Built for long-lasting Service!

AEROVOX

EXACT DUPLICATE ELECTROLYTIC REPLACEMENT CONDENSERS

ATWATER KENT CONDENSER

Atw'r Kent Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
24955	8-8-8	Cd'bd. Box	1 1/8 x 1 6/16 x 3 1/4	$1.75

CROSLEY CONDENSERS

Crosley Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
W25857B	8-8	Cd'bd. Box	1 1/8 x 1 1/8 x 2 1/4	$1.00
W27488	6-8	Cd'bd. Box	1 1/8 x 1 1/8 x 2 1/4	.95
W27677A	8-8	Cd'bd. Box	1 x 1 x 2 1/4	.80
W28068	12	Cd'bd. Box	1 1/8 x 1/8 x 2 1/4	.95
W28468	8-12	Invert Can	1 3/8 x 5 1/4	1.95
W29097B	8-8-8	Invert Can	1 3/8 x 5	2.20
W29150A	6-7-8	Invert Can	1 3/8 x 4 3/8	1.90
B30017	4-8	Invert Can	1 3/8 x 4 1/8	1.45
B30059A	8-8-8	Invert Can	1 3/8 x 6 1/2	2.25

GENERAL ELECTRIC CONDENSER

Gen'l Elec. Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
6487	4-4-10-4	Cd'bd. Box	1 1/2 x 1 1/2 x 3 3/4	$2.00

GENERAL MOTORS CONDENSER

Gen'l Motors Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
1203346	4-4	Invert Can	1 3/8 x 5 1/4	$1.70

INTERNATIONAL CONDENSERS

Internat'l Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
A-424	4-10-10	Cd'bd. Box	1 x 1 1/4 x 3 3/8	$1.70
A-426	7-7	Cd'bd. Box	5/8 x 1 7/16 x 2 1/4	.90
A-427	3.5-3.5-3.5	Cd'bd. Box	5/8 x 1 1/4 x 2 1/4	1.20

MAJESTIC CONDENSERS

Majestic Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
4713	8	Cd'bd. Box	1 1/4 x 1 5/8 x 4 1/8	$ .95
5414	8	Cd'bd. Box	1 1/4 x 1 5/8 x 4 1/8	.95
6443	4-4	Cd'bd. Box	15/16 x 1 3/8 x 4 1/8	1.20
7173	8	Cd'bd. Box	1 x 1 3/8 x 4 1/8	.95
7278	7-10	Cd'bd. Box	1 1/16 x 1 1/16 x 2 3/8	1.25
7402	10	Cartridge	5/8 x 2 1/4	.50
7489	16	Cd'bd. Box	1 7/16 x 1 9/16 x 4 1/8	1.45
7988	7	Cd'bd. Box	1 1/16 x 1 1/16 x 2 3/8	.75
8118	20	Cd'bd. Box	1 1/16 x 1 1/16 x 2 3/8	.60
8286	5	Cartridge	5/8 x 2 1/4	.50
8385	8-8	Cd'bd. Box	1 7/16 x 1 9/16 x 4 1/8	1.50
8722	8	Invert Can	1 3/8 x 4 1/8	1.05
8755	4-8	Cd'bd. Box	1 3/8 x 1 1/4 x 4 7/8	1.35
8774	10	Cartridge	5/8 x 2 1/4	.50
9019	10	Cd'bd. Box	1 1/16 x 1 1/16 x 2 3/8	.50
9219	8-8	Cd'bd. Box	1 7/16 x 1 9/16 x 4 1/8	1.50

RCA VICTOR CONDENSERS

RCA Victor Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
3536	5-5	Cartridge	29/32 x 2 1/2	$ .90
3538	4-4	Cartridge	15/16 x 3 1/8	1.00
7589	4-4	Cd'bd. Box	1 x 1 1/2 x 3 3/4	1.05

RADIO KEG CONDENSER

Cap. Mfd.	Type Container	Size Inches	List Price
5-8-12	Cd'bd. Box	1 x 1 1/2 x 3	$1.75

SPARTON CONDENSER

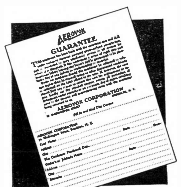
Sparton Part No.	Cap. Mfd.	Type Container	Size Inches	List Price
A9550	5-25-5	Cd'bd. Box	1 5/8 x 1 5/8 x 2 9/16	$2.30

Cardboard Box Unit — Cartridge Unit — Inverted Can Unit

All condensers listed here are exact duplicates of original condensers employed in the various standard sets according to the manufacturers' part numbers. Voltage ratings of many units, however, are in excess of manufacturers' specifications where it has been deemed necessary to insure longer life and more satisfactory operation in service.

Additions to this list of replacement condensers will be made from time to time in accordance with the popular demand. We invite all service men and dealers to submit samples of condensers which have proven defective and which they would like to have genuine Aerovox replacements. When sending samples please furnish with each unit the make of the set, model number, condenser part number, capacity, voltage ratings, etc.

BEWARE OF SUBSTITUTES FOR AEROVOX PRODUCTS!



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The AEROVOX Research Worker

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The Proper Use of Condensers in High Voltage Filter Circuits

By the Engineering Department, Aerovox Corporation

IN the design and construction of rectifier filter systems the use of electrolytic condensers for relatively low voltage filter systems in the order of 400 or 500 volts maximum has become almost standard. For these voltages there is little question that electrolytic condensers meet the requirements of such filter circuits as well as any other type of filter condenser. At the same time the electrolytic condenser is cheaper and more compact.

However, the problem of what types of condensers should be used on higher voltage circuits has not been discussed in previous issues of the Research Worker to any considerable extent. Many readers have written us regarding this problem and hence this issue is devoted to a general discussion of this subject of condensers for high voltage filter circuits.

Condensers for filter circuits are of three types. These three types are the electrolytic condenser, the wax condenser and the oil condenser. The following discussion will, we hope, serve to indicate the essential problems connected with the use of these types of condensers.

In the case of electrolytic condensers where voltages higher than 400 or 500 volts are required, the practice is to connect several condensers in series to obtain a combination capable of withstanding higher voltages. The usual practice is to use for this purpose standard 450 volts working voltage 525 volts surge peak condensers, and to figure on the basis of allowing one extra condenser so as to reduce the voltage across the condensers. For example, for 1000 volts, three condensers should be used in series; for 1500 volts, four condensers would be used in series, and etc.

The problem of using a series combination in this manner naturally raises the old problem that always arises when condensers are connected in series across a source of direct current. If several condensers of

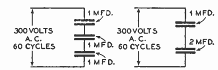

FIG. 1 FIG. 2

equal capacity are connected across a.c. voltage then the voltage divides evenly among the several condensers. For example, if three 1 mfd. condensers are connected across 300 volts a.c. then there will appear across each condenser 100 volts. The important point is that the division of voltage, when a series group of condensers are connected across a.c., is determined purely by the capacity of the individual section, and the only time the voltage division will be on equal is when the capacities are unequal. As an example of this take the case of a 1 mfd. condenser and a 2 mfd. condenser both connected in series across 300 volts. In such a case there would be 200 volts a.c. across the 1 mfd. unit and 100 volts a.c. across the 2 mfd. unit. Note that the voltage division is an inverse function of the capacity. The higher the capacity, the lower the voltage.

Although the reason why the a.c. voltage divides in this manner is probably known to most readers nevertheless, it might be worth while to indicate briefly why the a.c. voltage divides as it does in order that the difference between the division of the voltage on a.c. and the division of the voltage on d.c., to be discussed later, will be entirely clear.

Let us, therefore take a typical example and work it through. For example, suppose, as in Fig. 1, three 1 mfd. condensers are connected in series across 300 volts a.c. Assume that the frequency is 60 cycles. By referring to the chart given in the December 1931 issue of the Research Worker (Vol. 5, No. 1) it will be found that a 1 mfd. condenser has at 60 cycles a reactance of approximately 2600 ohms. If we work out this figure accurately it will be found that it is 2654 ohms, but for the purpose of our example, we will take the approximate figure of 2600 ohms obtained from the chart.

Since each 1 mfd. condenser has at 60 cycles a reactance of 2600 ohms then 3 in series will have a reactance three times 2600 or a total of 7800 ohms. The current flowing through the circuit will be equal to the voltage 300 volts divided by the reactance 7800 which gives a current of .0385 amperes.

The voltage across any one of the condensers will then be equal to the reactance of that condenser multiplied by the current. The voltage across any one of the condensers will therefore be equal to 2600 times .0385 which gives 100 volts. Since the same current flows through all the condensers, and furthermore since all the condensers have the same capacity, and therefore the same reactance, it is obvious that there will be 100 volts across each of the three condensers. This indicates that the voltage divides equally among the various condensers, provided they have the same capacity.

FIG. 3

Now let us take the case of unequal capacities, as shown in Fig. 2. Assume again that the source of voltage is 300 volts a.c. 60 cycles and that we have connected across this voltage one 1 mfd. condenser and one 2 mfd. condenser. The reactance of the 1 mfd. condenser as indicated above is 2600 ohms. By reference to the chart it will be found that a 2 mfd. condenser has one-half the reactance or 1300 ohms. This makes a total reactance of the two in series 3900 ohms. The current through the circuit will therefore be the voltage 300 volts divided by the total reactance 3900 ohms which gives a total of .077 amperes.

The voltage across the condensers will again as in the foregoing example be equal to the reactance of the condenser multiplied by the current. In the case of the 1 mfd. condenser this gives us 2600 x .077 or 200 volts. In the case of the 2 mfd. condenser we have 1300 multiplied by .077 or 100 volts. Note in this case that the voltage division is unequal and that the larger capacity has the lower voltage across it.

The above example indicates what happens when condensers are connected in series on a.c. When condensers are connected in series to a source of d.c. voltage the results are, however, entirely different.

In the case of direct current circuits the division of voltage bears no direct relation to the capacities of the condensers connected in series. In the case of series sections on d.c. the voltage across any one section depends entirely upon the insulation resistance of the condenser.

Let us work through a few examples for series sections on d.c., for in this way we can show most clearly the difference between series sections on d.c., and series sections on a.c. Suppose, we have three sections connected in series on d.c. as shown in Fig. 3 in which the three sections are marked C1, C2, and C3. In the case of d.c. operation we must take into consideration the insulation resistance of the condensers. Assume that the three condensers connected in series for this first example have the following characteristics:

UNIT	CAPACITY	INSULATION RESISTANCE
C-1	1 mfd.	1000 megohms
C-2	1 "	1000 "
C-3	1 "	1000 "

When these three series condensers are connected across d.c. the condensers immediately take a charge but after the initial charging current, the current drawn from the d.c. source will be determined by the insulation resistance of the three sections in series. In this case the insulation resistance of the three sections in series is 3000 megohms. The current through the circuit will therefore be

$$I = \frac{E}{R}$$

$$I = \frac{300}{3000 \times 10^6}$$

$$I = 0.1 \times 10^{-6} \text{ amperes}$$

Therefore, the current is 0.1 microamperes.

The voltage across any one section is equal to the insulation resistance of the section multiplied by the current. Since in this example the sections have the same insulation resistances the voltage across each section will be equal to the insulation resistance 1000 megohms multiplied by the current 0.1 microamperes. This gives

$$E = IR$$

$$= 0.1 \times 10^{-6} \times 1000 \times 10^6$$

$$= 100 \text{ volts}$$

Therefore, in an example of the type given each section will have 100 volts across it, and the voltage will divide equally.

However, in the manufacture of paper condensers the procedure is to check the capacity to be sure that it is within tolerance and to then check the insulation resistance to make certain that it is above a certain minimum value. For example a 1 mfd. condenser might have an insulation resistance of 1000 megohms or it might, as an example have an insulation resistance of 2000 megohms. Both condensers would be considered entirely satisfactory. Suppose, however, we connected three condensers in series which have the following characteristics.

UNIT	CAPACITY	INSULATION RESISTANCE
C-1	1 mfd.	1000 megohms
C-2	1 "	1500 "
C-3	1 "	2000 "

In such a combination the total insulation resistance would be 4500 megohms, and if the voltage was 300 volts d.c. the current would be

$$I = \frac{300}{4500 \times 10^6} = 0.0667 \times 10^{-6} \text{ amp.}$$

The voltages across the individual sections will again be equal to the current 0.0667 microamperes multiplied by the insulation resistance. This gives the following values for the voltages across the sections.

UNIT	VOLTAGE
C-1	66.7 volts
C-2	100 volts
C-3	133.3 volts

It will be noted from the above that while, quite naturally, the total voltage adds up to 300 volts the voltage does not uniformly divide between the various sections due to the fact that the sections have unequal resistances.

Because of the above problem, and the fact that the voltage division may be even more unequal, unless proper care is exercised, it is desirable always to use condensers rated at the proper voltage, rather than for the user to make up a bank out of several individual condensers. If, however, several condensers are used in series then the precaution should be taken to connect across them a group of resistors as shown in Fig. 4. These resistors should have values as low as can be tolerated in the circuit.

These resistors should have values considerably lower than the probable insulation resistances of the condensers. In fact, in the case of paper condensers it will generally be possible in ordinary circuits to use a bank of resistors to give a current drain of 1 mil. This current, while small, is still much greater than the leakage current of the condensers, and the resistor will therefore serve to equalize the voltages.

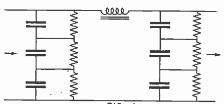

FIG. 4

As a typical example, in the case of a 1000 volt circuit the total value of the shunt resistance connected across the circuit will be 1 megohm, and the bank would consist of as many individual resistors (all equal in value) as there are condensers in series. For two condensers in series there would be two one-half megohm resistors; for three condensers in series there would be used 3 resistors in the order of 330,000 ohms each.

By using such an arrangement, the voltage will divide evenly and thereby greatly reduce the possibility of any condenser failures.

In a future issue of the Research Worker we will carry this discussion forward further with particular reference to the types of condensers especially designed for high voltage circuits.

Some Useful Data on A. F. Characteristics

The tables given below contain considerable information useful to workers in the field of audio engineering. One table indicates various important points in the frequency spectrum from 16 cycles up to 32,768 cycles. The other table indicates the peak audio frequency power developed by various musical instruments, played very loudly. These values for the maximum audio frequency output of musical instruments may be compared with the output of a violin played very softly which is 4 microwatts.

PEAK POWER OF MUSICAL INSTRUMENTS

(Fortissimo Playing)

INSTRUMENT	PEAK POWER, WATTS
Heavy Orchestra	70
Large Bass Drum	25
Pipe Organ	13
Snare Drum	12
Cymbals	10
Trombone	6
Piano	0.4
Trumpet	0.3
Bass Saxaphone	0.3
Bass Tuba	0.2
Bass Viol	0.16
Piccolo	0.08
Flute	0.06
Clarinet	0.05
French Horn	0.05
Triangle	0.05

NOTE	CYCLES PER SECOND	PIPE ORGAN	REMARKS
C^8	32,768		Beyond limit of audibility for average person.
C^7	16,384		Telephone silent with 40 volts on receiver terminals.
	10,000		
C^6	8,192	¾ in.	Considered ideal upper limit for perfect transmission of speech and music.
	5,000		Highest note on fifteenth stop.
C^5	4,096		Considered as satisfactory upper limit for high quality transmission of speech and music.
E^4	2,560		
G^4	3,072		Highest note of pianoforte.
	3,000		Approximate resonant point of ear cavity.
C^4	2,048		Considered as satisfactory upper limit for good quality transmission of speech.
	2,000		
	1,500		Maximum sensitivity of ear.
A^2	850		Mean speech frequency from articulation standpoint.
$A\flat^2$	800		
E^2	600		Representative frequency telephone currents.
A^1	426⅔		
C^1	256		Orchestral tuning. See note below.
	200		Considered as satisfactory lower limit for good quality transmission of speech.
C^0	128		
	100		Considered as satisfactory lower limit of high quality transmission of speech and music.
E_0	80		
C_0	64	8 ft.	Lower note of man's average voice. Lowest note of 'cello.
B_1	60		
C_1	32	16 ft.	Lowest note of average church organ.
	30		Considered ideal lower limit for perfect transmission of speech and music.
A_2	27		Lowest note of pianoforte.
G_2	25		
C_2	16	32 ft.	Lowest audible sound. Longest pipe in largest organ.

Notes of the "Gamut"	C	D	E	F	G	A	B	C
Vibration frequencies proportional to	1	9/8	5/4	4/3	3/2	5/3	15/8	2
Intervals between successive notes	9/8	10/9	16/15	9/8	10/9	9/8	16/15	

NOTE: Nearest note is indicated. Scale based on Middle C^1 (Physical Pitch)=256 cycles.