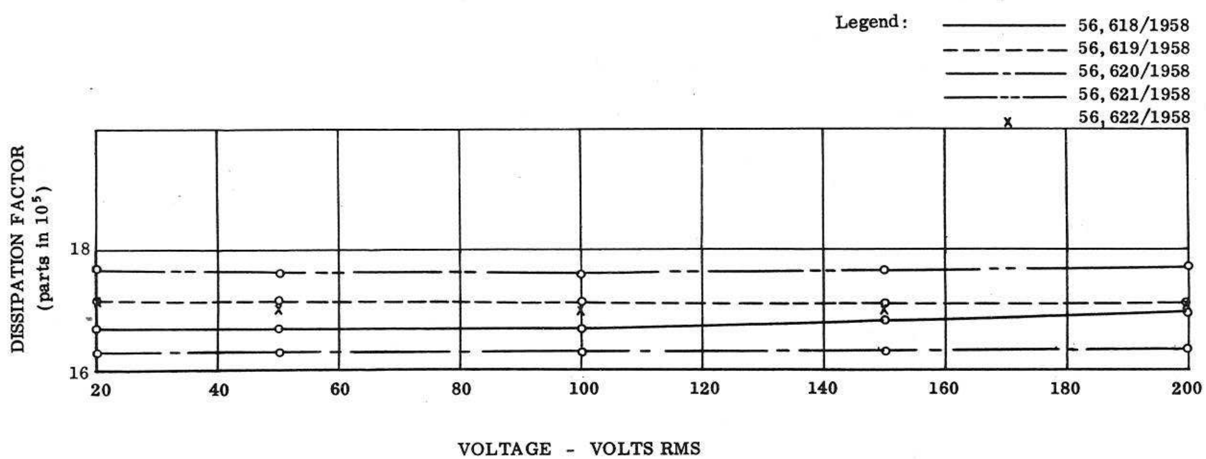


Fig. 3 Capacitance Variation with Voltage and Dissipation Factor
of Sullivan 0.01μf Capacitors
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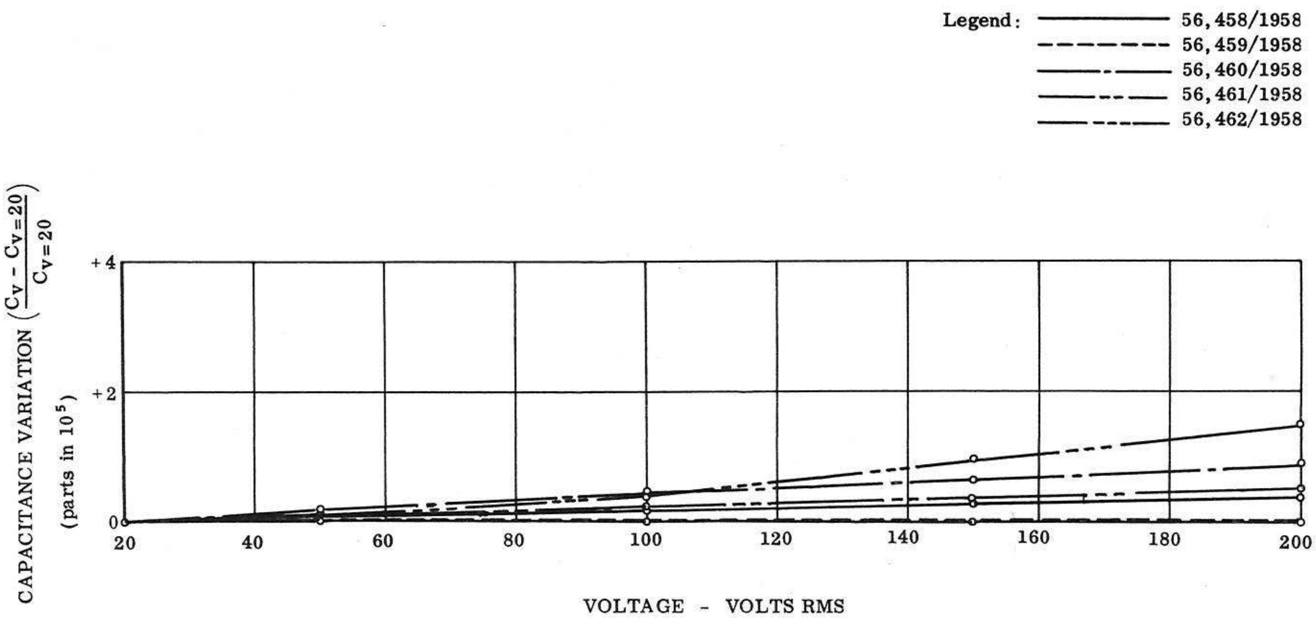
Frequency 60 Cycles per Second



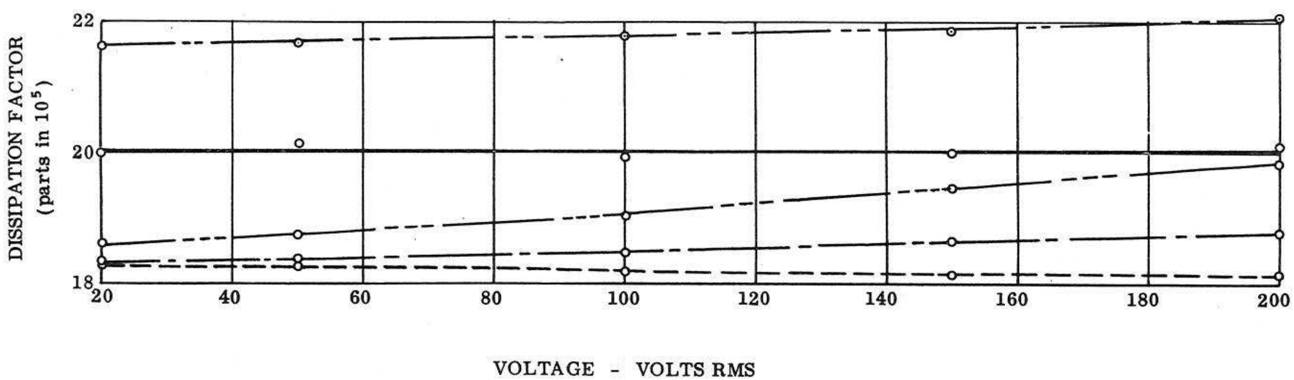


Fig. 4 Capacitance Variation with Voltage and Dissipation Factor
of Sullivan 0.001μf Capacitors
Serial Nos. 56,502/1958, 56,503/1958, 56,504/1958, 56,505/1958, 56,506/1958
Frequency 60 Cycles per Second

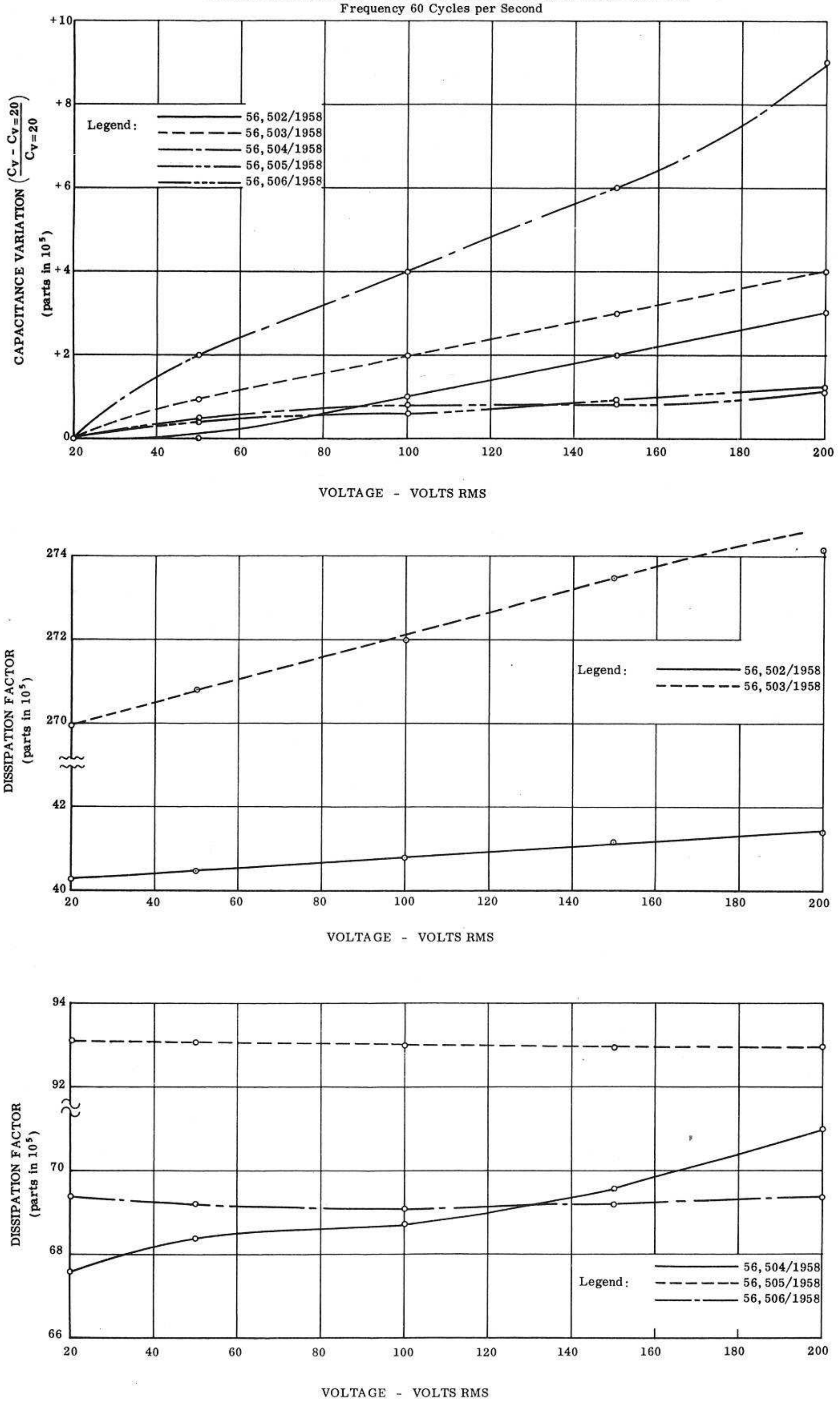
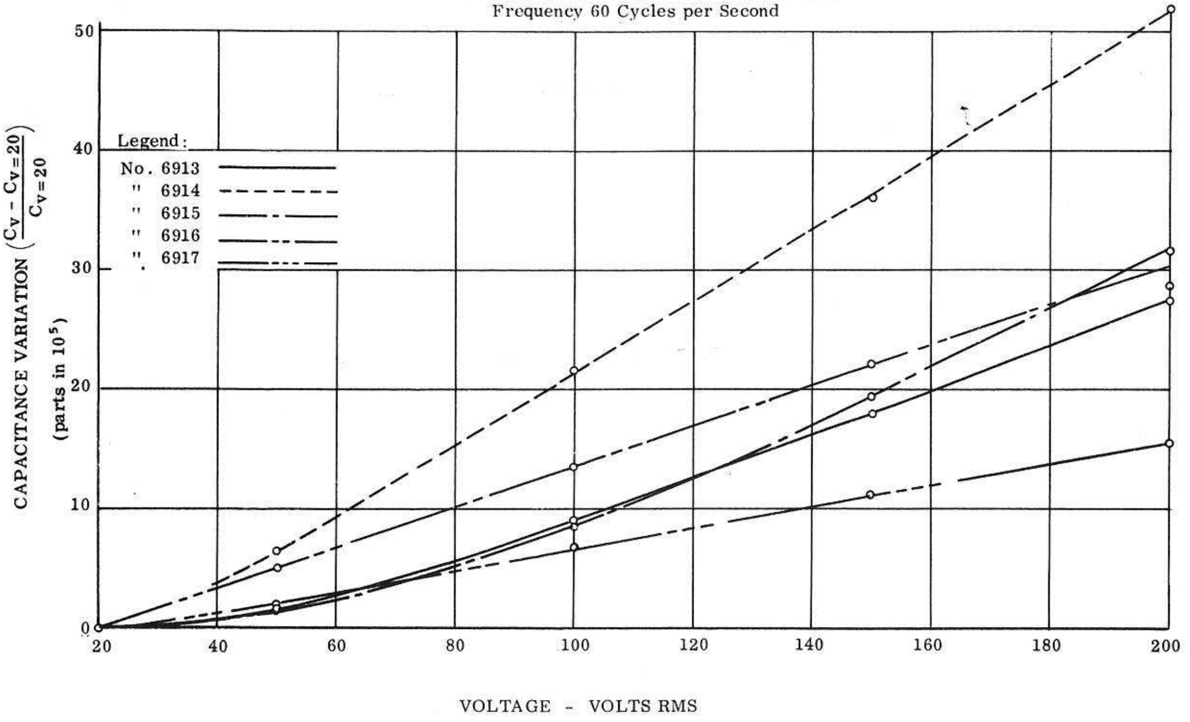


Fig. 5 Capacitance Variation with Voltage and Dissipation Factor of General Radio 999.5μμf Capacitors, Type 1409-FSI Serial Nos. 6913, 6914, 6915, 6916, and 6917 Frequency 60 Cycles per Second



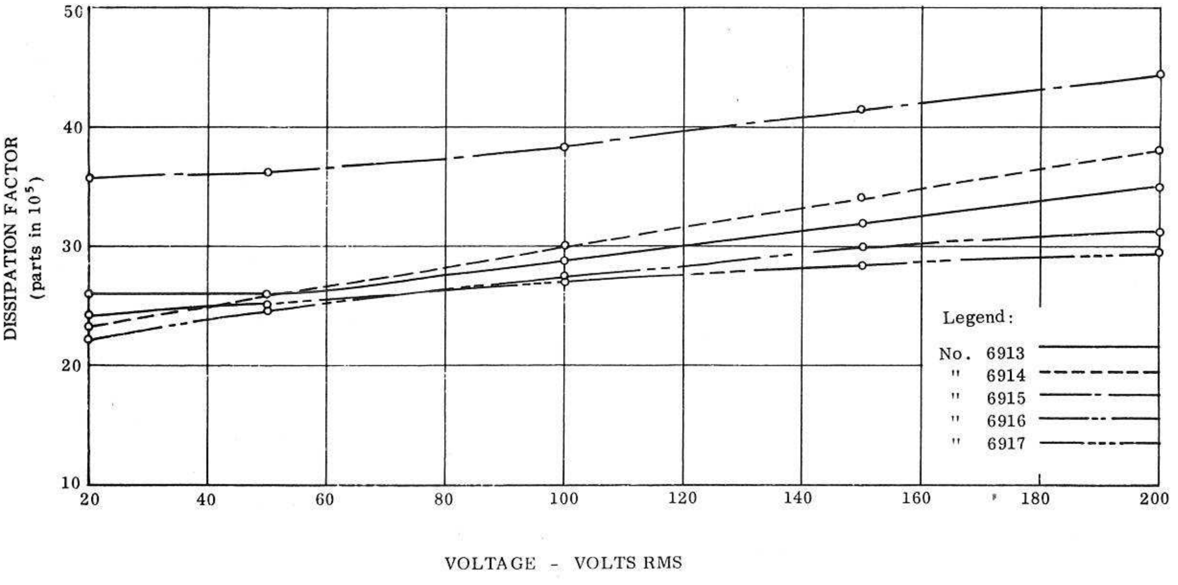
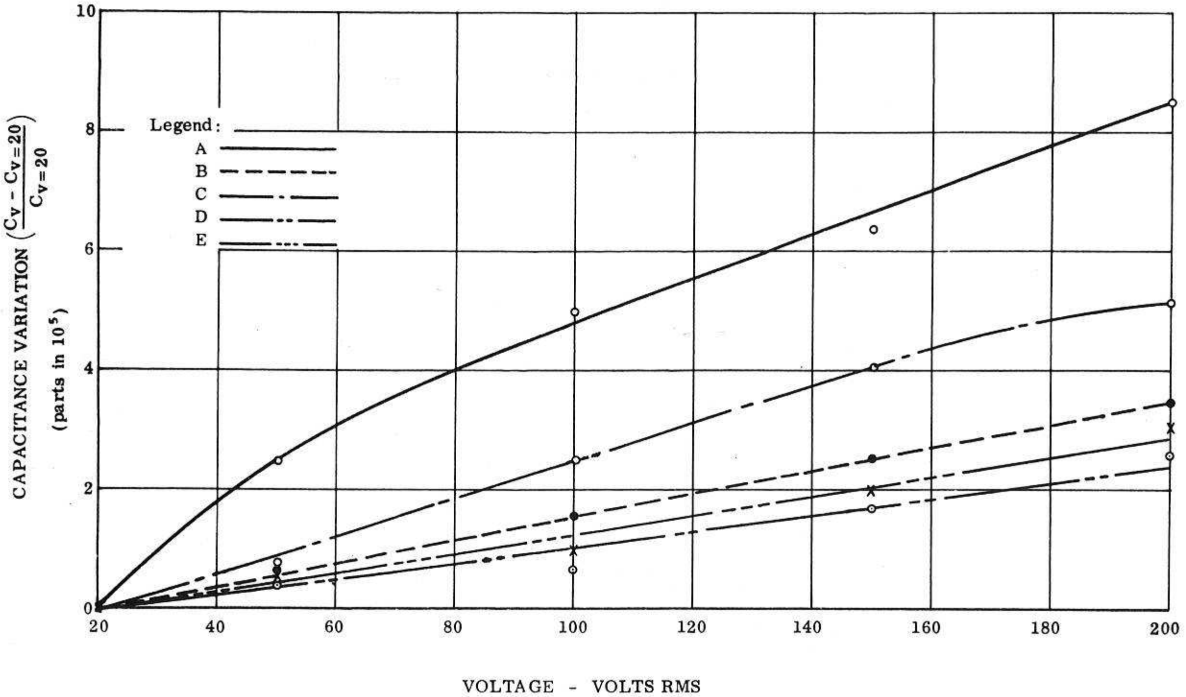


Fig. 6 Capacitance Variation with Voltage and Dissipation Factor of Leeds and Northrup 0.000999μf Capacitors, Type 1091
Frequency 60 Cycles per Second



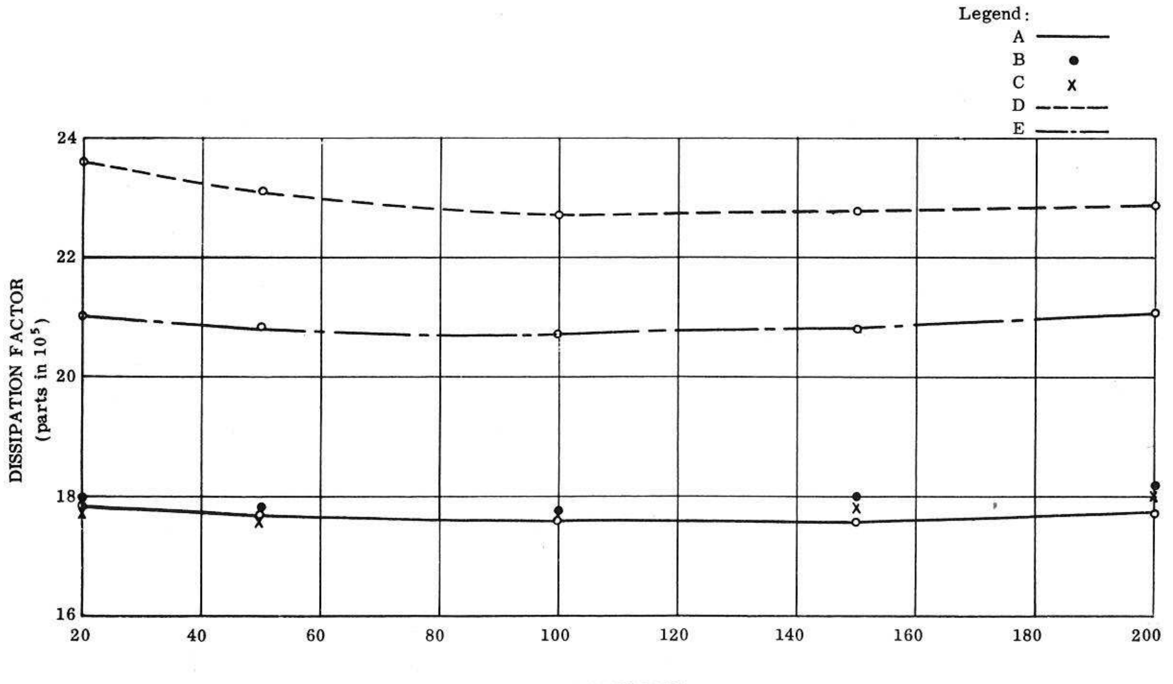
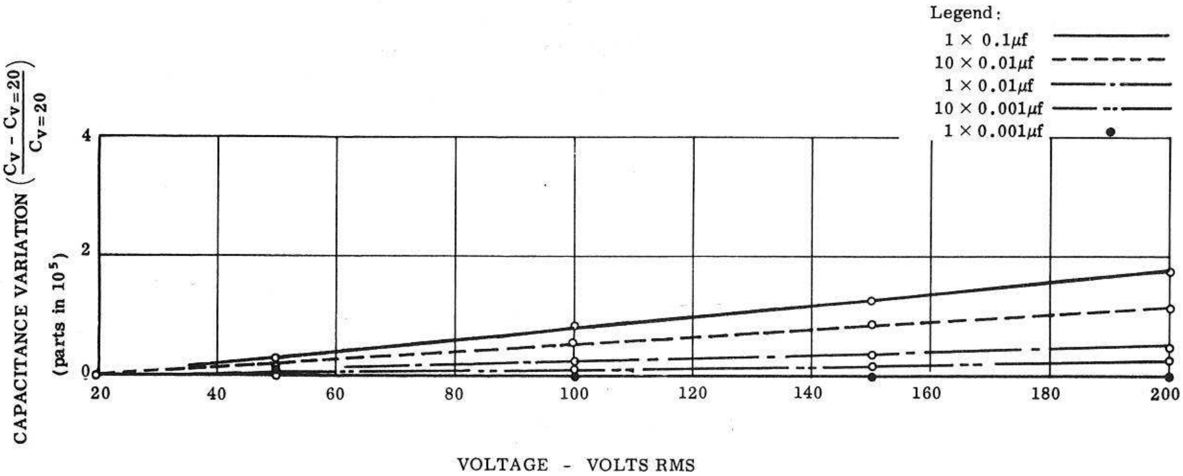
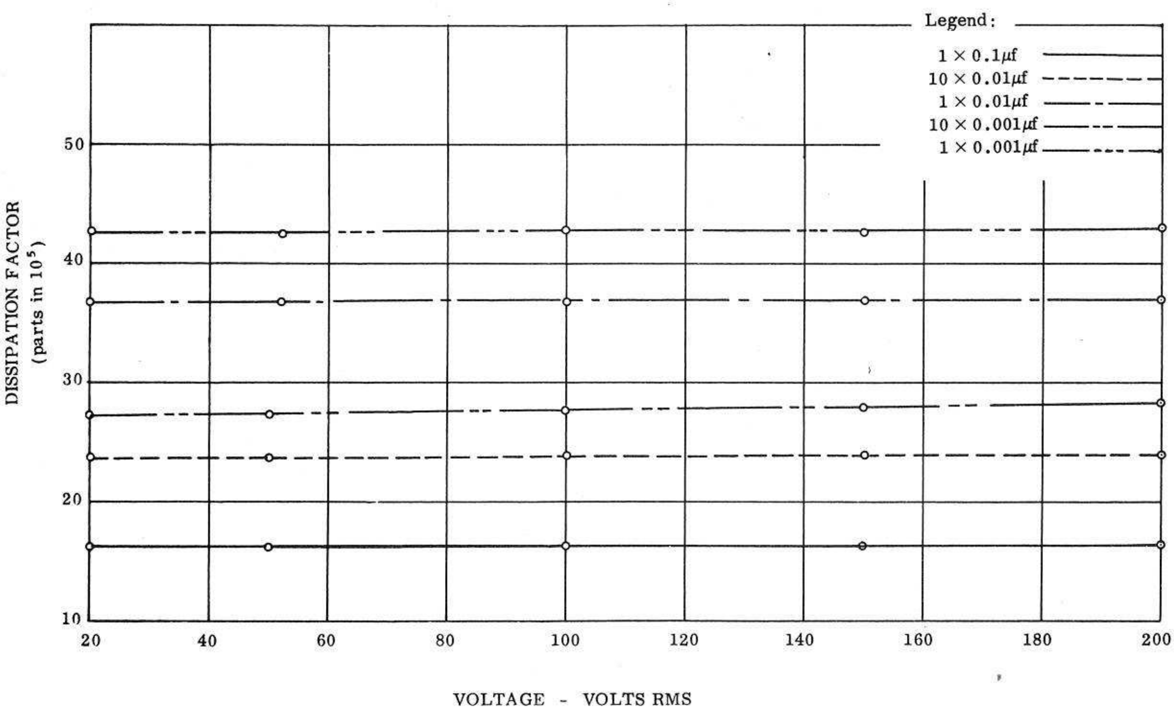


Fig. 7 Capacitance Variation with Voltage and Dissipation Factor of Sullivan Decade Box, Serial No. 54,731/1955
Settings: 1 × 0.1μf, 10 × 0.01μf, 1 × 0.01μf, 10 × 0.001μf, 1 × 0.001μf
Frequency 60 Cycles per Second





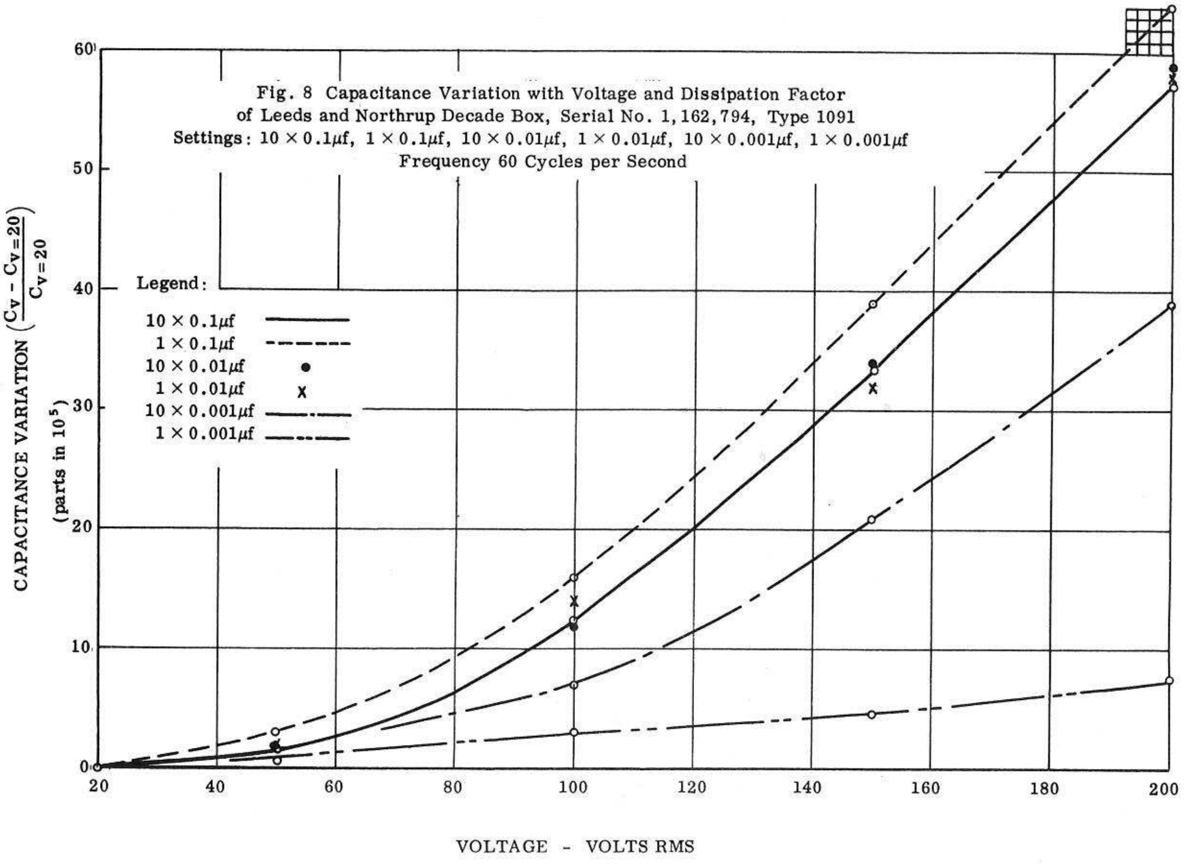


Fig. 8 Capacitance Variation with Voltage and Dissipation Factor
of Leeds and Northrup Decade Box, Serial No. 1,162,794, Type 1091
Settings: 10 × 0.1μf, 1 × 0.1μf, 10 × 0.01μf, 1 × 0.01μf, 10 × 0.001μf, 1 × 0.001μf
Frequency 60 Cycles per Second
Legend:
10 × 0.1μf
1 × 0.1μf
10 × 0.01μf
1 × 0.01μf
10 × 0.001μf
1 × 0.001μf
CAPACITANCE VARIATION $\left(\frac{C_V - C_{V=20}}{C_{V=20}}\right)$
(parts in 10^5)
0
10
20
30
40
50
60
20
40
60
80
100
120
140
160
180
200
VOLTAGE - VOLTS RMS

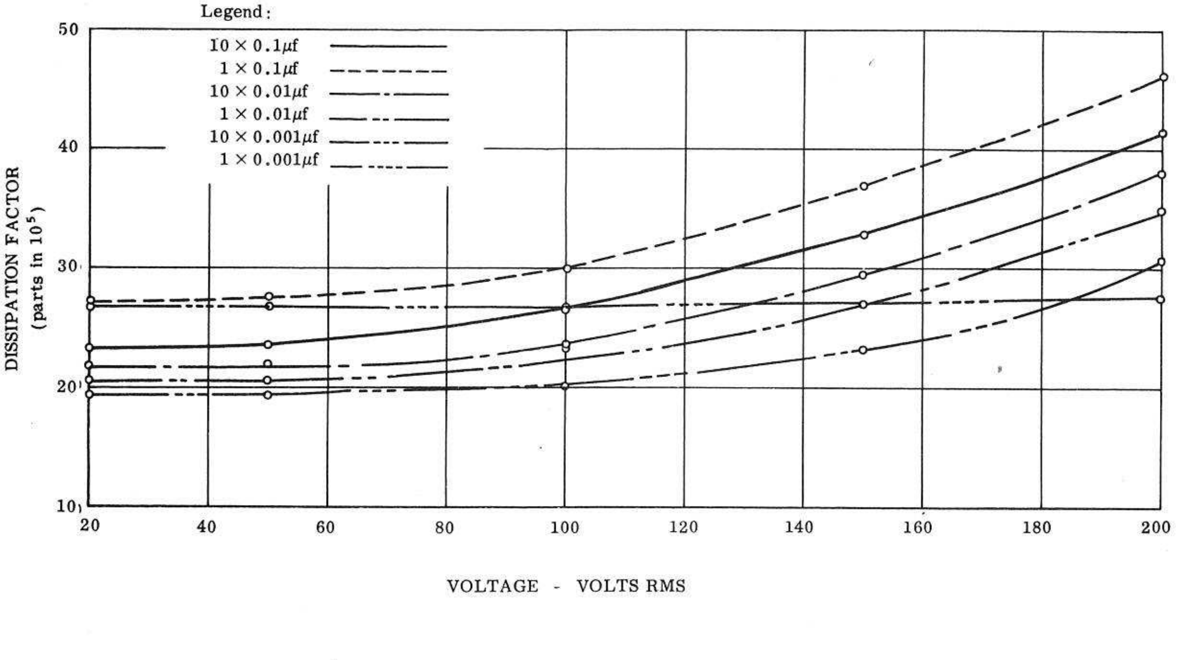
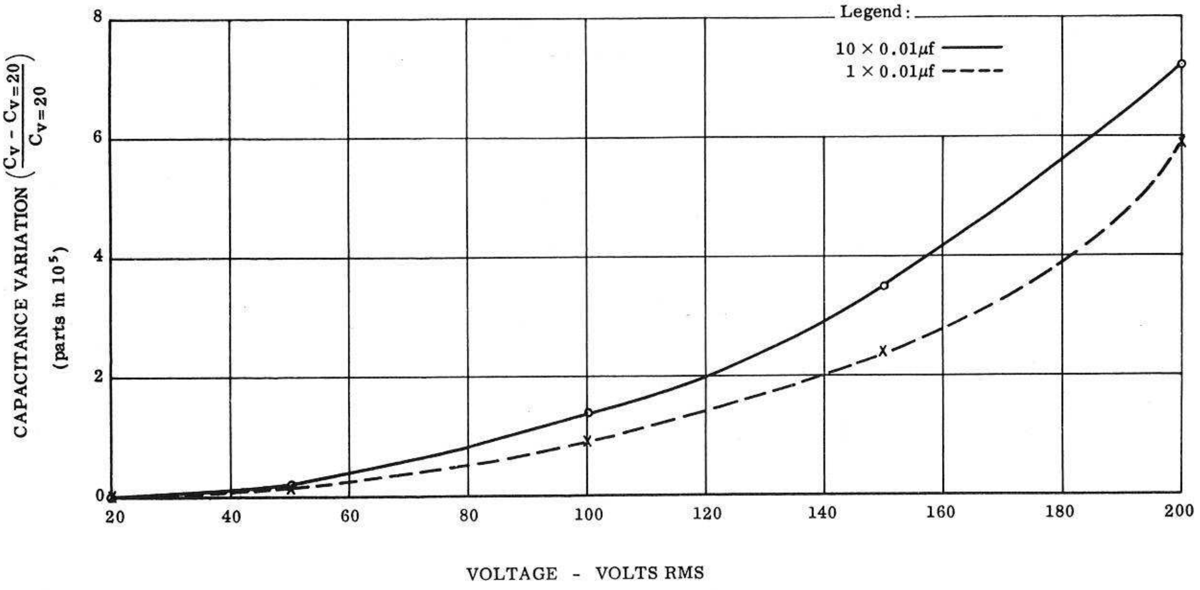

Legend:
10 × 0.1μf
1 × 0.1μf
10 × 0.01μf
1 × 0.01μf
10 × 0.001μf
1 × 0.001μf
DISSIPATION FACTOR
(parts in 10^5)
10
20
30
40
50
20
40
60
80
100
120
140
160
180
200
VOLTAGE - VOLTS RMS

Fig. 9 Capacitance Variation with Voltage and Dissipation Factor
of General Radio Decade Unit Type 980-B (Polystyrene), 0.01μf per Step
Frequency 60 Cycles per Second



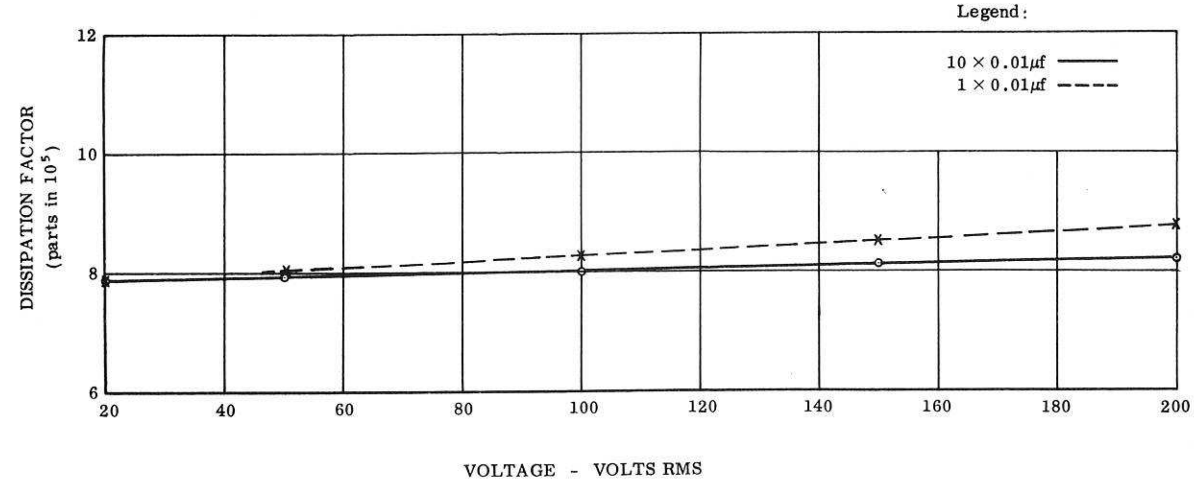
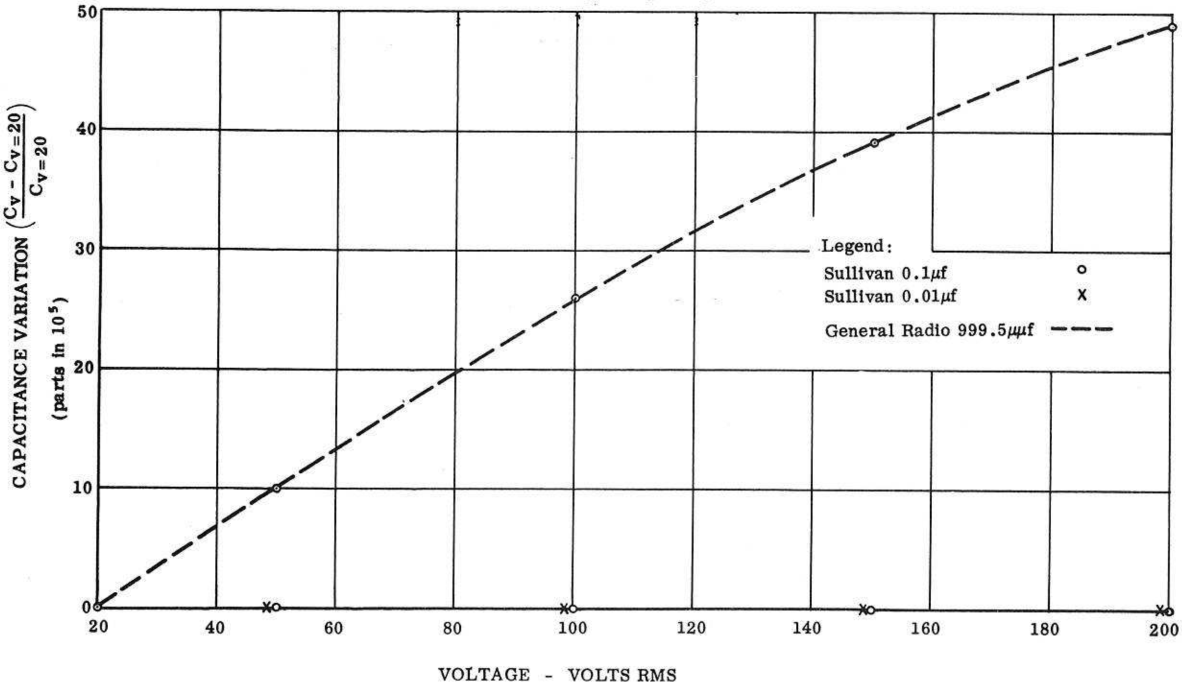


Fig. 10 Capacitance and Dissipation Factor Variation with Voltage of
Sullivan 0.1μf Capacitor, Serial No. 56,622/1958
Sullivan 0.01μf Capacitor, Serial No. 56,458/1958
General Radio 999.5$\mu\mu$f Capacitor, Serial No. 6914
Frequency 400 Cycles per Second



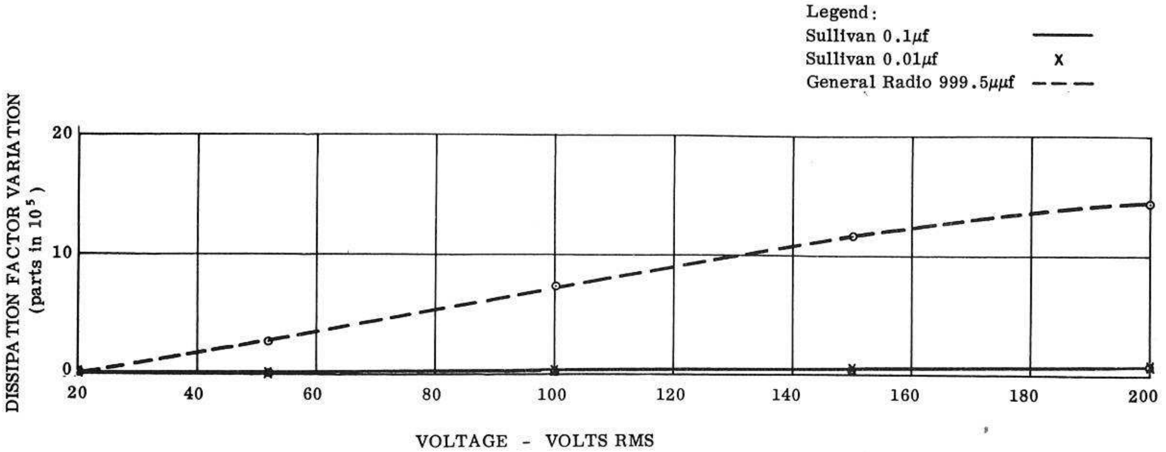
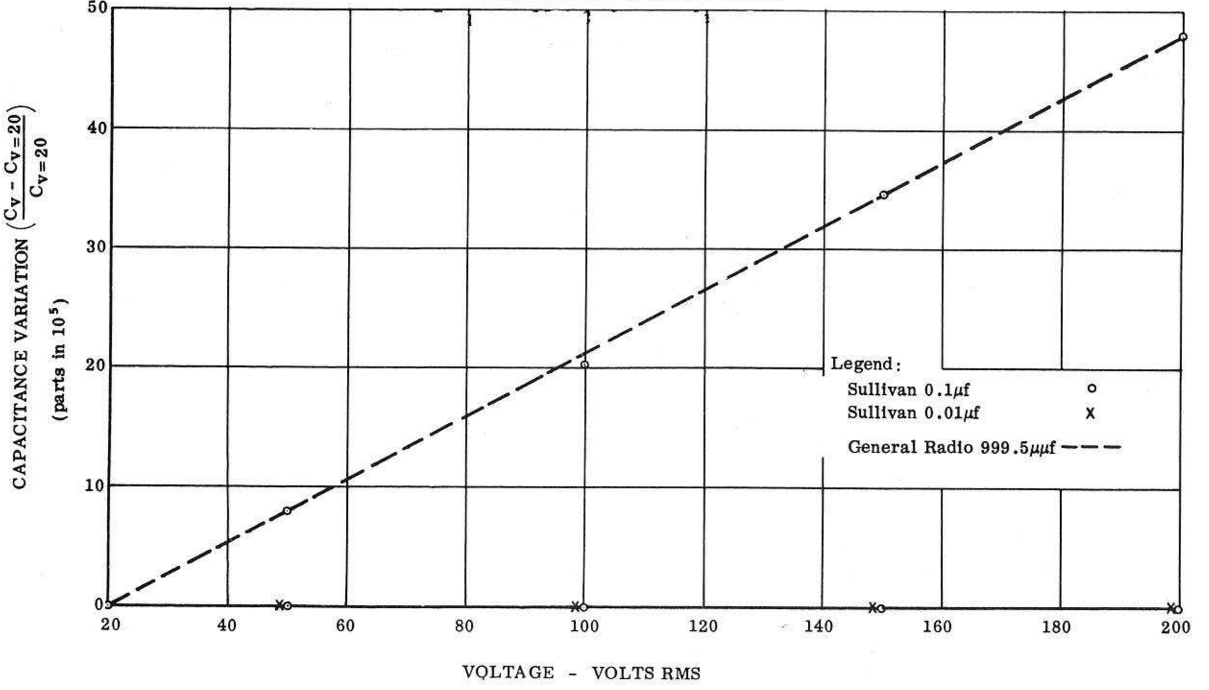


Fig. 11 Capacitance and Dissipation Factor Variation with Voltage of
Sullivan 0.1µf Capacitor, Serial No. 56,622/1958
Sullivan 0.01µf Capacitor, Serial No. 56,458/1958
General Radio 999.5µµf Capacitor, Serial No. 6914
Frequency 1000 Cycles per Second



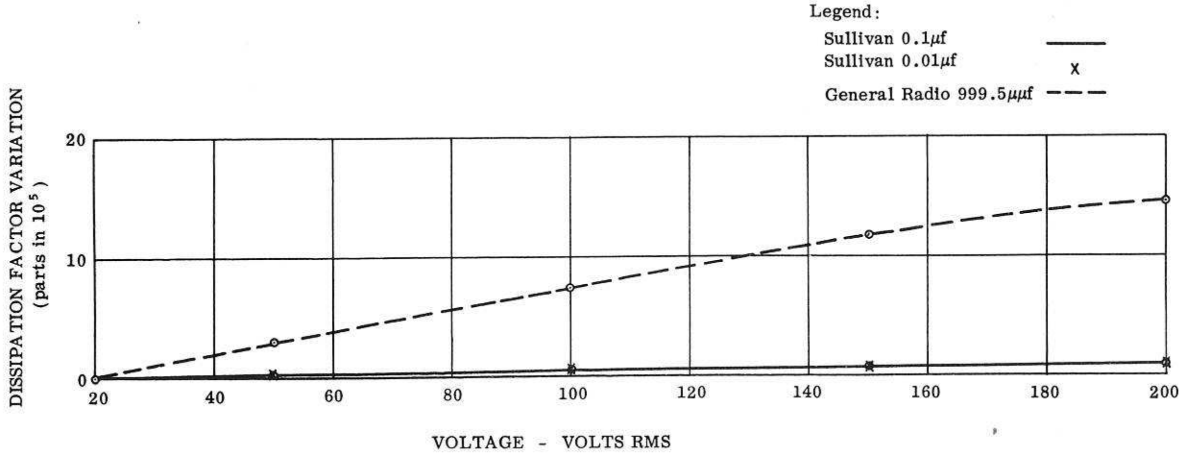
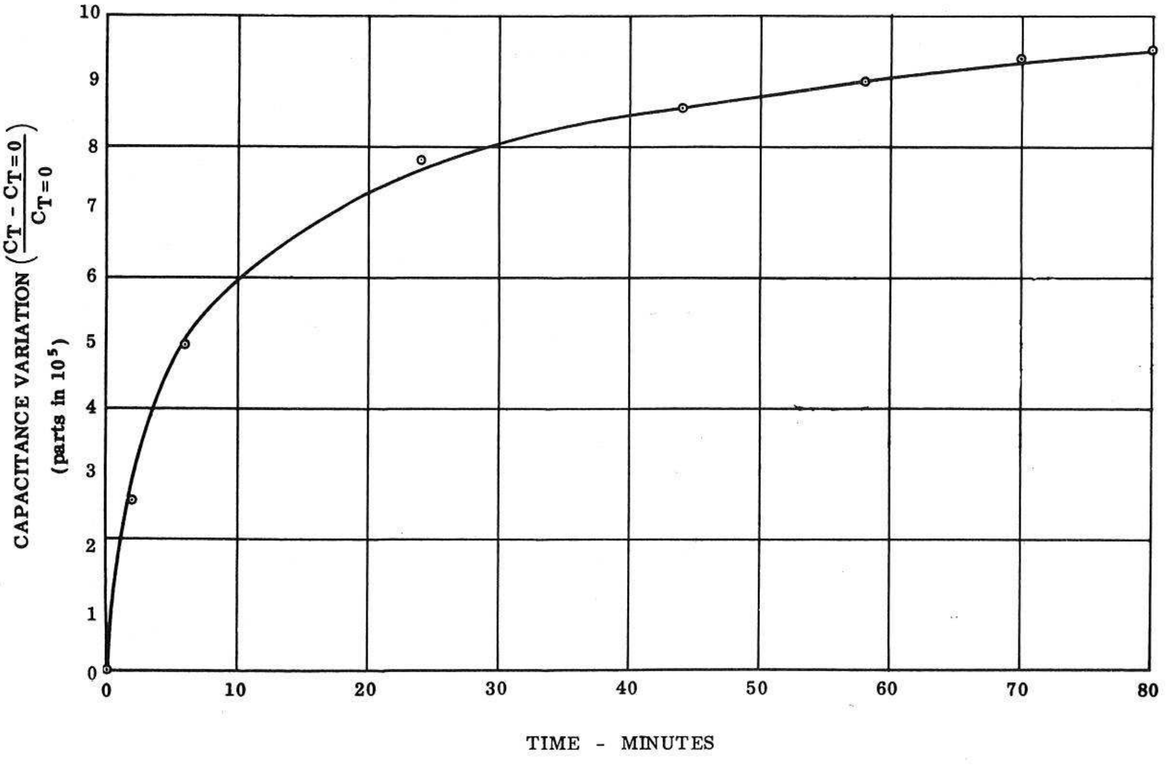


Fig. 12 Variation of Capacitance and Dissipation Factor with Time of General Radio 999.5$\mu\mu$f Capacitor, Type 1409-FSI

Serial No. 6914 Frequency 60 Cycles per Second

At time = 0 min. the voltage on the Capacitor was increased from 20 to 200 volts rms



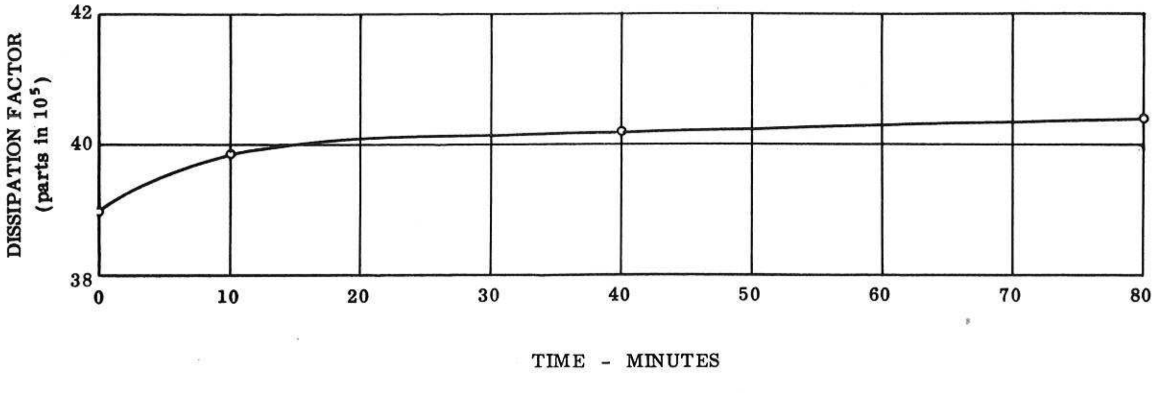


Fig. 13 Variation of Capacitance and Dissipation Factor with Time of General Radio 999.5$\mu\mu f$ Capacitor, Type 1409-FSI

Serial No. 6914 Frequency 60 Cycles per Second

At time = 0 min. the voltage on the Capacitor was decreased from 200 to 20 volts rms