

No. 682,690.

Patented Sept. 17, 1901.

P. C. HEWITT.
ELECTRIC LAMP.

(Application filed Apr. 5, 1900.)

(No Model.)

3 Sheets—Sheet 1.

Fig. 1

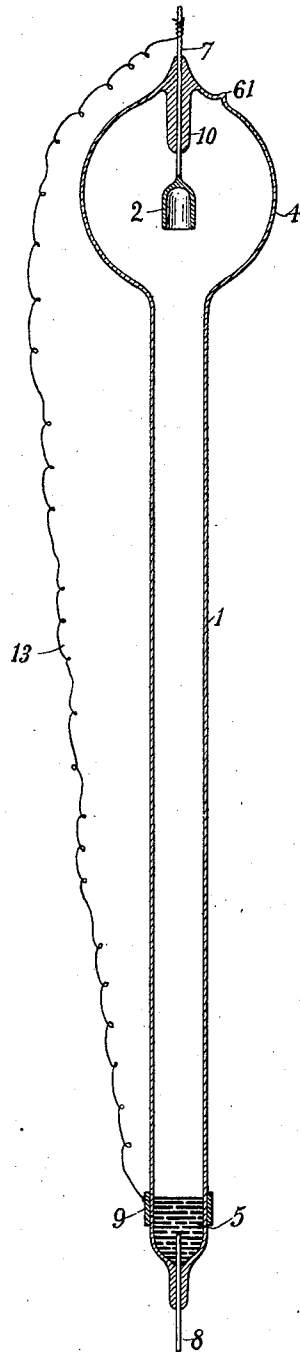
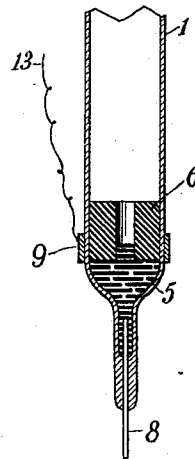


Fig. 2



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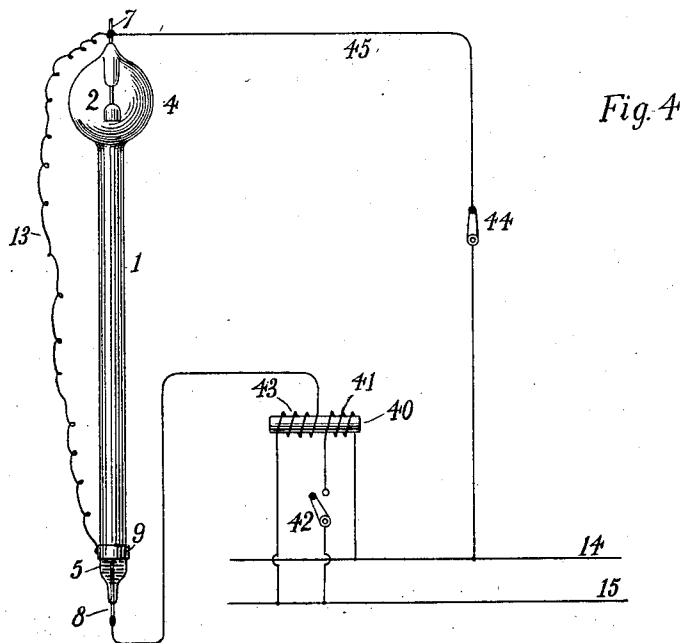
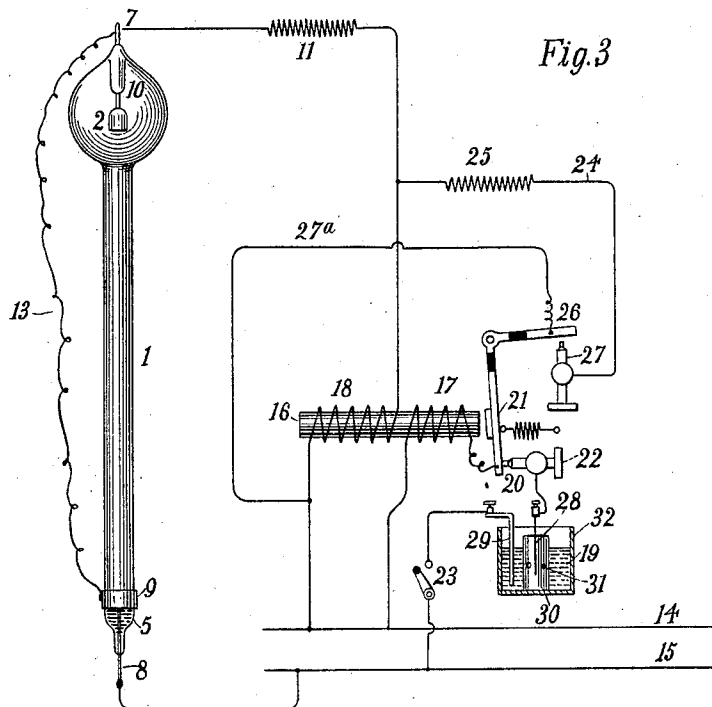
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3 Sheets—Sheet 3.

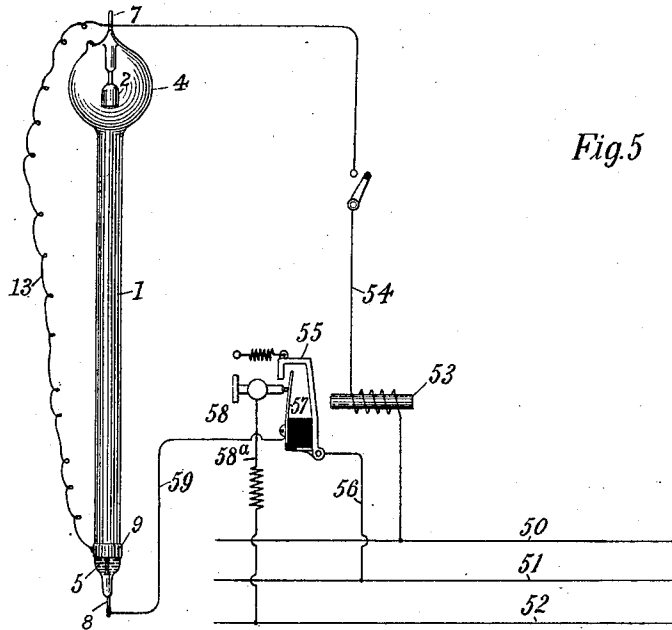


Fig. 5

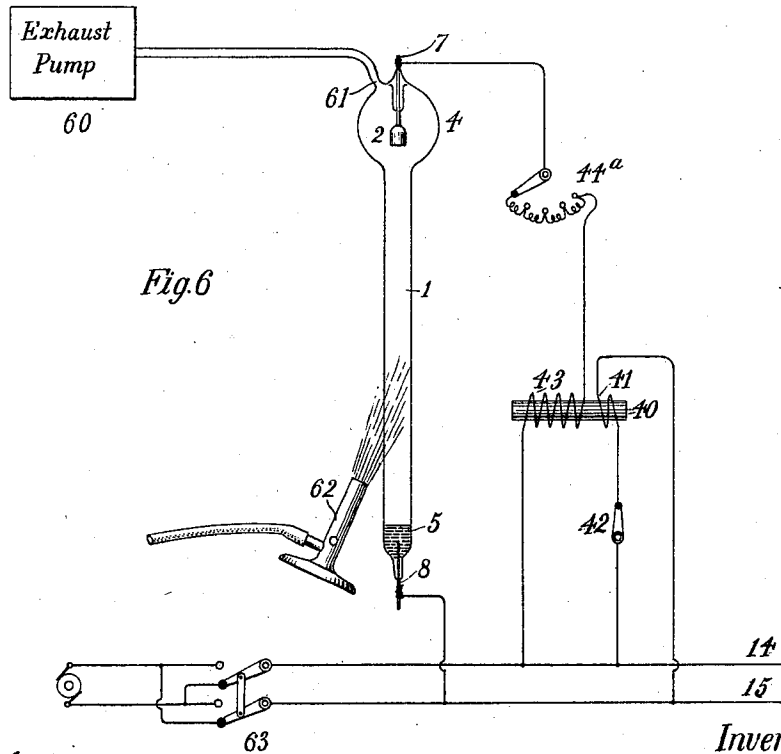


Fig. 6

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UNITED STATES PATENT OFFICE.

PETER COOPER HEWITT, OF NEW YORK, N. Y., ASSIGNOR TO PETER COOPER HEWITT, TRUSTEE, OF SAME PLACE.

ELECTRIC LAMP.

SPECIFICATION forming part of Letters Patent No. 682,690, dated September 17, 1901.

Application filed April 5, 1900. Serial No. 11,605. (No model.)

To all whom it may concern:

Be it known that I, PETER COOPER HEWITT, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Electric Lamps, of which the following is a specification.

My invention relates to methods of and apparatus for electric lighting.

The general purpose of the invention is to produce light by converting electric energy into light through the agency of vapors or gases as efficiently as possible and with simple and durable apparatus.

In the ordinary conversion of electric energy into light a large amount of the energy is wasted in heat, and while the development of heat is usually, if not always, attendant upon the development of commercial light, yet from theoretical considerations it may be assumed that the efficiency of a light-producing device, other things being equal, would be increased in approximate proportion as the development of heat is suppressed.

My invention aims, among other things, to produce light by the conversion of electrical energy with the coincident production of as moderate an amount of heat as practicable, and I have found that gases or vapors possess this property in a greater degree than matter in any other state, and therefore they offer a field of operation in which the highest efficiencies can be obtained if proper means are devised for rendering the gases or vapors light-emitting under the influence of electricity.

It has been proposed to obtain light by the passage of alternating or intermitted electric currents of very high frequency through a more or less rarefied gas contained within hermetically-closed tubes, such gas being so acted upon by the currents as to become luminous. This class of apparatus, commonly known as "Geissler tubes," has been found for various causes to have no commercial utility as a means of illumination. It has also been proposed in some instances to pass electric currents through two electrodes consisting of bodies of mercury contained in hermetically-closed tubes and to obtain light from the electric arc between the two mer-

cury electrodes; but prior to my invention no such devices, so far as I am aware, have been produced which are suitable for commercial use. They have usually been started by bringing the two bodies of mercury constituting the electrodes into actual contact with each other and then separating them, the electric current then being caused to arc across from one electrode to the other. Such method of starting has been found impracticable for any extended use and requires the presence of a considerable outside resistance to prevent an excessive current-flow when the bodies of mercury are in contact, and even when started they have been incapable of commercial operation with efficiency or for any considerable period of time. These and other difficulties have rendered such devices impracticable for use upon circuits in which the electromotive force is liable to vary, as in the ordinary commercial systems of electric lighting, or even in connection with other circuits, such as those supplied by storage batteries, and they have little or no value except, perhaps, for special scientific or laboratory experiments. These devices, so far as I am aware, have been essentially arc-lamps, as distinguished from those in which the current passing from one electrode to the other does not form an arc. The exact distinctions between an arc and conduction not involving an arc are somewhat difficult to define, although not difficult to detect in practical operation. It is noticeable, however, that in the case of an arc there is intense heating of both the positive and negative electrodes, but particularly of the positive electrode, and the current passes from the electrodes into the conducting-vapor at definite points or positions, whereas in the other form of conduction the effect is to produce a halo around the electrode, as if the current passed evenly from the electrode, except that a dark space appears at or around the electrode. This space and its appearance seem to differ with different vapors used; but there is always a marked and well-defined difference between it and an arc, and when in the process of manufacture the last trace of arc disappears it is plainly noticeable. In the other form of conduction little or no heat is developed at the points where the current

passes from the electrode into the vapor. Moreover, in the case of the arc there appears to be a narrowing at or near an electrode, whereas in the other form of conduction the body of light is of practically the same dimensions throughout the space between the electrodes or between points in close proximity to the electrodes. An arc, moreover, is striated, a condition which does not appear to be present in the other form of conduction. Again, the temperature established by the arc in any one place with a given flow of electric energy appears to be far in excess of that produced by a flow of the same amount of energy in the other form of conduction.

The lamps which I have produced do not operate upon the arc principle, but possess the characteristics of this special form of conduction. It is, moreover, essential that the proper adjustment of the resistance of the vapor path should be obtained, and I have found that this result can be secured in the case of vapors conducting in this manner, so that the electromotive force with which the lamp is adapted to be operated can be predetermined with as great a degree of accuracy as is usual in the manufacture of the ordinary incandescent lamps having carbon filaments, and the manner in which the resistance shall vary can be controlled in vapor-lamps with a much wider range of controllable resistance than is the case with a carbon filament, as the resistance of the carbon is a fixed factor, while the vapor resistance may be selected to vary at will within wide limits. It does not appear to have been appreciated prior to my invention that such a control of resistance on the part of a vapor was possible or practicable, and, as a matter of fact, in the forms of lamp hereinbefore referred to, wherein an arc is established between bodies of mercury, such control has not been obtained.

Under proper conditions certain vapors and also certain materials which normally exist in the form of gases may be caused to remain in such condition as to convey electric currents under the influence of moderate electromotive forces after a current-flow has once been established. By properly correlating the resistances between the respective electrodes and the vapor or gas and the resistance of the vapor or gas path itself and providing a proper heat-radiating capacity a lamp may be produced which will take considerable currents at moderate electromotive forces and be self-regulating to such a degree as to permit of its use upon commercial circuits even though their electromotive forces may fluctuate through wide limits. To render the lamp as stable and self-regulating as possible upon the circuit, it should have the resistance between the respective electrodes and the gas or vapor column reduced as much as possible, so that these resistances relative to the resistance of the gas column shall be small. The gas or vapor path then constitutes the principal por-

tion of the resistance of the lamp, and as the electromotive force at its terminals increases the total opposition to the passage of current may be made to increase also. This may be due in a measure at least to the fact that the greater amount of current flowing under the increasing pressure tends to develop a higher temperature, which in turn tends to increase the resistance of the lamp, so that a balance can be effected, rendering the lamp self-regulating. I do not, however, desire to be understood as advancing this theory of its regulation as the only one or as being necessary, but merely one which may be advanced from the results obtained.

Some materials when in a gaseous or vaporized state possess the capacity of emitting light under the influence of electric currents in a much higher degree than others. The vapor of mercury is efficient as a light-yielding material, and owing to its molecular weight and its low boiling or vaporizing point it is well suited to the purposes of my invention. Moreover, it readily serves under the influence of the current to transfer the heat generated in the lamp to convenient points for radiation. Some of the materials normally existing in the form of gases may, however, be used—such, for instance, as nitrogen. The amount of light, however, which may be obtained from nitrogen per unit of length appears to be less than that which can be obtained from mercury vapors, other things being equal. The spectrum is also a matter to be considered in determining the material to be used. Mercury gives a light which is clear and white, but wanting in red rays, so that while useful for many purposes it may be undesirable for others. Lithium and similar materials yield spectra with red and other colors. Nitrogen and other gases developed rays in abundance, and when combined with the mercury rays a beautiful result is obtained. The selection of the material for the vapor or gas must be determined by the conditions and requirements. The invention will be more particularly described with reference to mercury vapor as a matter of convenience and clearness, being among the most convenient to practice the art.

The lamp should be constructed to utilize as far as possible all the resistance of the lamp in the conversion of the electrical energy into light; but as there may be more or less heat developed the structure should be such as will radiate the heat at a suitable rate. Usually it is advantageous to employ a cooling-chamber at some portion of the device outside the path of the current. In the case of mercury, for instance, an enlargement of the tube may project a distance beyond one of the electrodes, so that the excess of heat will be radiated. In some instances it is practicable to cause the radiation to take place through the walls of the tube surrounding the gas column at a sufficient rate to meet the requirements. If the temperature

of the lamp is allowed to become too high, the lamp is liable to extinguish itself. When a fixed gas is used or vapors under such conditions that their densities cannot be unduly increased by heat in the tube, then the cooling-chamber may be dispensed with. The lamp may be made of such a size as to render a special cooling-chamber unnecessary.

The ability to start the lamp readily is of the utmost importance, gases appearing to present a greater resistance to the passage of the current before the current is passing than after, and I have found that certain materials added to the lamp before or while in the process of manufacture produce a condition which makes it possible to start a current under a moderate increase of electric pressure, and thereupon the continuous or an alternating current of low pressure readily traverses the lamp, producing an intense enduring light. I have obtained excellent results by the use of an independent substance for effecting the starting of the lamp, which produces a preliminary condition favoring the passage of current. One of the substances which I have used is sulfur or its compounds—for example, a small quantity of the sulfid of mercury introduced at the same time as the mercury when mercury is employed for forming the vapor. The tube containing these materials is then heated by any suitable means, the air, moisture, and foreign gases being pumped out by a suitable air-pump. I have found it advantageous during the process of exhaustion to heat the tube by convenient means until a vacuum is formed and to then subject the contents of the tube to the action of an electric current of high voltage. I am able to thus produce more or less heat throughout the length of the tube and produce such chemical reactions as may occur under the influence of the current and drive out foreign or deleterious gases and substances, leaving fairly pure mercury and a resultant sulfur compound, the exact nature of which I am not prepared to state with definiteness, although from such tests as I have been able to apply it would seem probable that it is a compound of mercury and sulfur containing a less proportion of sulfur than exists in the form of sulfid of mercury. Its effects seem quite different from that produced by pure red or black sulfids of mercury such as I have been able to make or procure in the markets. With this material present in the tube it is possible at starting cool to transmit an alternating or intermittent current from one end of the tube to the other with a much lower electromotive force than is required if the sulfur compound or its equivalent were not present. It seems also desirable to free the tube as far as possible from certain foreign substances, and particularly from oxygen, and I sometimes treat the tube with a bath of heated hydrogen before placing on the pump and also when the lamp is being exhausted. I

have found it sometimes advantageous to use interrupted currents of high voltage flowing in a given direction and to first constitute one of the electrodes the anode and the other the cathode and then to reverse the direction of the currents. I usually employ solid materials—such, for instance, as pure iron or other suitable substance—for one or both of the electrodes, and by thus constituting the respective electrodes alternately anodes and cathodes during the process of exhaustion I am enabled to heat each of them to a very high temperature, and thus drive out any occluded gases and foreign materials and produce any chemical reactions in them that might otherwise occur later on and ruin the efficiency of the tube. While the lamp is thus being treated and exhausted I connect the electrodes through a variable resistance with a suitable source of current of moderate electromotive force—such, for instance, as one hundred and ten or two hundred and twenty volts—the application of the high potential being also continued. In practice I find that the lamp should be run on the pump with a current at least equal to or, better, in excess of the current it is intended to afterward operate with. As the lamp approaches completion it suddenly becomes intensely luminous by reason of the passage of a considerable current of moderate potential from this source. The high-voltage current may then be temporarily withdrawn and the lamp further treated by current of low potential. Usually, however, it is desirable to use the currents of interrupted high potential at intervals, as they are useful for heating the electrodes and effecting the chemical changes as above referred to. When the lamp ceases to give off further foreign gases, it may be sealed off, and it is then in condition for operation.

When no starting material is present in the lamp, it is possible to start by heating it by any convenient means—such, for instance, as a Bunsen burner or an electric heating-coil of any convenient construction—and simultaneously applying to the terminals a difference of potential substantially equivalent to that upon which the lamp is designed to operate and at the same time a boosted electromotive force to enable the regular current to pass; but in the case of gases, owing to the electric phenomena the exact nature of which I am not as yet able to state, the lamp lights up, and when once lighted will continue in operation as long as required. When, however, the starting material is used, the lamp may be started without preliminary heating by means of electric currents of the proper electromotive force, usually higher than that upon which the lamp is normally intended to run. This may be conveniently done by placing in the circuit leading to the lamp the secondary coil of a transformer, the primary of which is connected with the supply-circuit through a suitable circuit-interrupter, or an

alternating current from a suitable transformer may be used, the purpose being to first cause a current to pass through the space between the electrodes, which then appears
5 to afford a path for the operating-currents of moderate potential. The readiness with which currents of lower electromotive force are caused to flow when a lamp provided with the starting material has been subjected for
10 an extremely short period to a higher electromotive force would indicate that the starting is not in this case due to the heat development of the current, but to some other electrolytic or electrochemical action, the exact
15 nature of which it is difficult to determine. For the purpose of constructing the lamp it is not essential that the theory of the action should be determined.

I have found that other materials than sulfur and mercury may be used to produce the starting material in the lamp. For instance, I have employed selenium and mercury with good results and also phosphorus and mercury and other material. After the lamp is
25 started it is probable that the starting material does not continue to act as a current-carrier, but that it is forced out of the path of the current or undergoes a change; but when the lamp is again cooled it resumes the
30 proper relation and condition to be availed of for again starting. I have found it advantageous when the lamp is to be started without heating and by means of moderately high voltage currents to surround the glass
35 or wall in the neighborhood of one of the electrodes, or in the case of an alternating-current lamp each of the electrodes, by a band of conducting or semiconducting material—such, for instance, as foil—which in
40 turn is placed in electrical connection with the other electrode or grounded by means of a small conductor. This device appears to lessen or neutralize to a certain extent at least the surface tension or static charge
45 which gathers about the electrode during the application of the starting-current, and it reduces the effective starting resistance of the lamp. A lamp which could be started only by extremely high potential currents,
50 if at all, without this band may be started without difficulty when it is present. When the lamp is once in operation under the influence of alternating or continuous currents of low pressures, the presence of the
55 conducting-band seems to no longer exercise its function to the same degree, although it may remain without interfering with the operation of the lamp, as it is insulated from the neighboring terminal of the
60 lamp.

In the accompanying drawings, illustrating my invention, Figure 1 represents one form of a complete lamp. Fig. 2 illustrates a modified form of electrode. Figs. 3, 4, and 5 illustrate systems of circuits for operating the
65 lamp. Fig. 6 illustrates, partly in diagram,

an organization of apparatus for exhausting and treating the lamp during exhaustion.

Referring to the figures, 1 represents a glass tube of such dimensions as may be required—
70 say, for example, a tube of three-quarters of an inch in diameter and two or three feet in length and having a wall of such thickness as not to be fragile. The particular dimensions of the tube to be chosen are determined
75 by the electromotive force and the current with which it is to be operated and other considerations which will be hereinafter pointed out. This tube is provided with two electrodes, (indicated at 2 and 5, respectively.)
80 If the lamp is to be run by continuous current, the electrode 2 is usually the anode and the electrode 5 the cathode. In the drawings I have shown the electrode 2 as being of an inverted-cup shape; but other forms may be
85 employed—such, for instance, as a closed spherical, oval, cylindrical, and other shapes. I have obtained excellent results by using a pure iron for this electrode; but other metals may be substituted. It is suspended within
90 or near the neck of an enlargement or chamber 4, which I usually employ, this chamber serving to increase the heat-radiating capacity of the lamp and to retain impurities. The electrode 2 is suspended by leading-in
95 conductor 7, of platinum or other suitable material, extending through the glass wall, and I usually provide a long seal 10 for protecting more or less of the leading-in conductor within the lamp. The electrode 5 is
100 shown in this instance as being a small quantity of mercury. A leading-in conductor 8 connects with this electrode. Surrounding the lower end of the tube, adjacent to and usually projecting a slight distance, say, one
105 eighth of an inch above the level of the lower electrode, there is placed a thin band 9 of conducting material—such, for instance, as foil—and this is electrically connected by a conductor 13 with the leading-in wire 7.
110 When the lamp is to be operated by alternating electric currents, it may be useful to place a circular band in similar relation to the other electrode and connect it with the leading-in conductor 8.

115 The lamp is started by means either of first heating it—as, for instance, with the flame of a Bunsen burner or other convenient means—or by applying to the terminals an electromotive force of higher potential—such, for instance, as may be obtained by a rapidly alternating or intermittent current. In Fig. 3 I have represented a system of circuits and apparatus for securing an intermittent current of higher potential from the same main
125 circuit 14 15, upon which the lamp is to be run. The apparatus consists in this instance of a converter having a core 16, provided with two coils 17 and 18. One terminal of the coil 17 is connected with the conductor 14. The remaining terminal is connected with an insulated contact 20 on an armature 21, which is
130

operated by the core 16. A contact-point 22, against which the point 20 normally rests, is connected with one terminal of a circuit-interrupting device 19. The remaining terminal of this circuit-interrupting device is connected, through a suitable key or switch 23, with the conductor 15. One terminal of the coil 18 is connected with the conductor 14, and the remaining terminal is connected with the leading-in wire 7. The leading-in wire 8 is connected with the main line 15. When the current is turned on—as, for instance, by the line-switch 23—the interrupter 19 causes rapidly-intermitted currents to pass through the coil 17. This induces a current of any desired potential in the coil 18. The effect of this high potential is to produce within the lamp such an electrical or electrochemical condition as will result in effecting a passage of the currents of normal potential which are simultaneously applied by the main circuit 14 15. When currents commence to flow through the lamp from the conductors 14 15 under the influence of the normal electromotive force upon the main circuit, the core 16 attracts the armature 21, separating the contacts 20 22. The same movement of this armature may operate to close a shunt-circuit 24 around the coil 18 through a resistance 25 offering sufficient resistance to the flow of current to cause enough current to still flow through the coil 18 to hold the armature 21 in its forward position so long as the lamp continues to operate. In this figure I have shown this as accomplished by an insulated contact 26, carried by the armature 21, coming into contact with a point 27, this point being connected with the conductor 24, while the insulated point 26 is connected by the conductor 27 with the opposite end of the coil 18.

During the starting of the lamp by the application of higher potential currents a high static charge appears to occur near the electrode 5 and upon the outer surface of the lamp, and this is removed or reduced by the presence of the band 9, connected through the conductor 13 to the leading-in wire 7. In practice I have found that with this band removed or the conductor 13 interrupted it is exceedingly difficult, if not impossible, to start the lamp with currents of reasonable electromotive force unless the lamp is heated by artificial means. The exact position at which the band 9 may be located appears to differ somewhat in different cases, probably owing to the good conductivity of the gas coming from or forming part of the electrode. The proper position is usually slightly beyond the effective joint between the electrode and the gas.

It should be noted that the potential of the main circuit 14 15 is applied to the lamp during the time that the higher potential starting-current is applied, and if an intermittent current in distinction from an alternating current is employed and a continuous current is to be used for operating the lamp it

is usually desirable, though not necessary, to so connect the terminals that the electromotive forces shall be in the same direction—that is to say, the positive side of the main circuit being connected with the electrode 2 the positive side of the higher potential circuit is connected with the same electrode. The connections may, however, be in opposite directions. With alternating currents, the electrode 2 being alternately anode and cathode, the connections may be followed out on the same principle.

The circuit-interrupter 19 which I have shown is an adaptation of a device commonly known as a "Wehnelt" interrupter. It consists of two electrodes 28 and 29, of lead, separated by a jar 30, of non-conducting material, having small perforations 31 and immersed in sulfuric acid contained within a vessel 32. An electrode 28 is placed within the jar and an electrode 29 outside of it. The action of the electric current is to generate gases which forming within the perforations temporarily interrupt the circuit, and the gases disappearing the circuit is again completed with great rapidity. Other forms of circuit-interrupting devices, however, may be employed.

Unless special means are provided to prevent it a lamp of this character using mercury vapor is liable to have a more or less flickering effect, probably due to the shifting of the position at which the current enters the cathode. I have succeeded in obviating such flickering in various ways. The tendency of the current seems to be to remain in the gas or vapor until it reaches the portion of the cathode most distant from the anode, and if a small body of mercury surrounds the cathode it will unless means are provided to prevent it wander over the surface of the mercury, and thus produce the flickering. I find that by sufficiently obstructing the path beyond the portion of the cathode nearest the anode the current will be forced to enter the cathode at a more or less fixed point, and thus become steady and obviate the flickering. A cylinder of porcelain or other suitable substance 6, as shown in Fig. 2, may be placed in the mercury, leaving only a perforation through which the current must pass. Where the cathode is at the end of the tube, this difficulty may be overcome to a large extent by making it concave and arranging it so that the current will enter it on the concave surface.

I have used in some instances in place of the form of apparatus above described for producing the higher potential starting-current a simple spark-coil, as shown in Fig. 4, comprising a core 40, with a primary coil 41, adapted to be connected, by means of a switch 42, between the main conductors 14 and 15, and also provided with a secondary coil 43, one terminal of which is connected with the electrode 5 of the lamp and the remaining terminal with the main conductor 15. A switch 44 is included in the conductor 45,

which leads from the electrode 2 to the main conductor 14. The coils 41 and 43 are so proportioned as to produce a higher difference of potential at the terminals of the coil 43 upon breaking the circuit of the coil 41, and the discharge from this coil suffices to produce in the vapor path of the lamp the proper conditions for permitting the current from the main circuit to flow through the lamp by way of the conductor 45 and the coil 43.

In Fig. 5 a modification in the circuit organization is shown in which a three-wire system of distribution is represented by the conductors 50, 51, and 52. The difference of potential upon the outside conductors 50 and 52 being assumed to be twice that between the middle or neutral conductor 51 and the respective outside conductors, the purpose is to apply the higher difference of potential to the lamp upon starting and automatically shifting the lamp to the lower potential when current commences to flow. For this purpose any suitable form of circuit-changing switch may be employed. In the drawings I have shown a magnet 53, having its coil included in the conductor 54, leading to one terminal of the lamp. The armature 55 of this magnet is connected by a conductor 56 with the neutral conductor 51. It is normally held away from the magnet, so that an insulated contact 57 is pressed back by a contact-point 58, which in turn is connected by a conductor 58^a with the main conductor 52. The insulated contact 57 is connected by a conductor 59 with the remaining terminal of the lamp. When the lamp is started, its terminals are in connection with the two conductors 50 and 52; but current flowing through the conductor 54 in sufficient quantity to operate the lamp causes the magnet to draw the armature 55 forward, closing the contact between the spring-contact 57 and armature 55 and simultaneously breaking the contact between the point 58 and the spring-contact 57, thus shifting the lamp to the lower voltage-circuit. A resistance may be included in the conductor 58^a to prevent a short circuit upon the conductors 51 52 when the armature is being drawn forward.

As already stated in connection with Fig. 1, the condensing and impurity-containing chamber 4 or its equivalent performs an important function in the operation of the lamp. As the lamp commences to operate heat accumulates, and the increasing temperature appears to soon result in increased resistance on the part of the vapor path. If the heat is not conducted away after the lamp has reached its proper working condition with the same rapidity that it is generated, the lamp may extinguish itself. The chamber 4 is therefore constructed with sufficient radiating surface to get rid of the excess heat and keep the lamp in the proper condition. The chamber 4 need not, however, necessarily surround the electrode 2; but it may be located else-

where and be of other form, provided it is out of the vapor-path.

It may sometimes be desirable to insert a small balancing or steadying resistance in series with the lamp. This resistance is of importance mainly on starting certain kinds of lamps, which when cold, owing to the starting material or other construction, would take too much current until they have acquired their working condition. When a given electromotive force is applied to the terminals of the lamp, such steadying resistance does not cause any material reduction of potential at the terminals of the lamp until current commences to flow, and thereafter the greater the amount of current flowing the greater will be the resistance opposed to the flow of current, and thus the difference of potential at the terminals of the lamp will be held down. The coils of the starting mechanism are therefore usually not objectionable when left in circuit, for their resistance in a large measure compensates for moderate changes of voltage upon the circuit in which the lamp may be placed and also prevents too great a rush of current when the lamp first starts, for when the lamp starts it is relatively cold and is capable of absorbing heat rapidly and may take a correspondingly large amount of current. This might in some cases melt the leading-in wires or crack the glass were it not prevented by some such means as the steadying resistance. I have shown such a steadying resistance at 11 in Fig. 3; but when the lamp is running the steadying resistance causes but slight loss, as the amount of current is less.

Referring to Fig. 6, the method of manufacturing the lamp will be described more in detail. The tube, properly shaped and prepared, is first thoroughly cleansed with acids, alkalies, and water. I have found it convenient to first rinse the tube with dilute hydrofluoric acid and then wash with distilled water, and therefore, if desired, it may be further washed by a bath of hot hydrogen. In case mercury is to be used for providing the conducting vapor, a small quantity of it is placed within the tube, and if the sulfid of mercury is to be used for forming the starting material a small quantity of that substance is added. Pure sulfur may be introduced instead of sulfid of mercury; but I have found that it usually is more difficult to secure the desired results with it than with the sulfid of mercury. The lamp is then sealed onto a suitable exhaust-pump 60 of any suitable character through an exhausting-tube 61, and the process of exhaustion is commenced. Meanwhile artificial heat is applied to the tube—as, for instance, by a Bunsen burner 62 or an electric heater or in some other convenient manner. After the free gases and air have been exhausted, an electric current of higher potential is applied to the terminals of the lamp—as, for instance, by a system of

circuits and apparatus such as described in connection with Fig. 4—and the passage of this current through the lamp produces an effect somewhat similar to that noticeable in Geissler tubes. The operation of the exhaust-pump is continued, and a difference of potential approximately equal to that under which the lamp is intended to be operated is applied to the terminals of the lamp. As the lamp approaches completion it suddenly becomes intensely luminous by reason of the passage of a current of considerable quantity. If the higher potential current employed is an interrupted current, it is desirable to reverse the terminals of the lamp with reference to that current one or more times, for the cathode is thereby readily heated to a very high temperature, which aids in driving off any occluded gases and impurities. A circuit-reverser 63 may be employed for that purpose.

In the form of apparatus shown in Fig. 6 the connections of the spark-coil are somewhat different from those of the similar coil shown in Fig. 4; but the principle of operation is the same, and the action of the apparatus can easily be determined by reference to the description of it in connection with Fig. 4. In place of the switch 44 (shown in Fig. 4) I substitute a variable resistance 44^a, the object of which is to permit of varying the current passing through the tube 1 during the process of manufacture. The switch 42 may be replaced by an automatic circuit-interrupter—such as illustrated, for instance, in connection with Fig. 3.

The process of exhausting the lamp does not appear to remove the starting material, although apparently a different chemical compound is formed, and it is possible that some of the sulfur is thrown off or formed into some other combination and withdrawn from the tube. In any event sufficient of the starting material remains in the tube to permit the ready starting of the lamp when it is completed. The amount of sulfid of mercury to be introduced may be varied within wide limits. I have used in a lamp of approximately the dimensions hereinbefore referred to a quantity as small as may be taken upon the point of a pocket-knife and be plainly visible. Too much does not seem to exercise any very bad effect, except retarding the process of exhaustion and possibly to blacken or coat the glass somewhat. When the pump ceases to withdraw any gases other than the mercury-vapors, the lamp is completed and may be sealed off the pump at 61.

While I have described the lamp more particularly with reference to mercury vapors, I desire it to be distinctly understood that I do not limit myself to those vapors nor to materials which at ordinary temperatures exist in the forms of solids or liquids, for permanent gases may be employed. Usually with permanent gases the necessity of the chamber 4 is obviated, for the proper gas density

is obtained when the lamp is constructed, and the lamp being made self-regulating the temperature controls and is controlled by the quantity of current flowing. I have also found that with the mercury vapors the lamp operates successfully without the enlargement 4, if the diameter of the tube is an inch or more, or even smaller.

In certain other applications filed by me April 5, 1900, Serial Nos. 11,606 and 11,607, and Serial Nos. 44,647, 44,648, and 44,649, filed January 25, 1901, claims are made to certain features which are disclosed herein.

The invention claimed is—

1. A lamp for producing light by electric energy consisting of an inclosing chamber, a gas or vapor contained therein capable, under proper conditions, of conducting currents of considerable quantity under the influence of moderate difference of potential, and a starting material also contained within the chamber and serving to convey a starting-current under the influence of a higher difference of potential.

2. In a gas or vapor lamp, the combination with a conducting vapor or gas constituting the sole path for the current while the lamp is in operation, of a starting material serving to permit the initial passage of the electric current through the lamp.

3. An electric lamp consisting of a hermetically-sealed inclosing chamber, electrodes within the same, means for securing electrical connection therewith, respectively, through the walls of the chamber, a vapor or gas contained within the chamber having, when traversed by an electric current, a resistance so varying with increments of current as to render it substantially self-regulating, and a steadying resistance in series with the lamp.

4. In an electric vapor or gas lamp, the combination of two electrodes located at or near the respective ends of the lamp, a conducting medium between the electrodes consisting of a vapor or gas which is light-emitting under the influence of electric currents of moderate potential, means for applying a preliminary higher difference of potential to the terminals of the lamp for creating a condition on the part of the conducting-vapor which will permit it to conduct currents of moderate potential, and means for thereafter operating the lamp by the currents of moderate potential.

5. In an electric lamp, the combination of an inclosing chamber, two electrodes, a conducting medium between the electrodes consisting of a vapor or gas which is light-emitting under the influence of electric currents of moderate potential, means for applying a higher difference of potential to the terminals of the lamp for producing a condition on the part of the vapor or gas which will render it conductive for currents of considerable quantity and moderate potential, and means

for relieving the static charge at or near one of the electrodes caused by the action of the higher difference of potential.

6. In an electric lamp, the combination of
5 an inclosing chamber, two electrodes, a conducting medium between the electrodes consisting of a vapor or gas which is light-emitting under the influence of electric currents of moderate potential, means for applying a
10 higher difference of potential to the terminals of the lamp for producing a condition on the part of the vapor or gas which will render it conductive for currents of considerable quantity and moderate potential, and
15 means for relieving the static charge at or near one of the electrodes caused by the action of the higher difference of potential consisting of a band of conducting material located near, but out of contact with, that electrode, and electrically connected with the
20 other electrode.

7. A lamp for producing light by means of electric energy consisting of an inclosing chamber, a gas or vapor contained therein capable, under the proper conditions, of conducting currents of considerable quantity and moderate electromotive force, a starting material within the chamber facilitating the passage of current therethrough under the influence of higher differences of potential, a
30 conducting-band surrounding the inclosing chamber near one of the electrodes of the lamp, and electric connections for leading off the electric charge produced therein under
35 the influence of the electric currents of high differences of potential.

8. An electric lamp consisting of a transparent tube, a gas or vapor column contained therein, an electrode at the lower end thereof
40 consisting wholly or in part of liquid, a metallic electrode at or near the upper end of said tube, a cooling and impurity-containing chamber surrounding the upper electrode, and means for securing electric connections
45 with the respective electrodes through the wall of the lamp.

9. An electric lamp consisting of a transparent inclosing chamber, an electrode at or near one end of the chamber consisting
50 wholly or in part of mercury, an electrode at or near the other end of the chamber consisting of a body of iron, and means for forming electrical connections with said electrodes through the wall of said chamber.

10. An electric lamp consisting of an inclosing chamber, electrodes within said chamber connected with each other through an intervening gas or vapor column, and a static-charge dissipator located near one of the electrodes but insulated therefrom and electrically connected with the other electrode.
60

11. An electric lamp consisting of an inclosing chamber and two electrodes at or near the respective ends of said chamber, one of
65 said electrodes consisting of a solid body of not readily vaporizable material free from carbon and other materials liable to be given

off thereby in injurious quantities by the operation of the lamp.

12. An electrode for electric lamps employing a vapor or gas as a conducting medium consisting of a quantity of mercury and a non-conducting wall constricting the path of the electric current between said vapor or gas and said mercury.
75

13. The combination with an electric lamp wherein light is produced by the passage of electric energy through a hermetically-inclosed gas or vapor, a source of electric currents of moderate difference of potential, connections from said source with the terminals of the lamp, a potential-raising device also connected with said source of electric currents, and means for applying the higher difference of potential produced by said device to the terminals of the lamp while the moderate potential is also applied.
85

14. The combination with an electric lamp in which light is produced by electric energy traversing a hermetically-inclosed vapor or gas, a source of electric currents of moderate electromotive force, electric connections therefrom to the terminals of the lamp, and a potential-raising transformer having its secondary coil connected in the circuit leading to the lamp and its primary coil connected with the source of currents of moderate difference of potential, substantially as and for the purpose described.
90

15. The combination of an electric vapor or gas lamp having a gas or vapor path adapted to be rendered luminous by the passage of an electric current, said vapor path having a resistance so varying with increments of currents employed for its operation as to render it substantially self-regulating, a circuit of low potential for the normal operation of the lamp, and a local circuit of higher potential part of which local circuit forms part of the circuit of low potential, the vapor path forming a part of both circuits.
105

16. The combination with an electric lamp in which light is produced by electric energy acting on a hermetically-inclosed vapor or gas, a source of electric currents of moderate electromotive force, electric connections therefrom to the terminals of the lamp, and a potential-raising transformer having its secondary coil connected in the circuit leading to the lamp and its primary coil connected with the source of currents of moderate difference of potential, with means on starting for shifting from the higher potential to the lower potential circuit, substantially as and for the purpose described.
120

17. The combination in an electric lamp in which light is produced by electric energy acting on a vapor or gas, a source of electric currents of moderate electromotive force, electric connections therefrom to the terminals of the lamp, a potential-raising transformer having its secondary coil connected in the circuit leading to the lamp and its primary coil connected with the source of current.
125

rents of moderate potential, and an automatic circuit-interrupter for opening the circuit of the primary coil when currents of considerable quantity traverse the lamp under the influence of the normal electromotive force from said source.

18. The combination with an electric lamp in which light is produced by electric energy acting on a vapor or gas column, a source of electric currents of moderate electromotive force, electric connections therefrom to the terminals of the lamp, a potential-raising transformer having its secondary coil connected in the circuit leading to the lamp and its primary coil connected with the source of currents of moderate difference of potential, and means for producing rapid variations of current in the primary coil, thereby superposing a higher electromotive force upon the moderate electromotive force applied to the lamp.

19. The combination with an electric lamp in which light is produced by the conduction of currents through a path of vapor or gas, of a source of electric currents, connections therefrom with the terminals of the lamp, a converter having its secondary coil connected in said circuit with the lamp and having its primary coil connected with said source, means for rapidly magnetizing and demagnetizing the core of said transformer, a resistance shunt-circuit around the secondary coil of the transformer, and means for closing the connections of said shunt-circuit when the lamp is in operation.

20. The combination with an electric lamp in which light is produced by the conduction of currents through a path of vapor or gas, of a source of electric currents, connections therefrom with the terminals of the lamp, a converter having its secondary coil connected in circuit with the lamp, and having its primary coil connected with said source, means for rapidly magnetizing and demagnetizing the core of said transformer, a resistance shunt-circuit around the secondary coil of the transformer, means for closing the connections of said shunt-circuit when the lamp is in operation, and means for simultaneously interrupting the connections of the primary circuit.

21. The combination in an electric lamp in which a starting-current of higher electromotive force is required, of a transformer for producing such higher electromotive force having its secondary coil connected with the terminals of the lamp and its primary coil connected with a source of electric currents, connections from said source through the secondary coil, and a circuit-interrupting device for the primary coil operated by the magnetization of the core of the converter under the influence of operating-currents traversing the lamp.

22. The combination with a lamp for producing light by the conduction of electric currents through a hermetically-inclosed va-

por or gas path, of a source of high difference of potential and a source of moderate difference of potential, means for connecting the lamp with the source of high difference of potential for starting the lamp and with the source of moderate difference of potential for operating the lamp.

23. The combination with an electric lamp, two sources of electromotive force, means for connecting said sources in series for starting the lamp, and means for connecting the lamp with one of said sources for operating it when started.

24. The combination with an electric lamp having a light-emitting material consisting of a hermetically-inclosed vapor or gas capable of emitting light under the influence of currents of moderate potential, a source of electric currents, means for connecting the lamp with said source, means for creating from the moderate potential currents of higher potential, means for applying the higher potential to the lamp for starting it, and means for discontinuing the high potential when the lamp is started.

25. The combination with an electric lamp comprising an inclosing chamber and a vapor or gas forming a path for the current between the electrodes of the lamp, of a transformer, means for causing independent variations in the current traversing the primary coil of the transformer, and circuit connections through the secondary coil of the transformer with a source of electric currents.

26. The combination with an electric lamp comprising an inclosing chamber and a vapor or gas forming a path for the current between the electrodes of the lamp, of a transformer, means for causing independent variations in the current traversing the primary coil of the transformer, connections through the secondary coil of the transformer with a source of electric currents, and means for interrupting the flow of currents through the primary coil.

27. The combination with an electric lamp having a hermetically-inclosed gas or vapor path, of a circuit leading to the terminals thereof, a transformer the secondary coil of which is included in said circuit, means for causing a rapidly-varying current to traverse the primary of the transformer, and means for interrupting the circuit of said primary coil, by the action of current flowing through the lamp.

28. The combination with an electric lamp of the character described, of a circuit leading to the terminals thereof, a transformer the secondary coil of which is included in said circuit, means for causing a varying current to traverse the primary of the transformer, means for interrupting the circuit of said primary coil by the action of currents of lower potential flowing through the lamp, and means for cutting the secondary coil out of circuit when the lamp is operating.

29. The combination with a lamp of the character described, of a permanent source

of electric current connected to the terminals of the said lamp through the secondary of a transformer, a second circuit from the said source, including the primary of the said transformer, and means for varying the current in the said primary and afterward cutting out the circuit of the primary by the action of the current passing through the lamp.

30. The combination with an electric lamp, of a main supply-circuit, connections therefrom through the secondary coil of a transformer with the terminals of the lamp, a primary coil for the transformer, a circuit-interrupter, means for connecting said primary coil and circuit-interrupter with the supply-circuit, and means for interrupting the primary-coil circuit by the action of currents supplying the lamp.

31. The combination of a translating de-

vice, a source of current, a transformer having one coil connected in series with the translating device and with the source of current, means for creating independent time variations in the supply-current traversing the other coil, whereby the electromotive force of the current in the first-named coil is modified; and a device for automatically cutting out the means for creating the independent time variations, through the instrumentality of currents passing through the translating device.

Signed at New York, in the county of New York and State of New York, this 21st day of March, A. D. 1900.

PETER COOPER HEWITT.

Witnesses:

HENRY NOEL POTTER,
WM. H. CAPEL.