July 18, 1939. W. J. HITCHCOCK 2,166,781

ELECTRIC LAMP

Filed June 4, 1936 3 Sheets-Sheet 1

Fig. 1.

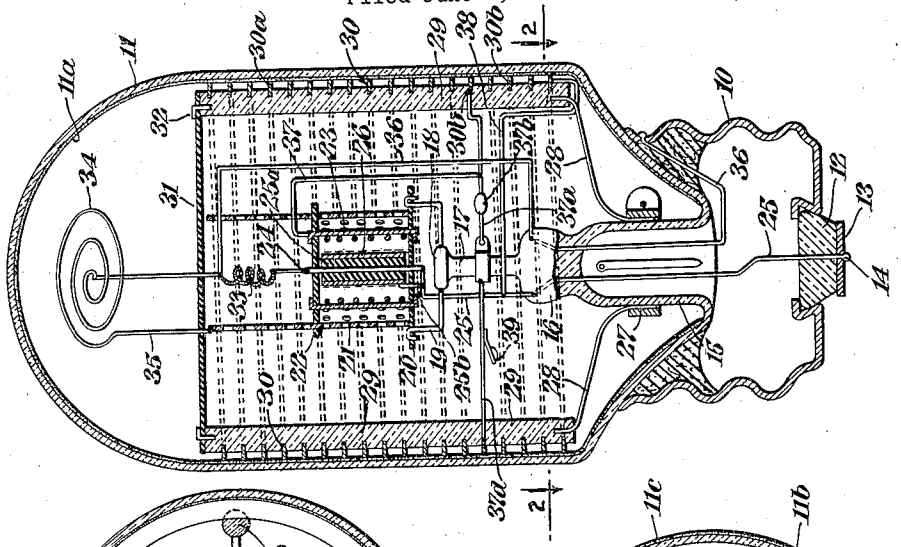


Fig. 2.

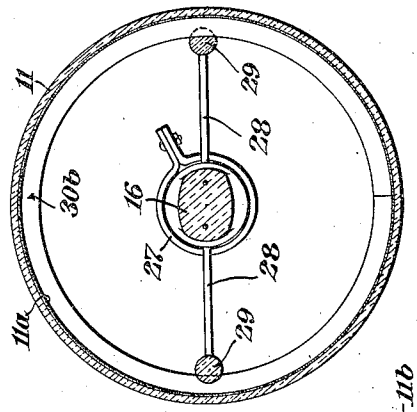


Fig. 4.

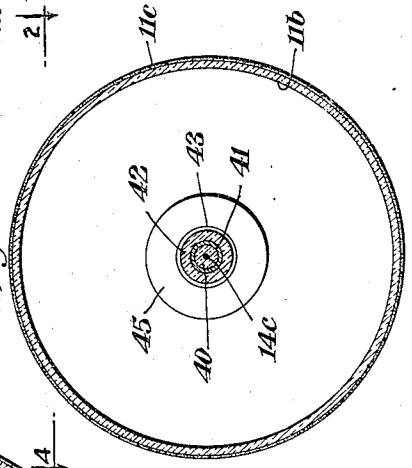
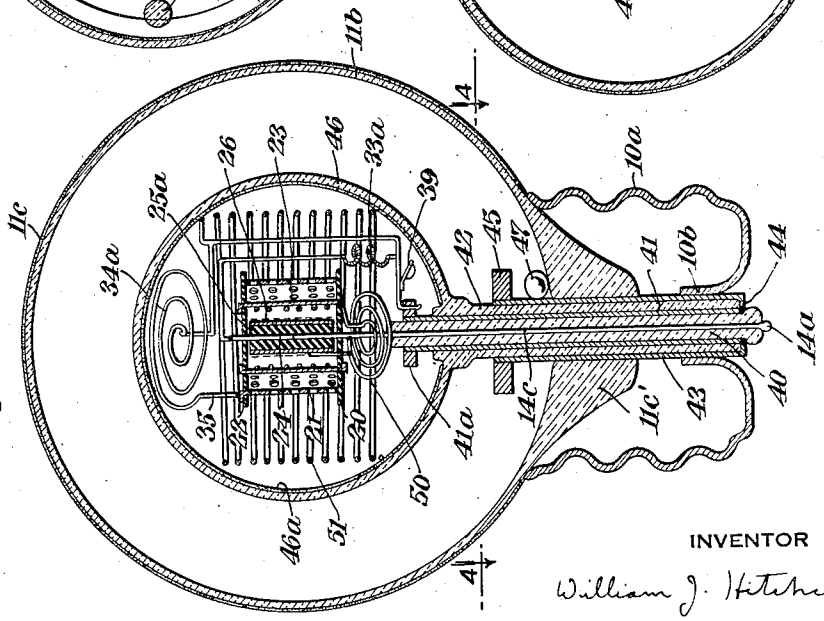


Fig. 3.



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July 18, 1939. W. J. HITCHCOCK 2,166,781

ELECTRIC LAMP

Filed June 4, 1936 3 Sheets-Sheet 2

Fig. 5.

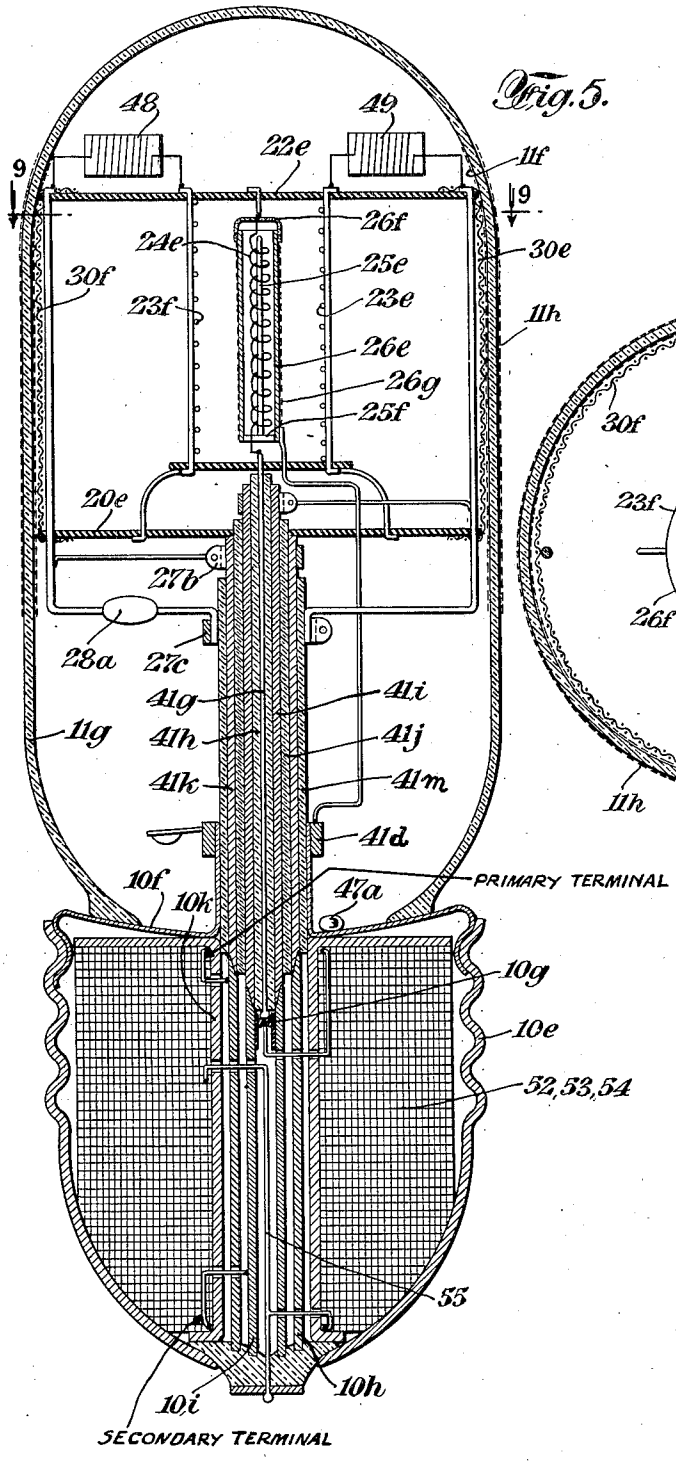
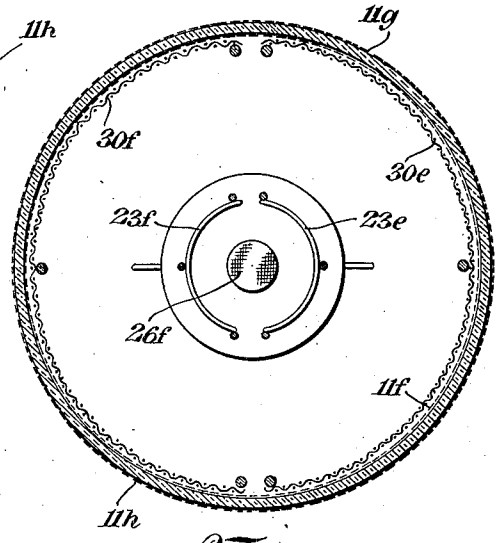


Fig6.



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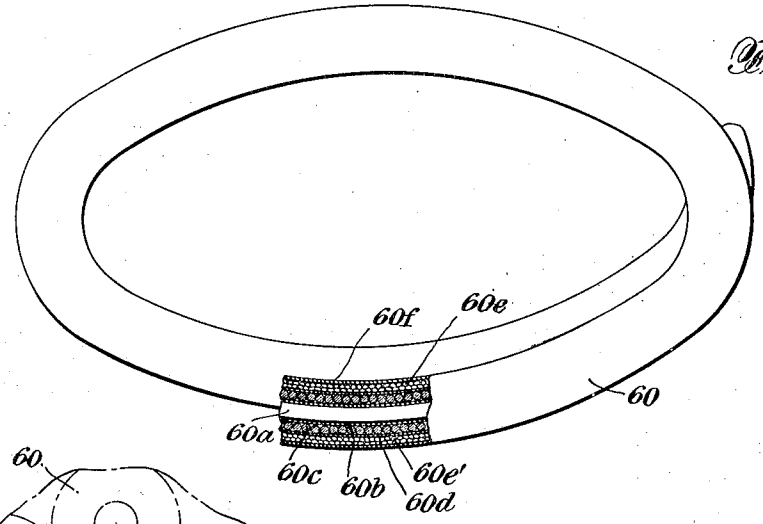
William J. Hitchcock

July 18, 1939. W. J. HITCHCOCK 2,166,781

ELECTRIC LAMP

Filed June 4, 1936 3 Sheets-Sheet 3

Fig. 7.



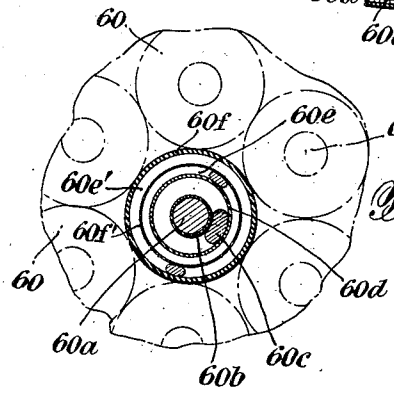


Fig. 8.

Fig. 9.

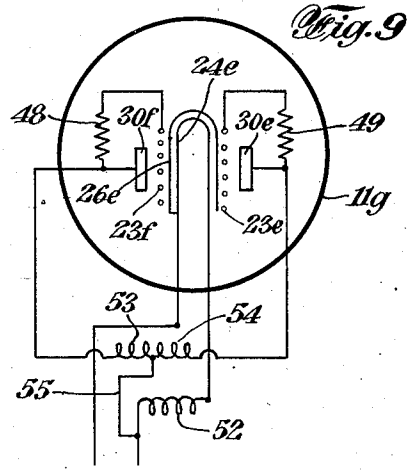


Fig. 10.

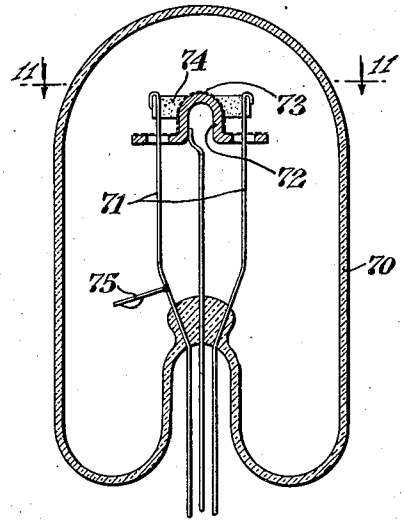
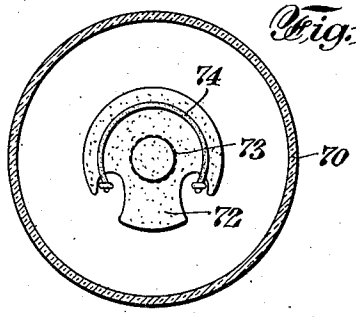


Fig. 11.



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Patented July 18, 1939 2,166,781

UNITED STATES PATENT OFFICE

2,166,781

ELECTRIC LAMP

William Jameson Hitchcock, Scotia, N. Y.

Application June 4, 1936, Serial No. 83,571

4 Claims. (Cl. 176—122)

My invention relates to electric lamps of improved light output and better color, particularly when secured by having moderate amounts of energy in the form of moving electrons, or light, incident upon substances that emit visible light, or luminesce, when so excited. It includes a structure which deals with the principles whereby the electric current ordinarily supplied for incandescent lamps may be used to generate the high frequency or high voltage usually advantageous in this sort of lamp and whereby a practical form of seal, economical of the space within the lamp base, is particularly suited to the exhaust of lamps having double walled bulbs, or to the exhaust of lamps that it would be desirable to fill with a greater amount of gas than that corresponding to atmospheric pressure and normal temperatures, such as some incandescent lamps. The arrangement for generating a high voltage consists of a Tesla coil if within the bulb. When without the bulb, it consists of an iron cored transformer of a particular form in which a high inductance may be secured in a small volume of space or of an ordinary iron cored transformer.

It will be remembered that some cathode ray oscillograph tubes produce a spot of light by the impact of a beam of electrons upon the luminescent substance zinc silicate, or Willemite. As is well known, this impact is inherently an efficient method of light production. If no energy is wasted forming a beam of the electrons or in the ohmic resistance inherent in returning the electrons to the cathode by a path including leakage over glass or discharge through a low pressure gas, the efficiency of light production for total power consumed can much exceed that of a tungsten filament incandescent; especially, as is well known, if the electrons hit with velocities corresponding to something more than those attained by falling through about a thousand volts. My anode is arranged in close proximity to the luminescent material when light is excited by electron impact, which is at high electron velocities. A further principle of operation arises from the well known similarity of electrons and photons in such processes as these and in a lamp designed to excite the luminescence of such materials as zinc silicate by the impact of photons rather than electrons the principle underlying my invention resides in a compact arrangement to develop a radio frequency and a high voltage within an outer enclosure occupied by an ionizable gas which then emits light, not necessarily wholly of a visible sort, but which if partly invisible is transformed into light of a wavelength visible to the eye by an appropriate choice of luminescent material. The anode of the electrical circuit need not be closely adjacent to the photo-luminescent material, but some light may also be developed by the direct impact of electrons within a highly evacuated interior space housing the generator of radio frequency electromagnetic waves.

A further principle underlying my invention resides in the means whereby such interior spaces may conveniently be evacuated: a seal excluding the atmosphere from the interior of the lamp which much facilitates arrangements of its parts and contacts requiring little weight and space. These seals combine leading-in conductors, stem, and arbor in one structure, largely dispense with the necessity for a flare, and consist of a metallic tube enclosing at least one electrical leading-in conductor electrically insulated from the metallic tube by a length of glass tubing and a glass bulb melted down upon the exterior wall of the metallic tube in a gas tight manner, the glass tubing also being melted down in a gas tight manner upon the interior wall of the metallic tube and the exterior wall of the leading-in conductor so that the lamp is sealed off from the atmosphere. It will also be made clear that several different bulbs may be exhausted after they have been assembled together. A particular method of making external contacts, useful even for radio tubes, will also be illustrated. No special materials different from those commonly used in forming leading-in conductors are needed for these specially shaped leading-in conductors and, as is well known in the art, if the leading-in conductor consists of copper or copper sheathed metal, it is necessary to borate its surface to have a gas tight union with glass. It is generally advantageous to apply the heat for making these seals gas tight by means of a radio frequency oscillator exciting eddy currents in a collar of well conducting metal, such as copper or nickel plated copper attached to the exterior of the metallic tube, which heats with the result that the glass insulator within the collar and the metallic tube is heated locally until it melts. When this is done, it is advantageous to make the rest of the metallic tube of some less well conducting material, such as the cobalt-nickel-iron alloys or chromium alloys now much used for radio tubes and sometimes sold under the trade name of 52 metal, as then the tube need be less thin to stay cool. Alloys of the ferrous group of metals or so called stainless steels must

be used if the lamps contain mercury, most other metals being considerably attacked by it, even platinum being attacked by it in spite of text book statements to the contrary. For use with sulphur vapor, these alloys may be enameled on surfaces in contact with sulphur vapor.

In the accompanying drawings illustrating in a purely diagrammatic manner some particular embodiments of the invention:—

Figure 1 is a vertical section through a lamp having an ordinary stem and base, a single bulb with material luminescent under electron impact on its inner wall, and containing an ordinary radio tube arranged to oscillate at a high frequency and generate a high voltage in a secondary or Tesla coil adjacent to the bulb wall.

Figure 2 is a section taken on the line 2—2 of Figure 1 looking in the direction of the arrows.

Figure 3 is a vertical section through a lamp similar to that of Figure 1 except the lamp has a stem and base facilitating its exhaust and assembly. The lamp has a double walled bulb and is provided with an ionizable gas or vapor in the space between the two bulbs, and a luminescent coating on the exterior of the outer bulb.

Figure 4 is a section taken on the line 4—4 of Figure 3 looking in the direction of the arrows.

Figure 5 is a vertical section of a lamp having a stem and base assembly containing a transformer in a base shaped portion, a single bulb with luminescent material on its walls, and anodes adjacent to the bulb walls. An indirectly heated cathode is provided in the center of the bulb. The stem is shaped to electrically contact jack shaped conductors within the base shaped portion.

Figure 6 is a section taken on the line 9—9 of Figure 5 looking in the direction of the arrows.

Figure 7 is a fragmentary perspective view of substantially one coil of the transformer of the lamp of Figure 5.

Figure 8 is a fragmentary sectional view, partly diagrammatic, of the coil of the transformer of Figure 5.

Figure 9 is a circuit diagram for the lamp of Figure 5 and its transformer.

Figure 10 shows a lamp similar in its essentials to the lamp of Figures 5 to 9 inclusive but having as simple a construction as possible, an ordinary stem and leading-in conductor assembly, and an anode surface on which designs or lettering may conveniently be applied in materials luminescent under the impact of electrons in differing and contrasting colors.

Figure 11 is a section taken on the line 14—14 of the vertical section of Figure 10 looking in the direction of the arrows.

Referring to Figures 1 and 2, the lamp assembly consists of the ordinary brass base 10, attached to the bulb 11 with basing cement, and provided with the usual glass insulator 12, through which the lead wire 25 passes and solders to the cap 13 at the point 14. These arrangements are identical with those usual in incandescent lamps and the stem 15 has the usual pressed portion 16 through which leading-in conductors 25 and 36 are brought into the evacuated space within the glass bulb 11. A vacuum tube, to oscillate at radio frequency, is mounted centrally in the bulb and is identical with those used for radio purposes except in minor details of structure and function, the principal difference being that its cathode also serves as a source of thermionic electrons exciting the luminescent coating 11*a*. The cathode circuit consists of the lead 25, conducting current to a heater wire 24 which is surrounded by insulation 25*a*, so that electrical contact to the barium oxide coated outer sleeve 26 of the heater is only made at the one point 25*b*. The circuit continues out of the heater wire 24 through a resistance 33, preferably made in the form of an incandescent oxide coated electron emitting filament similar to the cathodes of some radio tubes but coiled, mostly to save space, and thence returns to the exterior of the bulb by the lead 36. The resistance 33 may if desired also be an incandescent tungsten filament, and may be a coiled filament or a coiled coil filament, or it may be a resistance in any other form so long as it does not allow so much current to pass through the vacuum tube cathode that this is overheated when the current is switched on. A tungsten incandescent filament furnishes more instantaneous light at the instant of turning on the lamp than an oxide coated filament but has the disadvantage of giving less thermionic electron emission.

As to the grid circuit, a flat metal strip 30 is wound into the form of a solenoidal coil on a hot carbon mandrel having recesses to accommodate the glass rods 29. This is done at a temperature at which the glass will fuse to the metal and after cooling is firmly united with it. Any soft thin metal that is not volatile in vacuum may be used and nickel is preferred. The vacuum tube grid 23 connects to section 30*b* of coil 30 by the wire 37 part of which is also inserted in a glass bead 37*b* and helps in conjunction with collar 27 and supporting rods 28 to keep the assembly lined up. From 30*b* the circuit returns by means of the lead 38 to the conductor 25 which is the negative terminal of the circuit for that portion of the time when alternating current has the correct polarity to allow the lamp to function. If used on direct current this must be the negative terminal.

The anode circuit proceeds from the base through the stem and press on the conductor 36, through a coil 34, thence by lead 35 to junction with the anode 21 of the vacuum tube. The circuit is completed through the vacuum to the cathode by space currents as in the usual radio vacuum tube but in addition the anode plate 21 is perforated and has a perforated cylindrical extension surrounding the further source of electrons 33 and through these perforations electrons are projected from both cathodes to a luminescent coating 11*a* on the inner wall of bulb 11 whence they return to the cathode by means of the metallic conductor 30, thence through lead 38 to junction with the cathode lead or negative terminal 25. There is also an inductive coupling between coil 34 and the coiled strip 30 so poled in section 30*b* as to cause the vacuum tube to oscillate at a radio frequency determined by these various inductances and the electrical capacity of the wiring and the internal electrical capacity of the vacuum tube.

The general structure is such as is usual in radio tubes. A mica spacer 20 is supported on hook wires 19 inserted in the glass button 18 which has been formed by the usual methods from the glass arbor 17. A generally similar mica spacer is indicated at 22 and these two mica spacers serve to hold together the various parts of the vacuum tube. Another mica spacer 31 is employed in holding the glass rods 29 in position at their tops by any suitable means such as the hooks 32. Lavite or other electrically in-

sulating material may be substituted for the mica and glass without detriment.

The operation of the device will be apparent from the following description taken in conjunction with the illustration:—Electric power delivered to the vacuum tube causes it to generate radio frequency oscillations, at least on one half cycle of the supply frequency, depending somewhat on how much inductance is in series with leads 25 and 36. These oscillations energize the Tesla coil 30 which is so poled in section 30a as to generate a high positive anode voltage in the portion of it adjacent to coil 34 when the radio tube anode is at a positive potential. Both of these then act to project considerable quantities of electrons from the thermionic surfaces 33 and 26 against the luminescent coating 11a. This then emits visible light, as in a cathode ray oscillograph tube, but over the entire luminescent surface and in considerable quantity due to the considerable current flowing and the velocity of the electrons at the time of their impact upon it due to the high positive voltage secured by the transformer action of the Tesla coil co-operating with coil 34. No considerable quantity of gas is present within the lamp which is initially highly evacuated and maintained in that state by the action of a silver-barium alloy getter from a cup 39 welded to a support wire 37d. This support wire does not contact the member 25 and is prevented from short circuiting a portion of the Tesla coil 30 by the insulating glass bead 37b. As a result electrons are not slowed down by collision with gas during their passage from the cathodes to the luminescent coating which is also closely adjacent to the metal of the Tesla coil so there is also no great loss of power in ohmic resistance, even when flashing the getter has deposited no film perceptible to the eye. This results in a lamp having a greater output, measured in lumens per watt of power consumed, than the ordinary tungsten incandescent when the color of the light is the green-white of the luminescence of zinc silicate, and when other materials are used, of other color when luminescent, of which there is a great variety well known to the art, it will generally be true that the lamp gives a greater number of lumens of light than an incandescent of present ordinary commercial form and the same power consumption, at least when the incandescent is of the same color, approximately, as the luminescent lamp. There is; however, some interference with radio reception caused by the lamp of Figures 1 and 2 in that the radio frequency oscillations within the lamp start and stop on each cycle of the supply frequency when the lamp is used on alternating current and it appears that it is better to electrostatically and electromagnetically shield the lamp to prevent this, or supply the necessary high voltage at the same frequency as the supply frequency by means of a transformer with an iron core, rather than get the lamps to oscillate continuously at a radio frequency by putting sufficient inductance in series with them so that their action as self rectifying units would cause their terminals to be supplied with direct current for all practical purposes.

Figures 3 and 4 illustrate the structure of Figures 1 and 2 electrostatically and electromagnetically shielded by enclosing it within an outer bulb 11b containing an ionizable gas such as mercury vapor, or mercury vapor and argon, at low pressure. As is well known, such gas becomes ionized and in an electric or electromagnetic field of high frequency and emits light without the necessity for any electrodes in the space containing it. As the ionized gas is also highly conductive of electricity, absorbing high frequency radiation to produce light, it is also an effective shield against the passage of any radio frequency electromagnetic radiation from within it. Figures 3 and 4, besides illustrating this shield, also illustrate a structure for supplying the interior of the lamp with current which also serves to seal in, support, and exhaust the lamp; which processes are difficult on account of having the Tesla coil of as great a diameter as possible and having it within an evacuated bulb surrounded by a bulb containing low pressure gas.

In Figures 3 and 4, certain reference characters employed in connection with the description of the previous form of the invention refer to similar parts and describe a vacuum tube electrically oscillating at a radio frequency as in Figures 1 and 2. 33a is a resistance in series with the heater 26 of the vacuum tube, similar to 33 in Figure 1 but in this modification it is preferred to make this a coiled coil tungsten filament, and by this means there is some light the instant the lamp is switched on while there is no great disadvantage in lessening the thermionic emission from what it is in the former modification as in this present modification light produced by electron impact on a luminescent coating 46a on the inner wall of the inner glass bulb 46, while produced in an analogous manner to that produced by the modification of Figures 1 and 2, in the modification illustrated by Figures 3 and 4 is subordinate in importance to mercury discharge light, produced by electrodeless discharge in the vapor from mercury droplet 47, and subordinate to a luminescence from a coating 11c on the outer wall of an outer bulb 11b which luminescence is produced by an ultra-violet fraction of the light from the discharge in the mercury vapor. To produce this luminescence which might be described as a luminescence under the impact of photons, it is necessary that the glass of the outer bulb 11b should be of some material such as quartz or the glass known as Corex which will be translucent to the ultraviolet mercury line of wavelength 2537. It is not necessary that the coating be on the wall of the bulb, it may be a paint upon the surface of a reflector or upon the wall of a room and may consist of a great variety of fluorescent substances of which zinc silicate is one example, but which includes such substances as kerosene or coumarin, and may include substances melted into the outer wall of the bulb as well as substances from suspensions sprayed on its exterior. Zinc oxide; for instance, may be mixed with lead borate and a mixture of methanol and glycerine in about the proportions that would be used in making a bulb marking ink, for which silver oxide is used in place of zinc oxide, and this is applied to a bulb after ball milling the mixture which is then melted into the surface. There is some fluorescence from the zinc borate that results from the heating.

For a like reason, where the light from luminescence under the direct impact of electrons is of subordinate importance, the secondary coil 51, of Tesla coil, may be made as before or as illustrated in Figure 3, as an unsupported solenoid or bare wire partly out of contact with the wall of the bulb and the luminescent material thereon. If desired the luminescent material 46a may be omitted entirely and still produce a highly efficient lamp. The primary coil 34a, of the Tesla

coil, is similar to coil 34 in the former modification but as illustrated in Figure 3 now couples inductively with a coil 50 in the grid circuit which is wholly separate from the secondary of the Tesla coil and can therefore be arranged somewhat more compactly. This coil is arranged in the grid circuit between the grid 23 and negative lead 14c. Together with the coil 34a, the secondary coil 51, and the electrical capacities of the wiring and the vacuum tube, it forms a circuit oscillating at a radio frequency as in the modification of Figures 1 and 2. It will be clear that an additional condenser may be used if desired.

To assemble the lamp, metallic parts are spot welded together as in assembling a radio vacuum tube, suitable methods being well known in the art, and attached to a collar 41a of heavy well conducting metal such as copper, which is nickel plated and firmly attached to a thin walled metallic tube 41. Wire 14c, of fairly stout material, passes down the center of the metal tube 41 which is next surrounded by a closely fitting tube of glass 42 which has previously been flared somewhat where it is to join the bulb 46, necessarily of a somewhat wide mouthed sort but having no more clearance than is necessary to allow of the inserting of coil 51 within it. The flare and bulb are then heated until they are joined as illustrated and the glass tube 42 is firmly united to metallic tube 41. Another thin metallic tube 43 having a similar heavy collar of well conducting metal 45 is now placed over the glass tube 42 and metallic tube 41 but not pushed all the way up on them. Next bulb 11b is placed in contact at its top with the top of bulb 46 so that its open end hangs around the thin metal tube 43 to which it is now sealed, or united by fusion, at a place where metallic tube 43 includes no glass and in much the same fashion as if tube 43 were the leading-in wire of a neon sign lamp electrode.

In addition, if desired, care may also be taken not to fuse the glass tube 42 to the metallic tube 43 by covering tube 43 with a temporary sleeve that is withdrawn just before the bulb unites with tube 43 or an air blast may be directed up within metallic tube 41 to keep the glass of tube 42 cool. The final appearance of the seal between the glass bulb 11b and metallic tube 43 is much that shown at 11c and after the seal has been made it is pushed up over glass tube 42 until the outer bulb 11b is more or less concentric with the inner bulb 46 as illustrated so that there will be a good thickness of well conducting material all about the radio frequency oscillator when it is in operation. The next step in the assembly is to introduce a droplet of mercury 47 through the opening at 44 into the space between the inner and outer bulbs. Then the bottom edge of tube 43 is crimped over the bottom of tube 42, as is shown in the illustration, so as to hold the two bulbs in proper relative position to each other and a length of soft glass tubing 40 is inserted within the metallic tube 41 with the wire 14c in the center of the glass. Air is now exhausted from within both bulbs by placing the metallic tube 43 in a tightly fitting rubber hose on an exhaust machine or other pumping apparatus, just as is customary in making radio tubes or incandescent lamps.

When the exhaust of the inner bulb has been completed by methods well known to the art, the last step in the radio frequency heating is to heat the collar 41a to a temperature sufficient to render the glass tube 40 somewhat molten and to firmly melt it down upon and cause its attachment to the metal of the tube 41 and the wire 14c, thereby sealing off the inner bulb from the pump and later from the atmosphere. The outer bulb may now be exhausted without removing the lamp from the rubber and I have found that this is best done not by the action of heat and the pumps alone but that it is also advisable to add a little argon gas to the mercury vapor within the outer bulb and cause a violet electrodeless discharge to flow in the space between the inner and outer bulbs by means of an oscillator wholly external to the lamp. This argon becomes quite impure and should be pumped off, whereupon the space between the bulbs may be refilled with pure argon and the lamp sealed off by placing the high frequency oscillator coil in the neighborhood of the collar 45 as was done in the case of the inner bulb. This collar should be as close as possible to the wall of the bulb 11b and of thicker metal then the collar 41 as it will be found that the ionized argon in the space between the bulbs has a marked shielding effect and much interferes with efforts to heat the collar 45 alone. Such effects are less marked with mercury vapor alone and can be minimized to any desired degree by controlling the pressure of mercury vapor through controlling the temperature of the liquid mercury. Collar 45 also should be kept as far as possible from the inner bulb so as to absorb little energy during the operation of the lamp and if desired may be omitted entirely and the lamp sealed off, at least as far as the space between the bulbs is concerned by a gas flame applied to tube 43 externally to the outer bulb as is done in making a glass tip. It will also be evident that this particular method of sealing off the lamp is not an indispensible method but merely a convenient one; that this lamp may be evacuated if it has the same structure now common for lamps having an inner and outer bulb, so called double walled bulbs, if only electrical insulation is placed over the leading-in conductors into the inner bulb so that they cause no arc in the mercury vapor in the space between the bulbs as a consequence of their being at different electrical potentials.

After sealing the lamp off, it may be taken from the pump and a brass base 10a is soldered to tube 43 at the point 10b. There is no necessity for basing cement. This soldering is done with a gase flame having sufficiently concentrated heat to put a small ball on the end of 14c, as shown at 14a, as a contact with the source of electric supply and to fuse it firmly into the glass. The other contact is by way of the brass base, as is customary, and if tubes 41 and 43 were not crimped together sufficiently before the exhaust to make good electrical contact now, they are soldered to unite them firmly together so that tube 41 serves as a leading-in conductor by the connections shown to the coil 34a, the resistance 33, and through them to the other portions of the circuit and back to the other leading-in conductor 14c. If the lamp has been sealed off from the atmosphere with a gas flame, a cadmium-lead-tin solder is preferred at the point 10b, otherwise a lead-tin or hard solder may be used without concern.

The operation of the lamp will now be generally described. So much of the lamp of Figures 3 and 4 as is within the inner bulb 46 will operate in a similar manner to the lamp of Figures 1 and 2 but radio frequency radiation will not be able to pass the layer of ionized mercury

vapor between the two bulbs 46 and 11b. In addition, both visible light and ultraviolet light will come from the electrodeless discharge in this space excited by the high frequency and high voltage within the inner bulb. This ultraviolet light may either be used as such, may be absorbed in the bulb wall, or may fall upon a luminescent coating to produce visible light and if desired the lamp may be operated without the light coming from a coating luminescent under electron impact solely as a mercury lamp, or as a mercury lamp in conjunction with fluorescent materials. It will also be clear to all skilled in the art, that many substances might be substituted for the mercury without departing from the spirit of the invention, such as sodium if the glass is such as to resist attack by sodium, or even sulphur if the metal of the seals is coated with material resistant to its chemical attack. In place of argon any of the inert gases may be used and if it is proposed to use an inert gas without the admixture of a vapor such as that of mercury, argon is not a particularly suitable gas to use as it gives little light by itself. Helium gives a yellowish white light and the striking red of neon is a matter of common knowledge.

Figures 5 to 9 inclusive illustrate a modification of the invention having a thermionic source of electrons and two anodes alternately positive according to the phase of the alternating current supply. As before the exhaust is preferably such that electrons in their passage to a luminescent coating on the inner wall of the bulb are not impeded by collision with gas. This modification also has a stem generally similar to that illustrated in Figures 2 to 7 inclusive and through which it is exhausted in a similar manner but which serves in addition to make contact with terminals of a transformer in the form of split sleeves, generally similar to a telephone jack, arranged together with the transformer in a base shaped casing capable of being screwed into an ordinary lamp socket and into which the lamp proper is screwed. The transformer differs from that of the other modifications of the invention in being arranged for full wave rectification, in having an iron core, in being without the lamp bulb, and in furnishing current and voltage at the frequency of the supply.

Describing the novel features of this modification more particularly from the drawings thereof as they appear in Figures 5 to 9 inclusive:—a tungsten filament 24e is coiled on a thoria insulator 25e. This thoria insulator has an enlarged portion 25f which serves to hold the coil 24e in the center of a nickel cylinder 26e which has a cap of nickel mesh wire 26f and an external coating of barium oxide or other material 26g that readily emits thermionic electrons when heated. The nickel cylinder 26e is surrounded by a grid having two portions 23e and 23f electrically insulated from each other except through the windings of a transformer but which connect by means of high resistances of fine coiled wire wound on mica as at 49 and 48 respectively to an outer screen also comprised of two portions 30e and 30f respectively insulated from each other by the glass bead 28a. This screen is in close proximity to a coating of material 11f luminescent under the impact of electrons and on the inner wall of the translucent glass bulb 11g but there may be no coating on the inside of and a coating on the outside as indicated at 11h if the bulb is filled with mercury vapor, or mercury vapor and argon, and if the bulb is translucent to ultraviolet light, and is provided with a step down transformer instead of a step up transformer which is preferred as is the case in the former modifications. It seems advisable to show a droplet of mercury, as at 47a, similar to that of Figure 3, but it is preferred to have the lamp exhausted to a high vacuum.

The various portions of this modification of the invention which have been described are tied together and supported by two mica spacers 20e and 22e, in turn supported by suitable posts, and by a collar 27c fastened as illustrated to the glass tube 41m. The seal consists as before preferably of alternate layers of glass and metal in the form of tubing surrounding a central wire or hollow metallic tube 41g. The wire 41g carries one leg of the current to heat the cathode and the other leg is carried by the collar 41d and the specially shaped metallic flare 10f which makes electrical contact with a base shaped portion 10e. The wire 41g is surrounded by an insulating glass tube 41h, which in turn is surrounded by a metallic tube 41i carrying current for a wire screen anode 30e. Conductor 41i in turn is surrounded by an insulator 41j of glass tubing and next by another metallic tube 41k carrying current for the anode 30f on the other half cycle. Conductor 41k in turn is surrounded by an insulator of glass tubing 41m which before exhaust has had the metal part 10f carrying the heavy collar of well conducting metal 41d sealed to it. Metal part 10f is also sealed to the glass bulb. The seal is most conveniently made in much the same manner as before by assembling the interior metal parts and all the successive layers of glass and metal tubing except the innermost glass tube 41h which is inserted after the bulb has been attached to the metal part 10f and metal part 10f has been attached to at least the outermost layer of glass 41m by simultaneous fusion as in the other modifications of the invention. Contact within the bulb, when not directly by a wire, is made by the collars 27b, 41m, and attached wires. Within and without the bulb, the alternate layers of glass and metal are stepped on the end as shown to furnish electrically contacting surfaces. Without the bulb, these register with and electrically contact two split sleeves 10i and 10h which are the secondary terminals of a high voltage transformer having a primary winding 52 and secondary windings 53 and 54 in electrical contact with each other and, by means of the wire 55, in electrical contact with the primary winding. This conductor 10h registers with and contacts conductor 41k; conductor 10i registers with and contacts conductor 41i. Also a ball on the end of wire 41g registers with a contact 10g insulated from the sleeve 10i by a short length of Bakelite tubing forced into the interior of sleeve 10i. The sleeves 10h and 10i, the base shaped part 10e, and the core 10k upon which the transformer coils are wound consist of material of high magnetic permeability such as iron and its alloys. The primary power supply to the transformer is made by contacts disposed, shaped, and insulated as in the case of an incandescent lamp base.

The transformer, shown in purely diagrammatic fashion in the sketch of Figure 5 may be a transformer of the ordinary form with windings and connections appropriate to the operation of a full wave rectifier except the primary windings will generally furnish something more than about one thousand volts between the coating of luminescent material on the inner wall of the bulb and the thermionic cathode 26e. That is to

say, it may consist of an iron core of more or less toroidal form having electrically conducting windings separated into sections having, in general, different numbers of turns but all enclosing as far as possible the whole of the magnetic induction. I prefer; however, that the transformer of Figure 5 be built as shown in detail in Figures 7 and 11 where the wires 60 of the winding are composites having a core of iron wire 60*a* covered with a layer of insulation 60*b* carrying a copper or silver wire 60c wound in solenoidal fashion on the iron wire and its insulation as a core or mandrel and exteriorly insulated as at 60*d*. This has, if desired, further secondary coils 60*e* and 60*e'* wound upon it in the same manner and insulated interiorly as shown at 60*f'* and exteriorly as shown at 60*f*.

Secondary and primary coils about the core 60*e* have a mutual inductance since both enclose magnetic induction in the core 60*a*. The arrangement will therefore act as a transformer irrespective of the form of the composite wire as a whole but as the composite wire acts similarly to an ordinary wire when coiled upon an iron torus it is preferably coiled in a more or less solenoidal form, as is illustrated in Figure 7, and placed upon an ordinary transformer core as illustrated by the transformer core 10*k* of Figure 8. The detail of Figure 8 illustrates a fragment in section of such a transformer winding composed of the composite wires. Appropriate taps are taken from the windings about core 60*a*, before winding it on core 10*k*, so that these may serve in a full wave rectifier circuit. If desired skips may be left in the windings to facilitate this, similar to the skips in tungsten filament coils, left to facilitate cutting them to proper length.

Figure 9 is illustrative of the fact the operation of this modification of the invention is that of a full wave rectifier. This circuit being standard practice it requires no further description. The operation of this modification of the invention is generally similar to that of the preceding modifications except that light is produced when electrons emerging from the cathode of the full wave rectifier strike upon that section of the inner wall of the bulb which is coated with material luminescent under electron impact and is adjacent to the half of the mesh which is anode, or electrically positive, on that particular half cycle. These electrons are assisted in their passage to the rather remote anodes by voltages on the grids 23*f* and 23*e* like those on the anodes but never becoming as high as the voltages on the anodes on the positive half cycle owing to voltage drops in the resistances 48 and 49 consequent upon current flowing through them.

A lamp essentially similar to that of Figure 8 may operate as a half wave rectifier or as a full wave rectifier. The like is true of the other modifications of the invention depending upon the impact of electrons on luminescent substances. It is; however, somewhat more convenient to build a transformer for full wave rectification than for half wave rectification and twice the peak current, as is demanded in a lamp of equal light output to that operating on full wave rectification, when an iron cored transformer is considered. In case of half wave rectification for the lamp of Figure 5 the necessary alterations in connections are so slight they will readily be understood.

Much variation and simplification in the form of the lamp of Figure 5 is however possible. Figures 10 and 11 illustrate a particular one of these variations consisting merely of a glass bulb 70, nickel support wires 71 conducting heating and space current to a flat strip of barium oxide coated nickel-silicon alloy 74. The strip is thereby an emitter of thermionic electrons and is cathode to an anode 72, of any metal commonly used in vacuum, and bearing a coating of materials luminescent under the impact of electrons in different colors as is illustrated at 73. Zinc silicate; for instance, furnishes a green-white and calcium tungstate a blue. Other compounds, chiefly of the metals of the second column of the periodic table with amphoteric substances, may be used. Lettering or designs of one sort and another is applied to the surface of the anode and becomes visible in contrasting colors under the impact of electrons. The shape of the anode is such as to adapt it to particular uses of this sort but if desired such designs may be applied to a glass bulb wall, although with less convenience. The cup 75 initially contains a getter used to maintain a high vacuum.

Light is produced by the impact of electrons on the luminescent materials with great efficiency at high anode voltages similar to those of the modifications of Figures 1 to 4 inclusive and that of Figure 5. Light is also produced if no transformer of any sort is used and if instead a resistance is inserted in series between the line and the cathode, the other cathode terminal is connected directly to the line voltage, and the anode is connected to that side of the line which does not connect directly to the cathode, so that the voltage drop in the resistance is between the anode and the cathode of the lamp. As this is a very simple procedure, it is thought that lamps operated in this fashion may have some advertising value. The procedure is efficient at high line voltages and if desired a high line voltage may be used and a transformer used merely to heat the cathode. It will be understood that the materials luminescent in different colors are applied to different portions of the anode and that some portions of the anode may have no coating of any sort and will therefore appear black.

The examples given are not to be taken as limiting the scope of the invention to the employment of its principles in these particular types of lamps, since the functions of the invention are applicable quite generally to many specific forms of devices in which the operation depends on supplying energy to materials to produce light as conveniently and economically as possible.

I claim:

1. An electric lamp comprising a double walled bulb having an outer envelope at least partially permeable to light, luminous ionizable gas or vapor between its inner and outer walls, and a source of radio frequency electric oscillations within the inner wall of the said bulb.

2. An electric lamp comprising a double walled bulb having an outer envelope at least partially permeable to light, luminous ionizable gas or vapor between its inner and outer walls, a source of radio frequency electric oscillations within the inner wall of the said bulb, and at least one wall of the said bulb being provided with luminescent material.

3. An electric lamp comprising a double walled bulb having an outer envelope at least partially permeable to light, luminous ionizable gas or vapor between its inner and outer walls, a source of radio frequency electro-magnetic radiation

within the inner wall of the said bulb, and a leading-in conductor of electric power from an external source of supply to the said radiation source wholly sheathed in an electrical insulator in the space between the inner and outer bulb walls.

4. An electric lamp comprising an evacuated envelope having a wall at least partially permeable to light, a source of free electrons sealed in said envelope, and a radio frequency electric oscillator in said envelope having a coil coupled therewith and disposed between said source of free electrons and said wall, said coil developing a high voltage relative to said source of free electrons and being at approximately the same voltage as adjacent portions of said wall during its positive phase, said wall being provided with luminescent material exposed over an extensive area and in a substantially constant locality to the bombardment of electrons accelerated by the said voltage.

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