March 31, 1942. J. B. BRENNAN 2,278,161

ELECTROLYTIC DEVICE AND METHOD OF MAKING SAME

Filed Oct. 2, 1939

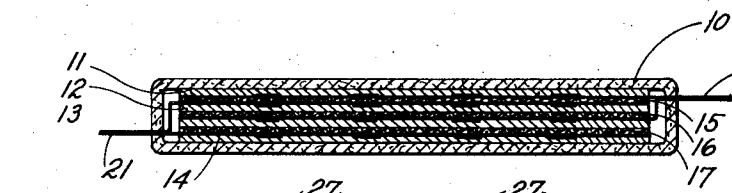



Fig. 1

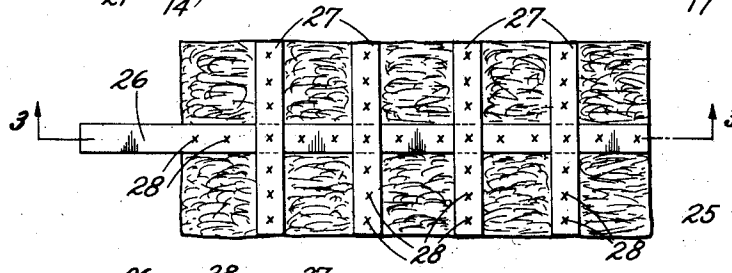



Fig. 2

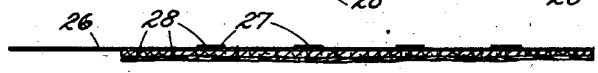



Fig. 3

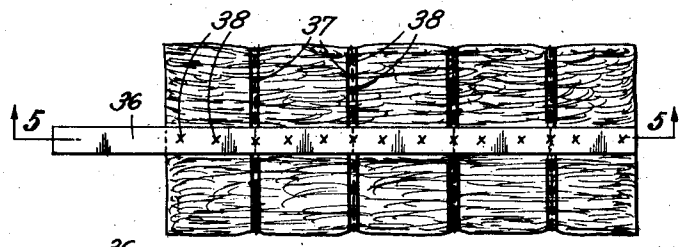



Fig. 4

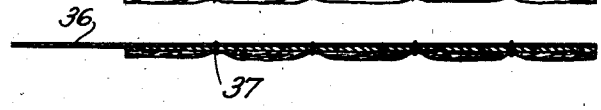



Fig. 5

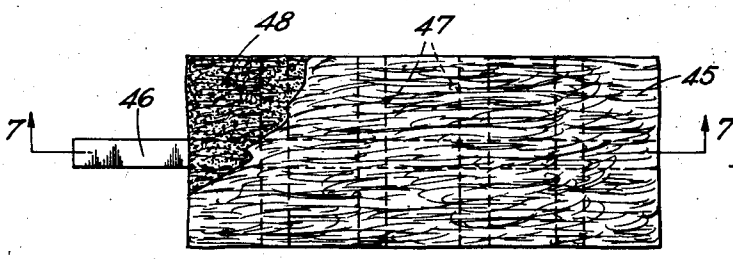



Fig. 6

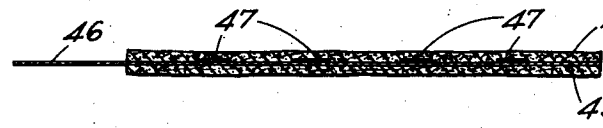



Fig. 7

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## ELECTROLYTIC DEVICE AND METHOD OF MAKING SAME

Joseph B. Brennan, Euclid, Ohio,

Application October 2, 1939, Serial No. 297,507

12 Claims. (Cl. 175—315)

This invention relates to electrolytic devices and more particularly to electrolytic devices such as condensers, rectifiers and the like wherein one or more of the electrodes is composed of film forming metal provided with an electro-formed dielectric film. This application is a continuation in part of my copending application Serial No. 275,481 filed May 24, 1939. The invention will be described herein with particular reference to electrolytic condensers of the dry or paste type embodying anodes composed of aluminum but it is to be understood that the invention may be applied to other types of electrolytic devices and to electrodes composed of other materials.

As pointed out in my copending application noted above electrolytic devices such as electrolytic condensers embodying one or more electrodes made up of accumulations or masses of fine metallic filaments, strands, or fibers, preferably intertwined, felted, bundled, bound, or matted together in the form of masses, mats or pads of metallic wool are highly advantageous in that in such form a small weight of metal has a very extended surface area. The result is that a condenser embodying such an electrode has a high capacity per unit of electrode mass and further such a condenser can be of compact form and can be economically manufactured.

The present invention relates to electrodes of this general type, i. e., constructed of metallic wool, and it is among the objects of this invention to provide an improved metallic wool electrode of very low resistance and of high efficiency. Another object is to provide electrodes, and particularly filmed electrodes, manufactured of aluminum alloys and which will have the desirable characteristics heretofore obtainable only with electrodes made of extremely high purity aluminum. A further object is to provide electrodes composed of metallic wool having increased effective surface area and capacity.

Briefly my present invention contemplates, in one of its aspects, the production of electrodes for electrolytic condensers from masses, mats or pads of metallic wool such as aluminum wool, the mats or pads being provided with one or more additional conducting members such as strips of foil or wires which are arranged to distribute the current throughout the condenser so that many of the strands, fibers or filaments of the metallic wool electrode are directly connected to such a conductor while substantially all of the filaments are in low resistance electrical circuit therewith, with the result that substantially all of the filaments operate efficiently, the resistance of the electrode as a whole is reduced, and its efficiency is increased. Preferably the individual filaments and the conductors are intimately bonded to each other as by welding or metal spraying. In any event a connection is made that will insure good electrical contact between the conductors and the filaments making up the metallic wool.

Heretofore it has been a quite general practice in the art to employ only aluminum of very high purity (for example, 99.8% pure) in the manufacture of filmed electrodes for electrolytic condensers. My invention not only contemplates the manufacture of electrodes from such high purity aluminum, but also contemplates the production of filmed electrodes from metallic wool composed of aluminum of lesser purity or of aluminum alloys and having the characteristics of low leakage and freedom from contamination ordinarily only found in electrodes of very high purity aluminum. When the metallic wool is made of an aluminum alloy such as "2S" for example, or of ordinary commercial aluminum, the wool is preferably subjected to an etching operation such as that described in my prior Patent No. 2,154,027 issued April 11, 1939. The etching operation is designed and intended as described in that patent to increase the surface area of aluminum and to remove surface impurities therefrom. However, in the case of aluminum wool the etching operation has an effect different from its effect on other materials such as aluminum foil or rods. In conjunction with the etching of aluminum foil or rods, it is desirable to use aluminum of the highest possible purity even though the etching operation does apparently operate to remove many of the surface impurities. However, according to my present invention aluminum alloys and aluminum of lesser purity can be employed with excellent results, the reason being, I believe, that the aluminum wool has such an extended surface area in comparison with its mass that the etching of the surfaces and apparent removal of the impurities from the surfaces of the fine filaments of the metal functions, in my opinion, to remove substantially all of the impurities from the entire mass of metallic wool. Whatever the reason may be, the result is that etched electrodes composed of aluminum alloy wool have excellent leakage characteristics and have the characteristics of durability and long life which heretofore have been obtained only by the use of electrodes made from aluminum of exceptionally high purity. Of course, the etching operation can also be applied to electrodes composed of aluminum wool of high purity, in which case the principal result is an increase in the capacity of the electrode.

Referring to the drawing, Figure 1 is a sectional view through a paste type of condenser embodying my invention; Figure 2 is a plan view of an electrode suitable for use in a condenser such as that illustrated in Figure 1; Figure 3 is a section through the electrode illustrated in Figure 2 as indicated by the line 3—3 of Figure 2; Figure 4 is a modified type of electrode also suitable for use

in the condenser shown in Figure 1; Figure 5 is a section as indicated by the line 5—5 of Figure 4; Figure 6 is a further modification of electrode which may be substituted for electrodes shown in Figures 2 to 5; and Figure 7 is a section through the electrode shown in Figure 6 as indicated by the line 7—7 on Figure 6.

An electrolytic condenser embodying a preferred form of my invention may take any convenient or conventional form and as shown in Figure 1, may comprise a suitable box or container 10 having electrodes 11, 12, 13 and 14 therein, the electrodes being separated from each other by suitable spacers 15, 16, and 17. Alternate electrodes are connected to a common terminal or lead, that is electrodes 11 and 13 are connected to terminal 20 while electrodes 12 and 14 are connected to terminal 21. The electrodes are pads or mats of metallic wool composed of a film forming metal such as aluminum. Both sets of electrodes are composed of such material and both are provided with dielectric films in a condenser intended for alternating current service. However, in a condenser intended for direct current service, only the electrodes comprising the anode need be dielectric filmed. The cathode in such a condenser may be of non-filming material such as copper, or if composed of aluminum filaments or aluminum foil the surfaces of the filaments or foil need not be filmed.

The fine filaments or threads of metal making up the pads may be produced by methods known to those skilled in the art for example by cutting off fine shavings from a metallic bar or tube. Preferably the filaments are of irregular cross section or at least are not round so that each filament will have a greater area per unit of mass than would be the case if the filaments were of round cross section. The filaments are all preferably very fine, the minimum cross sectional dimension being not greater than .005". In producing the filaments I prefer to employ a cutting oil or coolant which is maintained at a low temperature, preferably below 40° F. If the filaments are cut from a tube the coolant may be circulated through the interior of the tube during the cutting operation to further cool the material. I may use a mixture of kerosene and lard oil, for example, as a coolant and I find that by artificially cooling the oil the life of the cutting tools is prolonged and it is possible to produce filaments of greater length than can be produced by ordinary cutting methods.

The extensive surface of the filaments or strands may be provided with dielectric films in any desired manner known to those skilled in the art. For example, the electrode may be subjected to electrolysis as an anode in a suitable film forming electrolyte such as a solution of borax and boric acid. The film forming operation is continued until the leakage current is reduced to the desired low value at the maximum forming voltage, which is ordinarily somewhat in excess of the voltage for which the condenser is designed. Condensers of this type may be operated successfully under relatively high voltages, i. e., voltages of the order of 500 or 600 volts.

In condensers of the type illustrated in Figure 1 the electrodes are preferably impregnated with a suitable viscous or pasty film maintaining electrolyte, the urea formaldehyde electrolyte described and claimed in my Patent No. 2,095,666 being suitable. As those skilled in the art will appreciate, other suitable electrolytes may be employed.

The steps of forming the film and impregnating the electrodes with electrolyte are known to the art as applied to other types of electrodes and these steps per se form no part of my present invention which relates particularly to the electrodes. As shown in Figures 2 and 3, a suitable electrode in which efficient use is made of substantially all of the metal making up the electrode may comprise a pad of aluminum wool 25 having a conductor 26 extending longitudinally thereof and having an end portion projecting beyond the pad and constituting part of the terminals 20 or 21 shown in Figure 1. Preferably the conductor extends throughout the length of the pad and is crossed at intervals by supplementary transversely extending conductors 27. To insure a low resistance path for the flow of current from the terminal to substantially every part of the pad the conductor 26 is welded to the pad through substantially its entire length, preferably by closely spaced electric spot welds 28 indicated diagrammatically on the drawing. Further, the transversely extending conductors 27 are similarly welded to the conductor 26 and to the fibers or filaments of the pad with the result that many, if not substantially all, of the filaments are connected directly to a conductor and thus current may be distributed to the entire pad and substantially all of the filaments through short, low resistance paths, thus resulting in a low resistance electrode which will operate very efficiently.

In Figures 4 and 5 I have shown a modified form of electrode embodying a pad 35 and a longitudinally extending conductor 36 generally similar to the pad 25 and conductor 26 described above. However, in this modification the transverse conductors 37 comprise wires stitched through the pad and through the conductor 36 as shown particularly in Figure 5. To further increase the conductivity of the assembly the wires are preferably welded to the conductor 36 and to the pad 35 by spot welds 38. In this type of electrode, as in that previously described, the conductors 36 and 37 provide short, low resistance paths for the flow of current through the electrodes, and the stitched conducting wires 37 further function to compress and bind together the fibers or filaments of the pad. This construction is particularly advantageous in conjunction with mats or pads of metallic wool in which the fibers or filaments have been combed or straightened so that they extend generally parallel to each other longitudinally of the pad. In such a construction the stitching functions to bundle or bind the filaments together as well as to furnish highly conductive paths to the individual filaments.

A further modification is illustrated in Figures 6 and 7 wherein the electrode comprises two contiguous pads 45 having longitudinally extending conductors 46 and transverse conductors 47 disposed between the pads. In this instance the pads are bound together by spraying finely divided molten metal on and through the pads, the spraying operation preferably being carried out from both sides and in the manner described in greater detail in my prior Patent No. 2,104,018, dated January 4, 1938. The finely divided particles of metal, indicated diagrammatically at 48, penetrate the porous pads and effectively bind the pads together and electrically and me-

chanically bond the conductors to the pads. Further the finely divided sprayed particles function as noted in my copending application Serial No. 275,481 to increase the effective area of the electrodes and thus further to increase their capacity. As those skilled in the art will appreciate the spraying operation can be applied to the electrodes shown in Figures 1 to 4 if desired in substitution for or in conjunction with the welding and if desired a construction embodying two pads such as that shown in Figures 6 and 7 can be bound together by spot welding in the manner described in conjunction with the electrodes shown in Figures 2 to 5.

As described elsewhere in this specification, the aluminum wool may be made of substantially pure aluminum, i. e., aluminum of 99.8% purity or better, or commercial aluminum or aluminum alloys can be employed such as the well-known "2S" alloy. The conductors utilized with aluminum wool electrodes are preferably composed of substantially pure aluminum. In case an alloy or commercial aluminum is used it is desirable that the aluminum wool be etched, preferably by means of an acidified salt solution as described in my prior Patent No. 2,154,027 to increase the effective area of the electrode and to substantially remove impurities therefrom as described above.

The etching operation can be also used in conjunction with electrodes made of pure aluminum. The electrodes may be sprayed with finely divided molten particles of metal, preferably of the same metal as the electrodes are made, in order to further increase their capacity. The spraying operation can be carried out in conjunction with etched electrodes if desired, or if desired, the etching operation can be applied to electrodes which have been sprayed with molten metallic particles, thus further increasing the effective area of the electrodes.

In the foregoing specification I have described preferred forms of my invention as applied to a particular type of electrolytic device. Those skilled in the art will appreciate that my invention may be modified in various ways and may be adapted to other types of electrolytic devices, all without departing from the spirit and scope thereof. Therefore it is to be understood that my patent is not limited to the embodiments of my invention described herein or in any manner other than by the appended claims when given the range of equivalents to which my patent may be entitled.

I claim:

1. An electrode for electrolytic devices comprising a mat of metallic wool composed of film-forming metal having a main auxiliary conductor extending therealong and a plurality of conductors extending transversely of said main conductor, and making electrical contact therewith and bonded thereto at a plurality of points intermediate the ends of the mat, said conductors being directly in effective electrical contact with substantially all of the filaments comprising the mat.

2. An electrode for electrolytic devices comprising a mat of metallic wool having a main auxiliary conductor extending therealong and a plurality of conductors extending transversely of said main conductor, and making electrical contact therewith, said conductors consisting of strips of metallic foil welded to said pad.

3. An electrode for electrolytic devices comprising a mat of metallic wool, a conductive wire extending along said mat and stitched and welded thereto, and means for connecting said wire to an external circuit.

4. An electrode for electrolytic devices comprising two contiguous mats of metallic wool, a conductor disposed between said mats, said mats and said conductor being bonded together at a plurality of points intermediate the ends of said mats.

5. An electrode for electrolytic devices comprising two contiguous mats of metallic wool and a multiplicity of minute metallic particles adhering to the filaments of said mats and to each other, the electrode being porous throughout.

6. The method of making electrodes for electrolytic devices which includes the steps of forming a mass of metallic wool, spraying the wool with finely divided particles of molten metal and etching the wool to increase the effective surface area thereof.

7. In an electrolytic condenser, a film maintaining electrolyte, an electrode in contact therewith comprising a mat of metallic wool composed of film-forming metal having minute spray-deposited particles of film-forming metal adhering thereto.

8. An electrode for electrolytic devices comprising a mat of metallic wool having an auxiliary conductor comprising a strip of thin metallic foil extending therealong and bonded to a substantial number of the filaments comprising the mat by spray deposited metallic particles.

9. An electrode for electrolytic devices comprising a mat of metallic wool having an auxiliary conductor extending therealong and bonded to a substantial number of the filaments comprising the mat by spray deposited metallic particles adhering to the filaments and to the conductor.

10. An electrode for electrolytic devices comprising a mat of metallic wool having a main auxiliary conductor extending therealong and a plurality of conductors extending transversely of said main conductor and bonded thereto and making electrical contact therewith, said transverse conductors consisting of wires stitched to said mat.

11. An electrode for electrolytic devices comprising a mat of metallic wool, a conductive wire extending along said mat and stitched thereto, and means for connecting said wire to an external circuit.

12. An electrode for electrolytic devices comprising a mat of metallic wool having a main auxiliary conductor extending therealong and a plurality of conductors extending transversely of said main conductor, and making electrical contact therewith, said conductors electrically and mechanically bonded to a substantial number of the filaments comprising the mat by spray-deposited metallic particles adhering to said conductors and said filaments.

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