C. P. STEINMETZ.

MEANS FOR PRODUCING LIGHT.

APPLICATION FILED APR. 11, 1902.

1,025,932. **Patented May 7, 1912.**

4 SHEETS—SHEET 1.

Fig. 1.

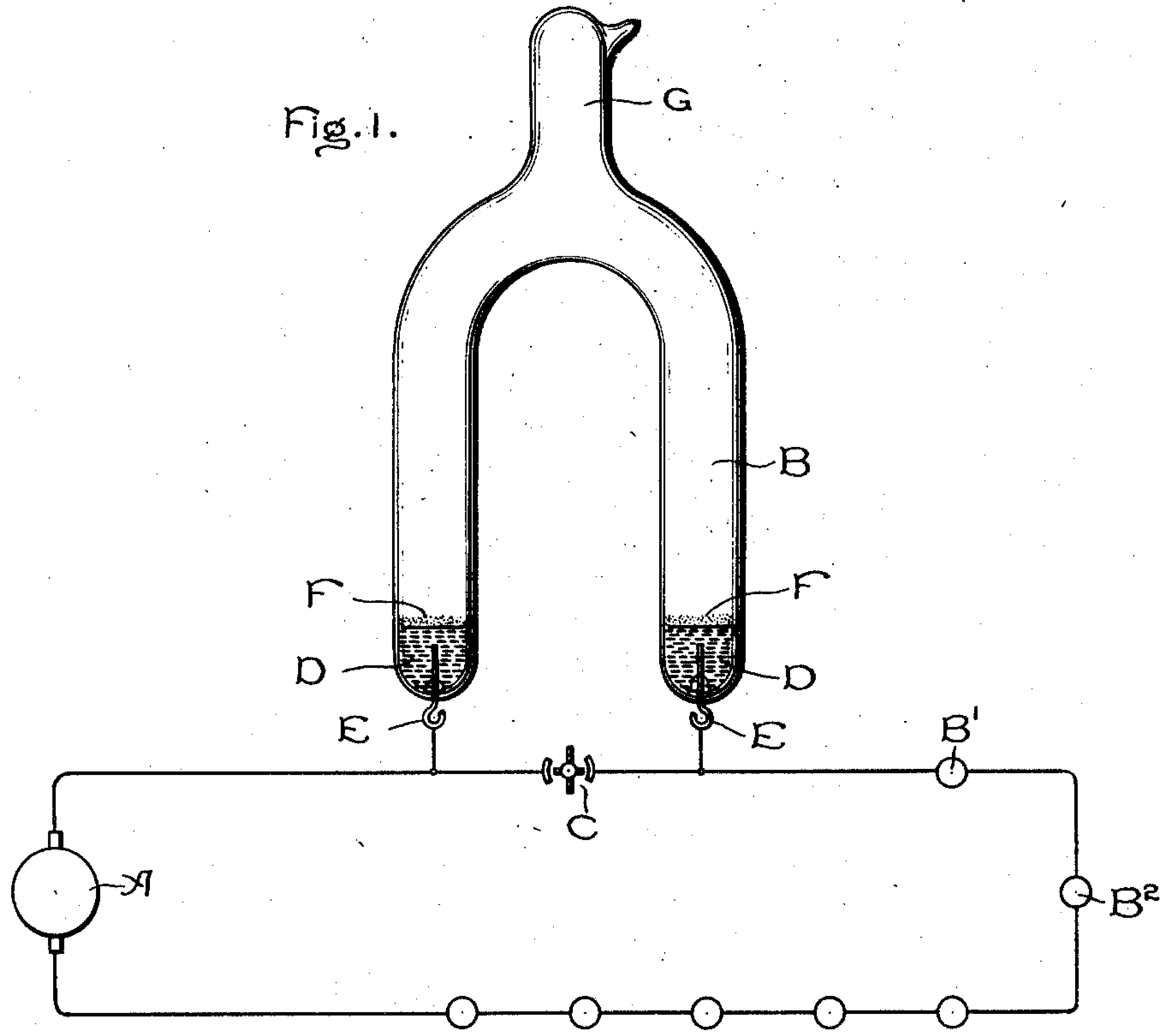

Fig. 2.

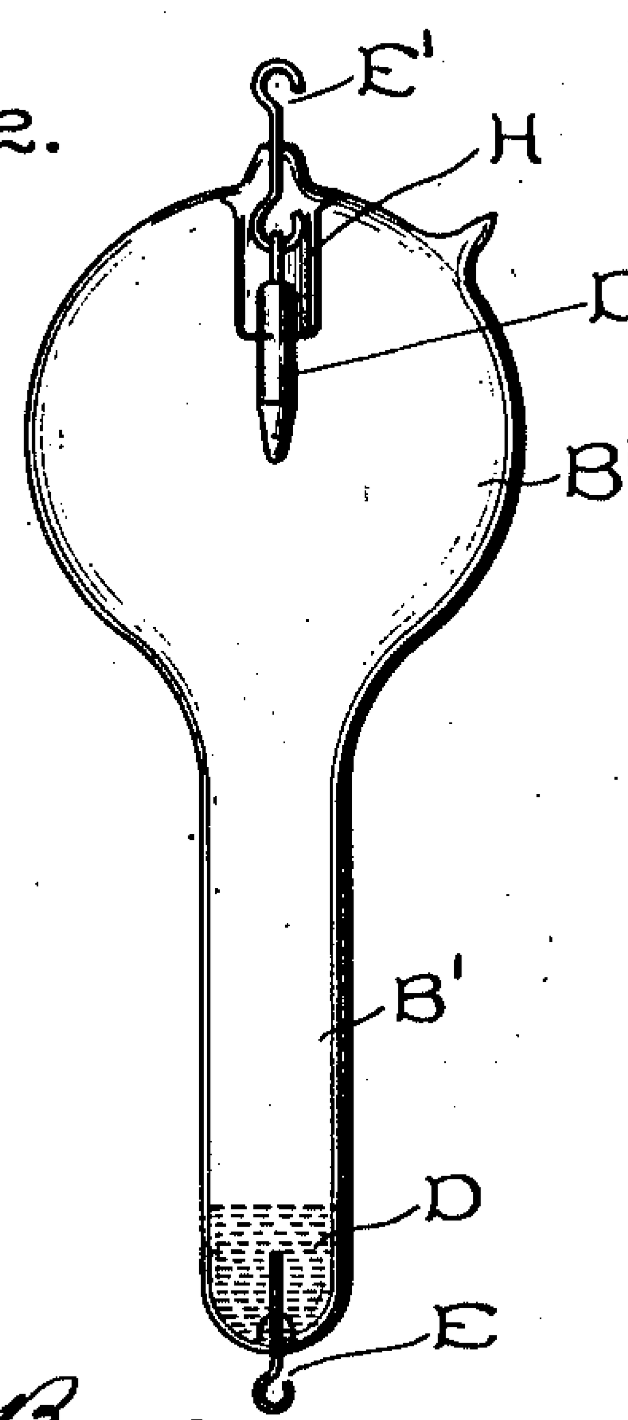

Fig. 3.

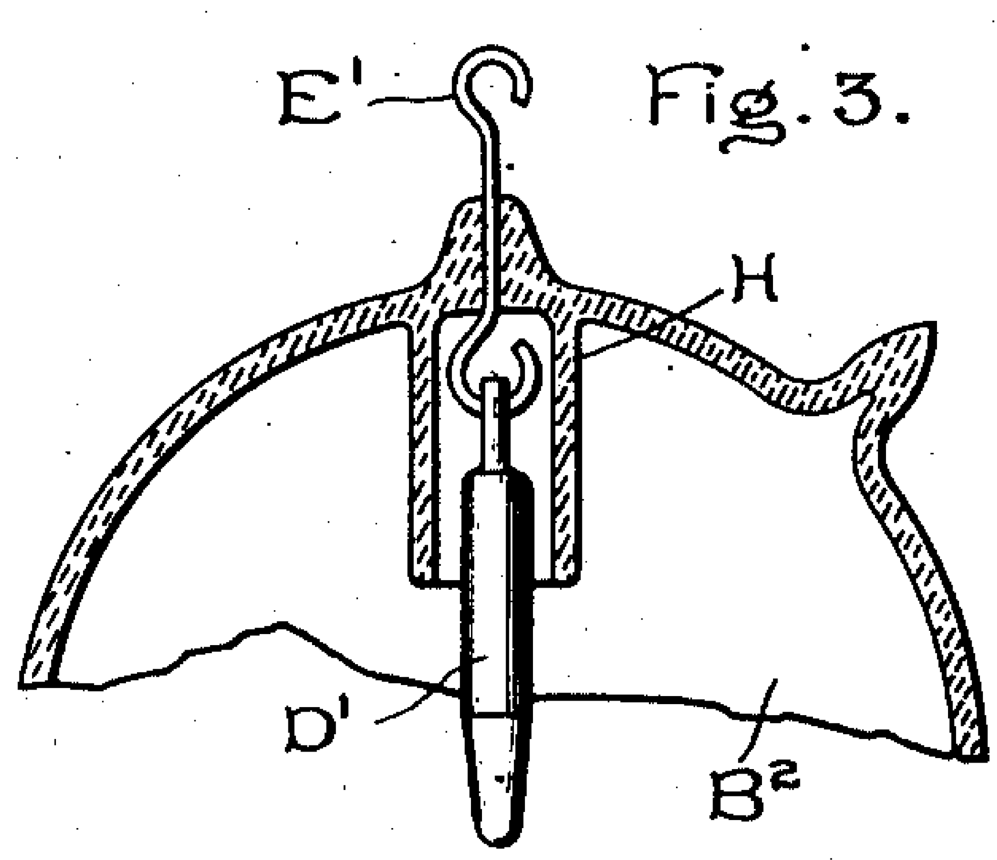

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Fig. 4.

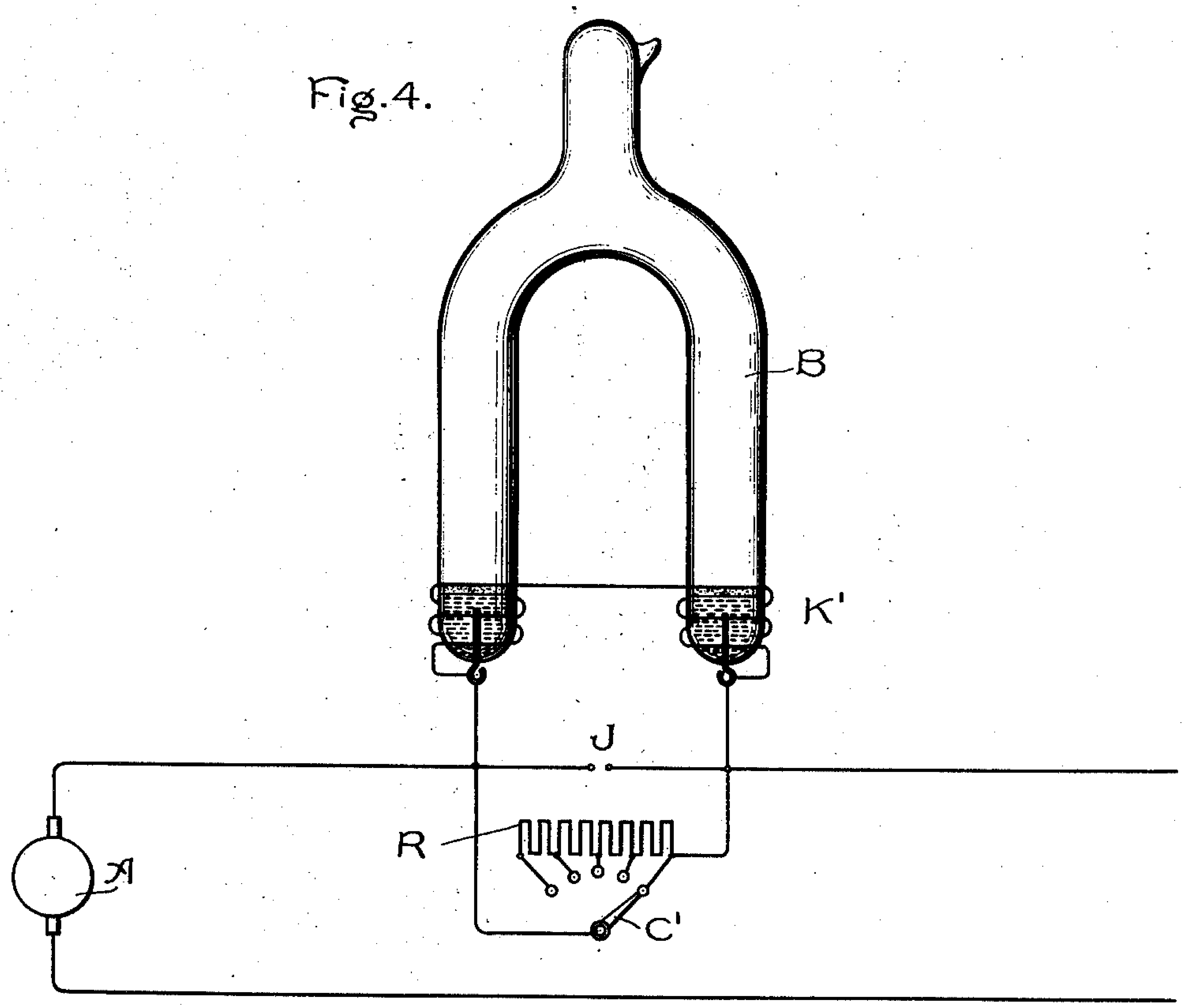
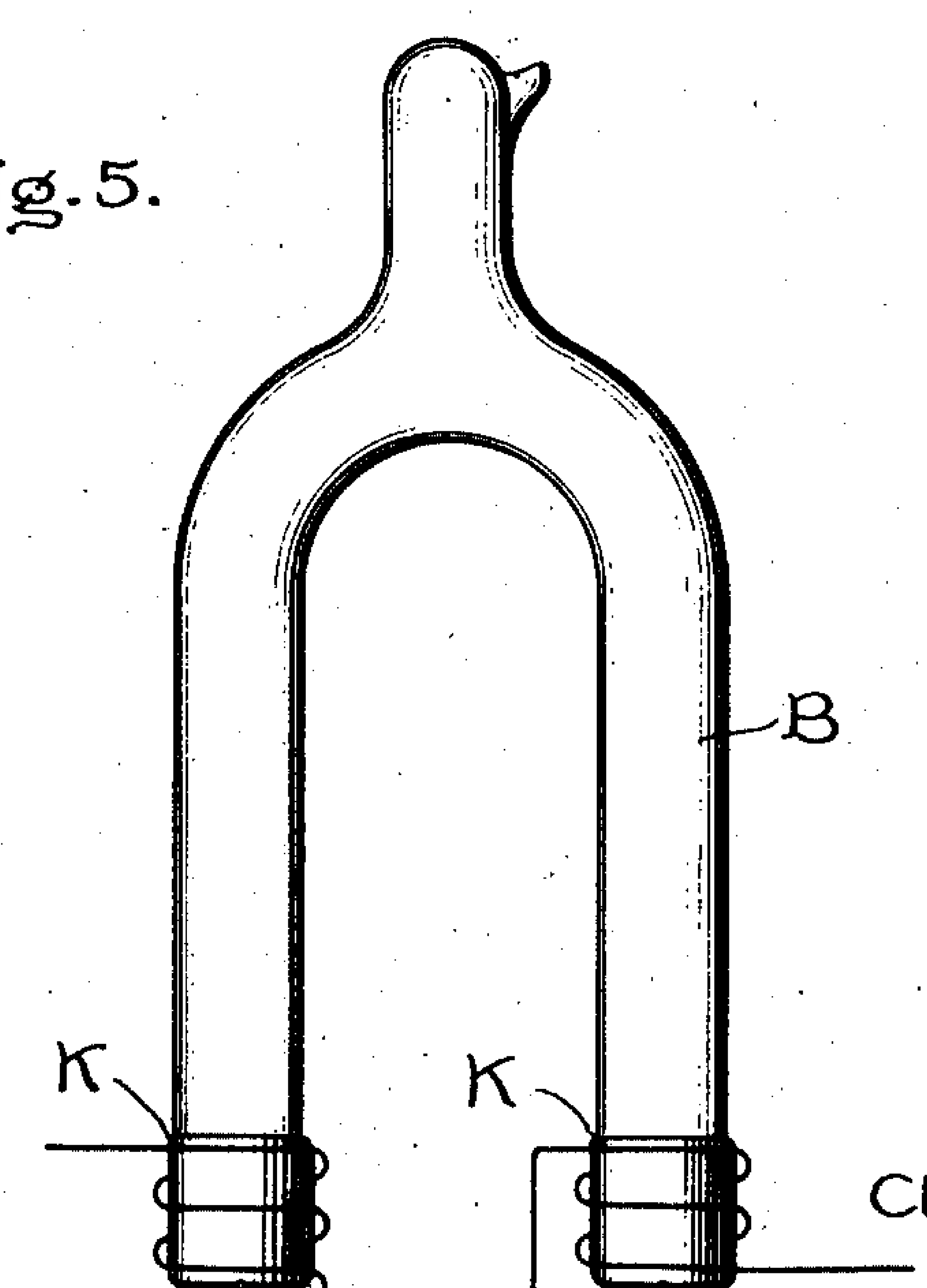


Fig. 5.



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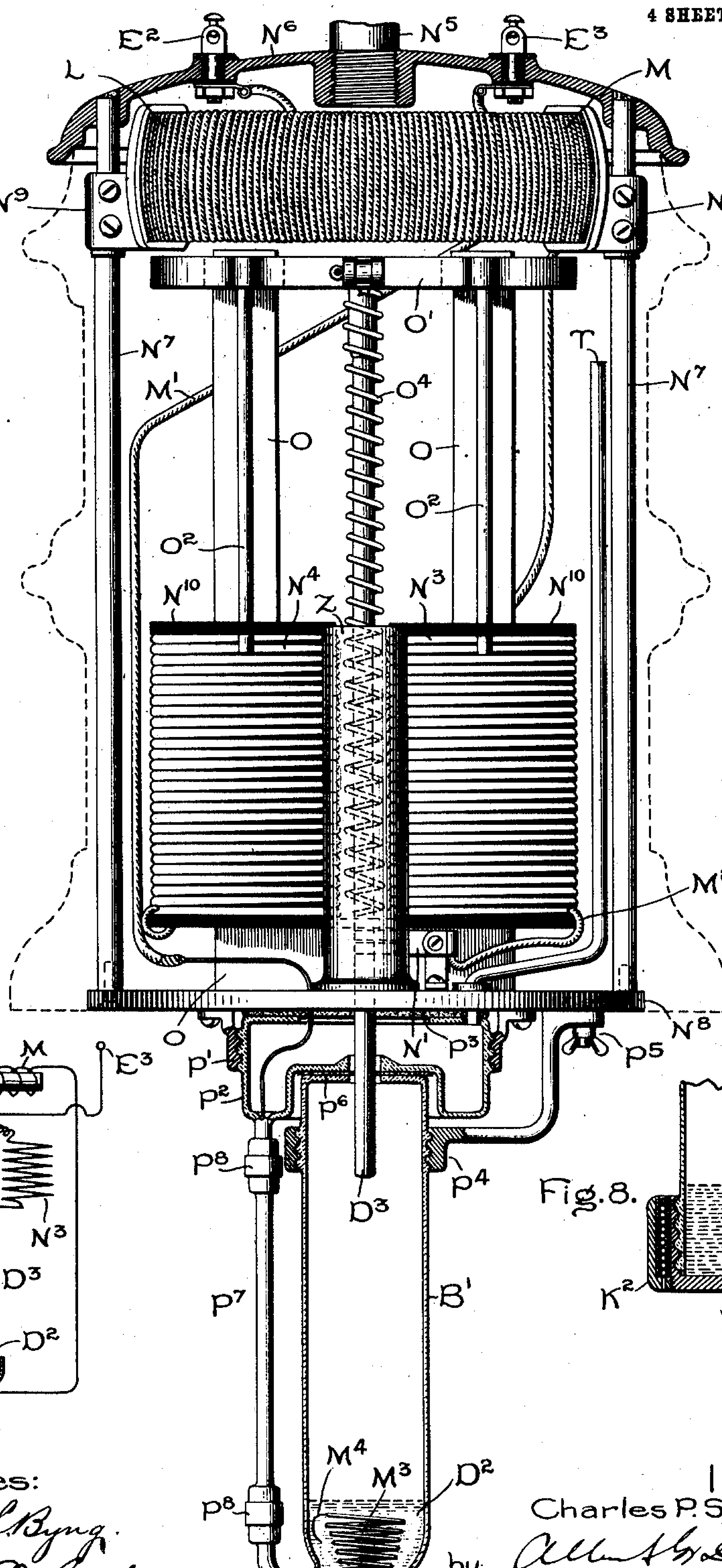
4 SHEETS—SHEET 3.

Fig. 6.



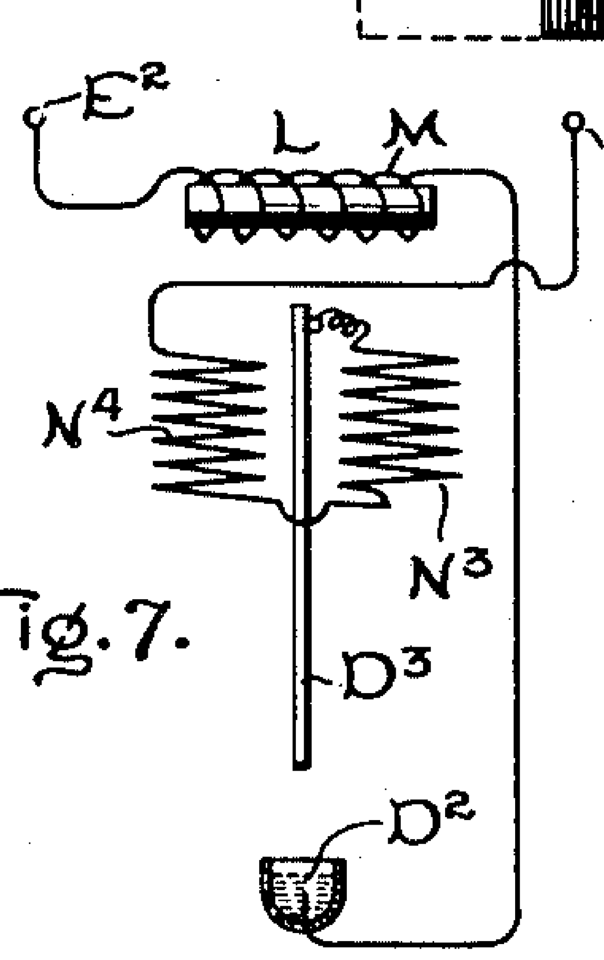
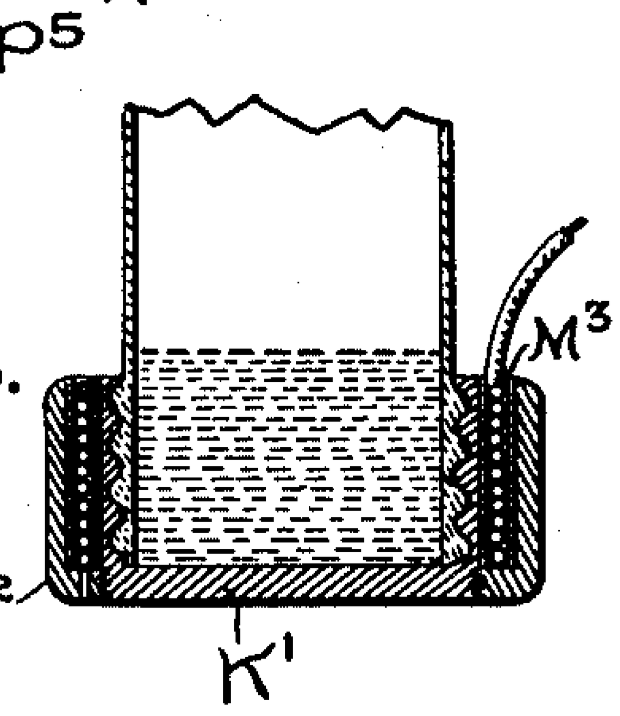


Fig. 7.

Fig. 8.



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4 SHEETS—SHEET 4.

Fig. 9.

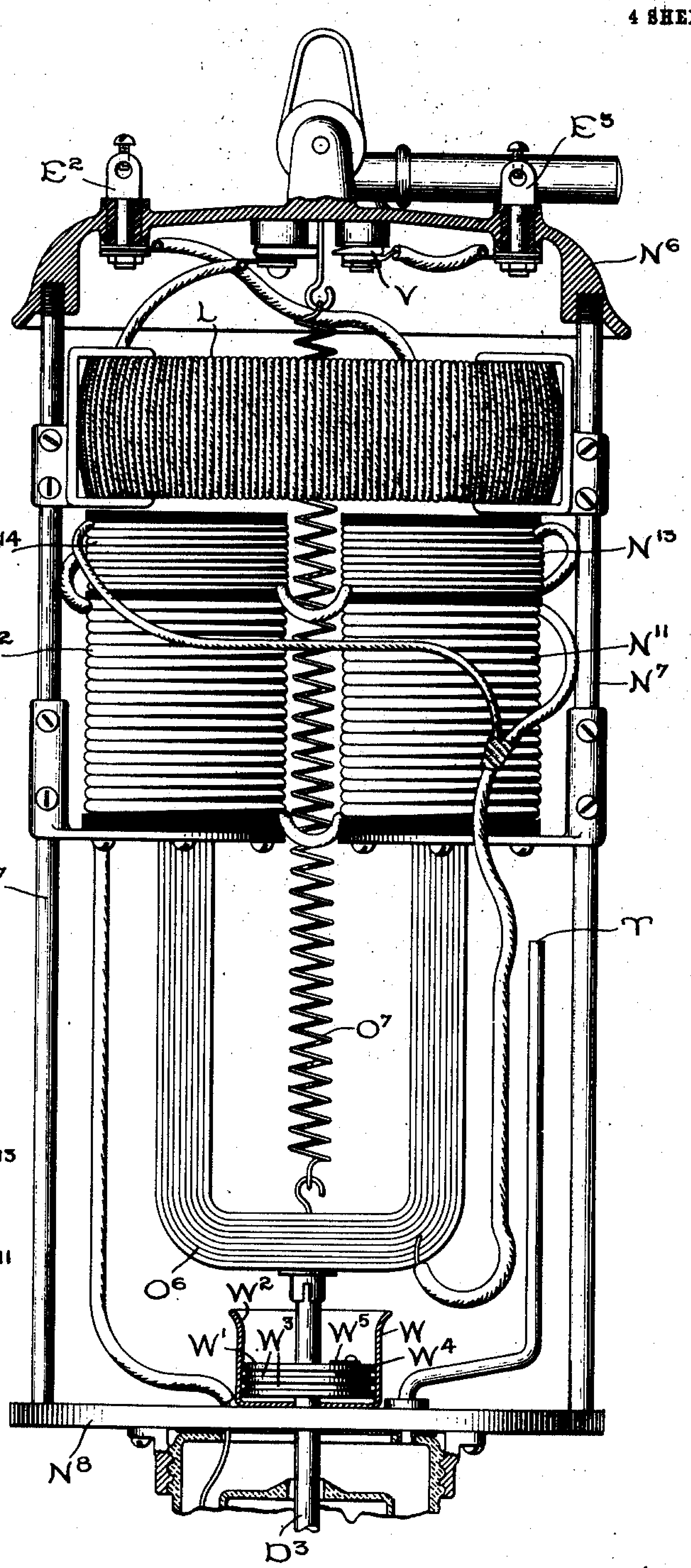
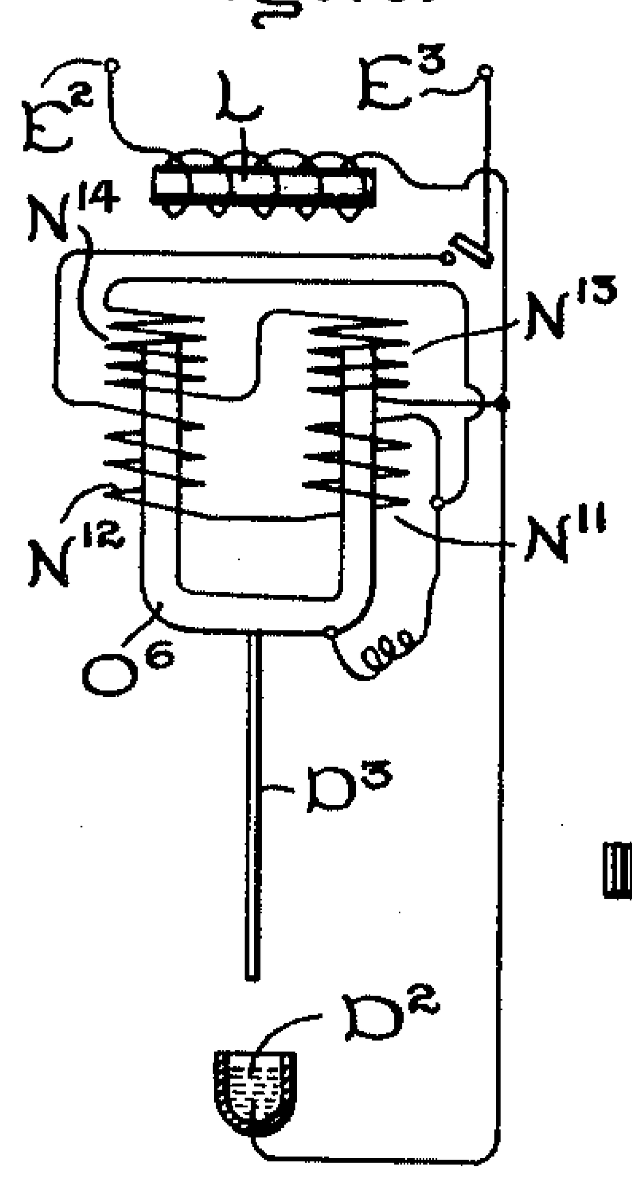


Fig. 10.



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UNITED STATES PATENT OFFICE.

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MEANS FOR PRODUCING LIGHT.

1,025,932. Specification of Letters Patent. **Patented May 7, 1912.**

Original application filed March 5, 1900, Serial No. 7,265. Divided and this application filed April 11, 1902. Serial No. 102,415.

To all whom it may concern:

Be it known that I, Charles P. Steinmetz, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Means for Producing Light, (division of my prior application, Serial No. 7,265, filed March 5, 1900,) of which the following is a specification.

My invention relates to the production of light of any desired color from electrical energy.

It is my belief that the light from an electric arc, excluding that portion of the light coming direct from the crater or from other incandescent surfaces, is due to a vibration of the ultimate particles of vapor in the arc stream, which vibration is probably caused by the electric stress due to the potential gradient of the arc. It is found that the color of the light, or, more broadly speaking, the wave length of the radiant energy derived from an arc, is practically independent of temperature, and dependent principally on the nature of the conducting vapor which forms the arc stream. The vibrations therefore appear to be, as it were, "sympathetic", and may take place very considerably below the temperature of incandescence.

In general, the temperature of an arc is fixed by the nature of the electrode, just as the temperature of any boiling liquid is fixed by the nature of the most volatile component of that liquid. It is common in practice to use electric arcs between carbon electrodes for commercial lighting. In carbon arcs the major portion of the light comes from the craters, so that it is perhaps not strictly correct to speak of these devices as "arc" lamps. This incandescence is the result of the very high temperature of the carbon arc, but the high temperature causes very heavy radiation losses.

The temperature of the carbon arc stream is fixed by the volatilization temperature of carbon, as is the temperature of any true vapor, and this temperature is such that a very large proportion of the energy from a carbon arc is radiated in the form of dark heat waves, so that the carbon arc becomes an extremely inefficient means of converting electric energy into light. I find it highly advantageous in my new method of producing light to avail myself of substances vaporizing at very low temperatures, and by using such substances I am able to greatly reduce the radiation losses, and to correspondingly increase the efficiency.

It is obviously necessary for the maintenance of the arc that the vapors from the electrode should be conductors of electricity, and it is therefore necessary to use as an electrode a substance producing conducting vapors. This requisite is fulfilled by mercury, and further, mercury is a substance vaporizing at very low temperature. Hence it appears that an arc between electrodes, at least one of which is formed of mercury, should be an extremely efficient light-giving arrangement, and this is indeed the fact, but the mercury arc is, unfortunately, of an extremely disagreeable color. It gives a discontinuous spectrum containing the Fraunhoefer lines 4047; 4359; 5461; 5769 and 5790, and some fainter intermediate lines. The sodium line, 5890, sometimes appears faintly, but this is probably due to the action of the glass or the presence of some impurity. It will be seen that all of these lines are either violet, blue or green, and that the spectrum is practically devoid of yellow, orange and red. As a result of this deficiency, red objects appear black or gray when viewed by light from a mercury arc, and human faces acquire a peculiar and disagreeable pallor, so that the light from the mercury arc seems to be utterly unsuited to commercial application.

It is one object of my invention to so modify the light from the mercury arc as to produce a soft, brilliant, white light with very low radiation losses, and with an efficiency rising as high as three to five candle-power per watt; whereas ordinary incandescent lamps, with which my improved lamp may properly be compared, require about three watts per candle-power, while even the carbon arc, which is in many ways unsuited to interior illumination, requires in general about one watt per candle-power.

Further, my invention is not necessarily restricted to the production of a pure white light, but I am able to so modify the light of the mercury-arc stream as to cause almost any desired wave length to strongly preponderate, and I may thus produce a colored light, for example red light, at an efficiency hitherto impossible. The ordinary method for producing red light by electricity is to pass the current through a suitable lamp of any ordinary type, and to modify the light from this lamp by passing the light through red glass. It is well known that the action of such red glass is simply to screen out the larger proportion of the violet, blue, green and yellow rays, and to allow only the red rays to pass. This, obviously, takes away a very large percentage of the radiant energy generated, and greatly reduces the efficiency of an already inefficient lamp. By virtue of my improvements it is possible to generate once for all red light, so that a very large proportion of the radiant energy actually issues from the lamp in the form of red rays, and the same principle may be applied to the production of light of any desired color. Nor is my invention necessarily restricted to the use of mercury, as certain other substances fulfil fairly well the conditions above set forth, though I have thus far found mercury best adapted for practical use.

My improvement in modifying the color of an electric arc consists, broadly speaking, in introducing conducting vapors of substances whose arc spectra have the desired wave length. This, however, is not as simple in practice as the above statement, for it seems essential that electric arcs, particularly from mercury, should be inclosed in glass tubes or vessels. I will discuss below the starting of the arc. One method of starting is to have an initial high voltage in combination with a lamp exhausted to a high vacuum. Obviously, for such a lamp as this, glass is the only suitable material, and even in lamps which are started much as is the ordinary carbon arc, it is highly preferable to surround the arc by a glass-inclosing chamber, both to prevent unsteadiness and to prevent the poisonous vapor of mercury from escaping into the surrounding space. Now I find that all of the substances which might naturally be introduced to the mercury arc to modify its color, and particularly lithium, sodium, potassium and rubidium, violently attack this glass envelop, or any other transparent or translucent envelop known to me, and within a few minutes or at most a few hours destroy its transparency by causing a black deposit or incrustation in the interior.

It is, therefore, another important feature of my invention to artificially maintain the translucency of the envelop in which that arc exists, and though I point out in this specification one particular means which in practice I have found most advantageous for this purpose, and though I intend by the claims attached to this specification to claim the means both broadly and specifically, nevertheless it should be understood that in many aspects my invention is not limited thereto, but I have devised other means for accomplishing this beneficial result, which means, though included under the broad claims of the present application, are, nevertheless, to be specifically covered by other and later cases. The particular means of this case consists in adding the modifying conducting vapors in a chemically inert condition, and, preferably, in what is known as the "ionized" state, that is to say, as free atoms co-existing with free atoms of some other substance combining with the conducting vapors at ordinary temperatures, but at complete or partial dissociation at the temperature of the mercury arc.

I find that the elements of the halogen class, that is to say: iodin, bromin, chlorin and fluorin, are useful in the order named; that is to say, iodin is the best, since the iodids dissociate at a comparatively low temperature. Thus, for example, if a certain shade of red is desired, I introduce into the arc-stream a large quantity of lithium vapors in the ionized condition, by covering the surface of the mercury with anhydrous lithium iodid. If, again, I wish to produce pure white light I use a comparatively small quantity of a mixture of the iodids of lithium and sodium or even of lithium, sodium and potassium.

If I wish to produce a bright blue light I use the iodid of indium; if I wish to produce a dark green light I use iodid of thallium; a yellow light is produced by iodid of sodium, and another shade of red is produced by iodid of potassium and rubidium. When producing these highly-colored lights it seems that the mercury-arc stream acts principally as a carrier of the vapors of the substances introduced, while when producing white light the mercury arc will itself give the violet, blue and green, and the rays of longer wave length may be produced by the substances artificially introduced.

It is best in any case to cause the powdered iodids, or speaking more generally the color-modifying substance or compound, to cover completely the mercury electrode or electrodes, in order to prevent the arc from striking uncovered mercury, which would cause its color to vary. But I find that it sometimes happens that an electrode covered in this way gives a light in which the spectrum lines of the color-modifying substances are too prominent. It is another object of my invention to overcome this difficulty, and this I am able to do by diluting the color-modifying substance by adding thereto a relatively inert substance, and by preference one which does not dissociate at the temperature used. Calcium fluorid works well, as it is inert in the presence of the halogen salts used as color-modifiers, and so stable that it does not dissociate at the temperature of the mercury arc.

By varying the proportions of active coloring substances and inactive diluting substances any shade may be produced, and candle-light, incandescent-electric light, etc., may successively be imitated.

I have, then, in compliance with the statutes, briefly indicated the nature and object of my invention. I will now proceed to describe the apparatus which I use for carrying it out in practice, with reference to the accompanying drawings, and will, in the claims attached to this specification, indicate the scope of my invention in its several aspects.

In the drawings attached to this specification, Figure 1 is a view of a lamp constructed in accordance with my present invention, connected in a series system; Fig. 2 is a view of a modified form of lamp; Fig. 3 is an enlarged detail in cross section of the form shown in Fig. 2; Fig. 4 shows an improved method of connecting into the circuit the lamp of Fig. 1; Fig. 5 shows a still further modification; Fig. 6 shows a form of lamp devised to take the place of the ordinary inclosed arc lamp of commerce; Fig. 7 is a diagram of connections; Fig. 8 is a view in section of a modification; Fig. 9 shows a still different form; and Fig. 10 is a diagram of circuit for Fig. 9.

In Fig. 1, A is a generator, which may be supposed to typify any source of constant electric current, whether alternating or direct, and B, B′, etc., are lamps connected in circuit in series. C is a switch shunting the lamp B, and similar switches will be used to shunt each lamp of the system. The lamp B is shown as consisting of an inverted U tube with mercury electrodes D D and platinum terminals E E. The surface of the mercury is covered with a thin layer, F, of iodid of some material or materials giving conducting vapors, in accordance with the general principle above set forth, and in the particular lamp shown we may suppose that this layer is composed of a mixture of the iodids of lithium and sodium with or without the addition of dilutant substances such as fluorid of calcium. These iodids are introduced into the tube, and care must be taken to have them perfectly anhydrous, since the presence of moisture is extremely harmful. The tube is then exhausted in the manner usual with ordinary incandescent lamps, but I find it advantageous to replace the residual air by hydrogen, since an atmosphere of rarefied hydrogen requires a very low initial voltage as compared with the atmosphere of rarefied air. With helium or argon, where either of these gases can be obtained, the starting voltage may be still further reduced. If now the tube be sealed off and the switch C be thrown to the position shown, and particularly if the mercury electrodes D D be artificially heated, a luminous arc or discharge will strike from one electrode to the other, and the whole tube will seem to be filled with a white, soft light of considerable intensity. When the light is once fairly started the voltage across the lamp falls considerably. The action appears to be somewhat as follows: A true mercury arc exists between the terminals D D, that is to say, the current flows from one terminal to the other through a path of mercury vapor, and this mercury vapor, under the influence of the electric current, gives a brilliant light containing violet, blue and green rays, at a temperature far below the temperature of incandescence, and with an efficiency much greater than can be obtained from any known incandescent light. The mercury is evaporated from moment to moment, and during the operation of the lamp condenses in the condensing chamber G, whence it trickles back to the electrodes. The arc stream is thus maintained as a continuous body of mercury vapor. The arc, which is more definite at its ends than at any other point, plays back and forth over the surface of the mercury electrodes, and continuously vaporizes small quantities of the halogen salts of alkali metals. I have in this particular case assumed these salts to be iodids of lithium and sodium. These salts are evaporated as above stated, and are carried into the arc stream. At this temperature they partially dissociate, so that free atoms of lithium and sodium exist in the arc stream, at least as far as their light-giving function is concerned, and the arc shows the characteristic spectra of lithium and sodium. These substances, however, are not chemically free, but are in very intimate relation with the iodin atoms from which they have ously combining, dissociating and recombinously combining, dissociating and recombing in the arc stream. Their chemical affinities are in each case, if not satisfied, yet capable of being satisfied, and they do not attack the glass. I am thus able to produce at low cost and with high efficiency a light which may be pure white, or which may, on the other hand, be of any desired color. The particular lamp shown has the disadvantage that it is adapted for a series circuit, and also that it requires to be started by bringing the mercury nearly to the point of boiling by artificial means. This particular lamp, however, is typical of my main invention, though other types of lamps, to be hereinafter described, avoid in a greater or less degree the difficulties above mentioned. I have found that it is not necessary that both electrodes should be formed of mercury or other substance vaporizable at low temperatures, for the reason that if one of the electrodes is of such a substance the evaporation from this electrode will tend to reduce the temperature of the arc to an efficient point. I, therefore, am able to form one electrode of iron, or other conductor, as carbon, etc., though when direct current is used it is preferable to make the refractory terminal the cooler and the mercury or volatile terminal the hotter electrode, in order to insure the maintenance of the proper temperature in the globe. The negative electrode is the cooler at atmospheric pressure and at low vacua, but this relation may sometimes reverse at higher vacua.

In Fig. 2 I show another form of lamp which I have found to operate well. This lamp is composed of a single vertical tube B′, expanding at its upper portion to a globe B^2. The lower electrode D is of mercury as before, and should be provided with color-modifying substances as above explained. This electrode is connected through the terminal E to one side of the system, or to one terminal of the generator. The upper electrode D′ is formed of metal, as iron, and is conductively supported from the negative terminal E′. I have found in the use of lamps of this type that the arc has a tendency at high vacua to run up the side of the electrode D′, and to fuse the glass at or near the point where the terminal passes through. I attribute this phenomenon to the fact that the transition resistance between the vacuum and the electrode is larger than the resistance of the vacuum. Whatever the cause may be, the phenomenon is highly objectionable, for the reason that it tends to melt and discolor the glass. I find in practice that the trouble can be overcome by surrounding the electrode D′, for a part of its length, by a glass tube H, which is fused directly to, or forms part of, the lamp itself. It is difficult for the arc to exist in the narrow space between the sides of the tube and the electrode, so that the arc naturally tends to strike the electrode at or near the lower portion of the tube, at a point where the electrode is out of contact with the glass.

Fig. 4 shows the lamp of Fig. 1 with an improved device for connecting it in circuit. In this figure, A is a constant-current generator. B is the lamp and C′ is a switch. The resistance R is shunted around the lamp and the amount of this resistance in circuit is controlled by the resistance of the switch C′. In the position shown in the drawings current passes freely from the generator through the switch around the lamp. When the switch is moved to the left one point, a small portion of the resistance R is connected in series in the constant-current circuit and the lamp is shunted around the drop of potential caused by this resistance. For example, in a ten-ampere circuit, if the first step of resistance is 5 ohms, the drop of potential across the lamp will be about 50 volts, supposing that the lamp itself takes no current. It is thus evident that a motion of the switch handle to the left will raise the voltage across the lamp until finally an arc is struck and that in the meantime the constant-current circuit will not be interrupted, provided that the switch arm C′ is constructed as such switches usually are constructed, with a terminal wider than the distance between contact segments. When the lamp is heated into condition of stability, the arm C′ can be thrown still farther to the left, which will open-circuit the resistance R and cause all of the current to pass through the lamp. I prefer to place lightning-arrester spark gaps or film cut-outs J around each lamp in order that if for any reason the arc breaks, the constant-current circuit may not be interrupted. In practice I find that the arc tends to flicker unless the mercury is maintained at its boiling point, and with some designs of tube it is not possible to accomplish this by the heat developed by the arc itself. I, therefore, find it advisable in some cases to artificially generate heat at each electrode. The arrangement for this purpose is shown at Fig. 5, in which the lower ends of the tube B are surrounded by soft iron caps K K, and around each of these caps is coiled a number of turns of the wire which carries the current to the lamp. If the current is alternating it will tend to set up eddy currents in the iron caps and these caps will thus become heated and tend to maintain the mercury at the proper temperature. If the current is direct it is necessary to use more wire and to place it in heat-conductive relation to the cap. The heating coils may be placed in series with the lamps, as shown in Fig. 5, or they may be placed in multiple as shown in Fig. 4 at K′. The advantage of the latter arrangement on constant-current circuits is to increase the effect of the heating coils at starting, when they are most needed.

All of the lamps hitherto described may be connected as shown in Fig. 1, or may be connected in multiple to constant potential circuits, with or without a steadying resistance and a starting device.

I will now proceed to describe a type of lamp particularly designed for multiple arc connection on constant potential alternating circuits, though it will be understood by those skilled in the art that it may readily be altered to work on constant-current circuits as well, or to consume direct current.

Referring to Figs. 6 and 7, which show this lamp, it will be seen that current enters by the terminal E^2 and thence passes to a regulating device L. As this particular lamp is intended for alternating current, this regulating device may well take the form of a self-induction coil with a nearly closed magnetic circuit, such as is ordinarily employed in alternating arc lamps. The usual taps or connections may be provided for regulating the amount of this reactance in circuit. From this reactive coil, current passes by the wire M′ to the mercury electrode D^2, and thence through the arc in the tube B′ to the upper terminal D^3, which is preferably formed of iron. From this terminal it passes by the collecting spring N′ through the wire M^2 to the solenoid coils N^3 N^4, and thence to the terminal E^3. It will be seen that these are the ordinary connections of an arc lamp to be operated in multiple arc on a single-phase alternating circuit. To describe the structure more in detail, it may be said that the support N^5 is screwed to a cap N^6, and that from this cap depend a plurality of rods N^7 N^7, fastened at their lower ends by screws as shown, or otherwise, to the lower plate of the lamp N^8. These rods also carry, by the clips N^9 N^9, the reactive coil L. A U-shaped core O of laminated iron is fastened to the lower plate N^8, and the solenoids N^3 N^4, above referred to, are mounted respectively on the limbs of this core, and are so connected that they have a tendency to polarize the magnetic circuit formed by this core in the same direction. A repulsion device O′, which may consist of a solid casting of copper, aluminum, or other suitable material, is pierced with two holes in order that it may fit over the two limbs of the laminated piece O, and to this repulsion device are attached four guides O^2 O^2, two only of which are shown in the drawing, which work through suitable openings in the upper flange N^{10} of the spools of the solenoid cores N^3 N^4. The upper flange is expanded for this purpose, while the lower flange is of smaller diameter. The upper electrode D^3 is fastened to the repulsion device O′, and is so adjusted that the weight of the parts is sufficient, when no current is passing through the lamp, to compress the coil spring O^4, and to cause the lower end of the electrode to dip into the mercury at D^2. Z is a dash-pot, serving to steady the lamp and to prevent "pumping." It will be seen that a screw-ring P′ is attached to the lower plate of the lamp, and that into this ring is screwed the glass condensing chamber P^2. A suitable washer P^3, of felt or asbestos, is interposed between this condensing chamber and the lower plate. A second screw-ring P^4 is fastened to the lower plate of the lamp by the screw-clamp P^5, and into this ring is screwed the tube B′, with a second washer of felt or asbestos P^6. Considerable clearance is allowed between the electrode and the edge of the opening, in order to make it possible for the vapors to pass to the condensing chamber. In order to carry current to the lower terminal of the lamp, and also in order to provide for the return to the lower terminal of the mercury vapors which may escape into the chamber P^2, I provide a glass tube P^7, which is connected by asbestos washers P^8 with an extension from the chamber P^2, and in a similar way is connected with an extension from the lower end of the tube B′. Through this tube I pass the wire M′, which at its lower portion is covered with an enamel insulation in order to protect it from the mercury vapors. I further prefer to coil this wire into a heating coil M^3, and to uncover the insulation only at the extremity M^4, whereby current will pass through the heating coil M^3 and will tend to maintain the mercury at D^2 at a sufficiently high temperature. Another way of accomplishing this same result is shown in Fig. 8, in which a metal cap *K′* is screwed on to the lower end of the tube, and a second cap K^2 is screwed on the cap K′, leaving between the two an annular space in which may be coiled the resistance wire M^3. The parts K′ K^2 may be formed of iron in which case the Foucault currents generated will tend to heat the mercury, as described in Fig. 5.

The operation of the lamp shown in Fig 6 is as follows: The current enters at the terminal E^2 and passes through the self-induction coil M, in the path above described through the heating coil M^3 to the mercury electrode D^2. If we suppose the lamp to be just starting into action, it is clear that the weight of the repulsion device O′ will have compressed the spring O^4, so that the electrode D^3 will be in contact with the mercury D^2. Current will therefore pass through the solenoids N^3 N^4 and out to the terminal E^3. The solenoids will set up lines of force in the core O, and by virtue of the action set forth in a patent to Elihu Thomson, No. 363,186, the repulsion device O′ will tend to rise, carrying with it the electrode D^3. The lamp will, therefore, burn until the arc is broken by too great lengthening. This will not occur if the mercury is at a sufficiently high temperature, but if it does occur the electrode will fall and the action will be repeated. This may be repeated several times, but finally the mercury will be heated to a sufficiently high temperature, and the electrode D^3 will rise to the position shown in the drawing. The length of the resultant arc will obviously be regulated by the design of the solenoids N^3 N^4, the design of the reactance coil, the voltage of the circuit, the diameter of the tube B′, etc. An increase in the resistance of the arc will weaken the current, weaken the repulsive action, and cause the arc to be shortened. The tendency is toward constant current in the branch including the lamp, as in most commercial arc lamps. In this position the tube B′ will be filled with a brilliant glow of light, and the color of this light will be regulated by introducing the various substances above mentioned in the portion D^2. The vapors will tend to escape from the tube B′, but they are collected in the condensing chamber P^2, and pass back through the tube P^7. I find it much better to pass the condensed substance back outside the tube B′ than to allow it to trickle down the sides of this tube.

It is important in non-exhausted lamps to provide some device for equalizing the pressure, but it is best not to allow mercury fumes to escape from the lamp. I am able to accomplish these objects by the tube T, which is inserted in an opening in the lower plate N^8, and registers with a round or crescent-shaped opening in the washer P^3, and with a corresponding opening or recess in the upper wall of the chamber P^2. This tube extends vertically upward, being bent around the lamp mechanism. It allows air esctto escape from or to reënter the chamber P^2, but the mercury vapors, which are very heavy, will not rise to the top, but will be condensed on the sides and will trickle back to the condensing chamber, and thence through the tube P^7 to the lower electrode D^2.

As an illustration of another manner in which the principles of my invention may be applied, I will now describe the lamp shown in Figs. 9 and 10. This lamp is, or may be, identical with the lamp shown in Fig. 6 with respect to all portions below the lower plate N^8, so that further illustration or description of these parts is deemed unnecessary. Referring more particularly to Fig. 10, which shows the circuit of the lamp, current enters, for example, at the terminal E^2 and passes through the self-induction coil L, thence through the lower electrode D^2, to the upper electrode D^3, through the series coils N^{11} and N^{12} and the switch V to the terminal E^3. It will be seen that in this lamp the repulsion armature O′ is replaced by a U-shaped core of laminated iron O^6, which tends to be pulled up into the solenoids N^{11} N^{12}. Further, I provide two additional solenoids N^{13} N^{14}, which are shunted around the arc. The presence of these shunt solenoids enables me to weaken the series coils, while obtaining the same ultimate separation of the electrodes, but as the shunt coils do not begin to act powerfully until the arc has become fairly long, the first separation of the electrodes takes place more gradually, which gives the mercury a longer time to heat, as the lamp is first started. This tends to prevent the jumping action described above with reference to Fig. 6. The parts are seen more clearly and on a large scale in Fig. 9. In this figure the reactance L, the cap N^6, the side rods N^7 and the lower plate N^8 are substantially identical with the corresponding parts in Fig. 6, and the portions of the lamp below the lower plate N^8 are also substantially identical with the corresponding parts in Fig. 6. The series solenoids N^{11} N^{12} and the shunt solenoids N^{13} N^{14} are connected as shown in Fig. 10, and the upper electrode D^3 is fastened rigidly to the U-shaped core O^6, which is preferably composed of iron wire bent to the form shown. This U-shaped core O^6 is suspended by a spiral spring O^7 from the cap-plate of the lamp in order to assist the coils in springing the very long arc which is preferable in lamps constructed in accordance with my present invention.

I have said that the object of the cumulative shunt solenoids was to reduce the rapidity with which the separation of the electrodes took place. I am able to still further reduce this rapidity of separation by the use of the dash-pot W. This dash-pot is provided with a piston W′, which is mounted on the upper electrode D^3, and the upper portion of the dash-pot is flared to a funnel shape, as indicated at W^2, in order to facilitate the entrance of the piston into the dash-pot as the electrode descends. The sides of the piston are grooved, as shown at W^3, to increase the dash-pot action, and the piston is pierced with one or more openings W^4, controlled by valves W^5. The valve shown is a simple piece of thin sheet asbestos, or other soft material, arranged to open as the dash-pot descends but to close as it ascends.

The operation of this lamp will be apparent from the description already given.

When the switch V is closed current passes through the lamp in the path above traced, and the series coils tend to lift the core O^6 and the electrode D^3. This action is, however, weaker than the corresponding action in the lamp shown in Fig. 6, since neither the series nor the shunt coils alone are required to be strong enough to sustain the moving system in its upmost position. The action is still further resisted by the dash-pot W, so that some little time elapses before any considerable separation of the electrodes takes place, and during this time a heavy current is flowing through the lamp, sufficient to heat the mercury forming the lower electrode D^2, shown in Fig. 6. The parts are so adjusted that as soon as the mercury is fairly well heated the dash-pot piston W^3 passes beyond the narrow portion of the dash-pot W, and the series coils are then left free to raise the core O^6 and strike the arc. As the arc lengthens the shunt coils also become energized, and these coils, together with the spring O^7, assist in extending the arc to a proper length. If, however, it should happen that the arc became long before the mercury was properly heated, the circuit would be broken and the upper electrode would fall into the mercury cup, when the action would be repeated, if necessary several times, until the mercury attained the proper temperature.

It should be understood that the series coils are so powerful, with reference to the shunt coils, that if the current becomes weakened by reason of an excessive lengthening of the arc, or otherwise, the series coils allow the upper electrode to fall sufficiently to maintain the current taken by the lamp at approximately its proper predetermined value.

It will be evident that the dash-pot W is entirely independent from the dash-pot Z shown in Fig. 6. The dash-pot Z is intended to take the place of the ordinary dash-pot of the ordinary arc lamp to prevent the lamp from pumping, while the dash-pot W acts only for a few seconds and is intended merely to facilitate the heating of the mercury terminal. Both dash-pots may be used in either of the forms shown, or by an obvious modification they may be combined in one.

It will, of course, be understood that in both of the forms of Figs. 8 and 9, I cover the mercury electrode by some suitable color-modifying substance, as above fully set forth, and that I adjust the operation of the color-modifying substance or substances by proper proportioning and if necessary by the addition of a halogen salt stable at the temperature of the mercury arc, as calcium fluorid, or by other suitable inactive dilutent substance.

What I claim as new and desire to secure by Letters Patent of the United States, is—

1. The combination with an arc drawn from a mercury terminal, of means for continuously furnishing to the arc diluted salts of alkali metals.

2. The combination of a glass container, a mercury electrode therein, means for maintaining an arc from said electrode and means for continuously furnishing to the arc metallic compounds in a chemically inert condition, said compounds being ionizable at the temperature of the arc.

3. The combination with an arc drawn from a mercury terminal, of means for continuously furnishing to the arc halogen metallic salts.

4. The combination with an arc drawn from a mercury terminal, of means for continuously furnishing to the arc iodids of alkali metals.

5. The combination with an arc drawn from a mercury terminal, of means for continuously furnishing to the arc anhydrous iodids of alkali metals furnishing red rays.

6. The combination with a terminal, of means for drawing an arc therefrom at a temperature below the temperature of incandescence, a surrounding globe or inclosure formed of glass or similar material, and means for modifying the color of the arc comprising an anhydrous powder of iodids of one or more alkali metals.

7. The combination with a terminal, of means for drawing an arc therefrom at a temperature below the temperature of incandescence, a surrounding globe or inclosure formed of glass or similar material, and means for modifying the color of the arc comprising an anhydrous powder of iodids of one or more alkali metals mixed with flourid of calcium.

8. The combination in an arc lamp, of a mercury electrode with a layer of coloring material mixed with dilutent material.

9. In an arc lamp, a mercury electrode covered with a mixture of stable and unstable halogen salts of alkali metals.

10. In an electric arc lamp, a terminal volatile at comparatively low temperatures, with a mixture of halogen salts of alkali metals in operative relation with said terminal, some of said salts being of such a nature as to dissociate below and some above the boiling point of the material forming the electrode.

11. The combination in an arc lamp, of a mercury terminal, a movable terminal, a heating coil for the mercury terminal, and a regulating magnet coil in series with the arc.

12. The combination of an inclosing globe, a mercury terminal, a movable terminal, means controlled by the current for operating said movable terminal, and means for continuously adding luminous conducting vapors to the arc, whereby its color may be modified.

13. In an electric arc lamp, an electrode of mercury, an electrode of more refractory material dipping in said mercury electrode, means controlled by the current for separating the two electrodes and for regulating the amount of separation, a heating coil for the mercury electrode, and artificial means for retarding the separation of the electrodes.

14. The combination in an arc lamp, of a volatile electrode, means for heating the electrode, and means for subsequently striking an arc from said electrode.

15. In an arc lamp, an electrode covered with a color modifying substance existing with a halogen salt with an excess of the halogen.

16. In an arc lamp, a mercury electrode covered with metallic salts which will dissociate at the temperature of the mercury arc.

17. The combination of a mercury electrode, a co-acting electrode, means for drawing an arc between said electrodes and means for furnishing the arc metallic compounds which will dissociate at the temperature of the arc.

In witness whereof, I have hereunto set my hand this fifth day of April, 1902.

CHARLES P. STEINMETZ.

Witnesses:

BENJAMIN B. HULL,
HELEN ORFORD.