No. 682,692. Patented Sept. 17, 1901.

P. C. HEWITT.

METHOD OF MANUFACTURING ELECTRIC LAMPS.

(Application filed Apr. 5, 1900.)

(No Model.)

Fig. 1

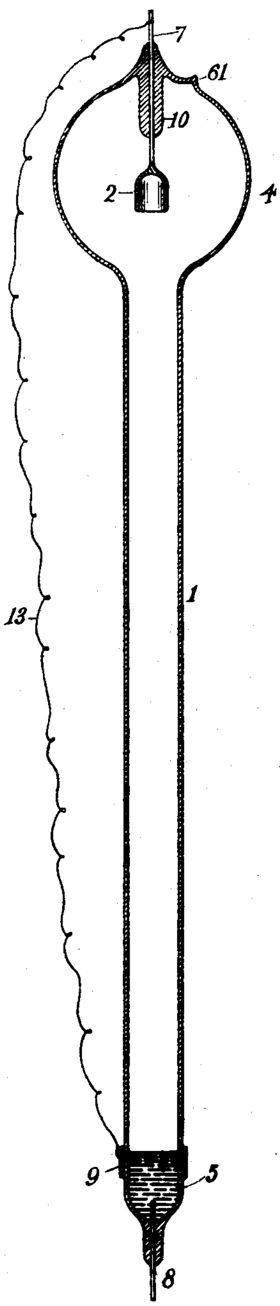
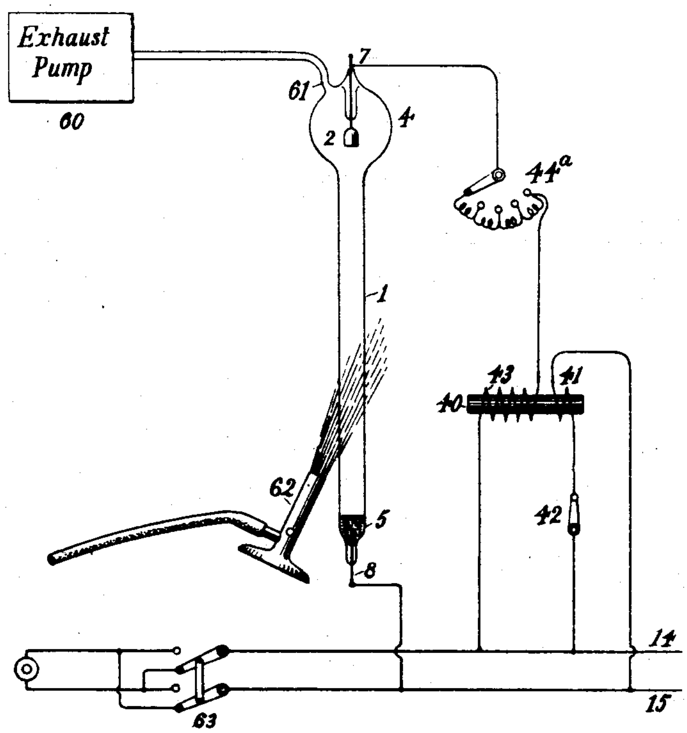


Fig. 2



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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.

METHOD OF MANUFACTURING ELECTRIC LAMPS.

SPECIFICATION forming part of Letters Patent No. 682,692, dated September 17, 1901.

Application filed April 5, 1900. Serial No. 11,607. (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 Methods of Manufacturing Electric Lamps, of which the following is a specification.

My invention relates to methods of manufacturing a novel class of electric-lighting apparatus.

The general purpose of the invention is to produce an electric-lighting device capable of 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 to produce a device capable of yielding light by the conversion of electrical energy, with the coincident production of as moderate amount of heat as practicable. Gases or vapors produce 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 mercury 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 not been capable of operation for any considerable period, if at all, by the conduction of current from one electrode to the other, but have been essentially arc-lamps.

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, 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 path 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 portion 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 current, 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 develop red 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 fixed 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 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 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 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 materials. After the lamp is 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 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 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 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 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, 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 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 lamp.

In the accompanying drawings, illustrating my invention, Figure 1 represents one form of a complete lamp. Fig. 2 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—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 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.) 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 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 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 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 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-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. When the lamp is to be operated by alternating electric currents, it may be useful to place a conducting-band in similar relation to the other electrode and connect it with the leading-in conductor 8.

As already stated, 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 elsewhere and be of other form, provided it is out of the vapor path. The tube, properly shaped and prepared, is first thoroughly cleansed with acids, alkalies, and water. I have found it convenient to first dilute the tube with hydrofluoric acid and then wash with distilled water, and thereafter, 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 is usually 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—as shown diagrammatically in Fig. 2 and consisting of a transformer 40, the primary coil 41 of which is connected between the main conductors 14 and 15 and through any suitable form of circuit-interrupter 42. The secondary coil 43 has one terminal connected with the main conductor 14 and the other terminal through a suitable adjustable resistance 44^a with the leading-in wire 7. In this manner induced high-potential currents may be applied to the terminals of the lamp, 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.

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. In practice I usually find that after a time, notwithstanding the successive applications of high-potential currents and the running of the lamp with the low or moderate potential currents, little or no vapor is withdrawn from the lamp. The lamp may be continued on the pump for a greater or less time after this; but usually when the gases or vapors other than those employed in the operation of the lamp have been withdrawn therefrom the lamp is in condition to be sealed off.

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—such, for instance, as nitrogen. A convenient method to employ when gases are used is to first treat the lamp in the manner described with mercury vapors or any convenient vapor and then exhaust the mercury, and afterward introduce the gas or gases in the required amounts.

In certain other applications filed by me—for instance, Serial Nos. 11,605 and 11,606, filed April 5, 1900, and Serial Nos. 44,647, 44,648, and 44,649, filed January 25, 1901—claims are made upon certain of the subject-matters disclosed herein.

The invention claimed is—

1. The hereinbefore-described method of manufacturing electric lamps in which light is produced by the action of electric currents upon a vapor or gas which consists in heating the containing-chamber of the lamp by applied heat, exhausting the air and deleterious gases therefrom, heating the electrodes within the lamps by electric currents, introducing or forming the vapor or gas designed to constitute the light-emitting body and causing electric currents to traverse it and then closing the chamber substantially as described.

2. The method of manufacturing electric lamps in which light is produced by the action of electric currents upon a vapor or gas, which consists in introducing or forming into a containing-chamber the desired conducting vapor or gas and an additional substance yielding a starting material, heating the tube and exhausting air and vapor therefrom, causing a relatively high potential electric current to traverse the tube during a portion of the process of exhausting and then causing a current of considerable quantity and moderate electromotive force to traverse the

tube while continuing the process of exhaustion and thereafter sealing off the tube.

3. The process of manufacturing lamps adapted to produce light by the action of electric currents, which consists in placing within an inclosing chamber a quantity of material adapted to afford a vapor which becomes light-emitting under the influence of electric currents of moderate potential and considerable quantity, adding thereto a quantity of material capable of imparting to the device the capacity of being traversed by electric currents, exhausting the atmosphere and impurities from the lamp and simultaneously heating the lamp by external heat and thereafter by the passage of electric currents.

4. The method of manufacturing lamps in which light is produced by electric energy acting upon a vapor or gas path, which consists in heating the elements of the lamp, exhausting the foreign substances therefrom, applying a sufficient difference of potential to the electrodes of the lamp during the process of exhaustion to cause the open space between the electrodes to be traversed by currents, varying the resistance of the lamp until currents of considerable quantity traverse the lamp at a moderate electromotive force, and thereafter sealing off the lamp.

5. In the process of manufacturing lamps having a vapor or gas path, the method of treating the electrodes during the process of exhaustion which consists in heating the electrodes by electric arcs formed at the junction of the gas or vapor with the electrodes.

6. The method of driving off occluded gases and foreign substances and producing chemical reactions within a lamp having a vapor or gas path, during the process of manufacturing the same, which consists in heating the electrodes within the lamp during the process of exhaustion by means of electric currents so applied as to render the electrode to be heated for the time being a cathode.

7. The method of manufacturing lamps, which consists in varying the density of the gas or vapor in the lamp while it is subject to the action of an electromotive force substantially the same as that with which the lamp is intended to operate, and also temporarily to a higher electromotive force, continuing such operation until the gas or vapor attains a standard luminosity and thereafter sealing off the lamp.

8. The method of manufacturing lamps having a vapor or gas path, which consists in applying a high alternating or interrupted difference of potential to its electrodes and gradually varying the resistance of the lamp by varying the density of pressure of the gas-path until a current of desired quantity traverses the lamp under the influence of the lower electromotive force with which the lamp is designed to operate.

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:
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