No. 685,724. Patented Oct. 29, 1901.

W. NERNST.

METHOD OF ELECTRIC LIGHTING.

(Application filed Apr. 28, 1898.)

(No Model.) 2 Sheets—Sheet 1.

Fig. 1.

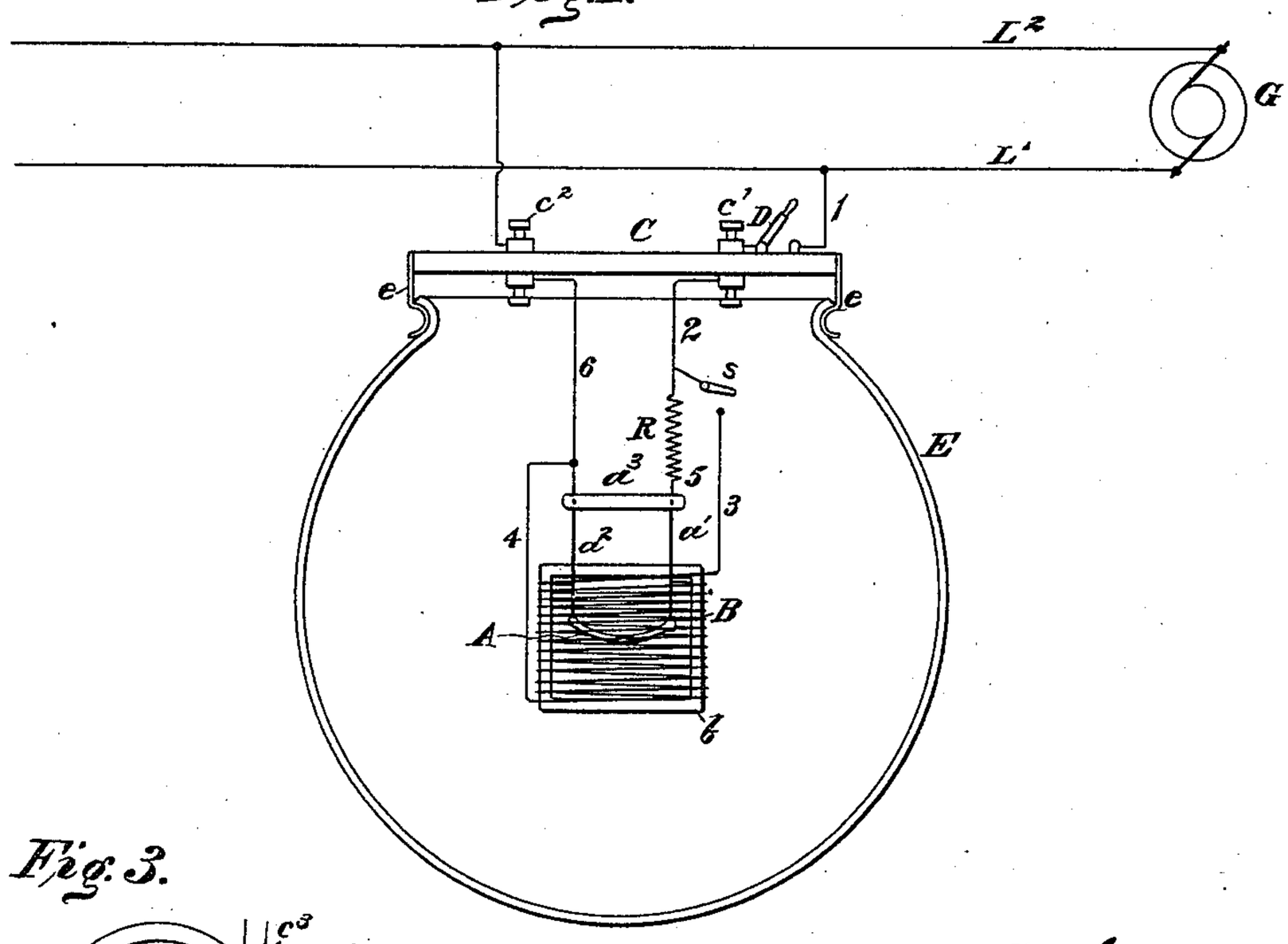


Fig. 3.

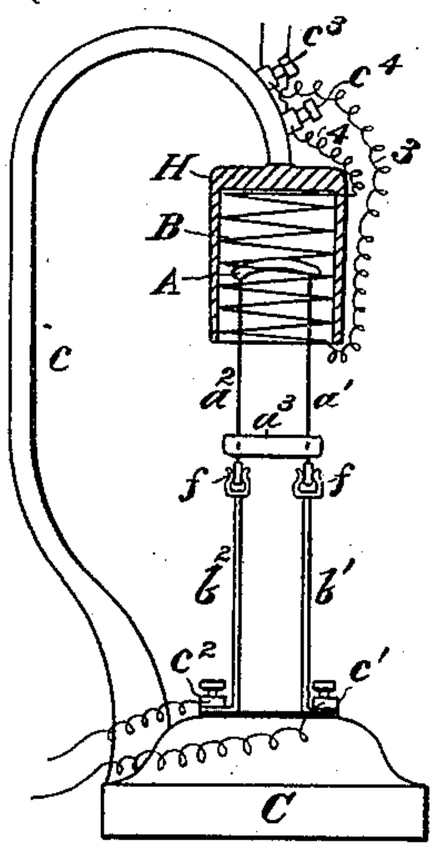


Fig. 2.

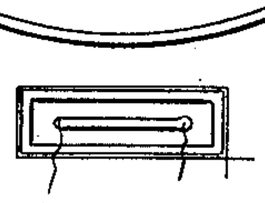


Fig. 5.

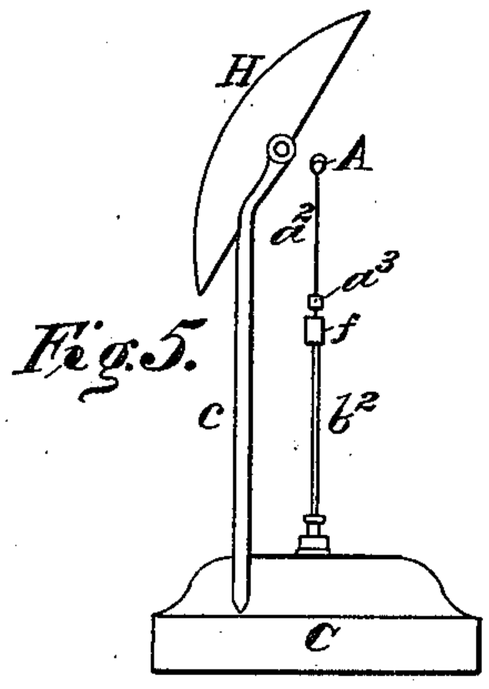


Fig. 4.

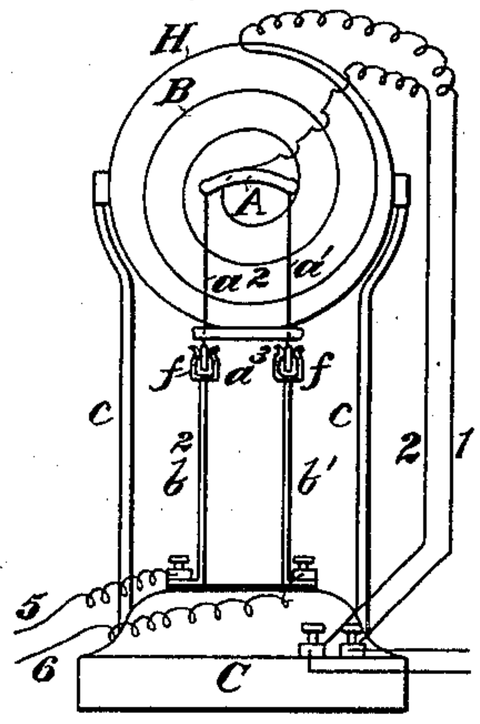
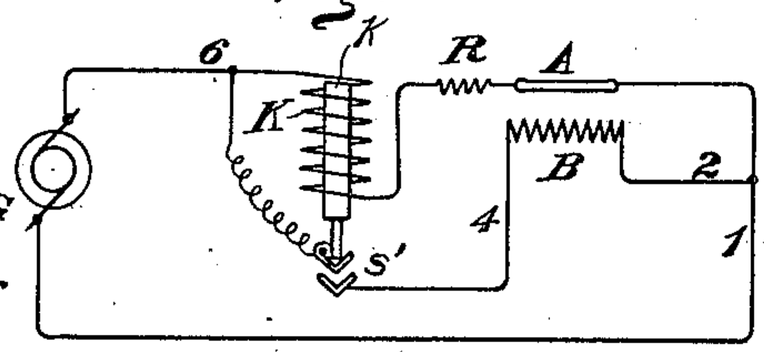


Fig. 6.



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No. 685,724. Patented Oct. 29, 1901.

W. NERNST.

METHOD OF ELECTRIC LIGHTING.

(Application filed Apr. 28, 1898.)

(No Model.) 2 Sheets—Sheet 2.

Fig. 7.

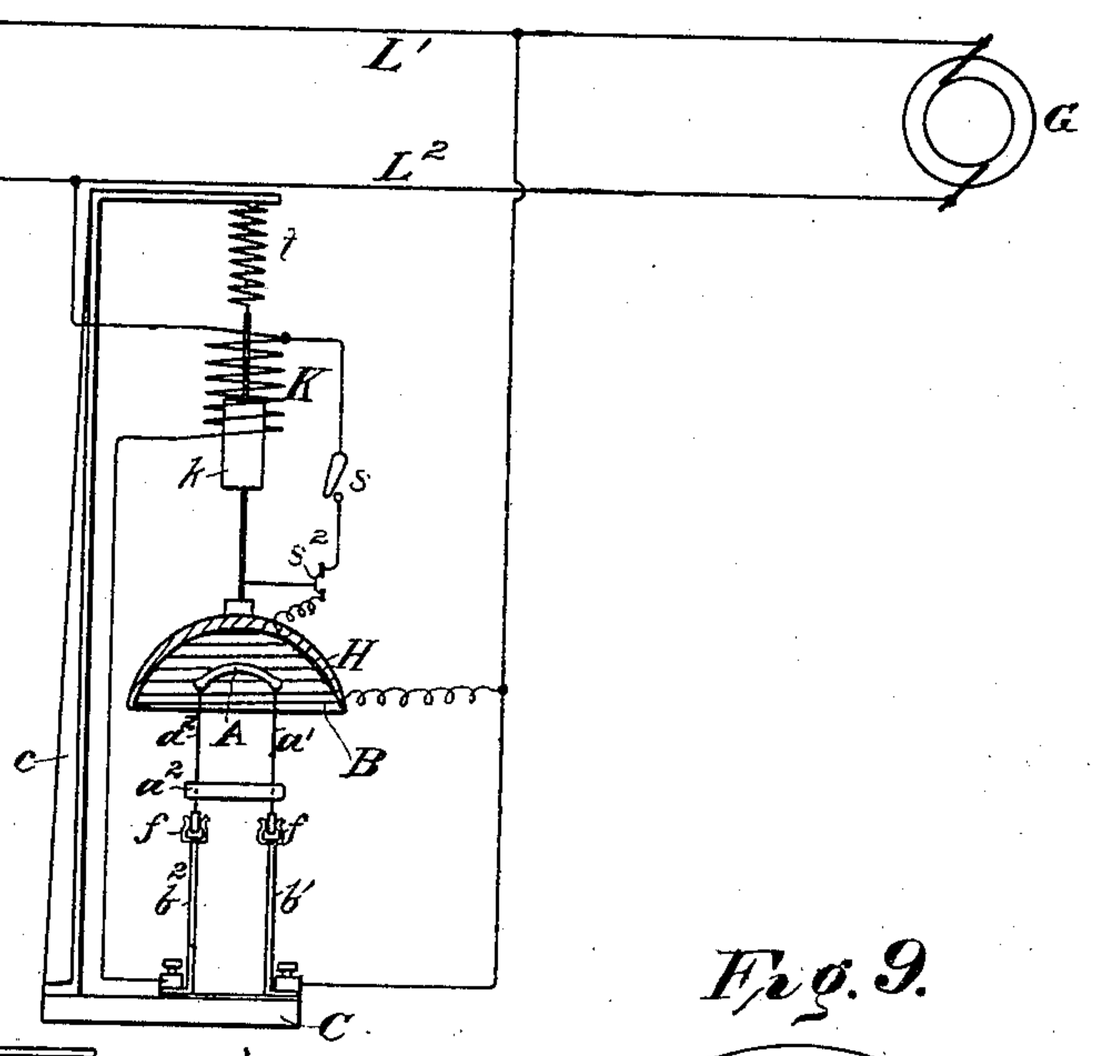

Fig. 9.

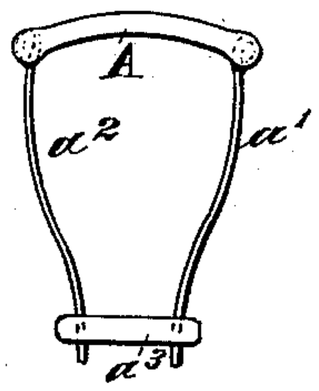

Fig. 8.

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UNITED STATES PATENT OFFICE.

WALTHER NERNST, OF GÖTTINGEN, GERMANY, ASSIGNOR TO GEORGE WESTINGHOUSE, OF PITTSBURG, PENNSYLVANIA.

METHOD OF ELECTRIC LIGHTING.

SPECIFICATION forming part of Letters Patent No. 685,724, dated October 29, 1901.

Application filed April 28, 1898. Serial No. 679,081. (No specimens.)

To all whom it may concern:

Be it known that I, WALTHER NERNST, a subject of the Emperor of Germany, residing in Göttingen, Germany, have invented a new and useful Improvement in Methods of Electric Lighting, of which the following is a specification.

My invention relates in a general way to the class of devices known as "incandescent electric lamps" and a method of lighting; but it differs fundamentally from the incandescent lamps and methods heretofore used and involves certain peculiar features and characteristics which justify its classification as a distinct and novel species.

Heretofore all practical incandescent electric lamps have comprised a filament of conducting material, usually, if not always, of carbon, contained within an inclosing chamber from which the air is exhausted. The fact that the filaments heretofore employed will oxidize when heated in the open air has necessitated inclosing them in vacuum-chambers.

Various refractory materials comprising certain oxids, sulfids, silicates, and other salt-like compositions of metals are specially qualified to emit light when heated to a high temperature. It has been proposed to utilize the light-emitting qualities of such materials by maintaining them in a state of incandescence by a gas-flame, as illustrated by the well-known "Welsbach burner," for instance. When the light-emitting qualities of these refractory materials were to be used in connection with electric lighting at ordinary voltages, it has heretofore been considered necessary to either maintain them in an incandescent state by placing them in proximity to conductors heated by electric currents or to coat them or add to them or in some way combine with them some good conducting material, such as a metal or carbon which should afford a conducting path for the current. For example, it has been proposed to impregnate or coat conductors—such, for instance, as platinum, iridium or carbon—with a refractory material—such, for instance, as calcium or zirconia—and to use the heat developed in the conducting material for maintaining the refractory material in an incandescent light-emitting condition. Such combinations, however, have been found to be inoperative for any useful purpose. The platinum or carbon or other conducting material either itself melts or disintegrates or causes the refractory material to crack off or disintegrate.

I have discovered that certain refractory, salt-like combinations, particularly oxids usually classed as the "rare earths," which are at ordinary temperatures, "non-conductors of electricity," as that term is usually employed, will, when raised to the high temperature of incandescence, become sufficiently good conductors to permit the passage of an electric current under moderate differences of potential and may be maintained sufficiently heated to retain their thus-acquired conducting qualities by the passage of the electric current therethrough. These materials when so traversed by electric currents not only emit more light under the influence of a given amount of electrical energy than the ordinary incandescent lamp, but they also resist decomposition and disintegration even in the open air, and therefore a lamp constructed in accordance with my invention does not require a vacuum-chamber, though a vacuum-chamber may be used in certain cases, if desired.

The general characteristics of the light-giving portion of my lamp are so widely different from those of the ordinary incandescent electric lamp that to term it a "filament" would be not only inappropriate, but to a certain extent misleading. The light is emitted therefrom without combustion or material disintegration even when exposed to the air, and being translucent it emits light from its interior and from its surface, and I have given the name "glower" to the light-giving portion and "glow-lamp" to the lamp itself as being properly applicable.

The materials which I have discovered to possess the qualities above referred to may be classed under the general term of "dry electrolytes" or dry conductors of the second class. By the expression "conductors of the second class" I refer to those which when in a conducting condition conduct current by electrolytic action.

Prominent among the materials with which I have obtained excellent results may be men-

tioned oxid of magnesium or magnesia and oxid of zirconium or zirconia; also, the oxids of yttrium, cerium, thorium, and the like. These materials when in a dry state and at normal temperatures are practically insulators or non-conductors; but when glowers made from them are heated to a state of incandescence they acquire conducting qualities to such an extent that electricity may be caused to pass through them at ordinary low pressures in sufficient quantities to keep them in the state of incandescence even after the means employed for imparting the original starting heat is withdrawn. Instead of using these materials individually or alone for forming the glower two or more of them may be mixed or combined in varying proportions with advantageous results. Glowers made from a proper mixture of certain of the materials will pass into the conducting state at a lower initial or starting temperature than will a glower made from one of the materials alone and will maintain under the passage of the electric current a luminous condition without deterioration better and for a longer time than will any single one of such materials. It is not, therefore, the mere mixture of such materials that I prescribe, but the utilization of such mixtures on account of their superior properties when brought to and maintained in a luminous condition. These materials, even when in their best operating conducting condition, have a specific resistance so great with reference to that of carbon that a glower to be used with a given voltage may be much shorter and thicker than the carbon filament of an ordinary incandescent lamp. For instance, a practical glower of, say, one-fiftieth of an inch in diameter and one-half an inch in length may be made, which when heated to a low incandescence will become a sufficiently good conductor to be traversed under a one-hundred-volt difference of potential by a sufficient current to bring it to and maintain it at a state of high incandescence. A current of, say, four-tenths of an ampere or thereabout will accomplish this result. As the material has sufficient strength to enable it to be used in much longer lengths than that above referred to it is possible to construct lamps adapted to be operated at very much higher voltages than is practicable with lamps using carbon filaments, a feature which may be utilized to obtain economy of transmission. This feature, in connection with the high efficiency of the lamp, renders it possible to secure either a given illumination with a much higher transmission efficiency than at present obtained or a higher illumination with the present transmission efficiency, or both the illuminating and transmission efficiencies may be materially increased.

There are numerous different proportions in which the different refractory materials adapted to the purposes of my invention may be used, and there is a very wide range for the selection of the different materials to be mixed together, and therefore I will attempt only and it will only be necessary to specify one or two examples. Very excellent results have been obtained from a mixture of approximately seventy per cent. of zirconia and thirty per cent. of yttria, (oxid of yttrium.) Another mixture which I have used with good advantage consists of approximately ten per cent. of zirconia, seventy per cent. of thoria, and twenty per cent. of yttria. I have also obtained excellent glowers from a mixture of about seventy per cent. of thoria and thirty per cent. of yttria. Another mixture consists of 0.5 per cent. of ceria, eighty per cent. of thoria, with 19.5 per cent. of yttria. These percentages may be widely varied, and, generally speaking, the oxids of the rare earths are well adapted for mixture in widely-varying proportions.

The process of preparing the glowers from which I have heretofore obtained the best results when two or more of the oxids are to be used together consists in thoroughly pulverizing and mixing the materials together into very intimate relations, then mixing therewith a binder of clear-starch paste, making a plastic mass which should be thoroughly worked. The water used in making the paste should be clear and preferably distilled to avoid the presence of lime, which is more volatile than the oxids of the rare earths, and therefore undesirable. The plastic mass may then be inserted in a press adapted to force the mixture through a small hole of the requisite diameter, dependent upon the ultimate diameter desired for the glower, and as the material leaves the press it may be hung over a glass rod or laid upon a suitable supporting-surface and allowed to dry. The material acquires sufficient strength when dried to be conveniently handled, and it is then heated to a very high temperature in any suitable manner—for instance, in an oxyhydrogen flame. It is desirable that as great a specific gravity as possible may be given to the material—that is to say, the smallest diameter for a given mass of a given length. Care should be taken that every part of the glower is brought to a high incandescence. Usually it is advantageous to heat the material gradually, so as to drive off the moisture and the binding material slowly, and thus lessen the liability of the surface becoming cracked. For example, it may be passed through a preliminary heat in a porcelain kiln. The eventual heating, however, should be carried to an extremely high temperature. When the material has been thus prepared, a proper length, dependent upon the voltage and current with which it is to be used, is mounted between two suitable conducting-wires. The ends may advantageously be fastened mechanically in any suitable way—as, for instance, by inserting them into suitable sockets made by forming into spirals the conducting-wires,

which may be of platinum or other good conducting materials which melt only at a very high temperature. The junctions of the glower with the respective wires are then built up by placing thereon in a liquid or paste-like condition small quantities of a cementing material and heating and drying the same in a gas-flame or otherwise. This process is repeated until a firm union is obtained between the respective ends of the glower and the wires. It is advantageous also to make the points of juncture with the wires of larger diameter than the main portion of the glower, for then the points of contact with the wire will not during the operation of the lamp be as hot as the remainder of the glower, and therefore the wires themselves are less liable to burn off. The paste or cement with which it is desirable to build up the ends may be of the same material as that used for forming the glower itself. I have obtained excellent results by pulverizing portions of glowers which have been previously prepared and heated to high temperatures and mixing the same with water; and, if desired, starch paste may be added. Any suitable means for supporting the conducting-wires and securing electrical connections therewith may be employed.

For the purpose of obtaining the preliminary or starting heating of the glower various different means may be employed. Usually it is desirable that the heat should be applied only during the starting process and then withdrawn, although in some cases it may be desired to continue the extraneous heat while the lamp itself is in operation.

A very convenient starting-heater consists of a coil of platinum wire or other conducting material which may be heated to a high temperature in the open air by the passage of electric currents without being melted. This wire is coiled or otherwise arranged in such proximity to the glower that when heated by the passage of an electric current it will raise the glower to a sufficiently high temperature to cause it to acquire the necessary conducting capacity to permit sufficient current to flow through it under the influence of the difference of potential of the circuit upon which it is to be used to carry it to a state of high incandescence and maintain it there. When the lamp has once been started, the circuit through the heater may be interrupted manually or automatically, and, if it is desired, the heater may also be withdrawn from the immediate vicinity of the glower. Instead of imparting the starting heat by the agency of electric currents other extraneous sources of heat may be employed—as, for instance, a gas-flame or the flame of a lamp, or even a match in some instances.

The temperature to which the glower must be brought in order to have sufficient conductivity to allow enough current to flow through it to maintain itself in that conductive condition varies somewhat with different materials and proportions. Some of the mixtures will produce a glower, which when heated to a conductive temperature will fall in resistance so rapidly under the influence of a constant difference of potential as to permit a current to flow which would be destructive to the glower. With such glowers means should be employed for counteracting this effect and cause the glower to receive and consume only a predetermined amount of current, and therefore remain at a predetermined safe temperature. A convenient means for accomplishing this result with such glowers consists in introducing in series with the glower a correctly-proportioned resistance, preferably having a high positive temperature coefficient, and therefore offering an increasing opposition to the flow of the current with increments of current. Resistances composed of materials having little or no positive temperature corrections may, however, be used in certain cases. In constant-potential alternating-current circuits reactive coils may be used in lieu of such a resistance as above referred to. The expenditure of energy in such compensating devices when required may be very low, as their effective resistance may be in some cases as low as two per cent. or even less of the resistance offered by the glower when in operation, if the lamps are used upon circuits having little or no variation in difference of potential—as, for instance, storage-battery circuits. When used upon circuits subject to wider variations, it may be desirable that this resistance should consume as much as five per cent., or even more. Upon alternating-current circuits where reactive coils are used less than this will usually suffice.

In the German patent of Jablochkoff, No. 1,630, there is suggested the possibility of heating the edge of a kaolin strip or plate placed between two electrodes separated by an intervening air-space by means of the electric spark of an induction-coil. Such a method has not been found capable of commercial use and differs from my method and lamp because of the facts, among others, that kaolin is easily melted and that my illuminant is primarily brought to a conducting temperature throughout and not merely along a line or portion thereof, and my lamp permits the use of currents of much lower pressure. Moreover, heating by means of electric sparks or an electric arc is open to very serious practical difficulties, which would render the lamp undesirable and probably absolutely useless for any commercial work. By the use of a continuous solid conductor in connection with a glower, such as I have described, it is possible to give the lamp a simple and effective commercial form and to readily and repeatedly start the lamp.

By the term "solid" I do not mean that the conductor must necessarily be of solid cross-section, as it might be perforated or hollow; but I mean a conductor which is continuous

in distinction from electrodes between which the current is forced to pass through an intervening air-space.

In certain publications relating to the Jablochkoff candle it has also been suggested that the heating of the upper part of a porcelain plate might be brought about by applying thereto a surface coating of gum and carbon or by using some other temporary expedient for leading the spark across the edge of the plate. These suggested constructions are not commercially practical, and they differ essentially from my invention not only in many of the particulars above set forth, but also in lacking any heating-conductor which is a permanent part of the structure, capable of repeated use. The Jablochkoff devices are not heating devices, but merely devices in the nature of switches for starting the arc. The plate is not rendered conductive by heat developed in the starting device; but if the plate were itself ultimately rendered conductive it would be because of the heat due to the sparks traversing its surface after the starter has performed its function of starting the arc.

In the accompanying drawings, illustrating my invention, Figure 1 is a view, partly in diagram, of a complete lamp. Fig. 2 is a detail thereof. Figs. 3, 4, and 5 illustrate modifications. Fig. 6 illustrates certain circuit connections which may be employed for operating the lamp. Figs. 7 and 8 illustrate certain other modifications of the organization of apparatus. Fig. 9 is an enlarged view of a glower.

Referring to the figures, C represents a suitable base for supporting the lamp. It is provided with a circuit-closing device D, by means of which the circuit from any suitable source G of electric currents may be completed to the binding-posts c' c^2 of the lamp. The light-giving portion or glower A of the lamp is made in accordance with the description hereinbefore given. It is carried by two conductors a' a^2 of any suitable character, and these are connected with the terminals c' c^2 of the lamp. A bridge-piece a^3 may be employed for holding the conductors a' a^2 in their proper relative position. A heating or starting conductor B is shown in Fig. 1 as carried upon a glass or other transparent support b, and it incases to a greater or less extent the glower A. The circuit through the heater B is completed from the terminal c' through the wire 2, circuit-closer or switching device s of any suitable character, and conductor 3 to one terminal of the heater, the other terminal being connected by the conductors 4 and 6 to the remaining terminal c^2 of the lamp. The terminals c' c^2 are connected across the circuit L' L^2. The glower itself is connected in parallel circuit with the heater by way of conductors 5 and 6 and the supporting-wires a' and a^2. When the switches D and s are closed, the current passes through the heater B, raising the glower A to such a temperature as will render it sufficiently conductive to be traversed by a current from the generator. The circuit through the heater may then be interrupted by the switch s, or in some cases it may remain in circuit while the lamp is in operation; but in such case the watts expended in the heater or starting-conductor B should be as few as possible consistent with its function of heating the glower. I usually prefer, however, to so arrange the starting-conductor that its circuit shall be interrupted when it has performed its function of heating the glower to its conducting condition, and in that case the watts consumed in the starting-conductor during the short time the circuit is closed through it becomes unimportant. The interruption of the starting-circuit may be either manual or automatic, as shown in Figs. 6 and 7, for instance.

The lamp itself may be, if desired, inclosed in a protecting-globe E of any suitable character; but it is not necessary that it should be incased at all, as it will operate in the air. As the light emitted by the glower is very intense, it may be desirable in some cases to use a so-called "opalescent" globe or other means to diffuse the light. The globe E may be held in place in any convenient manner, as by clips e e, for instance.

In Fig. 3 I have shown the starting-conductor B as carried by a transparent support H, completely encircling the glower, and I have also shown suitable supporting-clips f for receiving the ends of the supports a' a^2, so that a glower may be readily replaced. The support H of the starting-conductor is here shown as carried upon a standard c, extending from the base C. Conductors for establishing a connection with the heater are connected with the binding-posts c^3 and c^4, and the circuit to the glower A is completed through the binding-posts c' c^2 and the standards b' b^2.

In Figs. 4 and 5 a modification of the invention is illustrated in which a glower is placed at or near the focus of a concave reflector, which at the same time constitutes a support for the heating-conductor B. This support H is here shown as being concave, and it may be of any suitable non-conducting heat-resisting material—such, for instance, as porcelain. The heating-conductor may be embedded in the material.

In Fig. 6 I have shown an organization of circuits for automatically interrupting the circuit connections of the starting-conductor B. This consists of a movable core or armature k and its solenoid or actuating-coil K. This coil is placed in circuit with the glower A, and when the current is established through the glower the core is attracted by the solenoid and the switch s', which is interposed in the solenoid-circuit, is automatically opened and will remain open so long as the lamp is in operation. When the current through the

glower is interrupted, the switch will automatically close and be in position for relighting the lamp when desired.

In Fig. 7 I have illustrated a modification in which the support H and the heating-conductor B inclose the glower A when the lamp is not in operation. When, however, a current is sent through the lamp and the heat from the starting-conductor B is no longer required, then the core *k* of the solenoid K will be drawn upward, carrying with it the movable support H, which is thus lifted away from the glower. The circuit of the heating-conductor is closed through an automatic circuit-interrupting device s^2, of any suitable character, so long as no current traverses the coil K. When, however, the heater is removed from the glower, the circuit of the heating-conductor is automatically interrupted at the same time. I have shown a spring *t* suspending the core *k*, so as to render it movable under the influence of a relatively small amount of current.

In Fig. 8 I have illustrated a modification in which the glower itself is moved, while the heating-support H and its conductor B remain stationary. In this instance the movement of the core *k* within its solenoid will move the glower out from the inclosing support H. A rod *r*, passing through the opening *r'*, serves to guide the parts throughout their motion. I have also shown the heater as being supplied from a separate source G' of electricity instead of being in a branch circuit from the source G. Such a separate generator may of course be used in other instances. An automatic circuit-interrupting device may be placed in the circuit of the heater in this case as well as in the others, if desired. The interruption of the circuit through the glower automatically restores the parts to the positions shown, and the same is true of Fig. 7.

The initial starting heat may be given to the glower in other ways than by heat supplied by an electric current. Any source of heat which may be conveniently supplied in sufficient quantities to raise it to its conducting temperature may be used. By these and other similar methods sufficient initial starting heat may be given to the glower in a few seconds, and the flow of current through the glower itself then generates heat and thus quickly brings it to a state of high incandescence. The Joule heat thus generated in the glower will serve to maintain this high incandescence and light-emitting condition.

In cases where there is liable to be an undue increase in the amount of current flowing through the glower when placed upon a constant-potential circuit means such as indicated at R may be employed for preventing such an increase. The device R is shown as being placed in series with the lamp itself, and, as hereinbefore explained, may consist of a properly-proportioned resistance or impedance coil, according to the character of the circuit. For continuous-current circuits the resistance may be made of a suitable metal of high specific resistance—such, for instance, as platinum or iron—and properly proportioned to prevent an increase of current through the lamps except under the influence of an increase of potential. In the case of lamps used on an alternating-current circuit properly proportioned reactive or impedance coils may be used.

Although I have described the invention more particularly with reference to open-air use, I desire it to be understood that it may also be used in vacuum-chambers, if desired.

In certain other applications, which are divisions hereof—viz., Serial No. 718,624, filed May 29, 1899; Serial No. 736,122, filed November 7, 1899; Serial No. 55,221, filed April 10, 1901, and Serial No. 55,222, filed April 10, 1901—claims are made to the apparatus and devices herein described.

I claim as my invention—

1. The method of operating electric lights having glowers composed of dry electrolytes, and heaters comprising permanent continuous conductors capable of repeated use, which method consists in transmitting a continuous flow of electricity through the heating-conductor until the glowers become conductive without melting, applying a requisite difference of potential to the extremities of the glowers, and thereafter maintaining the glowers in a conductive state by current traversing the same.

2. The method of operating electric lamps having glowers composed of materials which are non-conductors when cold and conductors when heated, which consists in starting the glowers by electrically heating the same by developing heat by the flow of electric currents in the vicinity thereof but apart therefrom, whereby they are electrically heated, and continuing their operation by the passage of current through and developing within the glowers sufficient heat to maintain them in their conductive condition.

3. The method of operating electric lamps having glowers which are non-conductive when cold but become conductive when heated to a high temperature, which consists in heating the glower by causing an electric current to traverse a high-resistance circuit in proximity to but out of contact with the glower thereby raising the glower to a conducting temperature, causing an electric current to traverse the glower, and thereafter discontinuing the development of the external heat.

4. The method of operating electric lamps having glowers composed of a material which is a non-conductor when cold but a conductor when heated, which consists in developing a high temperature in the immediate vicinity of but apart from the glower by electric currents, thereby raising the glower to a conducting temperature, simultaneously applying a difference of potential to the termi-

nals of the glower sufficient to cause current to flow therethrough when so heated, maintaining the glower at a conducting temperature by current thus caused to flow throughout its entire length and cross-section, and then discontinuing the source of heat.

5. The method of developing light by the incandescence of a refractory body, substantially such as described, which consists in electrically heating a solid conductor in the neighborhood of the refractory body thereby raising the temperature of such body and thereafter maintaining incandescence in such body by the passage of an electric current therethrough.

6. The hereinbefore-described method of operating an electric lamp having a glower composed of dry electrolytes which consists in developing a high temperature in the immediate vicinity of the glower by means of electric currents transmitted from a source of electricity, and independently operating the glower by electric currents caused to traverse it when so heated.

In testimony whereof I, the said WALTHER NERNST, have hereunto signed my name this 27th day of April, 1898.

WALTHER NERNST.

Witnesses:
CHARLES A. TERRY,
HENRY NOEL POTTER.