The Aerovox Research Worker

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Methods of Testing Low-Voltage High-Capacity Condensers

By the Engineering Department, Aerovox Corporation

THE methods of measuring the capacity and power factor of low-capacity condensers are sufficiently well known but they are not suitable for the high capacity types. This article describes two ways of measuring the capacity and series resistance of low voltage high capacity condensers (from 100 to 10000 microfarads).

The first method, illustrated in Figure 1, employs the least amount of equipment. It rests on the principle of measuring the impedance of the condenser at a known frequency by the voltmeter-ammeter method. Assuming for the moment that the condenser does not have any resistance, it will be seen that the reactance of the condenser is equal to E/I, these values to be read simultaneously with the switch S closed. Then the capacity can be found from the relation

$$C = \frac{1{,}000{,}000}{2\pi f X} \text{ MICROFARADS} \quad (1)$$

or, expressing C directly in terms of E and I,

$$C = \frac{1{,}000{,}000\ I}{2\pi f E} \text{ MICROFARADS} \quad (2)$$

In these expressions, E and I are in volts and amperes.

Of course, no condenser has zero power factor and therefore, the above equation is somewhat in error but the error is never more than 2 or 3 percent so that it may not outweigh the advantage of this simpler method. Also, the error is in such a direction

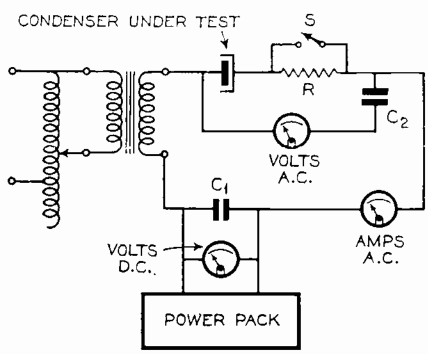


Fig. 1

as to make the condenser appear smaller than it really is.

Accurate determination of the capacity and of the series resistance of the condenser under test can be found with the circuit of Figure 1 in the following way. First close the swtich S and read the values of E and I which will here be denoted by E_1 and I_1. Then open switch S and again read the voltmeter and ammeter which gives the quantities E_2 and I_2. The desired quantities, Cx and Rx, can then be obtained from the readings by the expressions:

$$R_X = \frac{\left(\frac{E_2}{I_2}\right)^2 - \left(\frac{E_1}{I_1}\right)^2 - R^2}{2R} \text{ OHMS} \quad (3)$$

$$C_X = \frac{1{,}000{,}000}{2\pi f \sqrt{\left(\frac{E_1}{I_1}\right)^2 - R_X^2}} \text{ MICROFARADS} \quad (4)$$

This is equivalent to the so-called "three voltmeter method" of measur-

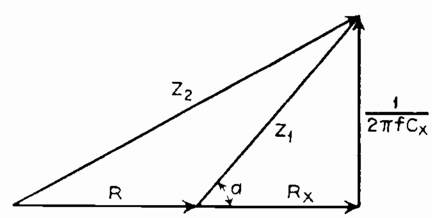


Fig. 2

ing resistance and reactance. If $E_1/I_1 = Z_1$ and $E_2/I_2 = Z_2$, the relation of the various impedance vectors is as in Figure 2. The triangle having the sides Z_1, Z_2 and R is completely known since the three sides are given. The angle a can then be figured out by the rule of cosines (this is the phase angle) and the values of Rx and Zx follow immediately.

All the above might seem rather complicated but the measurements are easily taken and the chart of Figure 4 avoids all calculations.

CIRCUIT DETAILS

The power supply for the measurement should consist of a variable transformer or some variable source of voltage. In the making of the chart 60 cycle a.c. has been assumed. The condenser must be given a polarizing voltage which is larger than 1.4 times the a.c. voltage to be applied. If the polarizing supply is a power pack, it must be bypassed by a condenser, C_1, which should be a condenser of about the same capacity as the condenser under test, or at least 200 mfd. The resistor R should be of a value to be given in a table below and should be able to stand the current.

The a.c. voltmeter is to be connected in series with another condenser, C_2, which should be an oil or wax condenser. This is to keep the voltmeter from being affected by the polarizing voltage. The proper size of C_2 depends on the resistance of the voltmeter. If it is a high-resistance rectifier type, the value of C_2 can probably be about 1 or 2 mfd. paper type for a 10,000 ohm instrument. Its range should be 0-10 volts.

The a.c. ammeter employed can be a movable iron type or a thermocouple type. It has some extra current flowing through it which is not desired; the voltmeter current and the d.c. leakage of the condenser. If the voltmeter is of the high-resistance type, its current is so small as to be negligible. However, it is easy to correct for it if one would care to go to the trouble. In order to avoid the leakage current one might employ thermal meters which add the d.c. and a.c. straight and make a correction. It is also possible to employ a meter with a current transformer or to substitute a voltmeter in series with a condenser across a resistor but the error is probably not large enough to warrant these precautions.

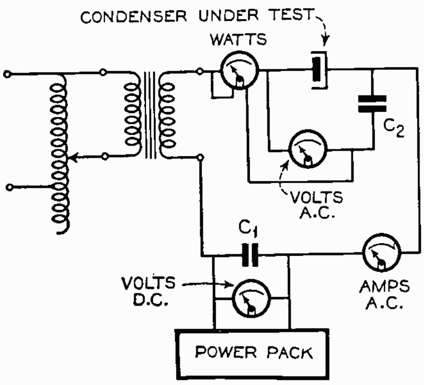


Fig. 3

MAKING THE MEASUREMENT

Make the polarizing voltage about 15 volts, connect the unknown condenser, close switch S and adjust the a.c. supply until the a.c. voltmeter shows 8 volts. Read the a.c. ammeter; this is the value to be known as I_1. With an applied potential of 8 volts, there is 3 ma. per microfarad, so the capacity is known immediately. (according to equation 2).

Next open the switch S, readjust the a.c. supply to 8 volts and again read the ammeter. This is I_2; the chart of Figure 4 shows the value of Rx for any combination I_1 and I_2. The chart is direct reading for the range 1000-3400 microfarads, when R equals 1 ohm and the ammeter range is 0-10 amps. For other ranges, the Table I shows the required value of R, the recommended ammeter range and the factors where one must multiply the values of the chart so as to make it cover that range.

The second method is illustrated in Figure 3. In additon to the meters employed in Figure 1 it also requires a wattmeter and then the resistance and switch are not necessary. One set of readings is sufficient to find both the capacity and the resistance of the unknown condenser.

The wattmeter must be a "low power-factor" wattmeter, its current coil should be able to carry a larger current than the wattmeter range would indicate. The voltmeter coil can be connected to the same terminal of condenser C_2 as the other voltmeter; in this way only one condenser is required. When all three readings have been taken, Cx and Rx are found from the following equations.

$$R_X = \frac{W}{I^2} \text{ OHMS} \tag{5}$$

$$C_X = \frac{1{,}000{,}000}{2\pi f\sqrt{\left(\frac{E}{I}\right)^2-\left(\frac{W}{I^2}\right)^2}} \text{ MICROFARADS} \tag{6}$$

Due to the fact that wattmeters with low ranges are not available, it will be necessary to employ a higher applied voltage for the low ranges. The recommended ranges with the required meter ranges are shown in Table II.

TABLE I

Range in microfarads	R	Ammeter range	In Fig. 4, multiply or divide I_1 and I_2	Rx
100-340	10 ohms	0-1 amp	divide by 10	multiply by 10
340-1000	3.0 ohms	0-3 amps	divide by 3	multiply by 3
1000-3400	1 ohm	0-10 amps	direct reading	direct reading
3400-10000	0.33 ohm	0-30 amps	multiply by 3	divide by 3

TABLE II

Range in microfarads	Ammeter range	Wattmeter range	Volts applied
340- 1000	0- 3 amps	0-20	24
1000- 3400	0-10 amps	0-20	8
3400-10000	0-30 amps	0-50	8

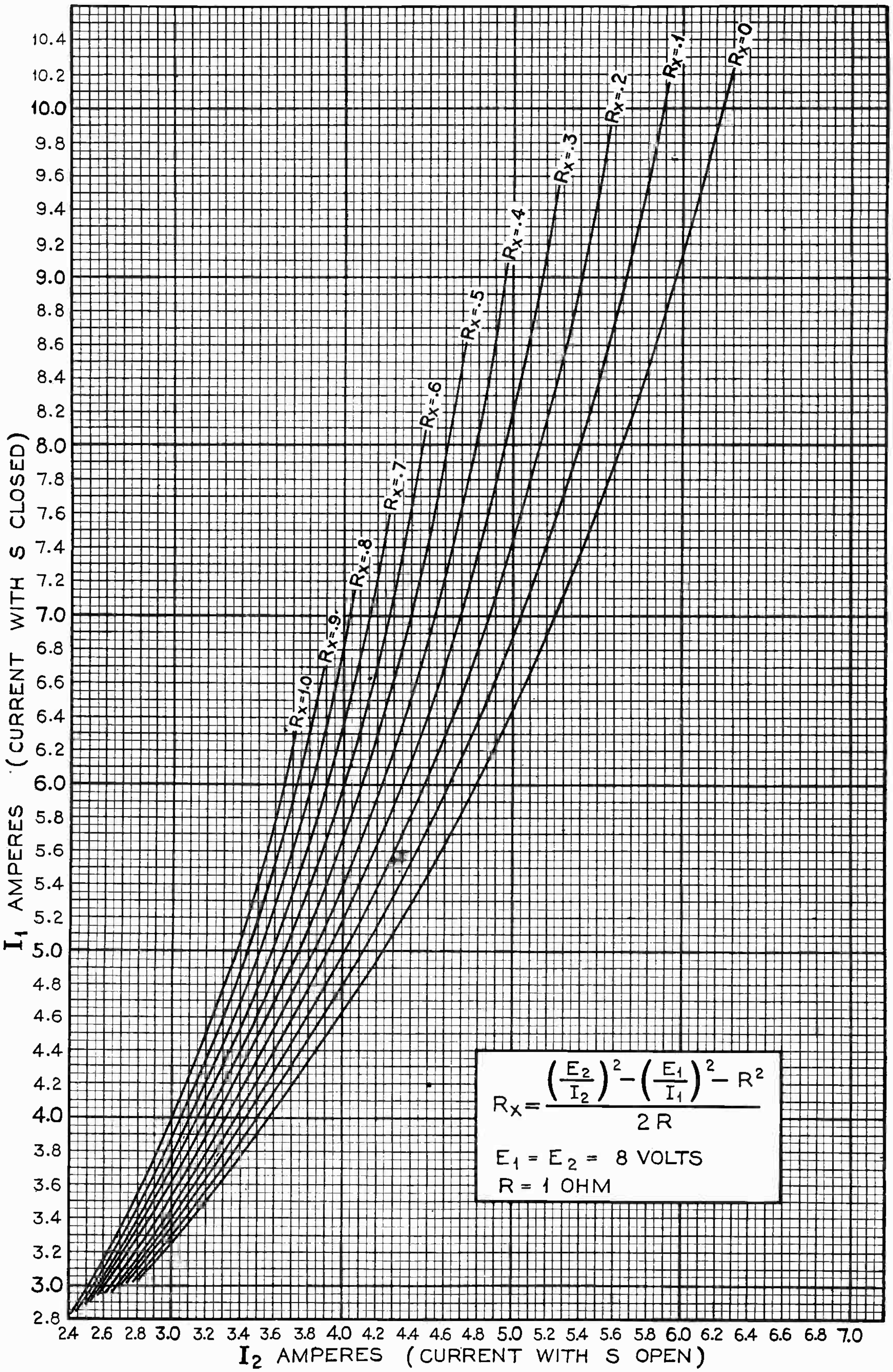
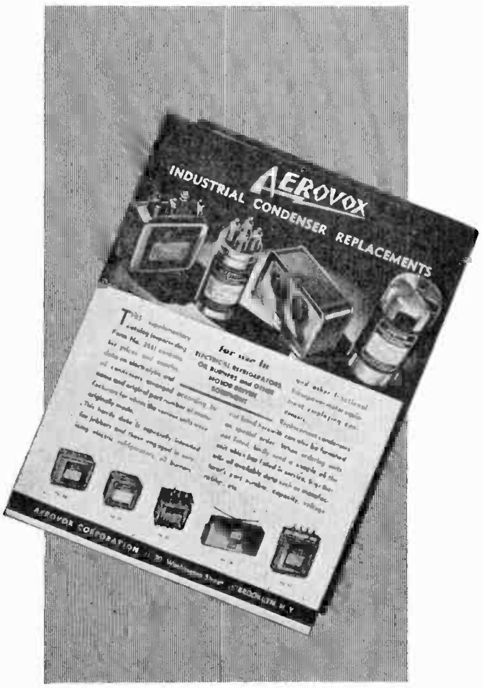

I1 AMPERES (CURRENT WITH S CLOSED)
I2 AMPERES (CURRENT WITH S OPEN)
Rx=1.0
Rx=.9
Rx=.8
Rx=.7
Rx=.6
Rx=.5
Rx=.4
Rx=.3
Rx=.2
Rx=.1
Rx=0
$R_x = \frac{\left(\frac{E_2}{I_2}\right)^2 - \left(\frac{E_1}{I_1}\right)^2 - R^2}{2R}$
$E_1 = E_2 =$ 8 VOLTS
R = 1 OHM

Fig. 4

Motor Starting Condenser Replacements



ELECTRIC refrigerators with condenser-starting motors have been in use for several years. In many instances their condensers are now worn out. Most servicing jobs disclose defective condensers. But what replacements to get and where to get them—that's been the hitch until now.

Many AEROVOX jobbers have begun to stock AEROVOX motor-starting condensers. Also, AEROVOX has just issued a special Industrial Condenser Replacements Catalog listing electrolytic and oil condensers employed by the standard types of condenser-start motors. This data gives you the precise facts you need for a satisfactory replacement. Meanwhile your jobber can supply the precise unit called for.

Write for Data Just state that you are interested in servicing electric refrigerators and other motor-driven appliances using condensers, and we shall send latest bulletins. And if your jobber does not stock the units you call for, let us know.

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