R. D. MERSHON.

ELECTROLYTIC CONDENSER.

APPLICATION FILED OCT. 27, 1909. RENEWED MAY 29, 1913.

1,077,628. Patented Nov. 4, 1913.

2 SHEETS—SHEET 1.

Fig. 1

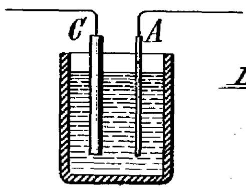


Fig. 2

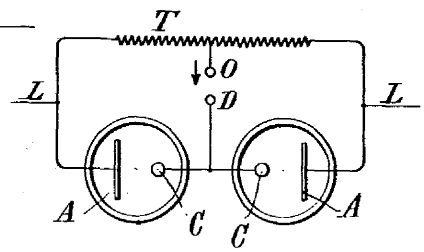


Fig. 3

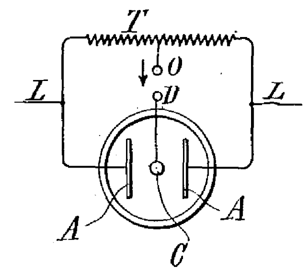


Fig. 4

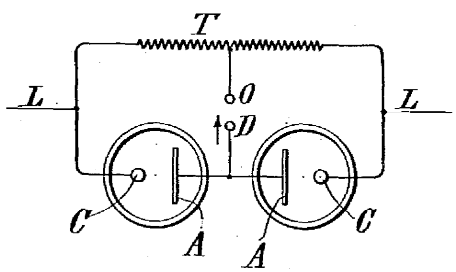


Fig. 5

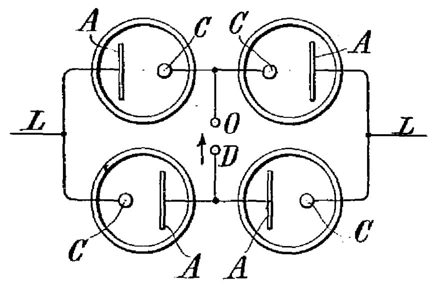


Fig. 6

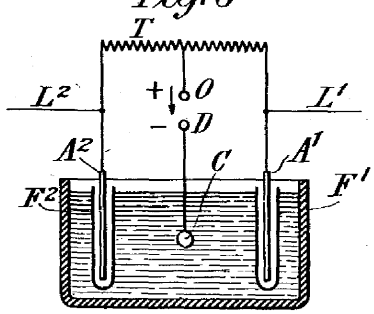
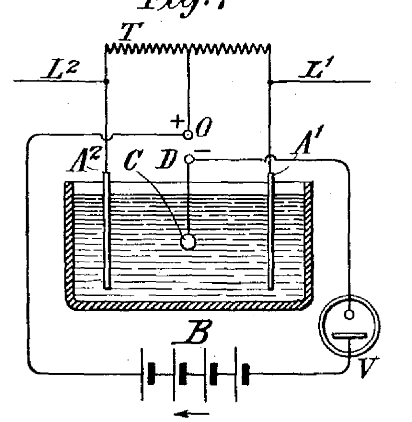


Fig. 7



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2 SHEETS—SHEET 2.

Fig. 8

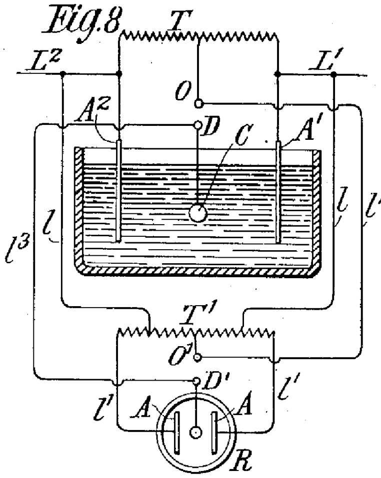


Fig. 9

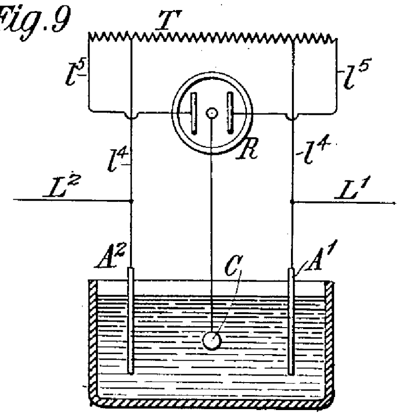


Fig. 10

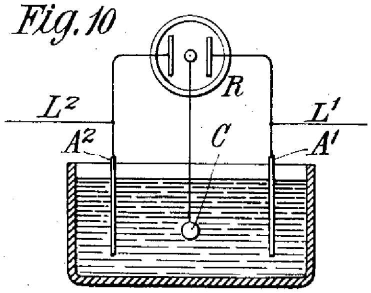


Fig. 11

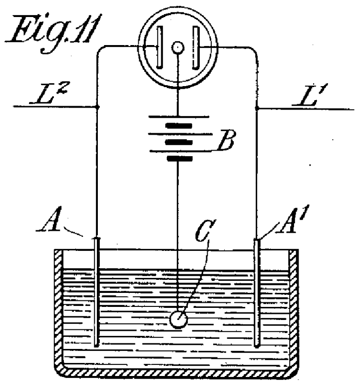


Fig. 12

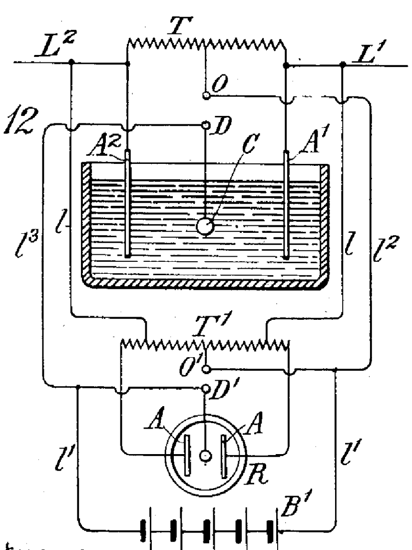
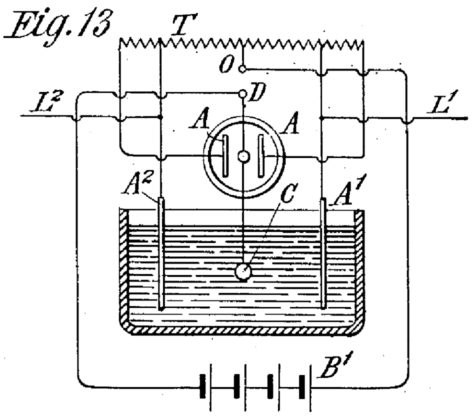


Fig. 13



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UNITED STATES PATENT OFFICE.

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ELECTROLYTIC CONDENSER.

1,077,628. Specification of Letters Patent. **Patented Nov. 4, 1913.**

Application filed October 27, 1909, Serial No. 524,874. Renewed May 29, 1913. Serial No. 770,792.

To all whom it may concern:

Be it known that I, Ralph D. Mershon, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electrolytic Condensers, of which the following is a full, clear, and exact description.

Urgent need of an efficient condenser for use in connection with electric motors, generators, and other apparatus has long been felt, and numerous efforts have heretofore been made to provide such a condenser; but so far as I am aware none of these efforts has resulted in practical success. The so-called electrolytic condenser is attractive in theory, but it is found in practice that its efficiency, which may be high at starting, falls off very rapidly, a few hours use being sufficient in many cases to cause serious impairment. I have therefore been led to devise my present invention, which has for its chief object to improve this type of condenser, so that it may operate indefinitely with the highest efficiency.

To this end the invention consists in the novel features and combinations of elements hereinafter described, and more particularly set forth in the appended claims.

Referring now to the annexed drawings, which are largely diagrammatic in character, Figures 1, 2, 3, 4 and 5 illustrate various types of electrolytic "rectifiers," by which uni-directional or direct current can be obtained from alternating current. Fig. 6 illustrates a simple electrolytic condenser; and Figs. 7, 8, 9, 10, 11, 12 and 13 show various embodiments of my present invention.

The electrolytic condenser, like the electrolytic rectifier, depends for its action upon the properties of the film which may be formed electrolytically upon the surface of aluminum, tantalum, magnesium and other metals when immersed in certain electrolytes and subjected to the electric current. Inasmuch as the electrolytic rectifier is concerned in my invention, and as its explanation leads up to that of the condenser, it will be first described.

Suppose, as in Fig. 1, a plate A of aluminum, magnesium, or other suitable metal, and a plate or rod C of carbon, iron, or other material suitable for the purpose, be immersed in an electrolyte consisting of a solution of borax, sodium or ammonium phosphate, citric acid, or other suitable chemical. If a direct current E. M. F. of small value be impressed upon this pair of electrodes in such direction that the current will flow from A to C, a current will flow at the instant of closing the circuit but its value will fall, at first rapidly and then less and less rapidly, always approaching a definite limit, which limit has a value approximating zero, or at any rate has a very low value. If after the current has ceased to fall rapidly the E. M. F. be raised the current will take a jump coincidentally therewith, again rapidly falling toward a limiting value. By increasing the E. M. F. in this manner, that is, by small steps, higher and higher voltage may be impressed without any great amount of current being transmitted, until a certain critical voltage is reached above which increase of voltage will cause large and permanent increase of current. On the other hand, if the E. M. F. had throughout the experiment been impressed on the electrodes in such direction as to cause the current to flow from C to A, no such action as that described would have taken place; large currents, approximately proportional to the E. M. F., would have flowed at all times, accompanied by corrosion of the electrode A.

On investigating the cause of the action first described, it is found to be due to a film which is formed on the aluminum electrode A. That is, the metal has not been corroded, or at any rate has been corroded only to the extent of forming a coating or film which protects it from further corrosion. It is found that the thickness of this film is proportional to the E. M. F. used in forming it; in other words, the higher the E. M. F. (so long as it is below the critical E. M. F. or voltage at which the film is no longer able to exercise its protective action) the thicker will be the film. In what follows it is assumed that such a film as that described has been formed upon the aluminum electrode, or electrodes, as the case may be. Without entering into the question of how or why this film is formed, what it consists of, or to what its various properties are due, it is found to possess the following characteristics: (*a*) It is very thin; so thin that it shows interference colors. (*b*) It has high specific inductive capacity. (*c*) It has, subject to the exception noted under (*d*) below, high specific resistance and dielectric strength, so that in spite of its excessive thinness it will withstand very considerable voltages without rupture, and with a very inconsiderable amount of leakage current. (*d*) The properties under (*c*), and perhaps under (*b*), are conditioned upon the voltage acting on the film always from the aluminum electrode toward the electrolyte. That is, the aluminum electrode must always be positive toward the electrolyte, for the film possesses the very remarkable property of having very little if any resistance and dielectric strength toward electromotive forces acting from the electrolyte toward the aluminum. In other words, the firm will allow currents to pass from the electrolyte to the aluminum with comparatively little opposition but will strongly oppose any currents tending to flow from the aluminum to the electrolyte. (*e*) The film has the further property that if a current has flowed from the electrolyte to the aluminum, producing, as it does, minute holes or perforations in the film for its passage, a reversal of the current, causing the flow to be from the aluminum to the electrolyte, will, in a very minute period of time, heal up these holes by re-forming the film over them. This perforation (effected mechanically or by some electro-chemical action) and reformation of the film means expenditure of energy, part of it appearing in the form of heat (C^2R) and part being accounted for in the electro-chemical action necessary to re-form the film.

From the foregoing it is clear that a device such as that shown in Fig. 1, which is commonly known as an "electric valve," will allow current to pass in one direction but will oppose current tending to flow in the other direction. Hence if such a device be put in series with a source of alternating current having a maximum value of E. M. F. equal to or below the proper operating voltage of the valve it will alternately transmit and suppress the impulses that come to it and might be used to charge a storage battery or do other useful work requiring uni-directional current. In other words, the valve so used becomes a rectifier. However, it utilizes only alternate half-waves, and hence the usual form of electrolytic rectifier is such a combination of electric valves as will permit the utilization of both halves of each wave. A combination for this purpose is shown in Fig. 2, in which T is an auto-transformer with a terminal O brought out from its middle point. A, A are the aluminum plates or filming electrodes connected to the main leads L, L, and C, C are carbon rods or non-filming electrodes both connected to a terminal D. (It may here be noted that in what has gone before the aluminum or other filming electrodes A may be plates, rods, or other forms, but inasmuch as in the condenser to be described later they are preferably plates, they will be so referred to hereafter. The carbon or non-filming electrodes C are most conveniently made in the shape of rods.) In Fig. 3 both aluminum plates are put in the same tank, with a single carbon rod, and in Fig. 4 the carbon rods, instead of the aluminum plates, are connected to the main leads. It will be understood, of course, that in these constructions, and in those described hereafter, the tank itself, if made of iron or other suitable material, may be used as the non-filming electrode. But for the sake of clearness I have shown an independent electrode (C) throughout the drawings.

Remembering that in these rectifiers current can flow freely from C through the electrolyte to A, it will be seen, on tracing the action in Figs. 2, 3 and 4, that if an alternating E. M. F. be impressed on the main leads a uni-directional E. M. F. will be produced between the terminals O and D, tending to produce a uni-directional current in the direction of the arrow in each case; the maximum value of the uni-directional E. M. F. being equal to the maximum value of the alternating E. M. F. wave. If the circuit be closed from O to D, as for instance through a resistance, the current and the E. M. F. will be pulsating; but if no current is allowed to flow the E. M. F. of open circuit will, as appears more fully hereinafter, be of constant value.

Fig. 5 shows a combination of the connections illustrated in Figs. 2 and 4, obviating the use of the auto-transformer and producing a uni-directional E. M. F. whose maximum value is equal to twice that of the alternating E. M. F. wave impressed upon the apparatus.

A device like that of Fig. 3 should, except for the asymmetrical properties of the films on the plates A, A, act like two condensers in series. This will be more clearly apparent by reference to Fig. 6, in which the films on the aluminum plates A′, A^2, are indicated graphically at F′, F^2. From this figure it is clear that the films, if they had symmetrical properties, that is, if they would not allow current to flow in either direction, would behave precisely like the dielectric of an electrostatic condenser; the aluminum and the electrolyte, (with the dielectric film between,) acting as the condenser plates. It is also evident that each aluminum plate A′, A^2, with its film and the adjacent portion of the outside electrolyte, would constitute an electrostatic condenser, and that the two would be in series. However, the films are not symmetrical in their properties; but nevertheless the rectifier shown in Fig. 6 does act as a condenser, though in a somewhat different fashion than would be the case if the films were symmetrical. The mode of action is as follows:

Suppose the apparatus of Fig. 6 be fed by alternating current through the leads L′, L^2, and suppose a positive impulse to come in on lead L′, rising from zero to its maximum. As the value of the E. M. F. rises from zero, the potential of the plate A′ become increasingly positive with respect to the electrolyte, since practically no current can flow from A′ to the electrolyte. At the same time the electrolyte becomes positive with respect to A^2, or would become so were it not that the film F^2 allows current to pass from the electrolyte to A^2 and out into the circuit. When the positive impulse coming in on the lead L′ has reached its maximum value we have therefore the condition that in the condenser constituted by A′, the dielectric film F′, and the electrolyte around the film, there are bound on the plate A′ a plus charge and on the electrolyte next to the film a minus charge, the magnitude of the charges being proportional to the capacity of the condenser formed by A′, F′, and the electrolyte, and to the maximum value of the E. M. F. between the points L′ and L^2. It is evident that the charge is proportional to the maximum E. M. F., that is, that the maximum E. M. F. exists between A′ and the electrolyte just outside the film, because through the breaking down or perforation of the film F^2 the plate A^2 is electrically in contact with the electrolyte.

Now let the positive maximum on L′ begin to fall toward zero. As it falls the positive charge on A′ is diminished, setting free a portion of the negative charge bound on the dielectric surface of the film F′ and lowering the potential of the electrolyte with respect to A^2. But no current can flow from A^2 to the electrolyte, so that as the positive half-wave coming in at L′ diminishes from its maximum, the potential of the electrolyte with respect to A^2 continually decreases. Finally, when the positive half-wave coming in at L′ has fallen to zero, making L′ and L^2 at the same potential, the whole of the negative charge which was bound in the electrolyte on the outside of F′ has divided between the portions of electrolyte adjacent to the film surfaces F′ and F^2, inducing upon the plates A′ and A^2, which are now at the same potential, positive charges each of half the value of that which existed on A′ at the time the positive impulse was a maximum. The result is that the difference of potential between the plates A′ and A^2, on the one hand, and the electrolyte on the other is equal to one-half the maximum of the E. M. F. wave and is in the direction indicated by the arrow and the algebraic signs at the points O and D.

If succeeding impulses of the alternating current wave be followed through, it will be found that the electrolyte will always be negatively charged with respect to the plate; that if for any reason the original charge is diminished it will be replaced in consequence of the perforation of one or the other of the films after the manner described above and flow of current from the electrolyte toward a plate. On the other hand, so long as the original charge persists, there will be no tendency for the current to flow from the electrolyte to a plate. If the film had such high resistance or dielectric strength as to make it impossible for any current ever to leak from a plate to the electrolyte, no perforation of a film would occur after the first perforation necessary to give the electrolyte its negative charge.

The perforation of the films means, as previously stated, increased loss, and therefore decreased efficiency and increased heating. Aside from the question of efficiency, the increased heating is a serious matter in that the films are very sensitive to temperature; in fact, their temperature must be kept below certain values in order to have them effective at all. But there is another and even worse consequence of the perforation, and that is that the film will gradually deteriorate, allowing more and more leakage and therefore necessitating more and more perforation to maintain the charge in the electrolyte. In other words, the more the perforation the worse the film will become, and the worse the film becomes the more the perforation.

In proof of the existence of the negative charge in the electrolyte it may be stated that if at any time an operating condenser be disconnected from the circuit, its plates connected by a lead and a voltmeter be connected to this common lead and to a carbon rod immersed in the electrolyte, there will be a discharge through the voltmeter from the plates to the electrolyte; the initial reading of the voltmeter corresponding to the voltage which it indicated between the points O and D while the condenser was in operation. As previously stated, this voltage between the points should, theoretically, and if no current is drawn from O and D, be of constant value and equal to half the maximum value of the alternating E. M. F. Due, however, to minor effects and polarizations in the cell, as well as to the current taken by the voltmeter, the voltage between O and D as measured by a voltmeter is usually about ten percent less than that indicated by theory.

As evidence of the deterioration of the cell due to perforation brought about by the loss of the charge of the electrolyte, consider an experiment such as has been frequently made with different cells. A condenser was prepared and the films were formed with alternating current, the forming voltage being 220. It was then operated at 125 volts, at which voltage its power factor was .04, corresponding roughly to an efficiency of about 96%. After 26 hours the power factor had increased to .082, and after several days it had increased to about .19 and the plates showed marked pitting and corrosion. A similar condenser operated after the manner described hereinafter holds its power factor constant, or if anything the power factor slightly diminishes.

My present invention attacks the problem of the electrolytic condensers from the standpoint, so to speak, of the charge in the electrolyte, and it consists, briefly stated, in the provision of means for maintaining such charge without concurrent perforation of the films by current from the electrolyte to the plates. In this way, the evil effects before described as due to perforation of the films are eliminated and the condenser continues to operate with unimpaired efficiency.

In Figs. 7 to 13 I have illustrated various convenient and effective methods for maintaining the negative charge in the electrolyte in accordance with my invention. Fig. 7 shows an electrolytic condenser in all respects like that of Fig. 6, but with a source of uni-directional current, such as a battery B, connected, as shown, so as to oppose the potential normally existing between O and D. If the E. M. F. of the source B is less than the voltage existing between O and D the condenser will operate as a rectifier and will charge the battery. This, of course, will mean perforation of the films, and will occur if at any time the alternating E. M. F. between the leads L′ and L^2 be raised to such value that the voltage produced thereby between O and D is greater than that from the battery B. In order to guard against this contingency, an electric valve may, if desired, be inserted in circuit with the battery, by making the rod or electrode C of aluminum or other suitable film-forming material, but it is preferable to have the valve separate from the condenser, as at V. If the voltage of the battery is just equal to that produced between the points O and D by the alternating current supplied to the apparatus, no current will flow from or to the battery unless the negative charge leaks away from the electrolyte, in which case current will flow from the battery in sufficient amount to replace the charge or the part of the charge so lost; thus obviating the necessity or possibility of perforation of the film. However, in order to certainly insure this result the voltage of the battery should be slightly in excess of that produced between O and D by the alternating current impressed upon the apparatus.

If the voltage of the battery B is greater than that generated between O and D, the voltage acting on each film and tending to produce leakage from the plate to the electrolyte will be increased by the excess; and the voltage waves between film and electrolyte, tending to produce leakage, will be the resultant of this excess and the impressed alternating E. M. F. waves. The result will be a slightly increased leakage and a tendency for the film to thicken, up to a thickness corresponding to the maximum of the resultant voltage; unless in the process of formation it has previously been formed to this voltage, in which case it will be maintained at this thickness against the dissolving action which takes place in some electrolytes if the film is operated at a lower voltage than that at which it was formed.

If it is desired to have always on the condenser a direct current voltage in excess of the potential generated between O and D, no matter how the values of the alternating E. M. F. may be varied through such range as might be permissible on the condenser, then the battery voltage will have to be in excess of the voltage generated between O and D, when the impressed alternating E. M. F. is raised to the upper extreme of the range over which the requirements of operation cause it to be varied. This means that at lower alternating voltages the leakage through the films would be higher than there is any necessity for. In other words, it would be desirable to have the external voltage (which may be conveniently termed the exciting voltage) vary as the impressed alternating E. M. F. varies, the ratio between the two remaining constant. Under such conditions the exciting voltage could be adjusted to a little above that generated between O and D. It would then always remain at this relative value, and we should always have the necessary excitation with a minimum leakage loss. The exciting voltage can be made to vary after this manner by any suitable means.

In order to accomplish the results desired it would not be absolutely necessary to have the exciting voltage on the condenser at all times; it might be put on and off intermittently, being left on each time long enough to charge the cell and put back again before the charge has fallen below the requisite value. This applies both to an exciting E. M. F. which is constant, and to a pulsating one as described below.

In order to secure the necessary excitation for the condenser it is not necessary to employ a uniform E. M. F., as a pulsating E. M. F. will, under most conditions, answer the purpose. Such pulsating E. M. F. may be obtained in any convenient way, as by means of an electrolytic rectifier such, for example, as shown in Figs. 2, 3, 4, and 5. For instance, the arrangement shown in Fig. 8 may be used. In this figure R designates a small electrolytic rectifier (which for convenience may be termed an exciter rectifier), having impressed upon it a voltage somewhat higher than the main voltage. This higher voltage may be conveniently obtained by means of an auto-transformer T′, taking current from the leads L′, L^2 through the taps l, l, and delivering current to the plates A, A through the taps l', l'; the points O and O′, and D and D′, being connected by the conductors l^2, l^3 respectively. Tracing now the operation of the arrangement illustrated in the figure just mentioned, it will be seen that the E. M. F. generated between O and D is opposed by E. M. F. derived from the main leads L′, L^2 through the instrumentality of the exciter rectifier R. The arrangement illustrated in Fig. 9 is analogous to that of Fig. 8, but in the former the main auto-transformer T is connected to the exciter rectifier R so as to perform the functions of both auto-transformers employed in Fig. 8. In Fig. 9 the value of the exciting voltage relative to that generated in the rectifier-condenser depends upon the relative positions of the taps l^4, l^4, and l^5, l^5, attached to the auto-transformer T. With the connections as shown, the exciting voltage will be in excess, by an amount dependent, as just stated, upon the relative positions of the taps.

The auto-transformer T can itself be eliminated, provided the films of the exciter rectifier are such as will undergo perforation at a lower voltage than those of the condenser. Thus in Fig. 10 the auto-transformer is omitted, the aluminum plates or filming electrodes of the exciter rectifier being connected directly to the leads L′, L^2 and the carbon rods or non-filming electrodes being connected together as in Fig. 9. The desired property of the exciter rectifier films of undergoing perforation at a lower voltage, may be brought about by the use in the exciter rectifier of an electrolyte which will produce a weaker film than is produced by the electrolyte in the condenser, or by operating the exciter rectifier at a higher temperature.

Instead of resorting to different electrolytes or higher temperatures, as explained above, the arrangement illustrated in Fig. 11 may be employed. This arrangement is exactly like that of Fig. 10, except that in Fig. 11 one or more cells of battery B are inserted in the connection between the carbon rods or non-filming electrodes, the E. M. F. of the battery being in such direction as to assist in the perforation of the films of the exciter rectifier.

Derivation of the exciting voltage from the main voltage by rectifiers or by rotary converters means that there would be no exciting voltage on the condenser when there was no alternating E. M. F. impressed on the apparatus. This might be a disadvantage, for the reason that some condenser films will dissolve if allowed to stand for any great length of time without current upon them. To obviate this a storage battery may be put in parallel with the device which supplies the exciting current, so that even when the exciting device is not supplying current the condenser will have excitation. This will mean, in the case where the exciting voltage is supplied from an electrolytic rectifier, that the films of both the condenser and the exciter rectifier will be maintained by the battery E. M. F. during the time when the alternating E. M. F. is not impressed upon the apparatus. An arrangement of this kind is illustrated in Fig. 12, which is exactly like Fig. 8 with the addition of a storage battery B′ connected to the points O′, D′, and having its E. M. F. in the direction indicated by the arrow. A modification of this type of apparatus is illustrated in Fig. 13, in which the single auto-transformer T is made to perform the functions of both the auto-transformers of Fig. 12. Where a battery is used in parallel with the rectifier, as for example in Figs. 12 and 13, it tends to smooth out the pulsating current and voltage of the rectifier. This smoothing-out effect might also be obtained by substituting capacity for the battery or by inserting reactance between O and D or between D and C.

In all the constructions in which electrolytic exciters are used, the operation of the condenser will involve corrosion of the aluminum electrodes employed in the exciter; but the consumption of these electrodes will be extremely slow, and since they may be relatively extremely small and cheap their replacement, whenever necessary, is a matter of small moment. Instead of being in the form of plates these electrodes are preferably thick rods, capable of lasting almost indefinitely; though in the drawings they are shown as plates so as to be more readily distinguished from the carbon rods. Instead of putting the exciter electrodes in the same tank with the condenser electrodes, as might be done, it is in general preferable to have them in a separate vessel, as shown, since in the former method there would be a potential existing between the exciter electrodes and the condenser.

From the foregoing it will be seen that the disastrous corrosion of the filming electrodes experienced in prior electrolytic condensers is in my invention either eliminated, as for example when a mechanical rectifier, rotary converter, or other electro-mechanical device is employed as the exciting means; or, when an electrolytic exciter is used, is transferred to this latter device, where such corrosion has no ill effects.

The arrangements specifically illustrated in Figs. 7 to 13 herein are given merely as convenient and effective embodiments of the invention, and it is to be understood that the same may be embodied in various other forms without departure from its proper spirit and scope.

What I claim is:

1. The combination with an electrolytic condenser, of a transformer connected to the condenser electrodes, means electrically connected with the transformer and the electrolyte to provide a unidirectional electromotive force opposing that between the electrolyte and the transformer, and an independent source of electromotive force in parallel with said means.

2. The combination with an electrolytic condenser, and means whereby uni-directional electromotive force will be generated between the electrolyte and the condenser electrodes, of a battery electrically connected with said means and the electrolyte to oppose said uni-directional electromotive force.

3. The combination with an electrolytic condenser, of a transformer connected to the condenser electrodes, a rectifier connected between the electrolyte and the transformer, and an independent source of current in parallel with the rectifier.

4. The combination with an electrolytic condenser, of a transformer connected to the condenser electrodes, an electrolytic rectifier electrically connected with the transformer and the electrolyte, and a battery in parallel with the rectifier.

5. The combination with an electrolytic condenser, of a transformer connected to the condenser electrodes, an electrolytic rectifier connected with the transformer and the electrolyte to provide a unidirectional electromotive force opposing that between the electrolyte and the transformer, and an independent source of electromotive force in parallel with the rectifier.

6. The combination with an electrolytic condenser, of a transformer connected to the condenser electrodes, a rectifier having a terminal electrically connected to the transformer and another to the electrolyte to provide a unidirectional electromotive force opposing that between the electrolyte and the transformer, and an independent source of electromotive force having a terminal electrically connected to the electrolyte and another to the middle point of the transformer.

7. The combination with an electrolytic condenser, of a transformer connected to the condenser electrodes, a second transformer having terminals connected to the condenser electrodes and its middle point to the middle point of the first transformer, an electrolytic rectifier having an electrode electrically connected to the condenser electrolyte and having filming electrodes connected to the terminals of the second transformer, and a source of electromotive force connected to the middle point of the second transformer and to the condenser electrolyte.

In testimony whereof I affix my signature in the presence of two subscribing witnesses.

RALPH D. MERSHON.

Witnesses:
M. LAWSON DYAR,
S. S. DUNHAM.