Chemical Condensers of Large Capacity

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"B" Battery eliminators require fixed condensers of several microfarads capacity for filtering purposes. In this article some interesting chemical condensers of large capacity are described.

THE extensive use of "A" and "B" battery eliminators for the radio set has created an enormous demand for filter condensers, of several microfarads capacity and capable of withstanding test voltages up to 500, which are usually made of sheets of tin foil separated by waxed paper. Such condensers were used in telephone circuits long before radio broadcasting started; but before machinery was perfected for manufacturing waxed paper condensers, chemical condensers were used, having been brought to a high state of perfection in the early days of telephony.

Due to lack of proper constructional data, experimenters have had little success with their use in filter circuits of "B" eliminators; but when properly made one will give surprisingly good results. While its use may not be practical in a commercial "B" eliminator, the chemical condenser may be highly recommended to the experimenter who builds his own and is familiar with its care and operation.

Certain metals, such as aluminum, magnesium, and tantulum, when immersed in an electrolyte, possess the property of allowing electricity to flow in one direction and not in the other, provided a certain critical voltage is not exceeded. Two electrodes of this kind practically prevent all flow of electricity and constitute what is known as an electrolytic or chemical condenser. This phenomenon was discovered by Wheatstone in 1855.

THE "RECTIFYING" ACTION

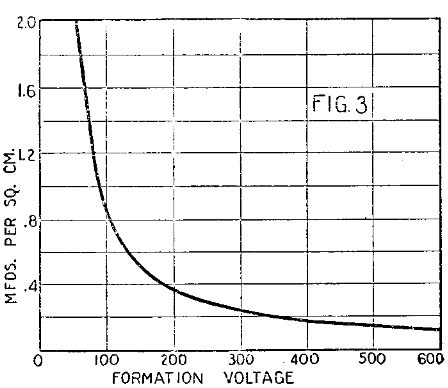
If an aluminum plate and a lead plate, in a solution of borax in water, are connected to an alternating current line (Fig. 1), an oxide or hydroxide film, covered by a thin gas layer, will gradually form on the aluminum plate. This film is an insulator of electricity, and when the aluminum is the anode or positive plate, current will not pass through it. It may be observed, however, that myriads of fine electric sparks dance all over the surface of the aluminum anode; these are caused by electricity jumping through small "pin-holes" in the film, the instant the aluminum plate becomes positive, forming what is called the "leakage current." Its flow almost instantly builds up the film which stops further flow of electricity. The leakage current therefore flows only at the beginning of each positive cycle.

When the lead plate is the anode, current flows from the lead plate, through the electrolyte and through the pin-holes in the film, to the aluminum plate. When the current flows in this direction, instead of sealing up the holes, it decomposes the film around them, and they open up wider, like a camera shutter, and allow more current to pass. The pin-holes thus act like small valves, opening up when the current flows from the electrolyte to the aluminum, and closing when it flows from the aluminum to the electrolyte. The device therefore serves as a rectifier, possessing a greater resistance to electricity in one direction than in the other. Its use as a rectifier has been limited commercially, partly on account of the loss of energy due to the leakage current mentioned above.

It has been determined that the greatest frequency, of the opening and closing of the pin-holes in the film, is in the neighborhood of 1/1100 of a second. Consequently an electrolytic rectifier will not function in a radio-frequency circuit. It cannot be used as a detector.

USE AS A CONDENSER

When the electrolytic cell (Fig. 1) is connected to a D.C. line with the aluminum plate as anode (Fig. 2) a uniform film, without pin-holes, is formed over the entire submerged surface of the aluminum plate, and reduces the current flow to almost zero. There is no leakage current caused by sparking, as when the cell is used for a rectifier.



Curve showing the variation of capacity with formation-voltage of a chemical condenser, using aluminum plates.

A small leakage current flows from the aluminum plate at its contact with the surface of the electrolyte, but this can be reduced to a negligible amount by making the surface line very short and insulating the aluminum plate where it enters the liquid. When so constructed the cell forms a very good condenser. The film acts as the dielectric. If worked below the critical voltage the film will not puncture. If the film is accidentally punctured, it immediately heals up again.

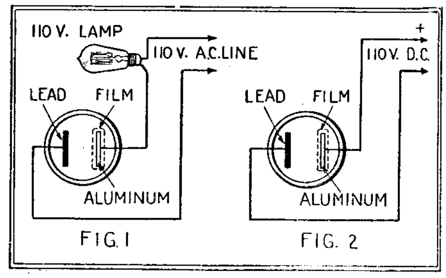


Fig. 1, connections of an electrolytic rectifier to an A.C. line. A lamp is used to limit the current flow. Fig. 2 shows the rectifier connected to a D.C. line.

The critical voltages for aluminum plates in electrolytes formed by 1 per cent. solutions of various chemicals, tested after 24-hour formation of the film, are as follows:

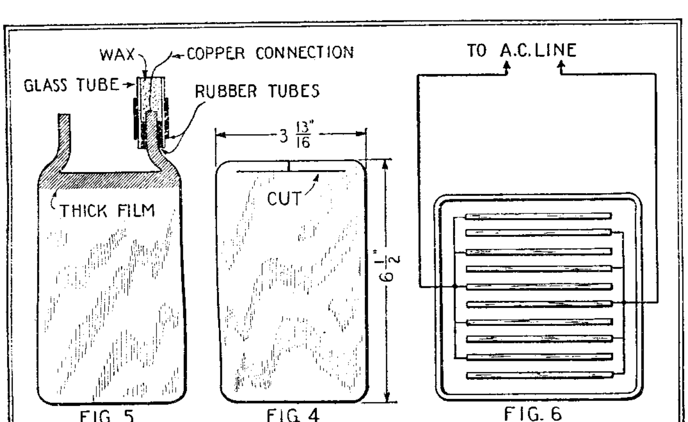
Sodium Sulphate (Na_2SO_4)	40
Potassium Permanganate ($KMnO_4$)	112
Ammonium Chromate ($[NH_4]_2CrO_4$)	122
Potassium Cyanide (KCN)	295
Ammonium Bicarbonate (NH_4HCO_3)	425
Sodium Silicate (Na_2SiO_3)	445
Ammonium Phosphate (NH_4HPO_4)	460
Ammonium Citrate ($C_3H_4OH[CO_2NH_4]_3$)	470
Sodium Biborate, "Borax," ($Na_2B_4O_7$)	480

To obtain the large capacities required for "B" battery eliminator circuits, we must use very large plates or a very thin dielectric. The electrolytic condenser, on account of its extremely thin gas-film dielectric, has an enormous capacity when only small plates are used. C. I. Zimmermon found that the thickness of the film is between 1/50,000 and 1/500,000 of an inch, depending upon the formation-voltage. The dielectric constant of the film is about 10, so that a capacity of ¼- to ½-mfd. per square inch of electrode surface is easily obtained.

The capacity of the electrolytic condenser depends only upon the voltage of formation and the material of the anode, and is independent of the nature of the electrolyte. Fig. 3 shows the variation of capacity with formation-voltage when using an aluminum anode. Note that the lower the formation-voltage the greater the capacity. A low formation-voltage produces a thin film and high capacity; a high formation-voltage produces a thick film and low capacity. In passing from a low to a high formation-voltage, the thickness of the layer increases and assumes its new value in a few minutes; in passing back to a lower voltage, it requires months before the gas layer assumes its former thinness.

BUILDING A LARGE CONDENSER

Dr. Gunther Schulze describes an interesting electrolytic condenser in the *Electro-chemical and Metallurgical Industry, Vol. VII*, page 216. The condenser is made up of ten aluminum plates 3 13/16x6½x1/25 inches, cut as shown in Fig. 4 and the lugs bent up (Fig. 5) to form the connections. The lugs and about half an inch of the top of the plates were placed in a saturated solution of ammonium borate, and a thick film formed at 500 volts, as indicated by the shaded area in Fig. 5. The purpose of this film is to help insulate the plate where it meets the surface of the electrolyte in the



Constructional details of a chemical condenser. Fig. 4 shows how the aluminum plate is cut and bent up to form lugs, as in Fig. 5. Fig. 6 shows the connections of the finished condenser, for use in an A.C. circuit.

finished cell. Small copper connecting wires are fastened to the ends of the lugs. A rubber insulating tube is placed over the lug, over which is placed a glass tube, and the space between is filled with sealing wax. Another rubber tube is then placed over the whole.

The total effective area of the ten plates is 503 square inches, and the length of the boundary lines 3 inches. The residual current, or leakage current, at 110 volts was .0005 amperes, which leaked through the insulation at the boundary line. The distance between the plates was about 3/16 of an inch. In this condenser, five plates were used for each side of the circuit; and as each set of plates is of aluminum, it makes no difference which way the condenser is connected in the circuit. The following table shows the measured capacities with different formation-voltages:

Formation-voltage	$\mu f.$ Capacity
40	147.7
80	73.1
132	44.0
160	37.7

Dr. Schulze's condenser is made up of ten plates, five for each side of the line, as shown in Fig. 6. This type of condenser is required for alternating current circuits. For filter circuits in "B" eliminators, where the current is not alternating but pulsating direct, we can connect all of the plates to the positive side of the line, and the electrolyte to the negative side by means of a small strip of lead dipping into it, as clearly shown in Fig. 7. This arrangement will give twice the capacity obtained with five plates on each side of the line. Therefore, instead of 147.7 microfarads at a formation-voltage of 40, the capacity is 295.4 microfarads.

It seems inconceivable that such a small device should give a capacity of nearly 300 microfarads. Think what it would cost to build a waxed-paper condenser of 300 microfarads—almost one dollar per microfarad.

UTILIZING THE CHEMICAL CONDENSER

Of course this capacity is obtained only provided the condenser is not used on voltages higher than 40—the forming voltage. If formed on 20 volts or less the capacity will be considerably greater; the condenser would then probably be suitable for filtering current in "A" eliminator circuits, where the voltage is not over 10. A capacity of 600 to 700 microfarads can be obtained at this low formation-voltage.

Extensive tests were made on the condenser described above; and it was found that for maximum efficiency the voltage at which the condenser is used should not exceed 90.

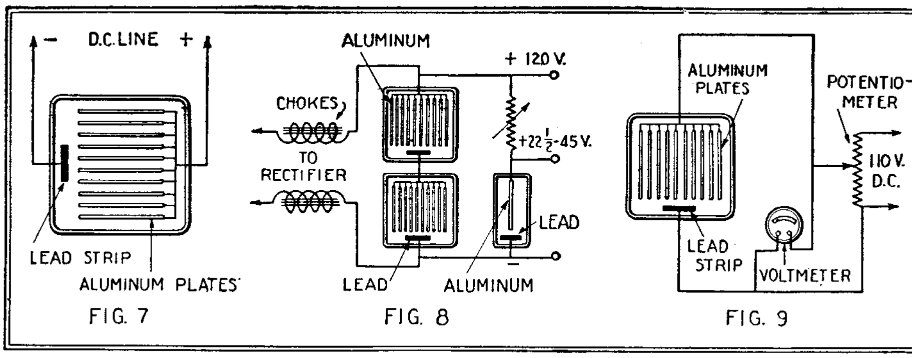


Fig. 7 indicates the connections of the chemical condenser for a D.C. circuit. A lead strip is used for the cathode. Fig. 8 shows the connections of a "B" eliminator filter circuit and Fig. 9 the connections for "forming" the plates.

For higher voltages two or more condensers should be connected in series. In "B" eliminator circuits the voltage seldom exceeds 150. Therefore two of these condensers should be used, connected in series. If the film on each condenser is formed at 75 volts, each will have a capacity of about 160 $\mu f.$ Connecting them in series, the total capacity across the two will be about 80 $\mu f.$, much greater than is necessary for a "B" filter circuit. The connections of the two condensers in series are shown in Fig. 8, with a complete filter circuit.

The experimenter who desires to build an electrolytic condenser should select a pure grade of commercial aluminum, either extra pure or No. 1, which is about 99.55 per cent. pure, with a slight amount of silicon and iron. The plates should be cut as shown in Figs. 4 and 5, and thoroughly cleansed in hot water. For the electrolyte a saturated solution of borax, to which a small amount of glycerine is added, may be used. The negative terminal of the condenser may be a strip of lead dipping into the electrolyte, and the whole placed in a glass storage battery jar. As aluminum cannot be soldered with the ordinary low-temperature lead solders, connections may be made to the plates by means of small screws and nuts. By taking extra care to insulate the aluminum lugs at the surface line of the electrolyte the leakage current will be reduced to a minimum and the efficiency will be very high. The condensers will not draw a heavy load from the rectifier tubes.

To form the film on the plates, the connections shown in Fig. 9 should be used. The voltage at which the condenser is to be used should first be determined, and the forming-voltage should be a little greater; if the condenser is to be used on an A.C. circuit, it should be greater than the maximum value of the A.C. voltage. If the 110-volt D.C. line is not available, a set of "B" batteries may be used to form the film. The current consumption is low and will not ruin the batteries. It is best to leave the forming-voltage on about ten hours. When using a 110-volt D.C. lighting line, a 400- or 500-potentiometer and a voltmeter are desirable, as shown in the figure. By starting with the potentiometer arm at the bottom, at zero voltage, and gradually swinging it up until the proper voltage is applied, the film will slowly thicken as the voltage increases, and a minimum amount of current will be drawn from the line.

One of the main reasons why chemical condensers and electrolytic rectifiers have not been more popular is the sloppiness of the liquid electrolyte. Perhaps some experimenters may overcome this disadvantage by using some form of jelly or fused electrolyte. Fused sodium phosphate has been used for the electrolyte of an aluminum cell rectifier with very good results. It would seem that much better efficiency would be obtained when using the rectifier for "B" eliminators, because the current used is much less than for charging batteries.

Storage batteries with jelly electrolyte have been made to give fairly good results. The experimenter who wishes to work along these lines may use sodium silicate, commonly known as water glass, for making the jelly electrolyte, to which the acid may be added. However, it shrinks away from the plates and of course increases the internal resistance of the cell, which may become entirely open-circuited.

We should be pleased to hear from experimenters who have had any great success with solid electrolytes.