

Oct. 20, 1925.

1,558,043

W. H. PRIESS

ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 1

Fig. 1.

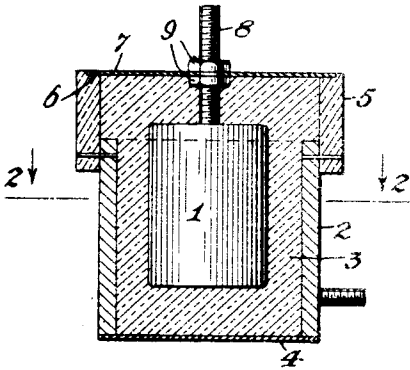


Fig. 2.

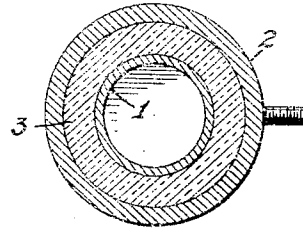


Fig. 3.

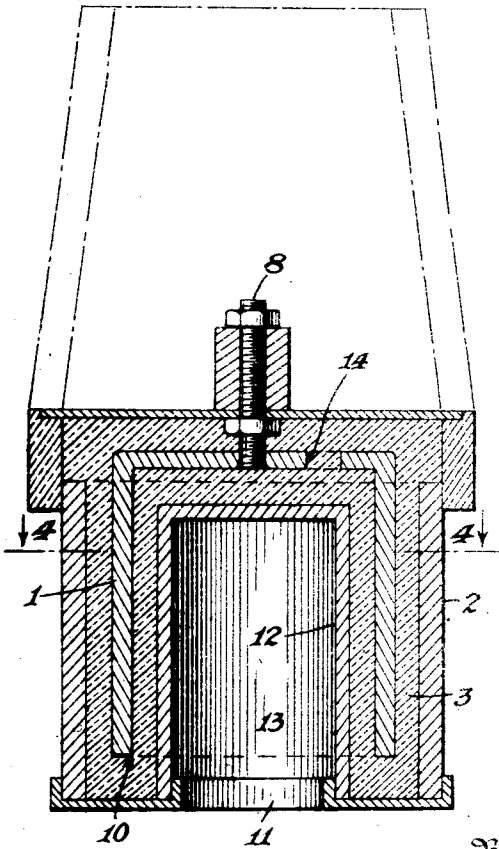
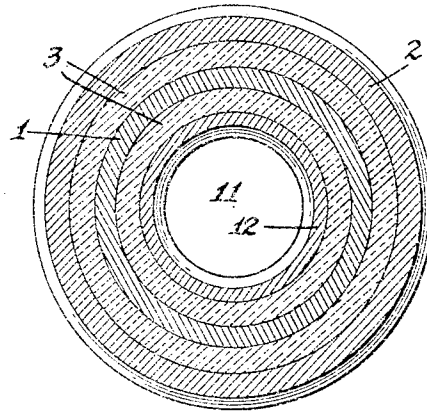


Fig. 4.



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ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 2

Fig. 5.

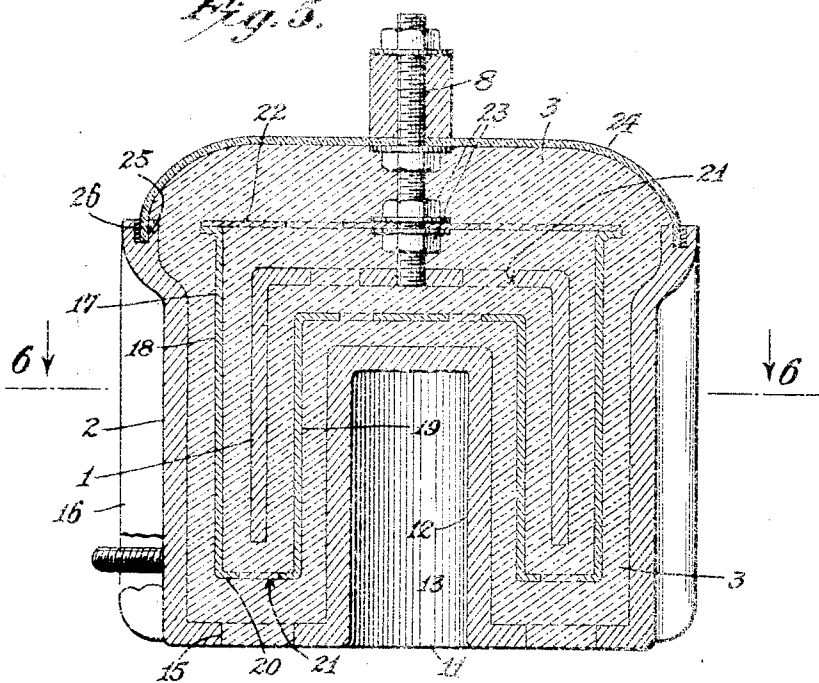
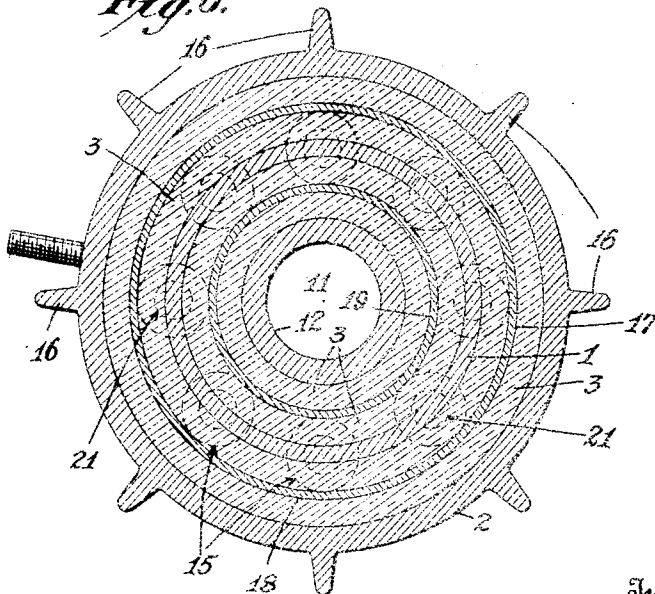


Fig. 6.



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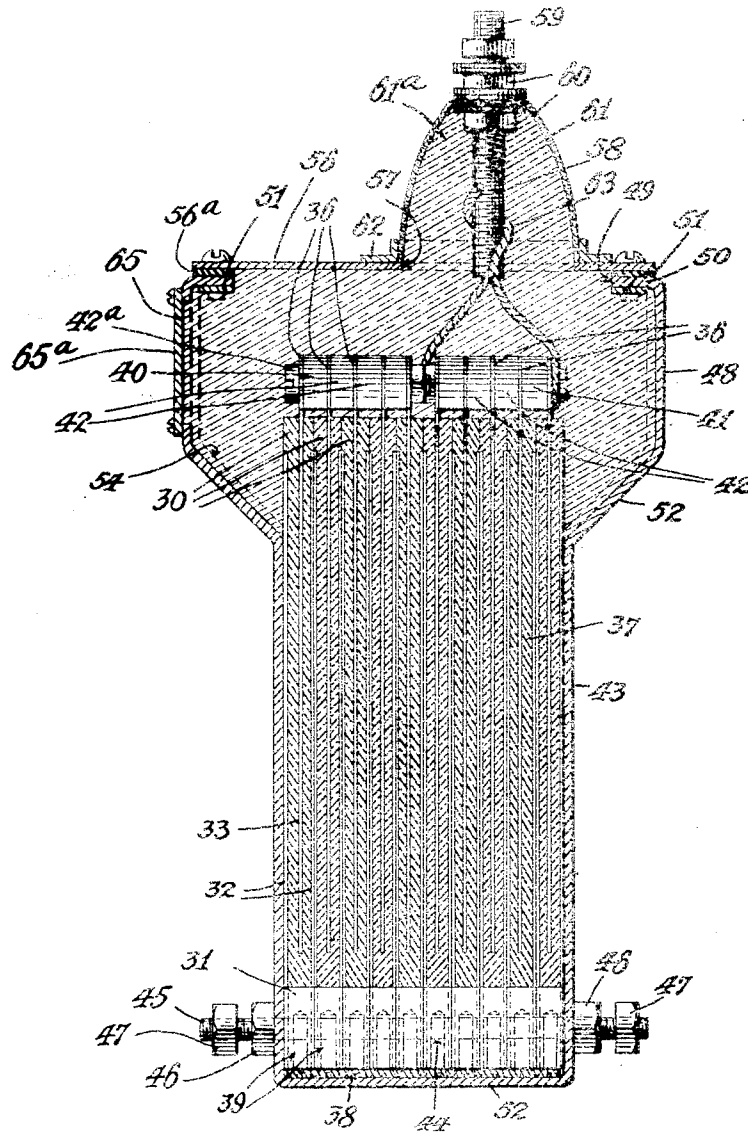
1,558,043

ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 3

Fig. 7



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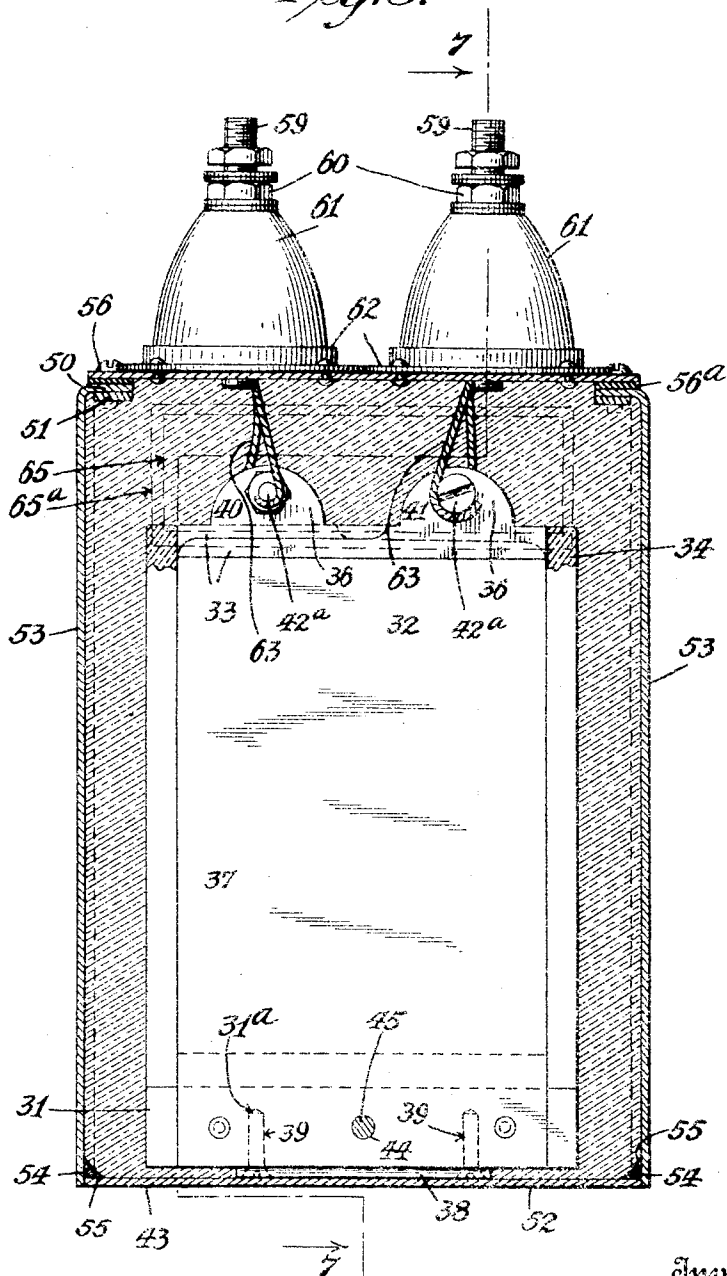
1,558,043

ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 4

Fig. 8.



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1,558,043

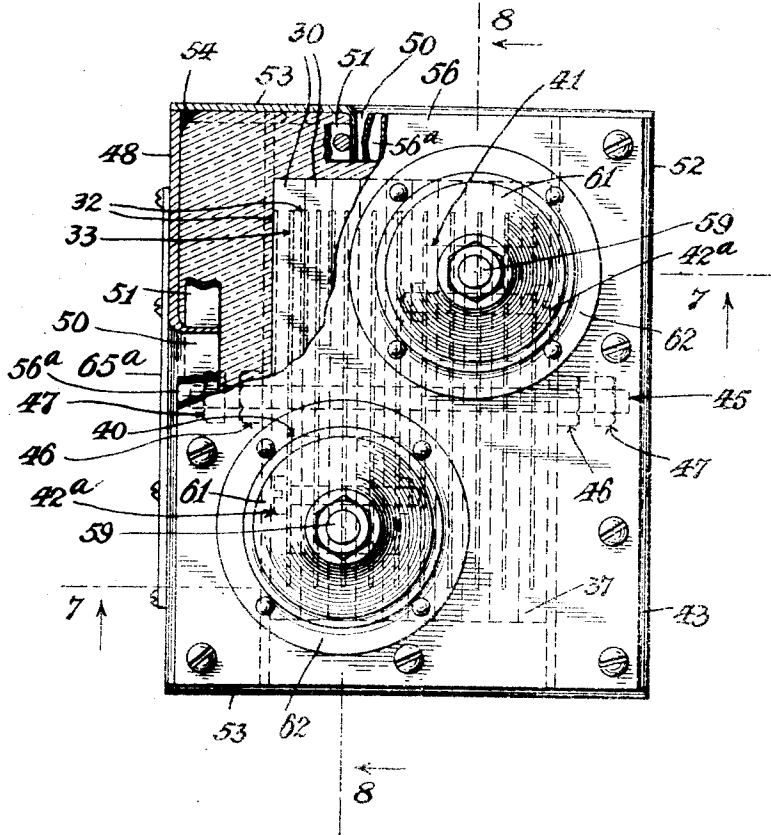
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ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 5

Fig. 9.



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1,558,043

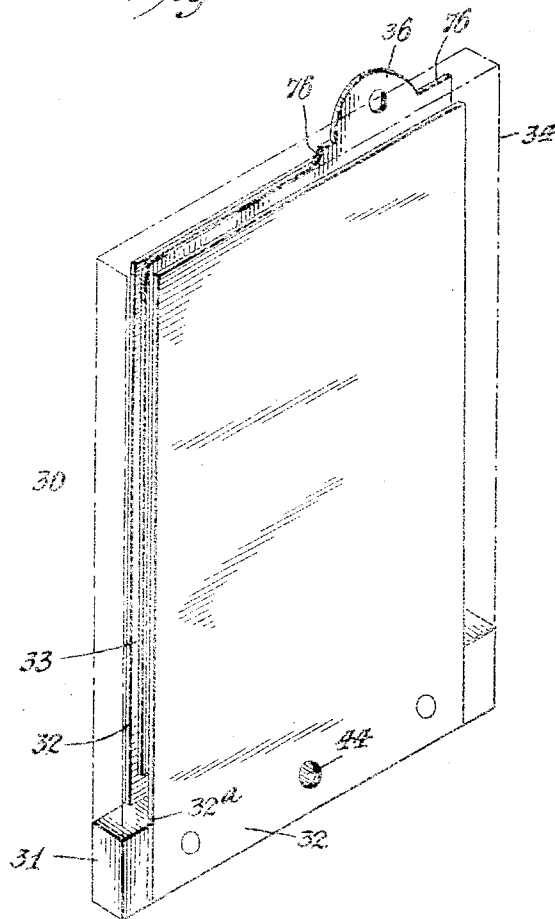
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ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 6

Fig. 10.



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Oct. 20, 1925.

1,558,043

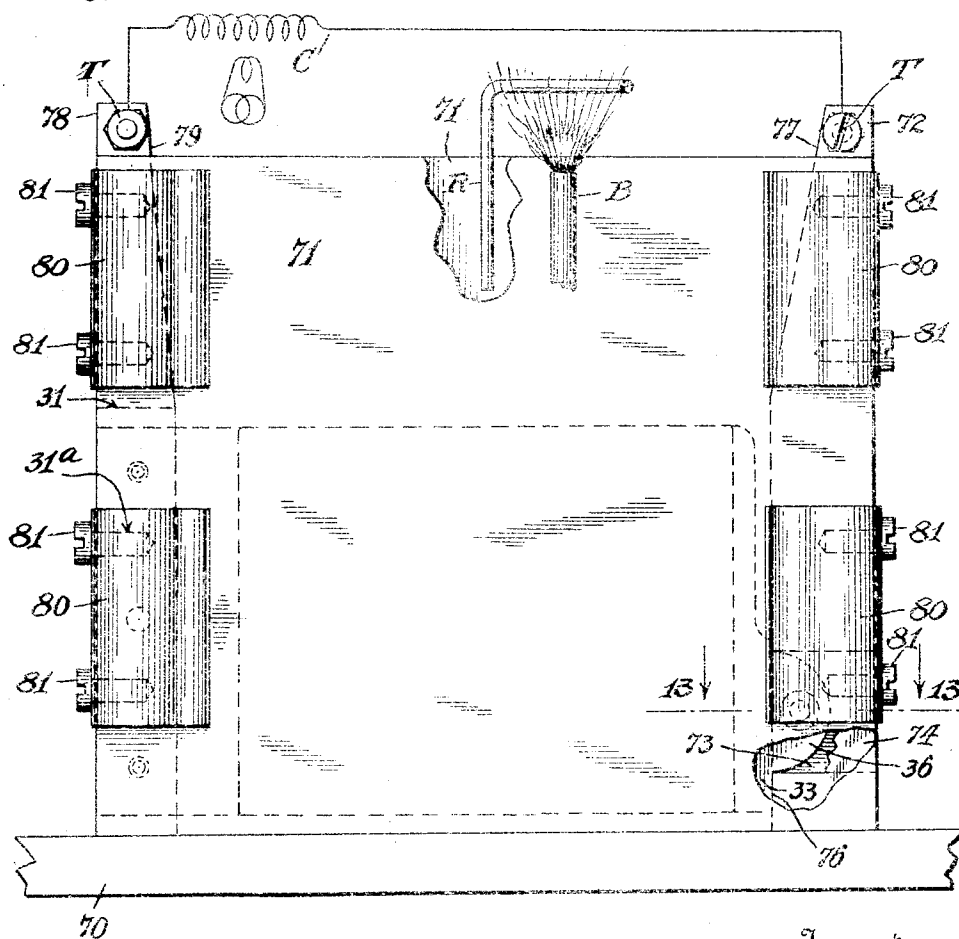
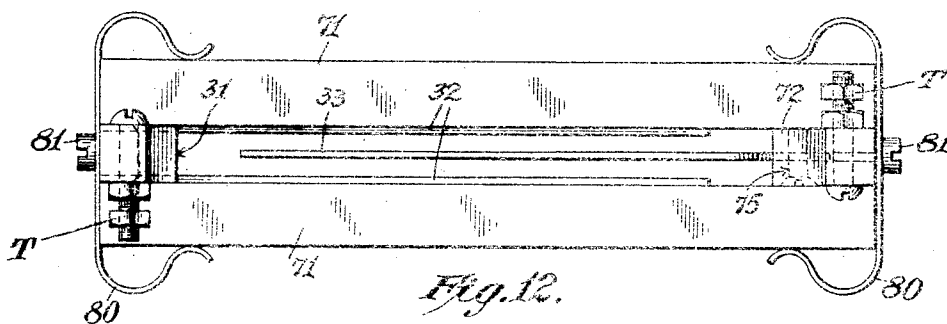
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ELECTRICAL CONDENSER

Filed April 23, 1921

11 Sheets-Sheet 7

Fig. 11.



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1,558,043

ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 8

Fig. 13.

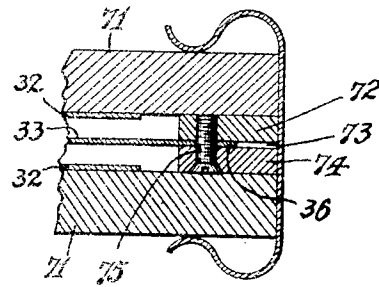
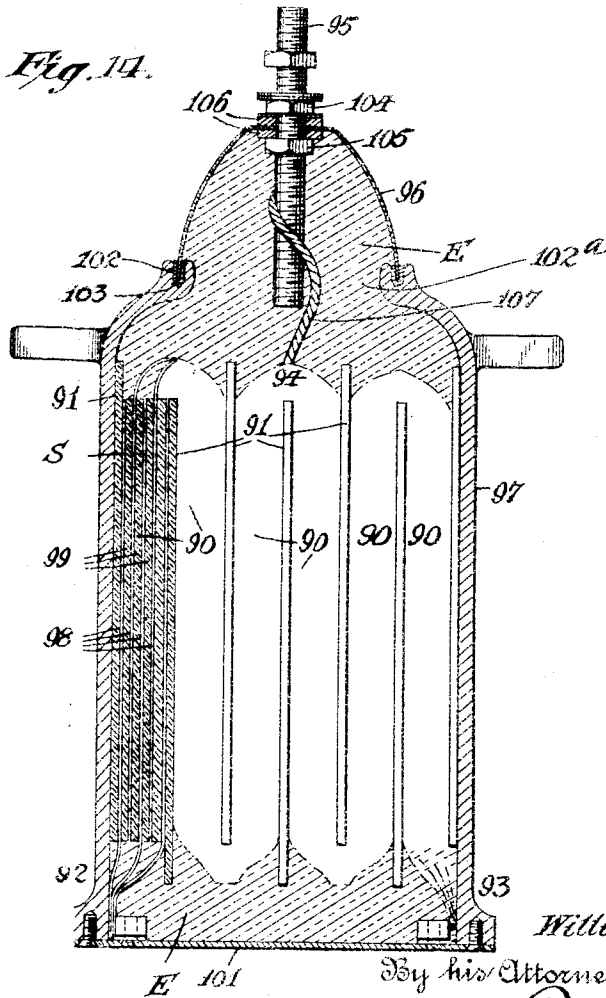


Fig. 14.



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1,558,043

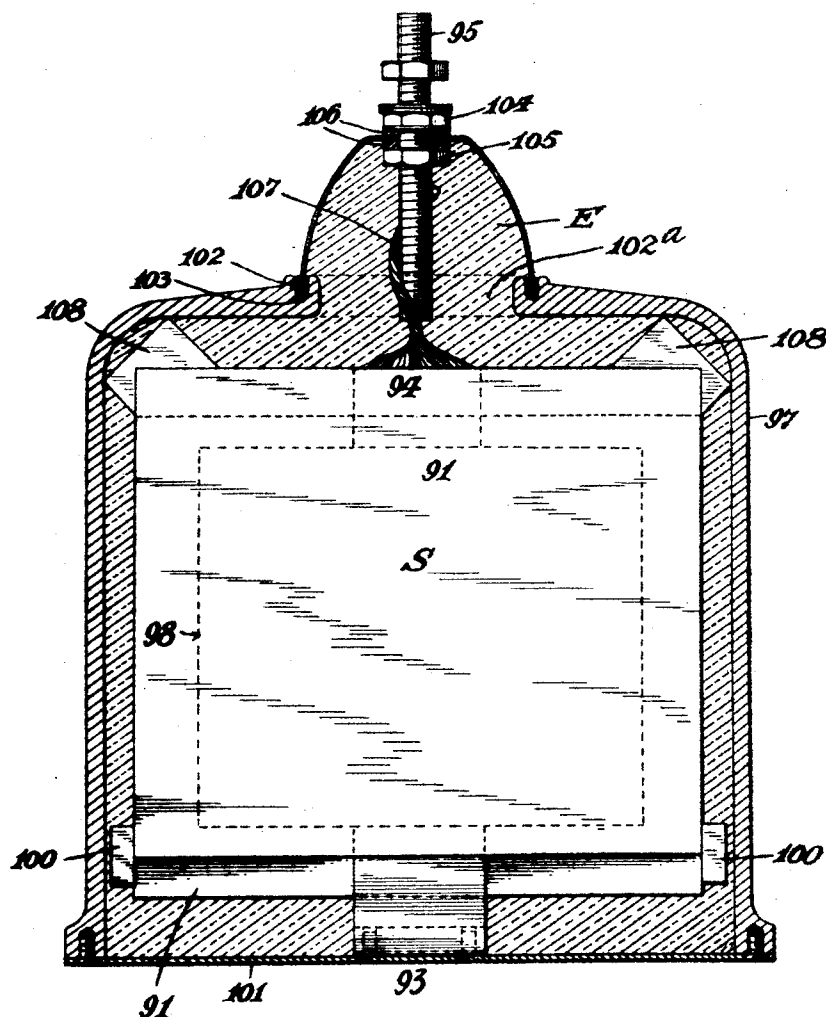
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ELECTRICAL CONDENSER

Filed April 23, 1921

11 Sheets-Sheet 9

Fig. 15.



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Fig. 16.

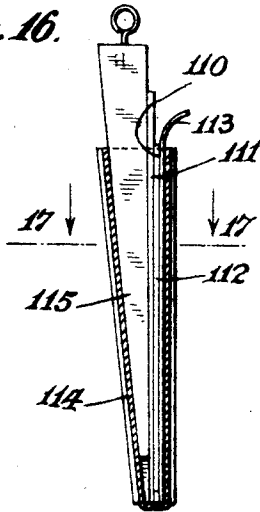


Fig. 17.

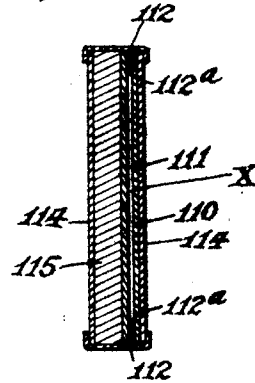
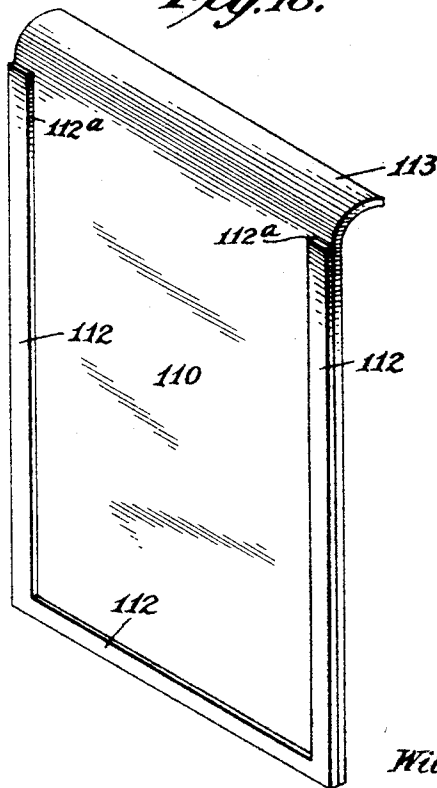


Fig. 18.



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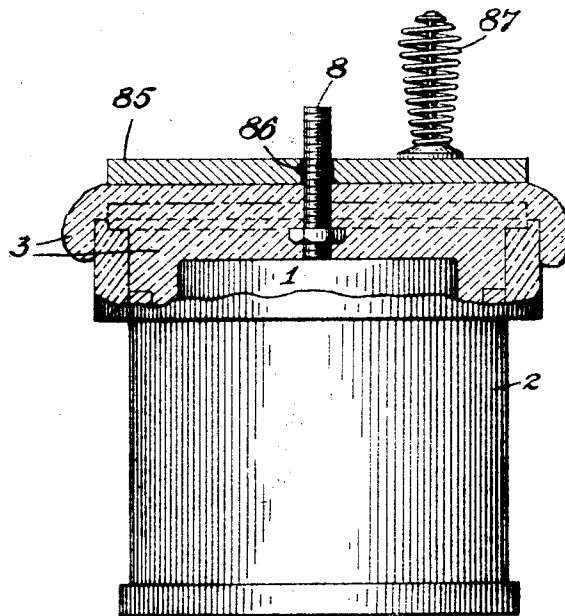
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ELECTRICAL CONDENSER

Filed April 28, 1921

11 Sheets-Sheet 11

Fig. 19.



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UNITED STATES PATENT OFFICE.

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ELECTRICAL CONDENSER.

Application filed April 28, 1921. Serial No. 465,137.

To all whom it may concern:

Be it known that I, WILLIAM H. PRIESE, a citizen of the United States of America, and a resident of Belmont, State of Massachusetts, have invented certain new and useful Electrical Condensers, the principles of which are set forth in the following specification and accompanying drawings, which disclose the form of the invention which I now consider to be the best of the various forms in which the principles of the invention may be embodied.

This invention relates to electrical condensers and methods of making the same.

In condensers now in use it is usual to build the same in stacks composed of sheets of dielectric, such as mica or paper, and foil. For high potential work, the stack is built up in sections connected in series, and the greater the number of sections the less the capacity will be for a given size sheet. Such condensers are unsatisfactory, however, where high potential high current is necessary with comparatively low capacity. In building such a condenser of mica, for instance, it has been found that the cost is almost prohibitive.

In order to provide a cheap compact condenser, it is contemplated in the present invention to use sulfur (in a special form) not only as a dielectric but also as a filler. Sulfur also may be used as a detergent, to wash out air and moisture from the condenser, and for impregnating. Sulfur has an extremely high insulation resistance, but up to this time its brittleness and porosity has prevented its use to any extent as a dielectric, especially for use in high tension electrical condensers. The advantages of sulfur are as follows:—low dielectric loss, high insulation resistance, cheapness, good dielectric strength and high melting point (115°–119° C.). Another characteristic of sulfur which is especially advantageous in condenser manufacture resides in the fact that it does not soften as it approaches the melting point as does a wax, but rather acts like ice, that is to say, remains hard up to the moment of melting and then changes to a thin liquid, nor is it subject to cold flow.

Sulfur as a solid exists in several allotropic forms as follows: the plastic or amorphous, monoclinic crystalline form, and the rhombic octahedra crystalline form.

An object of the invention is to provide a cheap condenser of high efficiency.

Another object of the invention is to employ and prepare the element sulfur in condensers in such wise as to take full advantage of its extremely low dielectric loss and high insulation resistance and at the same time to ensure a condition of the sulfur as to avoid the troubles resulting from the use of so brittle and porous a material.

Another object of the invention is to provide in a condenser a dielectric or filler having reheating properties.

Another object of the invention is to provide a condenser which can be operated at temperatures up to 95° C. without detrimental effect.

In the accompanying drawings, there is illustrated several of the numerous forms in which the present invention is capable of being embodied with apparatus for making the same.

Figure 1 is a sectional elevation of one form of condenser.

Fig. 2 is a sectional plan view thereof on the line 2—2 of Fig. 1, looking in the direction of the arrows.

Fig. 3 is a sectional elevation of a modified form of condenser.

Fig. 4 is a sectional plan view thereof on the line 4—4 of Fig. 3, looking in the direction of the arrows.

Fig. 5 is a sectional elevation of another form of condenser.

Fig. 6 is a sectional plan view thereof on the line 6—6 of Fig. 5, looking in the direction of the arrows.

Fig. 7 is a sectional elevation of another form of condenser taken on the line 7—7 of Figs. 8 and 9, looking in the direction of the arrows.

Fig. 8 is an elevation of the construction of Fig. 7 taken at right angles to the view of Fig. 7, the casing being in section.

Fig. 9 is a plan view, with part of the casing broken away, of the construction of Figs. 7 and 8.

Fig. 10 is a detail perspective view of an element used in the construction of the condenser of Figs. 7, 8 and 9.

Fig. 11 is a plan view of a mold for making the element of Fig. 10.

Fig. 12 is an elevation of the mold of Fig. 11, parts being broken away for clearness.

Fig. 13 is a detail sectional view of the mold on the line 13—13 of Fig. 12, looking in the direction of the arrows.

Fig. 14 is an elevation of another form of condenser with parts in section.

Fig. 15 is an elevation of the same condenser taken at right angles to the view of Fig. 14 and with parts in section.

Fig. 16 is a sectional view of an assembled mold for making sulfur sheets.

Fig. 17 is a sectional view thereof on the line 17—17 of Fig. 16, looking in the direction of the arrows.

Fig. 18 is a perspective view on an enlarged scale of one of the mold parts.

Fig. 19 is a view illustrating a method of melting off the sulfur embedment flush with the edge of the casing.

In Figs. 1 and 2 is illustrated one embodiment of the invention comprising spaced concentric cylindrical metal armatures 1 and 2, in which the armature 2 constitutes the casing of the condenser, the armature 1 being within the casing and embedded in a suitable dielectric 3, which may comprise elemental sulfur of the special form made by the process hereinafter described, this sulfur dielectric 3 not only constituting the dielectric of the condenser but also the filler within the casing 2. The casing 2 is provided with the bottom 4 which may be removed if desired for the purpose of filling the condenser with the dielectric through the bottom, although the same may also be filled through the top. This bottom 4 may be secured to the casing 2 in any desirable manner. Telescoping the upper portion of the cylindrical casing 2 is a ring 5 of insulating material which may be composed of any insulating material suitable for the purpose, such as bakelite dilecto, which is preferable by reason of its rigidity and hardness. This ring 5 is secured in any suitable manner to the casing. The upper edge of the bakelite ring 5 is provided with a recess or ledge 6 in which may be fitted a thin cover 7 of any suitable insulating material, but preferably of mica. Projecting through the insulating cover 7 is a threaded terminal 8 which is secured to the cover by means of a pair of nuts 9 arranged upon opposite sides of the cover 7 and clamped thereto. This terminal is connected to the armature 1. Inasmuch as the armature 1 is embedded preferably in a solid fusible dielectric such as the elemental sulfur of the special form of this invention, the cover 7 need not be of sufficient strength to suspend the terminal

thereon. Mica, inasmuch as it has a very low loss and prevents creepage to a high degree, is preferable, and this mica cover 7 co-operating with the insulating ring 5 effectively insulates the terminal 8 from the outer casing or armature 2. In order to rigidly support the cover 7, it is preferable to use the sulfur embedment 3 and to place it within the casing in such manner by the process hereinafter described, that the embedment is in close contact with the cover 7, providing a hard backing for the same. After solidification of the sulfur embedment, the mica cover is supported upon the annular shelf 6 and held on the condenser by means of its adhesion to the sulfur embedment. The nuts 9 assist in providing a central securing means for the cover.

In Figs. 3 and 4, I have illustrated a form of condenser in which the dielectric and filler is also cast in one operation in the casing. Referring, therefore, to these figures, the condenser comprises the inner metal armature 1, which is preferably of cylindrical form open at the bottom as indicated at 10, and an outer metal armature 2 which is concentric with the armature 1 and spaced therefrom. In this embodiment of the invention, the bottom of the casing or armature 2 is provided with an opening 11 aligning with the open end of an inverted cup-shaped metal member 12 connected to casing 2, having a space 13 therein communicating with the exterior through the opening 11, constituting part of the armature 2 and projecting into the space 10 of armature 1 and spaced therefrom. This condenser, like the construction disclosed in Fig. 1, is likewise filled either through the top or through the bottom with an insulating dielectric and filler 3, the armature 1 being provided with holes or perforations 14 therein to allow the complete embedment and anchoring of the dielectric. The preferred form of dielectric 3 is the special form of sulfur hereinafter described and made by the process hereinafter described just like the sulfur dielectric of the form of Fig. 1. In other respects, the construction of Figs. 3 and 4 is identical with the construction of Figs. 1 and 2. The space 13 in the form of Figs. 3 and 4 provides a large area surface exposed to the air for increasing the radiating and heat conducting elements of condensers for use either during the process of cooling the dielectric or for maintaining a comparatively low temperature in service.

In Figs. 5 and 6 is illustrated a condenser comprising metal armatures 1 and 2, the armature 1, like the armature of Figs. 3 and 4, comprising a cylindrical cup-shaped element open at the bottom and the armature 2, being cylindrical and concentric with the armature 1 and provided with an inverted cup-shaped part 12 projecting into the space

inside of armature 1 and spaced therefrom and having an interior space 13 communicating at 11 with the atmosphere whereby the heat-radiating and heat-conducting surfaces of the condenser are enlarged. The part 12 may either be integral with the outer cylindrical portion of the armature 2 as shown in Fig. 5 or separately attached thereto as shown in Fig. 3. Through the bottom of the casing 2 of Fig. 5, between the outside cylindrical portion thereof and the inner portion 12, is one or more openings 15 through which the dielectric and filler 3 may be poured in embedding the condenser. Openings 15 especially adapt the condenser for filling through the bottom as by the process hereinafter more fully described. Preferably, armature or casing 2 is an aluminum casting provided with radiating vanes 16 arranged circumferentially around the outside of the casing.

In order to equalize the stress in the dielectric 3 between the armatures 1 and 2, I have provided a stress-equalizing metal member 17 interposed between the armatures 1 and 2 and embedded in the dielectric 3. This member 17 has a cylindrical portion 18 arranged between the armature 1 and the outer portion of the armature 2, and another cylindrical or cup-shaped portion 19 arranged between the interior cup 12 and armature 1, the two portions being connected together at the bottom 20. Armature 1 and member 18 are provided with openings 21 whereby the condenser may be thoroughly filled and embedded. The stress-equalizing member 17 is supported within the condenser casing 2 in spaced relation to armatures 1 and 2 by insulating means 22, preferably a perforated mica disc, secured to the member 17 on the upper edge thereof on the one hand and to the lower portion of the terminal 8 on the other hand by means of nuts 23.

The cover of the embodiment of Fig. 5 differs from previously described covers in that instead of mica, I have shown a saucer-shaped or concavo-convex insulating member or shell 24, which may be composed of any suitable insulating material such as porcelain, through which the terminal 8 extends and to which it is clamped. This porcelain shell or insulator 24 has its lower circumferential edge resting in a circular groove 25 on the upper edge of the casing 2 with its concave portion facing inwardly. The shell 24 is secured to the casing 2 by any suitable means such as a lead antimony alloy 26 poured into the groove 25 around the edge of the porcelain shell holding it in place. The space within shell 24 during the embedding process is filled with dielectric 3, increasing its insulating properties and forming a hard backing therefor.

This construction of porcelain shell with

its backing of fusible dielectric (the special sulfur) provides a thorough insulation of the casing 2, which may be considered the low potential terminal, from the high potential terminal 8 extending through the central portion thereof, the porcelain having fine dielectric properties and preventing creepage to a high degree. The armature 1 is supported in the solidified dielectric embedment and hence the terminal 8 and armature exert no appreciable pull on the member 24.

The dielectric embedment 3 of the construction of Fig. 5 consists preferably of the special sulfur embedment of the present invention treated and poured into the casing by the process hereinafter described.

In Figs. 7, 8, 9 and 10, I have illustrated a form of the invention in which the casing does not constitute one of the metal armatures and in which the dielectric, which preferably comprises the special sulfur of the present invention, is made by a different process than that in which the sulfur is not only a dielectric, but also a filler. Briefly, this type of condenser comprises a number of individually-formed condenser elements or sections connected in parallel and two groups of such parallel elements being connected in series and united to form a stack and then enclosed in a suitable casing which may thereafter be filled by any of the processes hereinafter described with a suitable filler, preferably of the special sulfur of the invention. In Fig. 10, I have illustrated one of such elements 30. This element comprises a metal base or block 31 to the opposite sides of which are secured a pair of metal armature plates 32 constituting the armature plates of one polarity, a metal armature plate 33 being located between them as hereinafter described and constituting the armature plate of the opposite polarity. The plates 32 are secured to the opposite sides of member 31 in recesses 32^a therein, whereby they are flush therewith. The three plates 32 and 33 are embedded in a fusible solid dielectric 34, preferably the special sulfur of the present invention, the outline of which is shown with a dashed line in the figure and which, when it solidifies, supports the armature 33 in spaced relation to the armatures 32, the armature 33 projecting beyond the upper ends of armatures 32 and being provided with suitable connecting tab 36. The unit 30 is embedded, preferably in the special sulfur dielectric of the present invention, by the hereinafter-described process in which the apparatus shown in Figs. 11, 12 and 13 may be employed as more fully described hereinafter. Referring to Figs. 7 and 8, several of the elements 30 shown in detail in Fig. 10 are assembled together to form a stack 37, the several elements 30 abutting each other

forming substantially a solid stack or mass. In this embodiment of the invention, the several elements 30 are assembled with their armatures vertical upon a metal base plate 38 and secured thereto by means of screws 39 extending through the base plate and into threaded openings 31^a in the bottom of the supporting blocks 31.

In this embodiment of the invention, I have illustrated the elements 30 of each half or group of the stack 37 so arranged that the tabs 36 of one group are at one side of the top of the stack and the tabs 36 of the other group at the opposite side of the top in spaced relation thereto, providing two groups of tabs 40, 41, which are spaced from each other sufficiently for insulating purposes. The tabs 36 of each group 40 and 41 are electrically and mechanically connected together by means of metal washers 42 interposed between them and secured together by metal bolting means 42^a. After the several elements 30 are secured to the base 38, and the tabs 40 and 41 connected together, the whole unit is placed within a suitable casing 43 which is preferably of metal with plate 38 resting on the bottom of the casing in contact therewith. This casing 43 is substantially rectangular at its lower portion and of a size to provide sufficient clearance between the assembled units 30 or stack 37 and the casing. In order to secure the assembled stack 37 within its casing, the several members 31 are provided with aligned horizontal openings 44 through which and through the sides of the casing 43 is threaded a metal bolt 45 which not only secures the stack 37 to the casing but also constitutes an electrical connection between the lower armatures 32 of the stack and the casing when the casing is to constitute a terminal. The bolt 45 is secured in the holes 44 and to the casing 43 by means of nuts 46. Additional nuts 47 may be threaded on the bolt for the purpose of securing leads. The upper portion of opposite sides of the casing 43 is flared outwardly as shown at 48 (Fig. 7), to provide sufficient electrical clearance between the terminals 40 and 41 and the casing and also to provide supporting means inherent in the casing for supporting the casing 43 or several of them in a rack. The upper end of this casing 43 is provided with an opening 49, the upper edges of the casing being bent inwardly to form a ledge 50, an annular ring 51 being located below the ledge 50 for bracing and reinforcing same. The casing proper, not including the cover, in the form here illustrated, is built up in three parts, a U-shaped intermediate portion 52 as shown in Fig. 7 and a pair of end plates 53 as shown in Fig. 8, and having a shape shown in Fig. 7 to enclose part 52. The plates 53 are secured to the open sides of the member 52 to form a casing therewith

by soldering, and in the present structure I have illustrated wires 54 extending along the corners formed by the members 52 and 53 and which are soldered in such corners by suitable solder 55 for securing the parts of the casing together. Mounted over the opening 49 at the top of the casing and secured to ledge 50 is a cover 56 of metal having a pair of openings 57 therein through which the leads 58 from the tabs 40 and 41 are led. A gasket 56^a is interposed between the cover 56 and ledge 50 to form a tight joint. Each of these leads 58 comprises a threaded terminal rod 59 which is supported by means of suitable nuts and washers 60 (forming a tight joint) in an insulating shell 61, preferably porcelain, which is substantially cup-shaped or concavo-convex. Each shell 61 at its edge (the concavity in the shell facing the casing) is secured to the metal cover 56 over an opening 57 by means of an annular ring 62 of metal to which it is secured by some suitable means such as an antimony lead alloy. The terminal 59 is centrally arranged within this cup-shaped insulating member 61 and extends through its upper small end at a distance sufficiently spaced from the cover 56 for insulation, the open and large end of the porcelain member 61 being secured to the ring 62. The terminal 59 may be electrically connected to the tabs 40 and 41 by any suitable conductors such as the flexible conductors 63 illustrated. In order to fill this condenser with a filler, if desired, I have provided an opening 65 at the side of the condenser through which a suitable filler may be poured and the embedment formed in the manner hereinafter described. An opening in the side of the casing secures a condenser in which not only the stack proper with its sulfur dielectric may be thoroughly embedded but also the terminals 59 and the space 61^a within the shell 61, providing a solid backing for the shells 61 and improving the insulation between the terminals 59 and the casing 43. When such an embedment is used, it is preferable to not only use the special sulfur of the present invention but this embedment should be done by the processes or methods hereinafter described. This method of embedment provides an insulator for terminal 59 which is substantially a sulfur insulator preferably of the special compact sulfur of this invention, protected by a porcelain shell. After embedment, the opening 65 may be closed by a plate 65^a which is preferably a name plate.

The arrangement of terminals upon the top of the condenser and the electrical connection between the condenser and the casing allows the use of three different values of capacity in the condenser by—

(1) Employing the two terminals 59 as the connections.

(2) Employing one of the terminals 59 and the casing 53 as the connections.

(3) Employing both of the terminals 59 parallel connected as one terminal and the casing 53 as the second terminal.

It is preferable that the two groups of sections or elements be of equal capacity so that when used in series, the potential across each section will be the same. If the groups were of unequal capacities, the potentials would divide inversely as the capacities and the sections of the group of smaller capacity would receive a disproportionately greater strain than the sections of the group of larger capacity. When the groups are connected in series, twice the potential that can be applied to a single group may be applied to the condenser. The capacity of the condenser will then be half the capacity of one of the groups of elements. When the condenser is used with one terminal and the casing as the connections, the potential of a single group can be applied to the condenser and the capacity will be the capacity of a single group of sections. When both terminals are parallel connected and form one of the terminals of the condenser, and the casing the other terminal of the condenser, the potential of a single group may be impressed across the condenser and the capacity of the condenser will be twice the capacity of one of the groups. If the capacity of each group is taken as unity, then the capacity of the first grouping will be one-half, of the second grouping one, and of the third grouping two, respectively.

In Figs. 11, 12 and 13, I have illustrated, by way of an example, a mould which may be employed in building the elements 30 and embedding each in its dielectric 34. This mould comprises a base 70 of suitable insulating material such as glass and, a pair of vertically arranged spaced side plates 71 thereon which also are preferably of insulating material such as glass and adapted to engage, as shown in Fig. 11, the outer sides of the armatures 32 arranged on edge in the mold and of the metal supporting block 31 arranged on end in the mold and resting upon the base 70, the block 31 constituting a part of the mold closure between plates 71 at one end. At the opposite end of the mold is a vertically-arranged metal block or member 72 resting on end on base 70 and between plates 71 and closing the opposite end of the mold and forming with the member 31 and sides 71 a complete enclosure. The member 72 is provided with a recess 73 into which fits the tab 36 of the central armature 33, the tab and armature being properly centered and secured to the member 72 by means of a metal block 74 filling the remainder of recess 73 to make a tight mold and prevent sulfur from solidifying

around the tab 36 and screw 75 extending transversely through block 74, tab 36 and member 72 to hold them in place. The armature 33 is provided with flat edges 76 (see Fig. 10), on each side of the tab 36 which engage the inner surface of the vertical member 72. The armature 33 is electrically connected to the metal block 72 and is positioned centrally between the armatures 32 when assembled as shown in Fig. 11. The upper portion of this member 72 is tapered upwardly and outwardly at 77 to facilitate the embedding operation and extends some distance above the upper part of the condenser to be formed in order to provide a head of molten dielectric above the part which it is desired to embed so that voids and cracks will form at a point above the condenser being treated. Opposing the tapered portion 77 of the member 72 at the opposite side of the mold and constituting an upper continuation of block 31 and closure is a metal member 78 which is tapered upwardly and outwardly as shown at 79 to facilitate the filling operation and with member 72 and sides 71 forms a head for the molten material at a point above the condenser. The member 72 at one end and members 78, 31 at the opposite end of the mold are of some suitable conducting material such as metal, for the purpose hereinafter described, and are insulated from each other by base 70 and side plates 71. The side plates 71 are secured to the end closures 72 and 31, 78 after armature 33 has been secured to member 72 by means of U-shaped springs 80 which are secured intermediate their ends by screws 81 to the outer edges of members 72, 31 and 78 and which extend around the vertical edges and outside of the plates 71 and hold them tightly against the intermediate members. Furthermore springs 80 as secured prevent the vertical intermediate members from being pushed in too far between the plates 71, thus maintaining the proper relative position of armatures 32 and 33. The slot 73 of the member 72 is so arranged that the center armature 33 is centrally located between the armatures 32. The screws 81 which secure a spring 80 to member 31 may be threaded into the same holes 31^a which later secure the member 31 to the base plate 38 in the final assembly of the condenser.

In forming the embedment 34, the assembled mold, with the condenser element 30 in position therein as shown, is placed in an oven and brought to a temperature of approximately 140° C. or to temperatures at which sulfur is a thin, watery liquid. Sulfur which previously has been heat treated as hereinafter described is heated to approximately 140° C. or to a temperature between 115° and 155° C. and strained to remove extraneous matter. In this con-

dition, the sulfur is a thin, watery, limpid liquid, care being taken to maintain the temperature of the liquid such that it is entirely limpid. The mold is filled with

5 this sulfur to the top, forming a head of sulfur over the armatures. This filling may be under vacuum or without vacuum. When vacuum is used, a more complete assurance of the removal of air from the
10 mold is obtained than that obtained by the simple bubbling up of the air through the sulfur liquid due to the difference in the specific gravity of molten sulfur and air. The material is poured in limpid, for in
15 this condition entrapped air does not exist in the sulfur mass as would be the case if the sulfur were poured in its viscous state. After pouring or during the process of pouring, the end member 72 on the one side and
20 the members 31 and 78 on the opposite edge and consequently armatures 32 and 33 are subjected to an electric potential applied to them. In Fig. 12, I have illustrated diagrammatically a circuit C for doing this,
25 electrically connected to terminals T on the members 72 and 78. It is preferable that this potential be applied and its application maintained during the entire cooling process. The cooling is preferable from the
30 bottom up, i. e., the bottom of the mold is maintained at a temperature below the solidification temperature of sulfur by any suitable cooling means (not illustrated). Preferably, the head is heated and maintained
35 above the melting temperature of sulfur, i. e., the sulfur above the condenser is heated to a temperature of approximately 140° C. during the initial stages of the cooling operation. This means may comprise
40 a Bunsen burner B heating a metal rod R submerged in the liquid as illustrated. After the sulfur has solidified to the desired height above the armatures, which is preferably slightly greater than the upper margin
45 of the condenser, application of heat to the top of the mold may be stopped. The electric potential above referred to is applied continuously during the cooling and until the mass has solidified. The potential
50 is then discontinued, the mold opened, and the element 30 with its dielectric removed. The element 30 has attached to it the sulfur of the head. This may be cut off by a hot wire or knife, or sawed off. The
55 application of potential across armatures 32 and 33 during the cooling of the sulfur has a distinct advantage in forming a compact and non-porous form of sulfur free from internal strains and in securing very
60 close and intimate contact between the sulfur dielectric and the metal armatures.

The voltage applied during cooling of the sulfur between the condenser plates or armatures by the method described by way of
65 example in an actual use of the invention

was between 17,000 and 20,000 volts maximum across a dielectric 1/16 of an inch thick. In general, the potential applied during this process should be of the order
70 of magnitude of the breakdown strength of the sulfur. The current may be an alternating 500-cycle current.

The application of potential between the armatures during cooling results in very
75 close adhesion between the sulfur and the metal armatures which appears to be of a molecular nature. The armature when forced away from the sulfur embedment after this process appears mottled with sulfur, the sulfur sticking to it very closely
80 and intimately. The application of potential also increases the dielectric and mechanical strength of the sulfur. On the other hand, if a potential is not applied to the armatures across the dielectric during cooling,
85 the sulfur does not adhere when broken away and polished surfaces at the cleavage are obtained. The structure of sulfur dielectric obtained by this process is compact, non-porous, of a uniform nature,—that is,
90 holosteric,—and more or less plastic, there being very little internal mechanical strain within the dielectric. Suitable materials for the armatures and other metal parts not only in connection with the application of
95 potential during the process but also in the structures disclosed should be such as are not appreciably chemically attacked or corroded by sulfur, such as aluminum, iron or brass. It has been found that copper and
100 lead and aluminum alloys containing lead are unsatisfactory in this process. The sheets of metal may be of any desired thickness. It has been found that the sulfur dielectric formed as above described and
105 having a thickness of 1/16 of an inch would stand a voltage of 13,000 and has a breakdown strength of 30,000 volts.

The process above described may also be employed in the formation of dielectric
110 in other forms of condensers and by means other than the mold of Figs. 11 and 12. In constructions such as illustrated in Figs. 1 to 6, employing a suitable head, as illustrated in broken lines Fig. 3, attached to
115 the bottom or top of the condenser, according to whether or not the condenser is to be filled through the bottom or through the top, heat the condenser casing and head to a temperature of between 115° and 155°
120 C., then pour therein liquid sulfur heat treated as hereinafter described and heated preferably at the time of pouring to a temperature above 115° and below 155° C., then
125 apply a cooling gradient, that is, either by cooling at the bottom and applying heat at the top, or by cooling at the bottom alone, and apply voltage, of the order above specified, to the armatures and through the dielectric during cooling. In some cases, it
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may not be necessary to apply potential to the armatures. This last process of cooling may also be employed without the application of potential in cases where the sulfur is used simply as a filler around stacks of different types as hereinafter more fully described. In some cases, it is preferable to apply vacuum to remove air from the casing and head before and during the pouring in of the liquid.

In embedding from the top or bottom with the use of a head in the forms of condensers described in Figs. 1 to 6, owing to the physical characteristics of the sulfur, it has been found difficult to cut off the surplus embedment of sulfur in the head flush with the casing in order that the cover or bottom may be applied. This should preferably be done by melting away the surplus sulfur flush with the casing. For this purpose, I have provided the piece of apparatus disclosed in Fig. 19. In order not to strain the sulfur by breaking or cutting, it is preferable to melt any surplus sulfur which may be above the upper level of the casing. In the present case, I have provided a circular disc 85 of metal having a central hole 86 adapted to slide over the threads upon the central terminal 8. After the casing head is removed and as much of the sulfur is broken off as is convenient without damaging the embedment within the casing proper, the disc is heated to a temperature above 155° C. and placed upon the threaded terminal and rotated by the handle 87. Contact of this hot disc 85 with the sulfur melts the same until the disc is flush with the casing. The disc can then be removed and the cover put in position. In the present embodiment of the invention, the preferred type of cover is a mica disc which is secured preferably by contact with the sulfur embedment, and in the present case the surface of the embedment when the cover is applied should be sufficiently viscous or fluid whereby the cover may be stuck to the same upon solidification of the embedment. Thereafter the nut above the central terminal will hold the cover in place against possible dislocation. In cases where the condenser is embedded through the bottom, the cover is first secured in position by an annular ring securing the same to the top of the casing. The armature 1 and terminal 8 are centered and secured in position. The melted sulfur is then poured in forming a compact embedment up against the cover sticking to the same. After solidification, the ring is removed.

I have also devised a form of condenser which is made by building up a stack composed of alternate conductor sheets and sheets of sulfur, the sulfur sheets being so treated, preferably, that they are in plastic

condition; that is, more or less flexible and rubberlike during the building of the stack. In the embodiment of the invention shown in Figs. 14 and 15, the condenser stack S comprises a plurality of sections 90 connected in series and having between them separators 91 projecting beyond the ends of the sections at a difference of potential, these separators 91 being preferably composed of sulfur sheets. In this embodiment of the invention, the stack is illustrated as having its opposite ends 92-93 at substantially the same potential and electrically connected to casing 97, constituting the low potential terminal, while an intermediate part 94 of the stack, a point of high potential, is connected to a central terminal 95 secured in an insulating shell 96 of casing 97. Each section preferably consists of alternate sheets of metal conductors or foil 98 and dielectric, in the present instance a dielectric composed of sulfur sheets 99. After the several sections have been built and electrically connected together as illustrated diagrammatically in Fig. 14, they may be secured together for easy handling by pouring melted sulfur, which soon hardens forming strips 100, across the stack upon opposite sides as illustrated in Fig. 15. The stack S after construction is preferably placed in casing 97 of metal having a removable bottom 101 through which the casing may be filled and the stack S embedded with sulfur E. The casing 97 is substantially rectangular in cross section, converging at the top, and having an annular groove 102 surrounding an opening 102^a in the casing 97 at the top. Groove 102 receives the annular edge 103 of the porcelain shell or cap 96 facing opening 102^a and through which the threaded terminal 95 extends and which is secured to the shell by means of a pair of nuts 104-105 threaded upon the terminal upon opposite sides of the shell 96, suitable rubber washers 106 being interposed between the shell and the nuts 104-105 for water-tightness. The shell 96 is secured in the groove 102 of the converging top of the condenser by means of suitable solder such as a lead-antimony alloy, the terminal 95 being previously connected to the central portion 94 of the stack by a suitable conductor 107 as shown. The conductor 107 consists of stranded wires which are flared out or fanned out at their inner ends and the individual wires soldered to the connected foil bunches at 94 uniformly over the same as illustrated in Fig. 15. This form of connection prevents the tearing of the fragile foil tabs (which is preferably aluminum or tin) by the lead which heretofore has consisted of a more or less stiff copper strip which tended to tear the foil tabs. In order to support the normally upper end of the stack S in spaced relation to the casing when

inverted for filling purposes, the upper end of the stack is provided with sulfur lugs 108 (Fig. 15) which are molded thereon when the stack is being built and which are adapted to engage the corners of the metal casing 97 to maintain the stack spaced from the normal top and sides during the filling operation. After the stack is positioned within the casing with the leads from the ends 92--93 coming out above the casing, the condenser with its head is filled with melted sulfur, heat treated as hereinafter described and heated to a temperature of between 115° and 155° C. but low enough not to melt the sheets of sulfur as above described, either with or without the application of vacuum before and during the filling operation as desired. The sulfur plates 99 and separators 91 are embedded as it were in an embedment of sulfur, the outlines of the sheets being distinguishable in the embedment by reason of different characteristics. As in the forms of embedment previously described, this embedment E is compact and non-porous and holosteric, forming a solid insulation around terminal 95 within shell 96 and forming a backing for the latter as previously described.

The sulfur sheets 91 and 93 of the construction of Figs. 14 and 15 may be made by any suitable process or method, although I have devised one utilizing the following principle. If sulfur is heated to a temperature of between 160° and 180° C. and preferably to a temperature of around 170 to 172° C. and suddenly cooled, the sulfur assumes a plastic rubberlike form which can be easily formed into sheets. These sheets finally set into the compact, non-porous stable sulfur of the present invention.

In Figs. 16 to 18 is illustrated a mold especially adapted for the formation of sheets for use in condensers or in other connections. This mold comprises a pair of coacting parts 110 and 111, one part 110 being a plate provided with ribs 112 on one side along three edges thereof and the other edge 113 being bent outwardly from the general plane of the part. The ribs 112 are tapered at 112^a on their inner faces to allow the easy removal of the sulfur sheet after the formation thereof. The inner faces of the mold should also be highly polished for the same purpose. The part 111 comprises a rectangular plate adapted to fit upon the ribs 112 of plate 110 forming between them a space X in which the sulfur may be molded and into which it may be conveniently poured, the upper portion of the rectangular plate 111 and the flared portion 113 of the rib plate 110 co-acting to form a funnel through which the molten sulfur may be conveniently poured. There is also provided a water-tight tapered casing 114 open at its large end, converging toward its bot-

tom and adapted to receive the parts 110 and 111, the interior dimensions of the casing 114 being such as to easily receive the two parts 110--111, maintaining them, however, in alignment. In order to secure the two parts 110--111 of the mold together within this casing 114, there is provided a wedge 115 adapted to be jammed in between the two parts of the mold and one side of the casing to hold them in place. All the parts of the mold, including the casing and wedge, are preferably of some material not attacked by molten sulfur and having high heat conductivity, such as aluminum. The mold parts should also be rigid to maintain a space X of uniform dimension between them in order to secure sulfur sheets of uniform thickness.

I have devised the following process, which, if so desired, may be practiced with the molds above-described, for forming sulfur plastic sheets or embedments of flexible or plastic character, which process is also applicable in certain cases, and, wherever desired, for filling the embedments of other forms of condensers, especially those illustrated in Figs. 1 to 5. This process is substantially as follows. The assembled mold above described or any other suitable receptacle or condenser casing is heated to approximately a temperature of between 115° and 155° C., preferably around 140° C., the temperature of the thin, liquid, watery sulfur; then sulfur which is previously heat treated as hereinafter described, brought to practically the same temperature and, when thin and liquid, is poured into the mold or casing either with or without the application of vacuum before and during pouring. Thin liquid sulfur does not entrap air in its mass like the viscid sulfur. After the thin liquid sulfur, at this temperature, has been poured into the mold or other casing, the whole, both mold (or casing) and liquid sulfur, is raised to a temperature of between 160° C. and 180° C. to make the liquid more or less viscid or viscous. The whole, including the mold or casing, is then suddenly chilled, preferably by immersion in cold water or by the application of chilled air, forming the solid plastic form of sulfur having flexibility and of a rubberlike nature, and in case the mold is used, plastic sheets in form adapted for building condensers of the stack or roll form. It is preferred that the thickness of these plastic sheets when formed should be less than $\frac{1}{16}$ of an inch, as it has not, up to this time, been found practical to thoroughly chill a sheet throughout when the thickness is greater than that, and sheets of $\frac{1}{32}$ of an inch thick are desirable, it being now possible to obtain very good sheets of $\frac{1}{16}$ of an inch in thickness. The sheets after being formed in the mold above described are

removed and cut to size while still plastic. Afterwards sheets formed as above-described or by any other suitable process are incorporated in a stack such as in the
5 stack disclosed in Figs. 14 and 15, the stack being built while the sheets are plastic and the embedment E being also placed in the casing while the said sheets are more or less plastic before their final setting to the hard,
10 compact, non-porous, crystalline form which is a characteristic of the sulfur of the present invention. In the form of condenser shown in Figs. 14 and 15, the separators should have a thickness of ap-
15 proximately three times that of the dielectric sheets, and the foil should preferably be of aluminum and have a thickness of approximately 10 mils, although the materials of the foil and the thickness thereof depend
20 upon circumstances and the use to which the condenser is to be put.

Condensers such as the form disclosed in Figs. 1 to 5, 14 and 15 may be embedded by placing a head upon the top or bottom of the
25 casing, the latter then being in an inverted position, applying vacuum to remove air from the interior of the casing and head, and pouring sulfur previously heat treated as hereinafter described, in a molten con-
30 dition preferably heated to between 115° and 155° C., filling the head and casing and porcelain shell, if present, completely embedding the stack and terminals and forming a compact mass. The head should
35 preferably be maintained hot at the top and the casing cool at the bottom to provide a temperature gradient so that the solidification will take place from the bottom up-
40 wardly. After the molten sulfur has been poured into the casing, the vacuum may be removed and pressure applied to the cooling mass of sulfur, preferably air pressure, to ensure a solid and uniform mass of filler or dielectric, as the case may be.

Another method which may be employed for suddenly cooling masses of sulfur to form the sulfur dielectric or filler of the present invention is to heat the metal part
45 in which the sulfur is to be suddenly cooled to about 140° C.; fill this metal part, under vacuum if so desired, whether a casing or mold, with or without a head, with watery sulfur which is previously preheated as hereinafter described and brought to a
50 temperature of between 115° and 155° C.; heating both the receptacle and sulfur therein to a temperature of above 160° C. and below 180° C. to form the viscous sulfur; placing this viscous sulfur with its container
55 in the chamber; applying pressure to the mass of the sulfur while still hot, this pressure preferably consisting of the application of pressure such as compressed air to the same; and then suddenly cooling the con-
60 tainer and sulfur while maintaining the

pressure. This cooling may be done by forcing a spray of water over the condenser receptacle or mold under a force greater than the pressure of air within the cham-
ber.

The product formed by the above processes and methods in connection with heat treatment as hereinafter described and used in connection with the condensers of this invention such as disclosed, in which sul-
70 fur is used either as a combined dielectric and filler, or in the sheet form, or simply as a filler, is characterized by non-friability, toughness, non-porosity, cohesion in its mass, freedom from internal strains, and its great compactness compared to commer-
75 cial sulfur. The sulfur of the present invention, whether used as a combination filler and dielectric, or simply as a filler, or simply or a dielectric, is free from cracks, voids and internal strains which cause the well-known brittleness and breakdown. The de-
80 gree of compactness of the sulfur product of the above processes is such that its density is greater than the density of the commercial sulfur, roll form, which has a specific gravity of 1.92, the special sulfur of this invention having approximately a specific
85 gravity of a rhombic crystal of sulfur which is 2.07. This compactness is substantially uniform, the dielectric, whether used as a combination filler and dielectric or as a filler, having a uniform consistency or appearance free from voids and cracks and being homogeneous; that is, holosteric. The
90 comparative compactness and porosity of the sulfur of this invention and commercial sulfur may be determined by applying a mixture of red ink or other coloring mat-
95 ter and wood alcohol or other solvent to each. The colored mixture permeates the common form, being rapidly absorbed into the mass of the material by capillary attraction. In the product of this invention, no appreciable penetration occurs. The
100 processes or methods employed in the present invention not only provide a form of sulfur having the characteristics above described which distinguish it from the commercial form, but also places and maintains the sulfur in intimate contact with the ar-
105 matures without separating therefrom upon cooling. The means employed for doing this reside first in the application of potential through the armatures and dielectric during the cooling process, in the case of the first process; secondly, as in the case of rapid chilling, by the application of pres-
110 sure to the dielectric during the cooling, this compensating for any shrinkage due to the solidification of the sulfur and main-
115 taining it in intimate contact with the adjacent armatures.

In the above description of the sulfur embedment and dielectric of the invention used

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in connection with different types of condensers, I have referred to sulfur generally without any reference as to whether or not any other materials may be incorporated in the sulfur to render it more available for use in condensers. It is within the scope of the present invention, however, to incorporate or use in connection with sulfur as a dielectric other materials in order to enhance its value as a practical dielectric in condenser manufacture, such as the eutectic materials referred to in the accompanying application of G. W. Pickard, filed April 28, 1921, S. N. 465,079.

The present invention provides a compact, cheap condenser for general usage but especially adapted for low capacity and high voltage work and in which the sulfur is used as a dielectric, filler, or combination filler and dielectric. Sulfur when treated by the processes herein described is superior to wax for a filler or dielectric, or both, because of its higher dielectric constant and lower loss compared with wax at higher temperature and because sulfur withstands temperatures of a relatively higher order and where brushing occurs does not undergo chemical change. Wax, on the other hand, carbonizes and releases water at higher temperatures. Another property of sulfur is its ability to withstand breakdown and reheal without any change whatever and its apparent greater thermo conductivity as compared with waxes.

An advantage of the use of sulfur as herein processed or treated in condensers of this character resides in the fact that no binder or supporting material such as paper or other fibrous material, having poor dielectric properties, is necessary in order to maintain the sulfur in proper condition within the condenser. The condenser constructions of the present invention co-operating with the special processes or methods herein provided secure compact, non-porous, non-brittle, dielectric which requires no supporting medium of inferior dielectric properties such as the paper or other fibrous material above described, although it is contemplated in some cases to use a dielectric therewith in the nature of a eutectic in which small amounts of fusible dielectrics having lower melting points than sulfur may be incorporated and mixed thoroughly with the sulfur to render the same more available for the purposes of this invention.

A valuable feature in connection with the use of sulfur as a dielectric or filler is that when it breaks down, it heals immediately and is unimpaired. In cases where a section of sulfur dielectric has been broken down several hundred times, its final breakdown voltage was higher than its first. This is unique among condenser dielectrics, and

resides in the fact that sulfur is an element and cannot be decomposed by an electric discharge. All that happens when sulfur dielectric breaks down is the momentary formation of a gaseous or liquid sulfur, which interrupts the electric discharge, liquid sulfur having a higher breakdown strength than solid sulfur, and which at once solidifies and restores the condenser to its original or better condition. With wax, a breakdown forms carbon and the dielectric is weaker than before. Similarly, with mica, the solid is either punctured beyond repair, or the chemical composition is so broken down as to form a conducting path. Again, if the sulfur dielectric should happen to crack, this crack will rapidly be healed and sealed up because the rush of current following a breakdown seals the fault almost instantly. For instance, a $\frac{1}{8}$ " layer of sulfur showed initial breakdown of about 20,000 volts, but after a number of breakdowns its dielectric strength rose to over 42,000 volts. The ideal condenser dielectric is then a simple non-conducting chemical element, having suitable insulating and dielectric qualities, such as sulfur or selenium.

To ensure rehealing of sulfur or selenium dielectric, the armatures of the condenser should have a fairly good thermal conductivity and should be composed of relatively high melting point metals which are not appreciably attacked by sulfur to form sulfides under localized heating due to breakdown. For instance, thin foils are less suited than heavier elements having greater thermal conductivity. Suitable materials for rehealing condensers are aluminum, brass and iron, which are sufficiently chemically inert to sulfur under service conditions as contrasted with copper, which is readily attacked by sulfur. The degree of the several qualities or properties required in armatures can be varied relatively to each other. For instance, if the thermal conductivity is relatively high, the melting point may be relatively lower and the degree of chemical inertness to sulfur may be less. In any event, the character or quality of the armatures should be such that sulfides or metal streaks will not form a conductive path through the sulfur upon heating due to breakdown. Under the above conditions, the sulfur will immediately reheal, leaving the condenser in its original condition.

Before the above-described processes or methods are performed, the sulfur used therein is preferably previously prepared by melting the roll sulfur of commerce and heating the molten sulfur for a period of several hours at a temperature to maintain it in a molten condition (either viscid or liquid, or both). This heat treatment causes a change in the commercial sulfur, which may be due

to the removal of gases or water, or other entrapped volatile substances in the commercial sulfur, and produces a cast which is compact, hard and cohesive, as contrasted
5 with the cast prepared by simply bringing commercial roll sulfur up to the molten condition and allowing it to cool. The time required to produce the sulfur with the above properties will vary directly with the
10 temperature at which it is heated. For instance, I have obtained very good results by heating the sulfur for five hours while maintaining the temperature at about 185° C., and very good results by maintaining a
15 temperature of 170° C. for about ten hours. At temperatures above 185° C., the sulfur tends to catch on fire. Roll sulfur that has been simply heated and allowed to cool produces a cast which generally is a loose
20 crystalline mass having a very small cohesion in its body. All the sulfur used in the herein-described processes or methods should preferably be heat treated prior to its use as a condenser dielectric or filler material, or both.

It is to be understood that the invention is not limited to the embodiments and features specifically shown and described herein, but that such embodiments and features
30 are subject to changes and modifications without any departure from the spirit of the invention.

I claim:—

1. In an electrical condenser, concentric
35 metal armatures, the outer armature constituting a casing, a cover of insulating material for said casing, a terminal projecting centrally through said cover and connected to an inner terminal, and an embedment of
40 sulfur within said casing.

2. In an electrical condenser, a casing, a condenser member within said casing, an embedment of solid moldable insulating material cast within said casing surrounding
45 and mechanically supporting said member, a light, weak insulating cover secured to said casing by means of said embedment, and a terminal from said member extending through said cover and clamped thereto.

3. In an electrical condenser, concentric
50 armatures, one of said armatures constituting a casing for the other from which it is spaced, an embedment of moldable insulating material cast within said casing and
55 between said armatures constituting the

condenser dielectric, a light, weak cover of insulating material secured to said casing by means of said embedment, and a terminal projecting centrally through said cover and attached thereto and connected to an
60 inner armature.

4. In an electrical condenser, concentric armatures, one of which constitutes a casing, an annular member of insulating material enclosing the upper portion of said
65 casing, the upper edge of said annular member being provided with a recess, combined filler and dielectric of solid fusible insulating material within said casing and between said armatures, a thin cover of
70 mica mounted upon said annular member within said recess and secured thereto by the backing of fusible insulating material, and a terminal projecting centrally through
75 said mica cover and secured thereto and connected to an inner armature.

5. In an electrical condenser, concentric armatures, one of which constitutes a casing, an embedment of compact, non-porous sulfur within said casing constituting a di-
80 electric, a mica cover for said casing in close contact with said sulfur which forms a backing therefor, a terminal projecting centrally through said mica cover and secured
85 thereto and connected to said inner armature, and means interposed between the edge of said cover and the casing for increasing the creepage distance between the inner armature and the outer armature.

6. In an electrical condenser, a casing, a
90 condenser member mounted in said casing, an embedment of moldable dielectric cast within said casing, a mica cover supported upon said casing in recesses on the upper edge thereof and secured to and supported
95 by a backing of said dielectric, and a terminal projecting centrally through said cover secured thereto and connected to said condenser member.

7. In an electrical condenser, the combination with concentric metal armatures, one enclosing the other and having a terminal-opening; of a cover of insulating material for said opening; a moldable dielectric cast
100 in said casing-armature in the space between the latter and the enclosed armature, and a terminal from the enclosed armature extending out of the casing-armature by way of said casing-cover.

WILLIAM H. PRIESS.