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Paper Capacitors

As Mica Capacitor Substitutes

By the Engineering Department, Aerovox Corporation

As a means of meeting the critical shortage of mica capacitors, various capacitors of other types have been proposed as alternates. Included among the suggested substitutes are impregnated paper capacitors of both tubular and molded-bakelite construction.

Paper capacitors of several types have been tested by capacitor manufacturers to determine their suitability as mica capacitor substitutes. Among the electrical characteristics investigated are Q, power factor, insulation resistance, temperature coefficient of capacitance, and working voltages. In determining the suitability of substitute capacitors, it has been necessary to keep in mind the particular applications in electrical circuits in which mica capacitors have distinguished themselves, and to respect size requirements already set by mica capacitor dimensions.

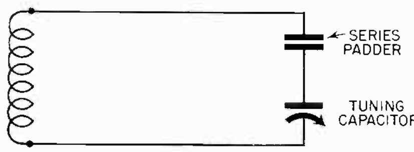

FIG.1

TYPES

Bakelite-molded paper capacitors resemble standard molded mica units in shape. Their sizes do not depart greatly from those of mica capacitors. The capacitor sections may be of stacked construction or may be wound and flattened. The molded paper capacitor may be impregnated with oil or wax.

Special tubular paper capacitors for mica substitution resemble standard tubular units except for their reduced size. These capacitors are oil impregnated and are provided with cylindrical metal containers, with or without an outer insulating sleeve.

Substitute paper capacitors of both types cover a wide range of capacitance values. While it is desirable to replace as many of the mica types as possible, it is particularly important that alternates be provided for the higher-capacitance units which employ the largest amount of mica. Prominent in the latter class are units with capacitance ratings of 0.002 mfd., 0.005 mfd., and 0.01 mfd. which are employed in various coupling, blocking, and by-passing positions in radio and electronic circuits.

SIZES

Bakelite-molded paper capacitors are supplied with approximately the same dimensions as corresponding mica capacitors up to 0.01 mfd. capacitance. These units are molded in black bakelite in accordance with tentative specifications of the American Standards Association.

Special small-sized oil-impregnated paper tubular capacitors up to 0.01

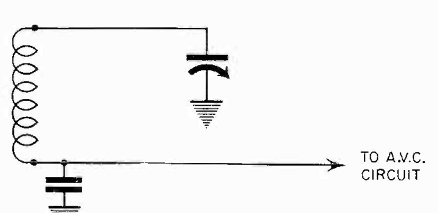

FIG.2

mfd. capacitance are obtainable in can lengths from 1 to 1-13/16 inches, and can diameters from 5/16 to 7/16 inch. Outer insulating sleeves add 1/16 inch to length and 1/32 inch to diameter. These small sizes enable direct replacement of mica units mounted in close quarters.

ELECTRICAL CHARACTERISTICS

The electrical characteristics of substitute paper capacitors depend upon the material employed as a dielectric (at least as far as dielectric constant is concerned) and the properties of the oil or wax impregnant.

In general, a low Q value (10 to 30 at 10 Mc.) may be expected. Power factor will be approximately 0.5 percent at 1000 cycles per second. Insulation resistance will be of the order of 8000 to 10,000 megohms at 500 volts dc. Residual inductance will depend upon the type of construction and lead length, and is usually of such magnitude that the resonant frequency of the 0.01 mfd. unit occurs in the vicinity of 10 megacycles.

Beyond the resonant frequency, the

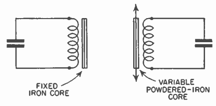

FIG. 3

capacitor is generally conceived as unsuitable for by-passing in high-frequency circuits. However, this is not entirely true. The reactance of the capacitor does become inductive at frequencies higher than the resonant point, but an inductive reactance can be as efficient a by-pass path as a capacitive reactance, as long as the reactive path is considerably lower in ohmage at the operating frequency than is the by-passed path. This will be true except when phase angle of the feedback voltage is of importance. Thus, an inductive reactance of 1 ohm or thereabouts might by-pass effectively a tube cathode resistor of the order of 500 ohms. At a certain high frequency beyond resonance, the inductive reactance will become equal to the resistance of the by-passed component and its by-passing ability will accordingly be destroyed.

Temperature coefficient of capacitance for the 0.01 mfd. metal-encased tubular substitute paper unit will be positive and of a low value. Temperature coefficients of both capacitance and power factor are governed by a number of factors which are of special concern to the manufacturers.

Capacitance tolerances of substitute paper units up to, but not including 0.01 mfd. capacitance are —20 to +50 percent; for units of 0.01 mfd. capacitance, the tolerance is —10 to +40 percent.

Common working voltages for the substitute paper capacitors are 300 to 800 volts dc for capacitance values between 0.001 and 0.01 mfd. Some of the types have already given good account of themselves on life tests conducted by the capacitor manufacturers and their customers.

Ability of the substitute units to withstand water immersion according to standard specifications is a function of the capacitor casing, rather than of the type of element or impregnant.

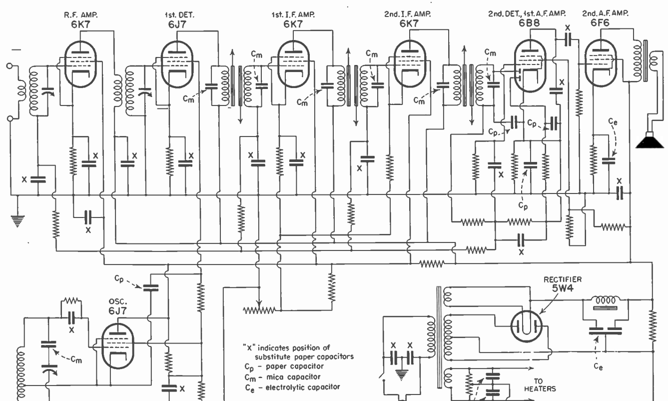

FIG. 4

AEROVOX BUILT BETTER CONDENSERS AND RESISTORS

APPLICATIONS

It has been common practice to employ mica capacitors in certain critical positions in radio-frequency circuits where equivalent series resistance of the unit must be of a low order of magnitude. One such application is the fixed-capacitance series padder in tuned L-C circuits in radio receivers, r. f. oscillators, and electronic test instruments (See Figure 1).

In order to prevent broadening of the selectivity curve of such a circuit, it is necessary that the equivalent series resistance of the padder capacitor be very low. Another manner of stating this requirement is by saying that the capacitor Q must be very high. Heretofore, mica capacitors have met this requirement with no difficulty. However, the low-Q characteristic of the substitute paper capacitor renders that unit totally unsuitable for use in high-frequency tuned circuits.

Certain receiver circuits in which automatic volume control is incorporated employ a fixed capacitor in series with the grounded end of the inductor in a tuned circuit, as shown in Figure 2. Here, as in the first case, the fixed capacitor is effectively connected in series with the coil and the variable capacitor and will reduce the circuit selectivity unless the fixed unit possesses low equivalent series resistance. Present substitute paper capacitors do not exhibit a sufficiently high Q to replace mica capacitors in this application.

Similar tuned or padded circuits containing only fixed capacitors (Figure 3) are employed occasionally at audio frequencies and do not demand the high capacitor-Q values imperative in r.f. circuits. Tuned audio amplifier plate and grid tanks, a.f. wave filters, and tone-control circuits are examples of this application in which the new substitute paper capacitors are entirely satisfactory, provided they show low power factor at 1000 c.p.s.

The paper units will be satisfactory also for by-passing in radio-frequency circuits operating at frequencies up to the capacitor resonant point and as far beyond as the ratio of reactance to by-passed-circuit resistance will permit. They are quite satisfactory for by-passing in all audio-frequency circuits.

Application of substitute paper capacitors to radio transmitters will be limited to low-powered oscillator, amplifier, speech amplifier, and modulator stages in which the combined dc and peak ac voltages do not exceed the relatively low voltage rating of these capacitors.

Figure 4 shows a superheterodyne receiver circuit in which permissible positions for substitute paper capacitors have been indicated. Figure 5 is the circuit of a radiotelephone transmitter with similar indications.

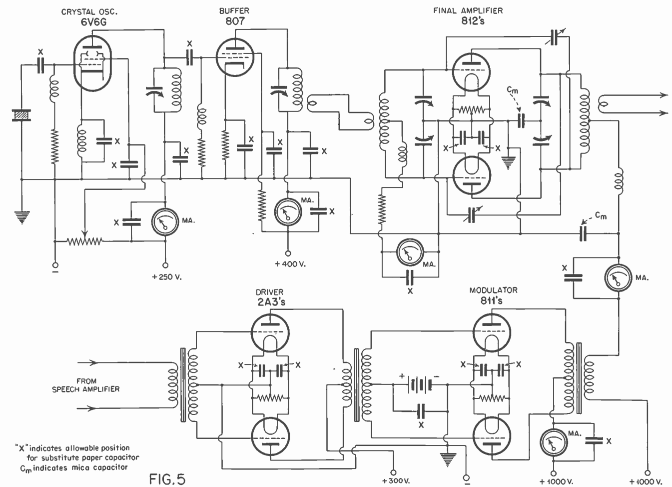

FIG. 5