Feb. 10, 1925. 1,525,778

C. A. HELLMANN

VARIABLE CONDENSER

Filed April 17, 1922 2 Sheets-Sheet 1

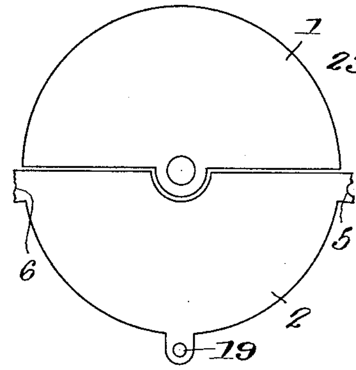

Fig. 1.

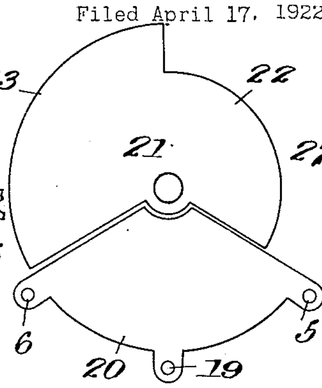

Fig. 2.

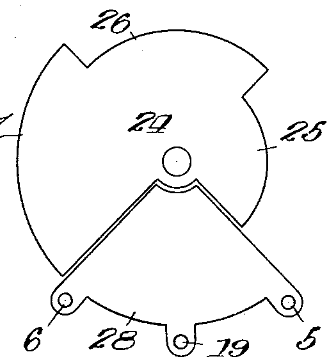

Fig. 3.

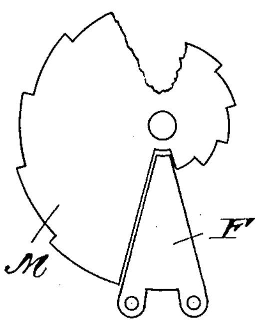

Fig. 4.

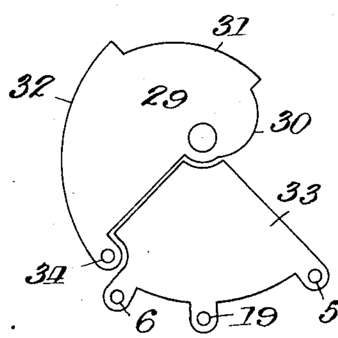

Fig. 5.

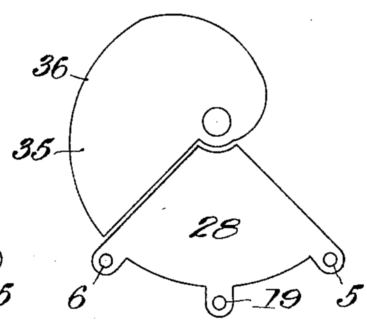

Fig. 6.

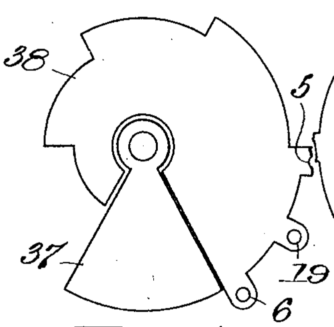

Fig. 7.

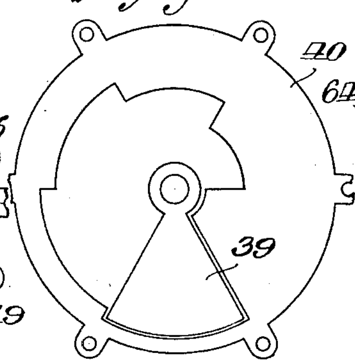

Fig. 8.

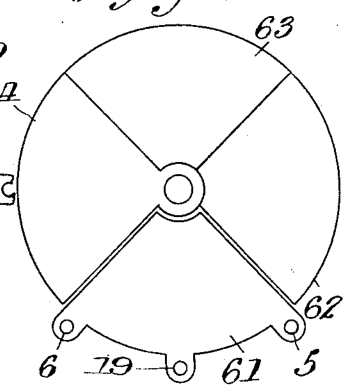

Fig. 9.

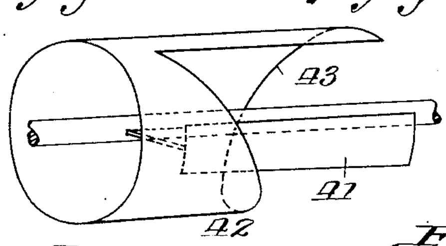

Fig. 10.

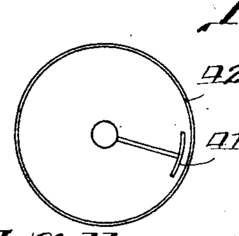

Fig. 11.

Carl A. Hellmann
INVENTOR.

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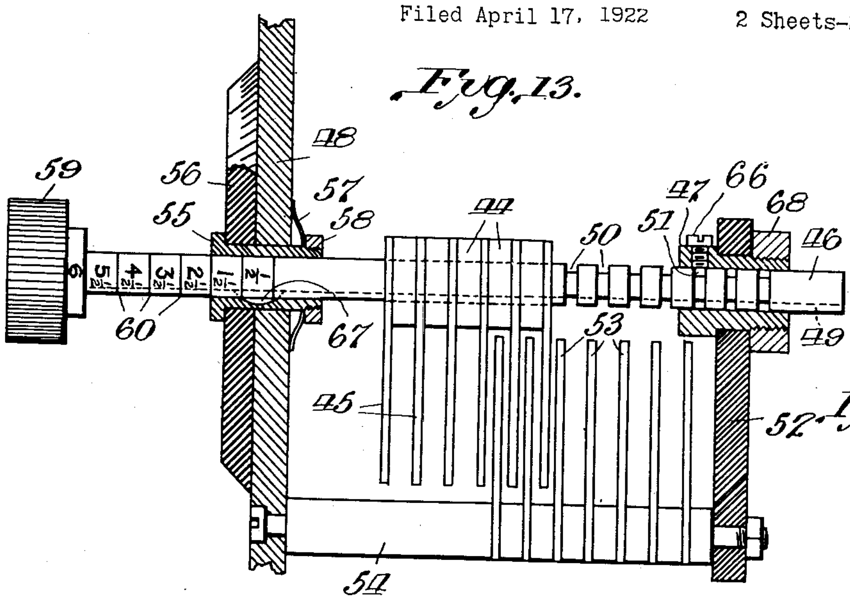
Fig. 13.



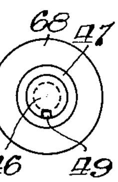
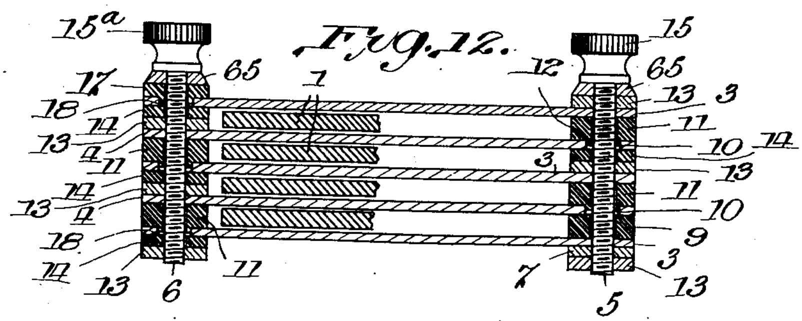


Fig. 14.

Fig. 12.



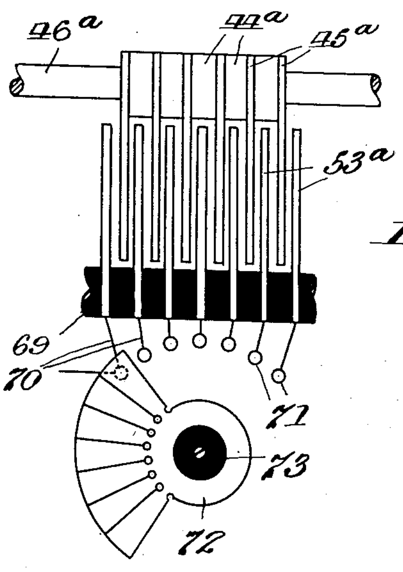


Fig. 15.

Carl A. Hellmann

INVENTOR.

Patented Feb. 10, 1925. **1,525,778**

UNITED STATES PATENT OFFICE.

CARL A. HELLMANN, OF WASHINGTON, DISTRICT OF COLUMBIA.

VARIABLE CONDENSER.

Application filed April 17, 1922. Serial No. 553,754.

To all whom it may concern:

Be it known that I, CARL A. HELLMANN, a citizen of the United States, residing at Washington, D. C., have invented certain new and useful Improvements in Variable Condensers, of which the following is a specification.

My invention relates to condensers.

The object of the present invention is to provide an improved variable condenser, adapted for general use in the electrical arts and particularly adapted for use in connection with high frequency electrical work, such as the radio art or carrier wave wire signaling.

More specifically my invention relates to a rotary variable condenser wherein a useful variation of capacity may be had over an angle of rotation exceeding 180° and approaching as near to 360° as may be desired in any particular case.

Another object of the invention is to provide a condenser having several distinct ranges of capacity, any one of which may be readily selected for service by mechanical or electrical means, or by both together.

A further object is to provide a condenser having no movable conducting plates, the dielectric instead being movable, whereby possibility of short-circuit between the conducting plates is practically eliminated.

Other objects and advantages of the invention will appear from the present specification and the accompanying drawing, wherein all the figures are purely diagrammatic. In said drawing:

Fig. 1 illustrates one feature of my invention applied to a rotary variable condenser of the ordinary type, at present well known, and having a useful range of approximately 180°.

Fig. 2 illustrates a rotary variable condenser having a useful range of approximately 240°.

Fig. 3 illustrates one wherein the useful range approximates 270°.

Fig. 4 similarly illustrates the general case of a rotary condenser constructed in accordance with my invention whereby a useful range of

$$\frac{n}{n+1}\times 360^\circ$$

is attained, n being any desired number, and

$$\frac{n}{n+1}$$

being as near unity as may be desired in any case.

Figs. 5 and 6 illustrate condensers having a useful range exceeding 180°, coincident with a variable rate of change of capacity instead of the uniform rate attained in the forms shown in the preceding figures.

Fig. 7 illustrates a condenser wherein the movable sector is of smaller angular extent than the stationary sector.

Fig. 8 likewise illustrates a condenser wherein the movable sector is of smaller angular extent than the stationary sector, which is here arranged peripherally instead of centrally as in the preceding figures.

Fig. 9 illustrates a condenser having movable sectors of individually different angular extents whereby a range exceeding 180° is obtained.

Figs. 10 and 11 illustrate a cylindrical type of condensers embodying features of my invention, in perspective and in end elevation respectively.

Fig. 12 is a section through a condenser wherein the dielectric is movable, the fixed plates being alternately of opposite polarity, (that is, connected to opposite terminals). This section is such as would be obtained on a plane passing through 5 and 6 of Figs. 1, 2, 3, etc.

Fig. 13 illustrates mechanical means for varying the range of a condenser by shifting its rotary member axially, thereby putting more or less plates in position to become active.

Fig. 14 illustrates a detail of Fig. 13.

Fig. 15 illustrates electrical means for selecting a desired capacity range instead of the mechanical means of Fig. 13. It will be understood that both said means together or either alone may be employed in any of the figures.

While in Figs. 2, 3, 4, 5, 6, and 9 the sector having the larger angular extent is shown as the movable one, it is obvious that although in general it is convenient to so construct the device, yet it is equally capable of construction as in Figs. 7 and 8 wherein the sector of smaller angle is rotatable. All these figures may therefore be reversed if preferred, in this respect, without departing from the invention.

In applying one feature of my invention to a rotary variable condenser of the ordinary type as shown in Fig. 1, the movable sector 1 is made of one or more sheets of an appropriate dielectric, for instance, mica, and is adapted to interleave between the corresponding conductive sheets of the stationary sector 2. As shown in Fig. 12, alternate conductive sheets 3 are connected to one terminal 15 of the condenser the remaining sheets 4 to the other terminal 15^a. When the rotary sector is in the position shown in Fig. 1 the capacity is a minimum, whereas it becomes a maximum upon rotation through 180°. If s is the distance between adjacent stationary sheets, and t the thickness of each dielectric sheet of the movable sector, and K its specific inductive capacity, then the capacity ratio of maximum to minimum will be

$$\frac{SK}{SK+T(1-K)}.$$

If t is equal to s, this becomes K, and such value may be nearly attained, inasmuch as no clearance is needed to prevent the dielectric from touching the stationary sheets, as would be the case if all the sheets were of conductive material, so that the dielectric needs be only thin enough to move freely between the conductive plates. The value of K for mica is roughly between 6 and 7, thus providing a condenser whose capacity varies from 1 at minimum to between 6 and 7 at maximum. Another construction of the dielectric sheet comprises a layer of a metallic salt, for instance powdered lead chloride or lead stearate (both of which have extremely high values of K, namely 42 and 74 respectively) held between two preferably very thin sheets of dielectric such as mica, bakelite etc., whereby a still greater ratio may be secured. Preferably such substances will be chosen as are free from any great dielectric losses. Metal sheets coated with dielectric will give still higher values of K, but are open to the objection that should the dielectric become abraded or otherwise pierced, short-circuits may result because of the conductivity of the metal. A finely powdered metal, such as "aluminum bronze" may be found satisfactory as a filler in some cases, and would be enclosed between thin dielectric sheets. An additional advantage in the type of condenser having no movable conductive plates is that no difficulty of making electrical contact with the plates exists, as would be the case with a movable conductive plate, requiring a sliding contact, or else a flexible lead soldered thereto. Fig. 12 shows how the plates 3 and 4 may be supported in proper spaced relation. The plates 3, 3, 3, are electrically connected to each other by means of a conductive rod 5 which is threaded throughout its length. A conductive nut 13 is screwed upon the lower end of the rod, followed by a conductive washer 7. The lowest plate 3 is then placed upon rod 5 as shown, the holes in said plates 3 being preferably just large enough to clear the threads. An insulating washer 9 is now slipped over the rod followed by the lowest plate 4. The plates 4 are provided with holes 10 considerably larger than the rod so as to clear same and leave a space concentric therewith. Next an insulating washer 11 having a reduced portion 12 which fits into this space is placed over the plate 4, and another plate 3 is then placed over this washer and secured by a conductive nut 13, which is threaded upon the rod 5. An insulating washer 14 follows, then another plate 4 and washer 11, and so on until the desired number of plates are assembled. A binding nut 15 may be threaded upon the projecting end of the rod 5, to serve as a connection for the plates 3, which are all connected in parallel by said rod. The other set of plates 4 is similarly connected together by a rod 6 as shown. Similar nuts 13, and 15^a and similar insulating washers 11 and 14 are provided but the parts are arranged on rod 6 as shown whereby the plates 4, 4 are in electrical contact with the rod 6 whereas plates 3, 3, 3 are insulated from same. A nut 17 of insulating material is threaded upon rod 6 and a nut 65 secures the top plate 3 in position. The plates 3, 3, 3 are provided with holes 18, corresponding to the holes 10 in plates 4, whereas plates 4, 4 fit fairly closely on rod 6.

Usually three or more supporting rods, for instance 5, 6 and 19, are used to properly hold and space the plates 3 and 4. The rods 5 and 6 are sufficient to provide electrical connections to the plates, and the third and any subsequent rods 19 may be of insulating material, or of metal either bare or covered with insulation, with corresponding insulating washers. While I have described these connection features in detail, it is obvious that the exact structure used is immaterial, inasmuch as any suitable means which connect the plates in the desired way may be employed.

An important feature of the invention is the provision of plates so shaped that a useful range of capacity variation materially exceeding 180° is attained. This feature is applicable whether the movable sector is conductive or dielectric in nature, and essentially consists in shaping the two sectors, fixed and rotary, so that neither comprises a semi-annular sector of approximately 180°, as is customary in most condensers of this general type now available. In addition, it is essential that the "active" parts of the two sectors be not symmetrically disposed about the center of rotation, (although they may be symmetrical with respect to a line, so called "mirror images" of each other) using the term "symmetrically" in its true geometrical sense, for instance as disclosed in my copending application, Serial No. 747,901, filed November 5, 1924, which is a continuation in part of the present case. For, in any condenser having a center of symmetry, a rotation of 180° from the "zero" or minimum point would cause maximum coincidence of the two sectors, with a resultant maximum of capacity and any further rotation would decrease the capacity again. Referring specifically to Fig. 2, there is shown a condenser whose fixed sector shaped plates 20 subtend nearly 120°, while the movable plates 21 subtend twice that angle, or about 240°. The fixed sector is of constant radius, whereas each of the movable plates comprises two adjacent circular sectors 22 and 23 each of 120° extent, the radius of the larger, 23, being approximately $\sqrt{2}$ times that of the smaller, 22. The radius of the fixed sector is of course large enough to allow the movable plates to be interleaved with the former. Inasmuch as the areas of similar circular sectors are proportional to the squares of their radii, the area of sector 23 will be twice that of sector 22. Upon clockwise rotation of plates 21, the capacity of the condenser will increase proportionally to the angle of interleaving of the plates, as usual, for the first 120°. Upon further rotation, the leading edges of the movable plates will emerge from between the fixed plates, but at the same time the larger sector 23 will now begin to enter between the plates of the fixed sector. Therefore, although sector 22 is emerging, yet the active area of the condenser is still increasing because the additional covered area of sector 23 is just twice that of the emerged area of sector 22, in all positions, whence it follows that a further increase of capacity for the second 120° proportional to the angle is secured, thus resulting in a useful active range of capacity extending over 240°, the increase of capacity being at a rate uniformly proportional to the angle of rotation.

It is obvious that if the movable element be made as shown in Fig. 3, wherein movable plates 24 comprise sectors 25, 26 and 27 each of 90° extent and of radii proportional to 1, $\sqrt{2}$, $\sqrt{3}$ respectively, and the fixed plates 28 are of 90° extent, a uniform useful active range of 270° is attained.

In general, as shown in Fig. 4, if the movable element M comprises n sectors, each of an angular extent of

$$\frac{360°}{n+1}$$

and of radii

$$1,\ \sqrt{2},\ \sqrt{3},\ 2,\ \sqrt{5}\ \ldots,\ \sqrt{n-1},\ \sqrt{n}$$

respectively, and the fixed sector F is of angular extent

$$\frac{360°}{n+1}$$

and radius somewhat greater than $\sqrt{n}$ a useful active range of capacity covering

$$\frac{n}{n+1}\times 360°$$

is attained, and the greater the value of n, the nearer this range approaches to 360°.

All the forms thus far described provide a uniform change of capacity, proportional to the angle of rotation. The radii are strictly proportional to the square roots of successive integers only in the theoretical form where the fixed sector terminates in a point at the center of rotation. In practice, this is of course impossible, and allowance must be made for the radius of the inner end of the fixed plates. If this radius be r, the exact expression for the radii of the movable plates is $r_n=$

$$\sqrt{nr_1^2-(n-1)r_0^2}$$

where r_n is the radius of the nth sector, r_0 the radius of the inner end of the stationary sector and r_1, is the radius of the first, or smallest, sector of the movable plates.

Should it be desired to provide a capacity variation proportional to other than the first power of the angle, and yet retain a continuous range of capacity exceeding 180° in accordance with some given relation, such variation may be attained by shaping the elements as shown for instance in Fig. 5. Here the movable element 29 comprises three sectors of curves 30, 31 and 32 respectively, presumably non-circular, and each shaped as desired to provide the correct relation between capacity and angle of rotation. The form shown in Fig. 5 corresponds to that of Fig. 3 in general structure and range, viz 270°. While in some cases it is possible to derive the curves by means of their polar equations, obtained by the methods of the calculus, in general it is preferred to shape them by "trial and error." The shape that is, radial extent, of the fixed element, 33 is more or less immaterial, except that it should be large enough to accommodate the largest portion of the movable element 29. A spacing member 34 may be provided at the outer extremity of the movable element, to retain the plates in properly spaced relation, in the way well known in the art. If desired, the plates of the movable element may be shaped as shown in Fig. 6. Here the element 35 is bounded by a smooth curve 36 instead of the plurality of arcs of the sectors of Fig. 5 for instance. While it is perhaps not possible to obtain as good proportionality of angle of rotation and capacity with this form, nevertheless it is amply satisfactory in many cases and is easier to manufacture.

Fig. 7 illustrates a form wherein the movable element 37 is a sector of uniform radius whereas the fixed element 38 comprises adjacent sectors of different radii, thus giving the same electrical results as the form of Fig. 4, though mechanically different. A still further variation in form is shown in Fig. 8, wherein the movable element 39 is a sector of uniform radius, the fixed element comprising a substantially circular disc 40 with portions cut away at its center as shown. The operation of this form is obvious and also is electrically identical with that of Figs. 4, and 7.

The form shown in Fig. 9 comprises a fixed sector 61 of any desired angle, here shown as 90°, cooperating with a movable sector made up of sectors of varying angle, for instance, 64 of 90°, 63 of 180° and 62 of 270°. The operation of this form is similar to that of Fig. 4, the first 90° of clockwise rotation putting only plate 62 into action, the next 90° making no change in the active area of 62 but gradually making 63 active, the last 90° leaving 62 and 63 unchanged electrically but gradually making 64 active, whereby a uniform variation of capacity from 0 to 270° is attained. Obviously any number of sectors 62, 63 and 64 may be used and the angle of 61 may be more or less than 90° as desired the number of sizes of the movable plates being of course correspondingly varied as well as their angular extents. For instance, if plate 61 were changed to 120°, only two sizes of movable plates would be used, of 120° and 240° respectively, and if plate 61 were changed to 60°, five sizes of movable plates would be provided, of 60°, 120°, 180°, 240° and 300° respectively. In these types the ranges would be 240° and 300° respectively. This form offers the advantage of simplicity of manufacture, but is not essentially different in operation from the previously described forms.

Another form which my invention may take is shown in Fig. 10, wherein the movable element 41 is an arc of a cylindrical surface, cooperating with a stationary cylindrical element 42 the latter having a variable longitudinal extent. It is of course immaterial what shape the space curve 43, which constitutes one edge of the cylindrical element, may take, and its shape in any particular case depends upon the relation of capacity and angle desired. This curve may likewise be either "stepped" or "smooth," and it is obvious that it is immaterial which element is the movable one, 41 or 42.

As shown in Fig. 13 the movable element 44 of the condenser comprises a plurality of sectors 45, which may be of any of the shapes or materials hereinbefore disclosed, mounted on a shaft 46, supported rotatably and slidably by a bearing 47 near one end and supported by the panel 48 near its other end. The shaft 46 has a longitudinal slot or key-way 49 therein and also has a series of annular grooves 50 in the portion adjacent the bearing 47. A screw 66 has an end 51 projecting into the key-way 49 or one of the grooves 50, both being of proper width to receive it. The bearing 47 is supported by the back 52 which serves in the usual manner to support the stationary plates or sectors 53 of the condenser, by means of the usual posts 54 only one of which is shown, which, if the plates 45 be of dielectrical material, will be preferably made as shown in Fig. 12, but if all the plates be metallic will be made in the ordinary manner. As illustrated, the front of the condenser is the panel 48 itself, though obviously in a portable condenser unit, front and back would be alike in general. A sleeve 55 carrying the dial 56 is keyed slidably as at 67 on the shaft 46 and is mounted to rotate in the panel 48. A spring washer 57 held by a nut 58 serves to retain the dial 56 in proper position against panel 48. The movable sectors 45 are keyed to the shaft 46 by means of the same key-way 49 and may be adjusted into the correct position and then secured to the shaft in any known way. The shaft terminates in a knob 59 and has a series of graduations 60 adjacent said knob.

In operation, the condenser will be manipulated just as any other rotary condenser, except that its effective angle is between 180° and 360° instead of being limited to 180° or less as in previously known types. When the dial is at its zero position, that is, when the movable sector plates are entirely clear of the fixed plates, the slot 49 is in register with the lug 51, and in this position it is possible to adjust the shaft 46 longitudinally to bring any one of the grooves 50 in alinement with the lug 51. These grooves are spaced the same distance apart as the sectors, so that whenever a groove is in alinement with the lug 51, the sectors are automatically alined with the spaces between the fixed plates, and may then be rotated by knob 59 to vary the capacity in the usual way. In this manner the range of capacity may be varied, and as many sectors as desired may be put in service; the said number being indicated by the scale 60 and the forward edge of sleeve 55 cooperating therewith. The dial 56, will always indicate the angular position of the movable sector, in the usual manner.

Fig. 15 shows electrical means for altering the range of capacity. The fixed sectors 53ᵃ are insulated from one another as by washers 69, and are connected by conductors 70 to contacts 71. A fan switch having a blade 72 and a knob 73, cooperates with these contacts to put as many as desired in parallel. The movable sector 44ᵃ is mounted on the usual shaft 46ᵃ and comprises plates 45ᵃ. This construction may be substituted for the corresponding portions of Fig. 13 if desired.

The subject matter just described, and illustrated by Figs. 13, 14 and 15 is claimed in my divisional application, Serial No. 745,769, filed October 25, 1924.

It is obvious that while I have described a condenser having several unique features, it is not necessary that all said features be present, and my invention is not to be limited except as specified in the following claims:

1. A rotary variable condenser having two elements of unequal angular extent, one greater than 180° the other less.

2. A rotary variable condenser having two elements of unequal angular extent, one greater than 180°, the other less than 180° the sum of the two being approximately 360°.

3. A rotary variable condenser having two elements of unequal angular extent one having an angle greater than the other, and greater than 180°, said element comprising sectors of radii corresponding substantially to the square roots of successive natural integers.

4. A rotary variable condenser whose fixed and movable elements are of unequal angular extent, one greater than 180°, the other less.

5. A rotary variable condenser whose fixed and movable elements are of unequal angular extent, one greater than 180°, the other less than 180°, the sum of the two extents being approximately 360°.

6. A rotary variable condenser having two elements one of which is movable with respect to the other, one of said elements being of variable radial extent and exceeding 180° in angular extent, the other element being of an angular extent less than 180° and so placed and shaped that a relative rotation exceeding 180° is required, in one direction, to vary the capacity from minimum to maximum value.

7. A rotary variable condenser having two elements one of which is movable with respect to the other, the said elements being non-symmetrically disposed with respect to the axis of rotation, whereby a continuous range of capacity variation exceeding 180° between minimum and maximum is attained.

8. A rotary variable condenser having two elements one of which is movable with respect to the other, the angular extent of one element being substantially greater than 180° and also substantially greater than that of the other, whereby the element of greater angular extent is not in any relative position entirely covered by the other element.

9. A rotary variable condenser having two relatively movable elements, one of greater angular extent than the other whereby a variation of capacity is attained by difference in area of the respective entering and emerging ends of the element of greater angular extent with respect to the other element.

10. A rotary variable condenser having one element of varying radial extent and a cooperating element of smaller angular extent than the former, whereby a range of capacity change is attained by relative rotation of the second element within the angular extent of the first.

11. A rotary variable condenser comprising two cooperating members, namely, a rotor and a stator, one of said members including a portion mechanically distinct from the remainder of said member and cooperating with the other member to provide a variable capacity, whose maximum value is smaller than the maximum capacity due to the above named remainder of said member, said portion being so positioned with respect to the said remainder of the member including it, and also with respect to the cooperating portion of the other member, that the first named portion and the remainder do not simultaneously produce their respective maxima of capacity at any position of the rotor with respect to the stator, said first-named portion being further so designed that during a certain part of the rotation of the rotor the capacity due to the portion decreases while that due to the remainder simultaneously increases, at a greater rate, whereby a differential rate of increase of capacity of the condenser as a whole is obtained.

In testimony whereof I affix my signature.

CARL A. HELLMANN.