July 18, 1939. R. G. GUTHRIE ET AL 2,166,139

DIELECTRIC DEVICE

Original Filed Feb. 9, 1934 2 Sheets-Sheet 1

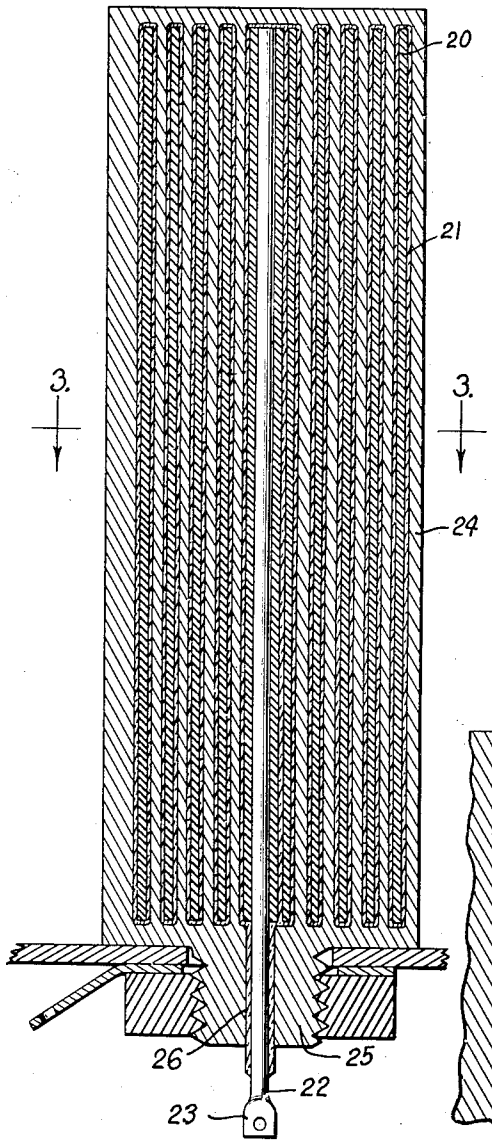


FIG.-2.

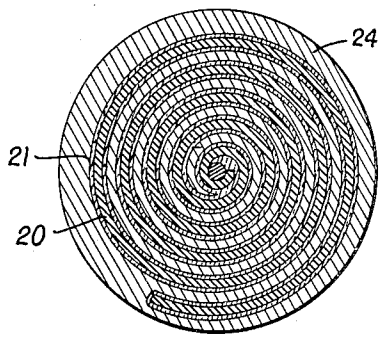


FIG.-3.

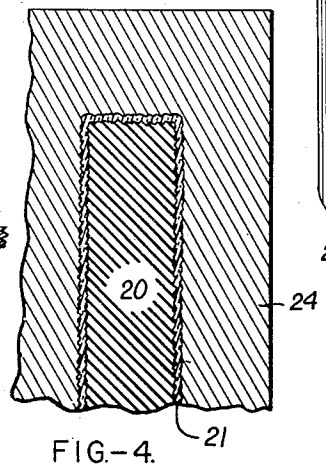


FIG.-4.

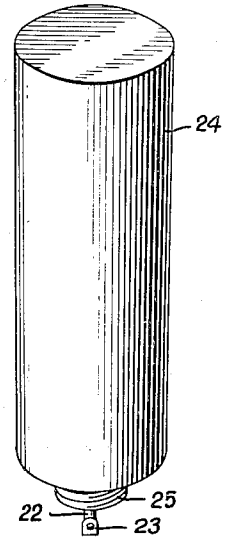


FIG.-1.

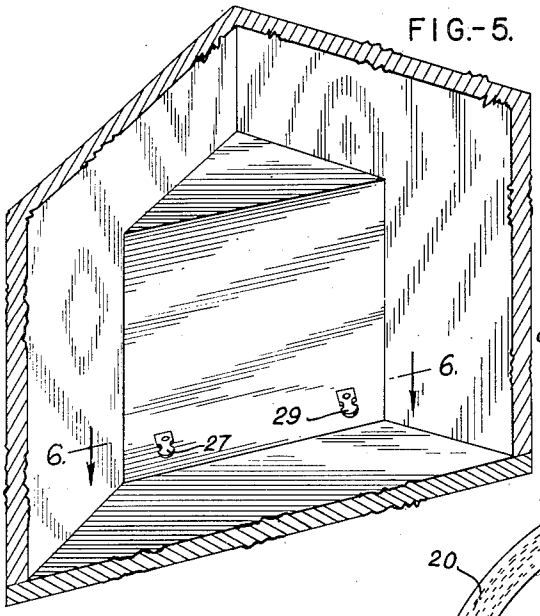
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FIG.-5.



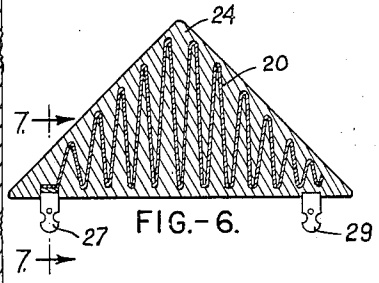


FIG.-6.

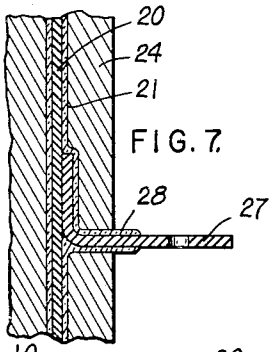


FIG. 7.

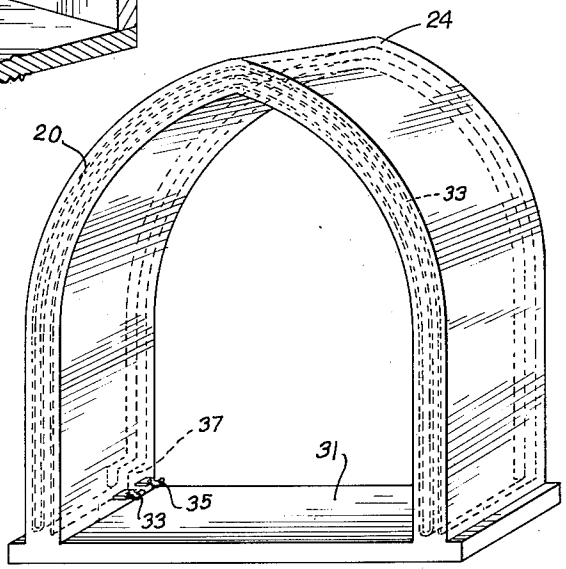


FIG.-8.

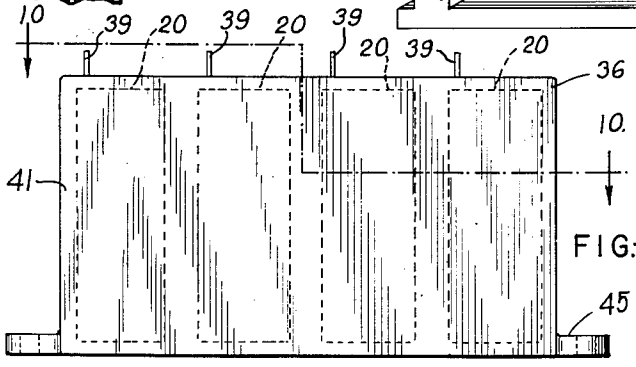


FIG.-9.

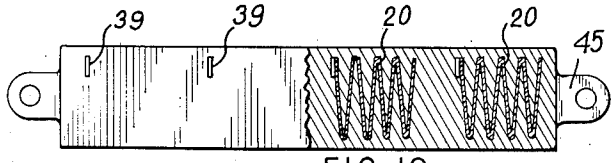


FIG.-10.

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UNITED STATES PATENT OFFICE

2,166,139

DIELECTRIC DEVICE

Robert G. Guthrie and Oscar J. Wilbor, Chicago, Ill., assignors, by mesne assignments, to Robert G. Guthrie

Application February 9, 1934, Serial No. 710,473
Renewed October 14, 1938

25 Claims. (Cl. 175—41)

Our present invention relates in general to dielectric devices and to improved methods of making the same, and while it is more particularly concerned with the fabrication of electrical condensers, the invention has other application as, for instance, to rectifiers.

A condenser is characterized by the employment of a material or a combination of materials forming a dielectric between spaced electrodes, which insulates against the passage of electrical current between the electrodes in either direction, while in rectifiers, the dielectric medium permits the passage of current between the electrodes in one direction while preventing the passage of current in the reverse direction.

Our invention, while not necessarily limited thereto, relates more especially to devices wherein the dielectric medium is arranged in substantially thin, film-like form and comprises, preferably, an oxide of one of the spaced electrodes, the dielectric medium in a condenser being preferably the oxide of aluminum formed as a film on an aluminum electrode, while, in a rectifier, the dielectric medium preferably comprises the oxide of copper formed as a film on a copper electrode. Aluminum oxide has insulating properties preventing the flow of current through the film in either direction, while copper oxide insulates against the flow of current through the film in one direction only.

Among the important objects of the invention is to provide a unitary, substantially indestructible device of the character described, having a cast electrode formed in contact with the dielectric material whereby not only to obtain intimate molecular association of the dielectric throughout substantially its entire surface contacting with the cast electrode, but also to force the contacting surfaces snugly and firmly together as a result of the internal pressure developed in the cast electrode material in changing from fluid to solid state during the casting process; to provide a device having a cast electrode which may be fabricated quickly, easily, and at relatively low cost and which may be formed in any desired shape or design due to the inherent ability of the electrode to be cast in any desired form or shape; to provide a device having a cast electrode forming an enclosing casing so that additional protective coatings need not be applied or used, the cast electrode itself forming a protective casing and affording also a rigid support for the dielectric and the mounting on which the dielectric is carried; to provide a device arranged to form a hollow housing for receiving other apparatus, the walls of said hollow housing containing dielectric means and affording electrode means in conjunction with the dielectric medium for the purpose of creating a dielectric device of the character described; to provide a device of the character described capable of being formed to fit into a particular space in which it is desired to mount the same; to provide a multiple unit device having a plurality of anodes formed each with a dielectric coating in molecular contact therewith and having a common integral cast cathode formed about the several anodes whereby the multiple unit device is formed as an integral unitary structure; to provide a device having electrodes separated by a dielectric film, with which each electrode is molecularly associated, wherein at least one of the electrodes is formed as a casting, that is, by applying the electrode material in fluid state and permitting the same to solidify upon and about the dielectric material and the electrode or support on which the dielectric material is carried whereby the cast electrode is intimately associated, electrically with the dielectric film and mechanically with the other electrode as well as with the film, whereby relative vibration of the parts and injury to the film during operation is substantially eliminated, a further object being specifically to form the device with at least one electrode formed as a metal casting, whereby maximum rigidity and freedom from vibration is obtained in the finished article.

Another object is to provide a condenser having the foregoing structural features and advantages.

Another object is to incorporate the foregoing structural features and advantages in a rectifier.

Still another object of the invention is to provide an improved method of making electrical devices of the character mentioned, which consists in forming at least one of the electrodes of the device as a casting, that is to say, by applying the electrode material in a fluid state and permitting the same to solidify upon and about the dielectric substance whereby the many advantageous features, including those specifically mentioned herein, as well as inherent features, not particularly specified, which will be apparent to those skilled in the art.

Yet another object is to provide devices of the character described having inherent functions and advantages, which will be apparent to those skilled in the electrical art as the invention is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses preferred embodiments of our invention.

Referring to the drawings:

Figure 1 is a perspective view of a condenser embodying our present invention;

Figure 2 is a longitudinal section taken through the device illustrated in Figure 1;

Figure 3 is a horizontal section taken substantially along the line 3—3 in Figure 2;

Figure 4 is an enlarged fragmentary view illustrating a section of the condenser;

Figure 5 is a perspective view illustrating a condenser embodying our invention and formed to fit the corner of a rectangular container such as a radio cabinet, in which the condenser may be assembled;

Figure 6 is a sectional view taken substantially along the line 6—6 in Figure 5;

Figure 7 is an enlarged sectional view taken substantially along the line 7—7 in Figure 6;

Figure 8 is a perspective view illustrating the manner of embodying our invention in the walls of a cabinet or container;

Figure 9 is an elevational view of a multiple condenser unit embodying our invention; and

Figure 10 is a sectional view taken substantially along the line 10—10 in Figure 9.

To illustrate our invention, we have shown on the drawings electrical devices comprising electrodes 20 and 24, one at least of which is formed as a casting. The electrodes are separated by a preferably relatively thin film or layer of dielectric material 21, which preferably, though not necessarily, comprises a compound of the material of at least one of the electrodes, said dielectric material having intimate molecular contact with both of the electrodes, and said molecular contact being accomplished at least in part by the internal forces developed in the cast material during the fabrication of the device at the time when said cast material changes from fluid to frozen or solid condition during the casting operation.

In the illustrated embodiments, the electrode 20 comprises a relatively thin sheet of preferably metallic foil, while the dielectric layer 21 preferably comprises an oxide of the foil material, which may be formed conveniently by oxidizing the electrode 20 in any convenient or preferred manner as by suitable treatment in the presence of an oxidizing agent.

The electrode 24 comprises a normally solid conducting material capable of being melted and cast upon and about the dielectric coated electrode 20, while in fluid condition, whereby the so cast material, in solidifying, will press itself into intimate molecular contact with the dielectric layer and press the layer into intimate contact with the electrode 20, due to the internal pressure developed in the cast material during its transition from the fluid to the solid state. The electrode 20, it should be noted, is provided with the dielectric film on all of its surfaces and the cast material, forming the electrode 24, surrounds and entirely encircles the coated electrode 20. After the cast material solidifies, the electrode 24 forms a rigid casing around the electrode 20 and the dielectric layer 21 thus forming a means for rigidly supporting the electrode 20 in position, whereby to prevent any relative movement of the electrodes which might result in cracking the dielectric layer. At the same time, the cast electrode 24 protects the dielectric layer from mechanical damage such as may result from the rough usage to which articles of this general character are subjected in service.

In order to provide a device capable of operating as a condenser, it is necessary to form the dielectric layer of a material capable of insulating against the flow of current through the layer in either direction between the electrodes 20 and 24. We have found that aluminum oxide has this and other properties rendering it particularly well suited for use as a dielectric in condensers embodying our invention. Consequently, in fabricating condensers, we prefer to form the electrode 20 as an aluminum foil of desired configuration and to apply the dielectric as a thin film, preferably of the order of 10–5 millimeters in thickness, on the foil surfaces preferably by electrolysis in an electrolytic cell comprising a suitable oxidizing agent such as an aqueous solution of boric acid and ammonium borate, with the foil in anodic relationship in the cell. Alternately, the foil may be oxidized by heating it in contact with pure oxygen although it is difficult to obtain desired uniformity of film thickness and to limit the film thickness within the desired maximum for use in condensers by heating the foil in the presence of oxygen. For this reason, we prefer to form condenser dielectric films by electrolysis which produces a film of substantially uniform thickness, which thickness can be easily maintained within the desired maximum limit.

In order to provide a device capable of operating as a rectifier, it is necessary to form the dielectric layer of material capable of insulating against the flow of current through the layer in one direction only between the electrodes 20 and 24. We have found that copper oxide has this and other properties rendering it particularly well suited for use as a rectifying dielectric in devices embodying our present invention. Consequently, in fabricating rectifiers, we prefer to form the electrode 20 as a foil of cupreous material of desired configuration and to apply the dielectric in film-like form upon the foil in any convenient manner as by electrolysis in an electrolytic cell comprising a suitable oxidizing agent such as sulphuric acid or other medium capable of liberating nascent oxygen at the anode of the cell, the foil being arranged in anodic relationship in the cell. Alternately, the foil may simply be heated in contact with pure oxygen and since a dielectric film of adequate thickness for use in rectifiers may be produced in this manner without difficulty, we prefer to form the rectifying dielectric film by heating the copper electrode in the presence of oxygen rather than by electrolysis since the manipulative steps may be performed with greater facility.

In both instances, but more particularly in the fabrication of condensers, we prefer to form the electrode 20 as a thin foil or sheet of material capable of being configurated to any desired shape in order to facilitate the manufacture of the device. Moreover, the capacity of a condenser is directly proportional to the electrode area in contact with the dielectric film and by forming the electrode as a thin sheet, its effective area in contact with the dielectric layer is greatly increased per unit weight of electrode material employed.

Although we prefer to form the electrode 20 as a relatively thin foil, thick enough only to withstand cracking of the foil when the same is bent to a desired shape, we do not wish to limit our invention necessarily to an electrode material in sheet form, but the electrode 20 may be fabricated in any suitable manner and form and of any proper material.

The dielectric also may be of any suitable material capable of being arranged as a relatively thin film between the electrodes 20 and 24. It is desirable, however, to utilize a material for the dielectric layer 21, which is capable of being formed as a layer of minute thickness without destroying its insulating character since the capacity of the condenser is inversely proportional to the thickness of the dielectric layer and in condensers made in accordance with our present

invention, the dielectric layer has a thickness of the order of 10–5 millimeters, which results in the production of a condenser having an unusually high capacity.

We prefer also to utilize a preferably inexpensive metal for the electrode **24** although any conducting material capable of being cast about the coated electrode **20** may be employed. For this purpose, we may employ so-called "white" metal, which is cheap, is suitable for die casting purposes, and forms a suitable electrical conductor capable of functioning as an electrode after solidification. Obviously, we may utilize any other suitable electrical conducting material which can be rendered fluid enough to flow into position without dislodging the dielectric material and which, after being cast in place, will solidify under normal conditions of temperature and pressure. Preferably, however, the material is of such character as will develop considerable internal pressure in changing its state from the fluid to the solid condition so that such internal pressure will be applied to firmly and snugly press the dielectric material between the electrodes **20** and **21** in order to obtain and preserve the intimate molecular contact between the dielectric layer and both electrodes. In addition, the squeezing of the dielectric material between the electrodes, as a result of the internal forces developed in the cast material during solidification, may have some effect in reducing the thickness of the dielectric film, and thus, in making condensers, to increase the capacity of the resulting product.

In accordance with our present invention, the electrode **20**, however fabricated, is first treated to form the dielectric layer **21** on all of its surfaces. The treated electrode, if in sheet form, is configurated to a desired shape, such as the spiral shown in Figures 2 and 3, the pleated shape shown in Figures 6 and 10, the serpentine form shown in Figure 8, or any other desired form, and is then preferably again treated in order to insure the healing of any puncture, perforations, or breaks which may have occurred in the dielectric layer during the forming of the coated electrode.

The dielectric layer may, of course, be formed in any suitable manner, as by heating in contact with oxygen, by spraying, plating or by treating the electrode **20** in a suitable oxidizing agent either with or without electrolytic action and we prefer to form the film by some process which includes the immersion of the electrode since we have found that the film formation is accomplished more uniformly over the entire superficial electrode areas by processes involving immersion.

After the dielectric film **21** has been formed upon the surfaces of the electrode **20**, the coated electrode may be placed in a suitable casting mould, all portions of the electrode being spaced from the walls of the mould and the layers of the formed electrode being maintained in spaced relationship. The casting material is then applied in fluid condition in the mould around the coated electrode **20**, the casting material entering between the adjacent layers of the formed electrode **20** into contact with all of the dielectric coated surfaces thereof. Upon solidifying, the casting material will form the electrode **24** and, as heretofore mentioned, the dielectric layer **21** will be squeezed between the electrodes and forced into intimate molecular contact with both. The cast material, upon solidification, will act as spacing means to maintain the adjacent layers of the flimsy electrode **20** rigidly in spaced apart relationship, will prevent movement of the electrode **20**, will provide a protective coating or casing for the dielectric layer, and, further, will function as a casing without additional protective layers since the cast material, forming the electrode **24**, after solidification, forms a rigid block which will support the electrode **20** firmly in position and also will prevent external forces from disturbing or injuring the dielectric layer as well as the electrode **20**.

In Figures 1, 2, and 3, we have shown a device arranged in cylindrical form. The electrode **20** comprises a spirally arranged foil, the inner end of which is electrically connected to a pole or post **22**, preferably formed of material of like character to that utilized for the electrode **20**. This pole or post **22** has an end extending outwardly of the spirally coiled electrode, which end also extends outwardly of the cast electrode **24**, the projecting end of the rod being insulated from the cast electrode as by means of an extension **26** of the dielectric film, formed preferably contemporaneously with the formation of the film on the electrode **20**. The cast electrode **24** also is formed with an extension **25** comprising a preferably integral externally threaded sleeve or bushing **25**, through which the projecting insulated end of the rod **22** extends. This extension affords means at one end of the cylindrical element for anchoring the same in place as on a perforated panel through which said projection may extend in position to receive a threaded nut or other fastening device whereby the panel may be clamped by and between the nut and the flat end surface of the electrode to thus mount the device upon the panel. Where the support panel is of electrical conducting material, it will be obvious that the electrode **24** will be electrically connected to the panel and may thus be grounded conveniently. The outer end of the rod **22** is preferably free of insulation and formed as at **23** to facilitate electrical connection with an external circuit. It will be noted that in the form shown, such electrical connection may be accomplished entirely on the side of the support panel opposite from that on which the device is carried, and where the electrode is not connected to the panel, it also may be connected in an external circuit entirely on the side of the panel opposite from that on which the device is carried.

One of the features of our present invention resides in the possibility of fabricating an electrical device in a shape to fit a space in which it is desired to mount the device when in use, and in Figures 5 and 6, we have illustrated the possibility of forming the electrode **24** as a triangular prism adapted to fit into an ordinarily unoccupied corner of a rectangular container. In the form illustrated, the electrode **20** is arranged as a series of accordion pleated layers, while the electrode **24** is cast around said pleated electrode to form a casing of prismatic shape. In this embodiment, the electrode **20** is provided with a terminal arranged in the form of a lug **27** connected to one end of the pleated strip in position to extend outwardly of the cast electrode **24**. The terminal **27** and the electrode **20** are preferably formed of like material and the surfaces of the terminal, which are embedded in the cast material, are insulated by means of an extension **28** of the dielectric film formed on the electrode **20**. The outer end of the terminal **27** is also

formed to facilitate connection in an external electrical circuit and a lug 29, similar to the lug 27, is embedded in any convenient position in the cast material and extends outwardly thereof to afford means for electrically connecting the electrode 24 in an external electrical circuit, said lug 27 corresponding, functionally, with the sleeve 25 shown in the embodiment illustrated in Figures 2 and 3.

The electrode 24 obviously may have any convenient or desired shape and in Figure 8, we have illustrated the possibility of forming it as a housing for any desired purpose, the housing shown being particularly well adapted for use as a cabinet to enclose electrical apparatus with which the dielectric device may be operatively associated. In this form of the invention, the electrode 20 is arranged to form a series of serpentine layers, while the electrode 24 is cast around the electrode 20 in the form of a hollow body forming a casing 31 with the layers of the electrode 20 lying within the walls of the casing 31. A suitable terminal 33, one end of which is connected with the electrode 20 and embedded in the material forming the electrode 24, has an outer end projecting from the walls of the casing 31 for the purpose of connecting the electrode 20 in an external electrical circuit, the terminal 33 being comparable to the terminal 22 shown in Figure 1 and the terminal 27 shown in Figures 5 and 6. A terminal 35, isolated from the electrode 20, which may be cut away as indicated at 37 to accommodate the terminal, is or may be embedded in the material forming the casing 31 for the purpose of effecting electrical connection of the electrode 24 in an external circuit. The terminal 35 corresponds, functionally, with the terminal 25 shown in Figure 1 and the terminal 29 shown in Figures 5 and 6. The terminal 33 and the electrode 20 are preferably formed of like material and the surfaces of the electrode and its terminal, which are embedded in the cast material of the electrode 24, are insulated by a dielectric film and extension thereof as previously described in connection with the devices illustrated in Figures 1–7.

In Figures 9 and 10 of the drawings, we have illustrated the possibility of embodying our present invention in a multiple unit device comprising a plurality of individual electrodes 20, each of which preferably comprises a foil configurated to desired compact shape either by forming the same in accordion pleated fashion, as illustrated, or spirally, or in serpentine fashion, or in any other convenient shape or manner. Each individual electrode 20 is provided with a projecting terminal 39 electrically connected therewith, each terminal and lug being preferably of like material and coated, as heretofore described, with a suitable dielectric film, preferably the oxide of the metal of which the electrodes are composed, and all of the electrodes 20 are enveloped in a common cast electrode 41 functionally similar to the electrode 24 heretofore described. The common electrode 41 may, of course, be cast in any suitable or desired shape, although, in the preferred embodiment shown, it is rectangular and is provided with integral lugs 43, by which the multiple unit condenser may be attached on a suitable supporting base and connected in external electrical circuits.

Condensers and rectifiers embodying our present invention have great mechanical strength and for this reason, among others, are, for all practical purposes, substantially indestructible. The electrode 24, being of cast material, offers a firm rigid housing and support for the relatively flimsy electrode 20, which is carried in substantially immovable condition. Disturbance of the dielectric film carried by the electrode 20 is thus prevented, the formation of the electrode 24 as a rigid casting preserving dielectric film substantially intact throughout the life of the device.

A further advantage arises from the fact that the material, of which the cast electrode is formed, is applied in fluid condition to the dielectric coated electrode 20, so that the dielectric layer is not disturbed in the casting operation. As the cast material solidifies, the dielectric layer is firmly pressed into intimate molecular contact not only with the electrode 20 but also with the contacting surfaces of the electrode 24 by the internal forces developed in the cast material as the same changes to solid state. These forces not only insure intimate molecular contact between the dielectric layer and both electrodes, but also tend to reduce the thickness of the dielectric layer without destroying its insulating character and this is of particular advantage in the fabrication of condensers since the resulting device has increased electrical capacity due to the reduced thickness of the squeezed dielectric film.

The ability to form condensers and rectifiers having any desired external shape, including the possibility of forming the device as a housing for other apparatus, is, of course, obvious and numerous other advantages and functions, inherent to devices made in accordance with our present invention, will be understood and appreciated by those skilled in the art and will become apparent as the invention is understood from the foregoing description.

It is obvious that numerous changes may be made in the form, construction, and arrangement of the several parts without departing from the spirit or scope of our invention or sacrificing any of its attendant advantages; the forms herein described being preferred embodiments for the purpose of illustrating our invention.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

1. An electrical device of the character described comprising an electrode formed as a casting of prismatic shape, another electrode embedded in said casting, and dielectric film means coating said embedded electrode, said film means being pressed into place and maintained in position under pressure of internal stresses developed in the casting during the formation of the same.

2. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode whereby said layer is held in position under pressure of internal stresses developed in the casting during the formation thereof.

3. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said dielectric material comprising the oxide of the material of the embedded electrode.

4. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said embedded electrode comprising aluminum.

5. An electrical device comprising an electrode formed as a casting, another electrode embedded

in said casting, and a dielectric layer coating the surfaces of the embedded electrode, the embedded electrode comprising a cuprous material.

6. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said casting comprising a block having a curved superficial surface.

7. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said casting comprising a block having a cylindrical superficial surface.

8. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said casting comprising a block of triangular sectional configuration.

9. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said casting comprising a block of rectangular sectional shape.

10. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said embedded electrode comprising a foil coiled in spiral arrangement.

11. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said embedded electrode comprising a foil folded in serpentine fashion.

12. An electrical device comprising an electrode formed as a casting, another electrode embedded in said casting, and a dielectric layer coating the surfaces of the embedded electrode, said embedded electrode comprising a foil arranged in zigzag form.

13. An electrical device of the character described comprising an electrode formed as a casting, a plurality of separate electrodes embedded in said casting, and dielectric film means coating said embedded electrodes, said film means being pressed into place and maintained in position under pressure of internal stresses developed in the casting during the formation of the same.

14. An electrical device of the character described comprising a cast electrode having an integral projection adapted to extend through a perforation on a support panel, an electrode embedded in said casting, dielectric film means coated upon said embedded electrode and maintained in position thereon under pressure of internal stresses developed in the casting during the formation of the same, and means extending through said projection and exposed outside of the casting whereby the embedded electrode may be connected in an external electrical circuit on the side of the panel opposite from the electrode.

15. An electrical device comprising a casting forming an electrode having an integral projection adapted to extend through a perforation in a support panel, an additional electrode comprising a sheet metal element, having a dielectric material coating all of the surfaces thereof, said additional electrode with its coating being embedded in said cast electrode and means electrically connected with said additional electrode and insulated from the cast electrode and extending through said projection of the cast electrode and exposed outwardly thereof whereby the imbedded electrode may be connected in an external electrical circuit on a side of the panel opposite from both electrodes.

16. An electrical device comprising a metal foil, a terminal of like material electrically connected to said foil portion, a white metal casting formed on and enveloping the metal foil and portions of the terminal, said terminal having other portions extending outwardly of said casting, and a dielectric material comprising an oxide of the material of the foil and the terminal coated on the enveloped surfaces of the foil and terminal.

17. An electrical device comprising a sheet metal foil, a dielectric material comprising an oxide of the material of the foil coated thereon, and a white metal casting formed on and enveloping the coated foil.

18. An electrical device comprising a plurality of separate sheet metal foil elements, dielectric material comprising the oxide of the material of the foil elements coated upon each of said elements, and a metal casting formed on and enveloping the several elements.

19. An electrical device comprising a white metal casting, a metal foil embedded in said casting, and a coating comprising the oxide of the material of the foil disposed upon the surfaces of the embedded foil.

20. An electrical device as set forth in claim 19 wherein the foil comprises aluminum.

21. An electrical device as set forth in claim 19 wherein the foil comprises a cupreous material.

22. The method of making an electrical device which comprises treating a metal electrode to form a dielectric coating thereon comprising an oxide of the material of the electrode, and thereafter casting a conductor material in molten condition upon and around the coated electrode and permitting the conductor material to solidify in place whereby to form a block of conducting material in which the electrode is embedded and in which the internal forces set up in the conductor material upon solidification serve to press the same intimately, firmly and tightly upon the coated electrode.

23. An electrical device comprising a metal foil coiled in spiral form, a stem-like terminal electrically connected to the foil at the inner end of the spiral and having a projecting end, a casting comprising a block of an electrical conducting material in which the foil and the terminal is embedded with the projecting end of the terminal extending outwardly of said block, and a film of dielectric material coating the surfaces of the foil and the embedded portions of said terminal.

24. An electrical device as set forth in claim 23 wherein the foil comprises aluminum and the dielectric material comprises an oxide of aluminum.

25. An electrical device as set forth in claim 23 wherein the foil comprises copper and the dielectric material comprises an oxide of copper.

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