July 9, 1935.   C. H. BRASELTON   2,007,923

ELECTRIC DISCHARGE LAMP

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Fig. 1

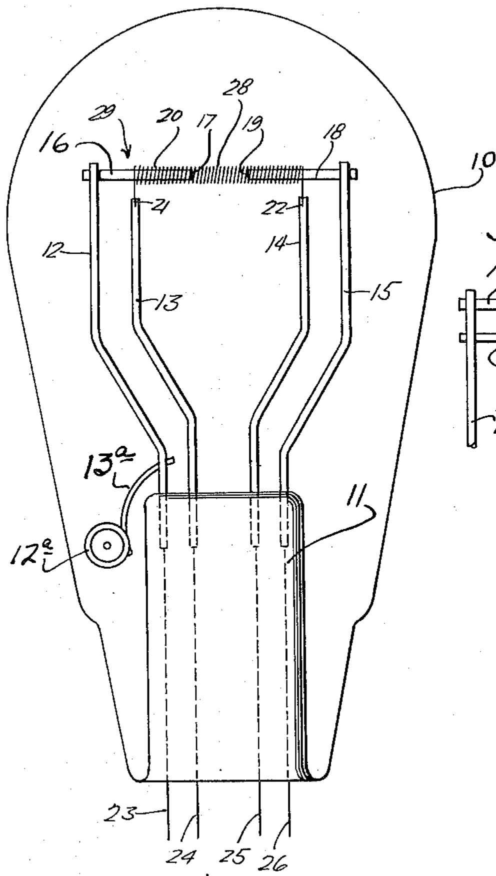


Fig. 1a.

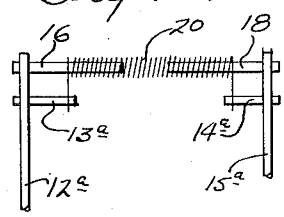


Fig. 2

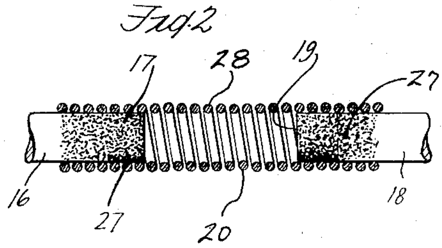


Fig. 3.

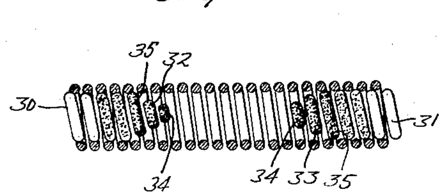
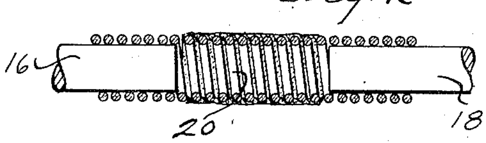


Fig. 2a



INVENTOR

Chester H Braselton

July 9, 1935.

C. H. BRASELTON

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Fig. 4

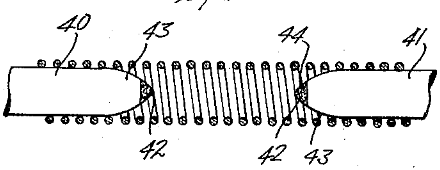

Fig. 5

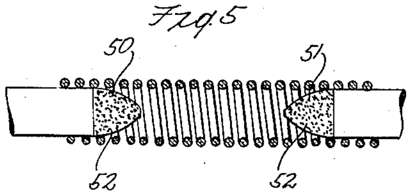

Fig. 6

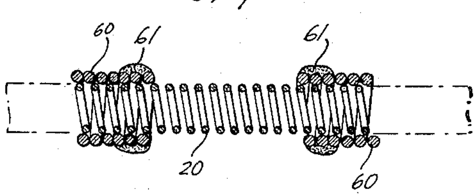

Fig. 7

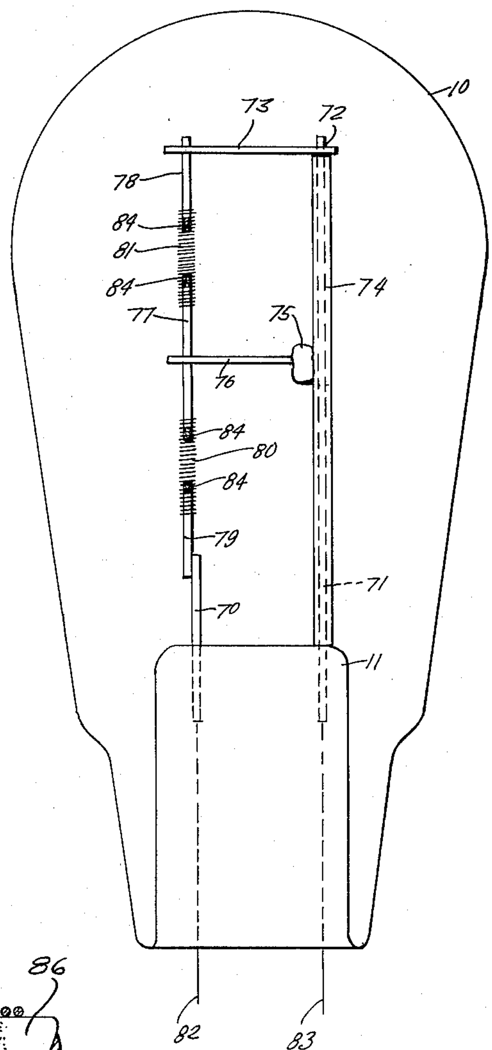

Fig. 8.

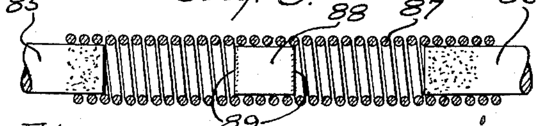

Fig. 9.

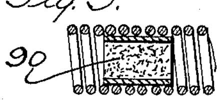

Fig. 10.

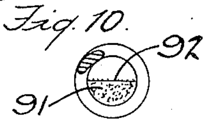

Fig. 11.

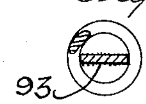

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Fig. 14.

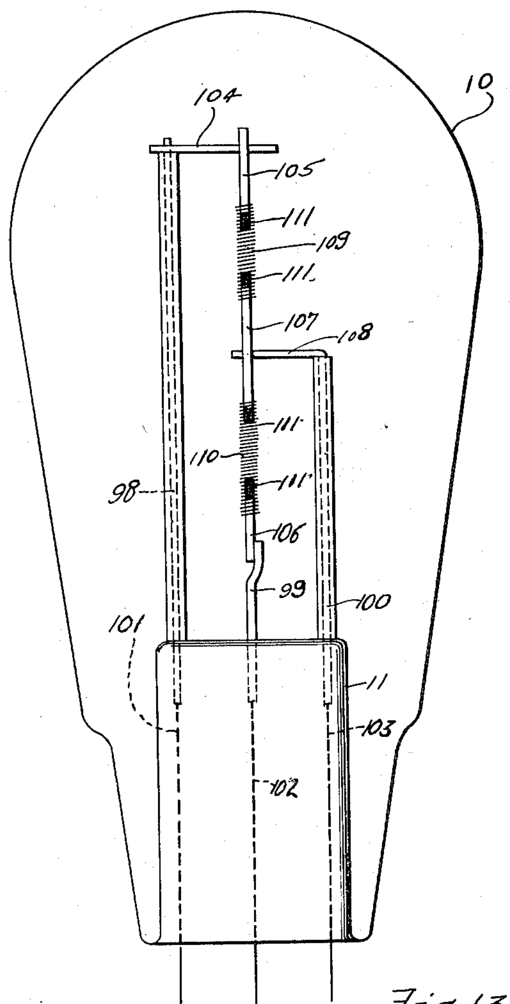


Fig. 12.

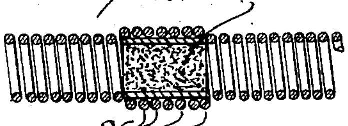


Fig. 13.

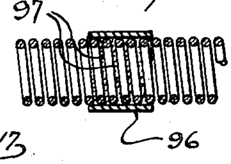
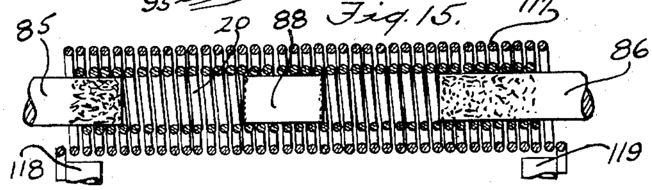


Fig. 15.



INVENTOR

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Fig. 16

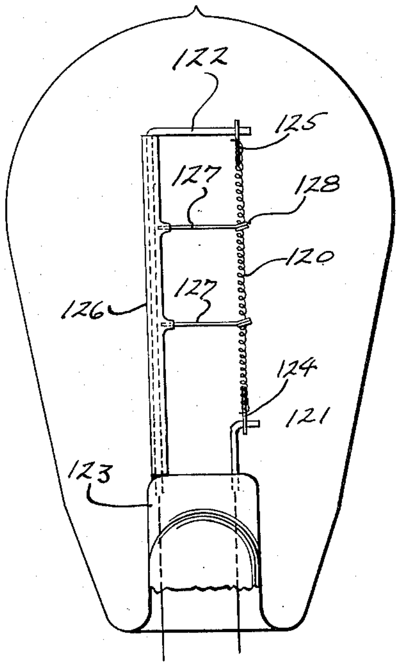


Fig. 18.

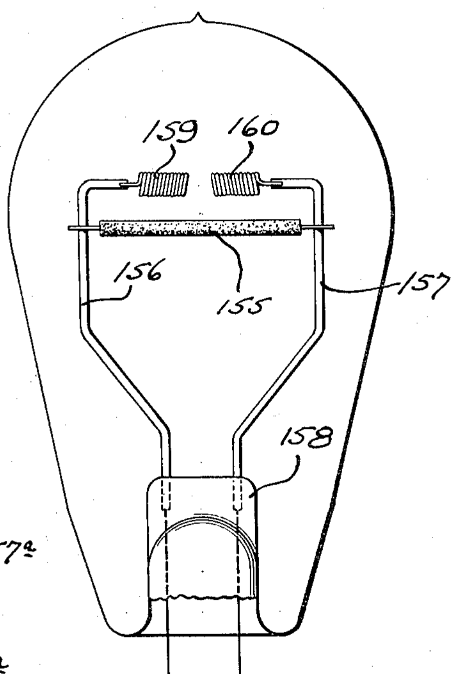
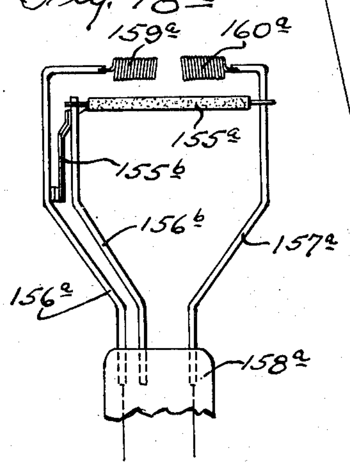


Fig. 18a



INVENTOR

Fig. 17.

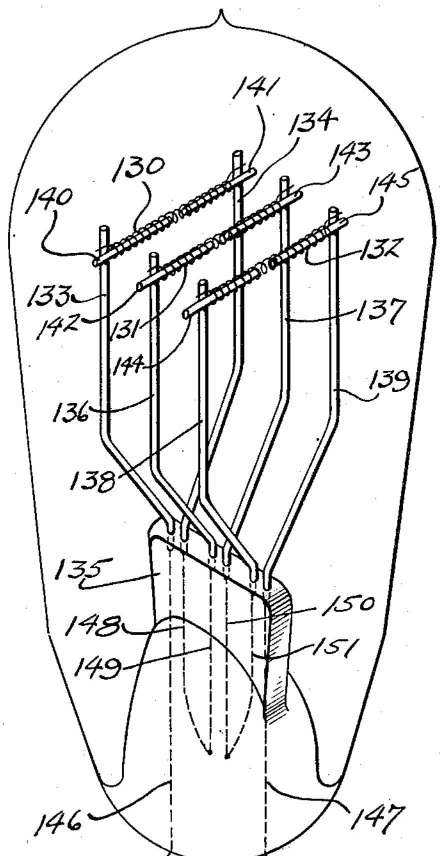


Fig. 19.

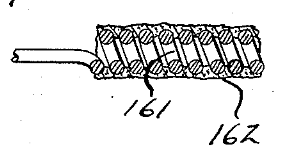
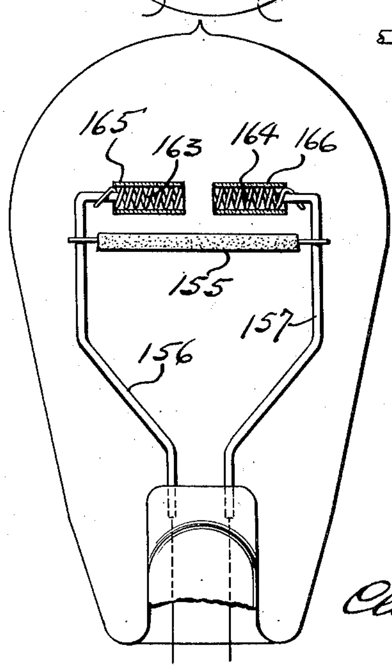


Fig. 20.



INVENTOR

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Fig. 21.

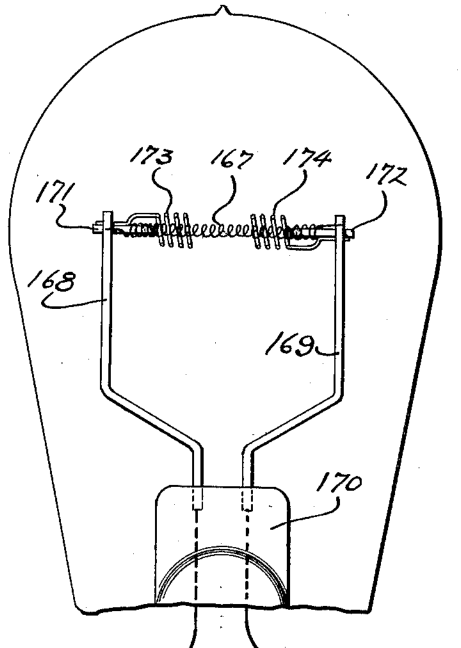
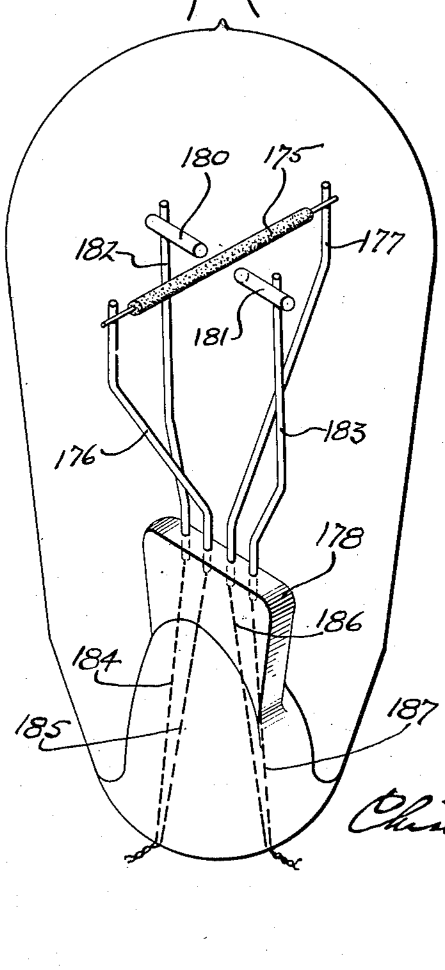


Fig. 22.



INVENTOR

Charles H. Braselton

July 9, 1935. C. H. BRASELTON 2,007,923

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Fig. 23.

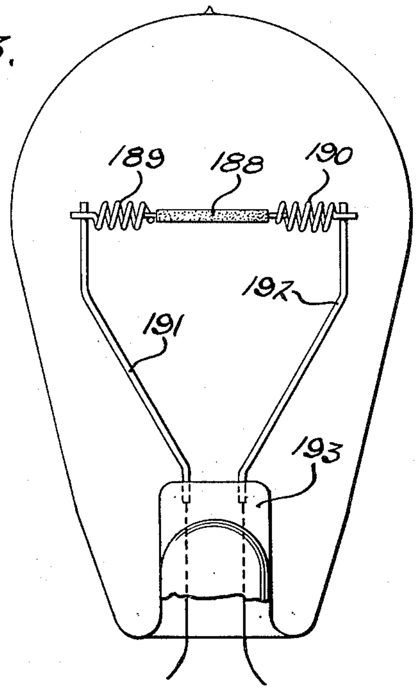
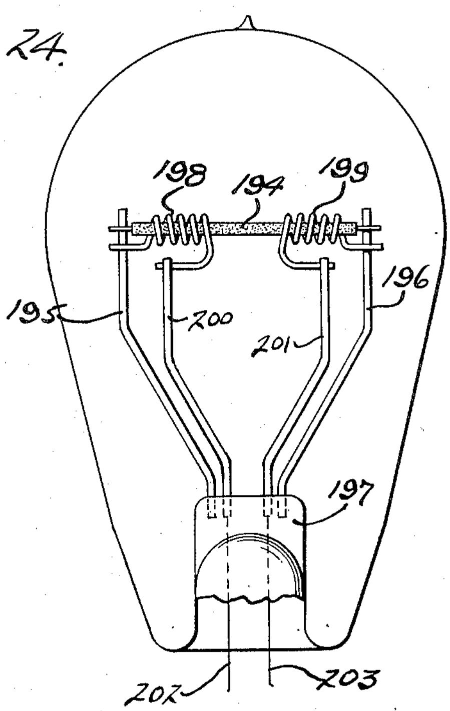


Fig. 24.



INVENTOR

Chester H Braselton

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Fig. 25.

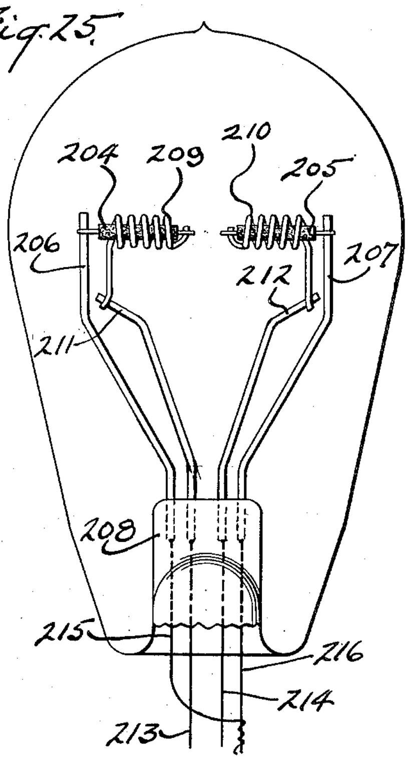


Fig. 26.

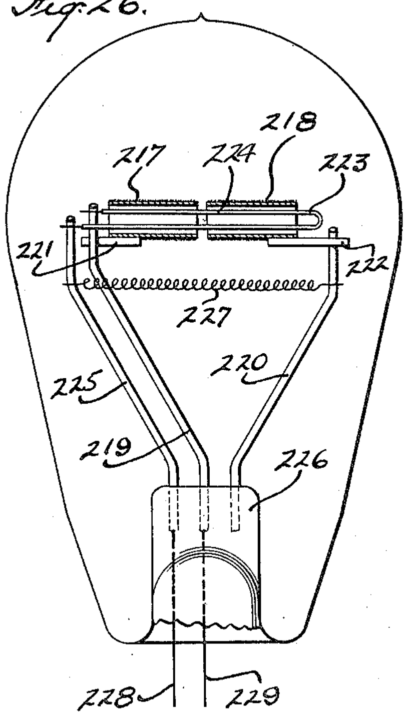
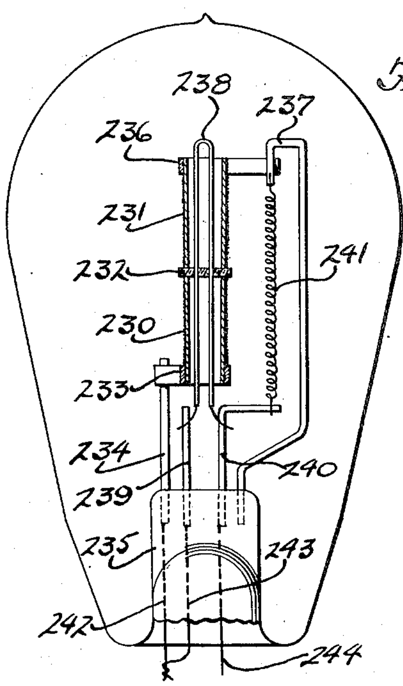


Fig. 27.



INVENTOR

Fig. 29.

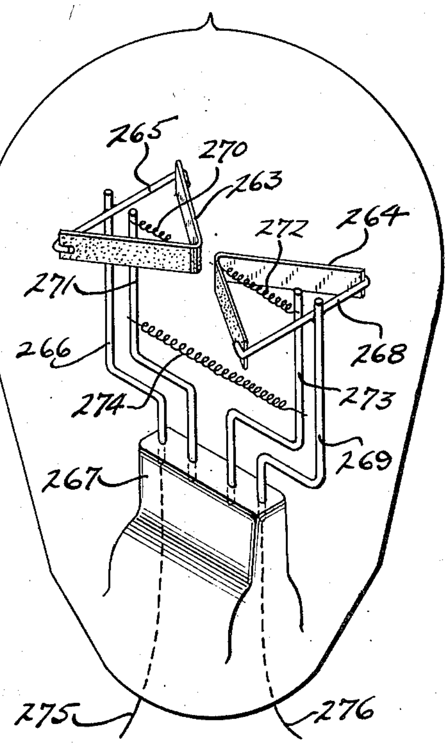


Fig. 28.

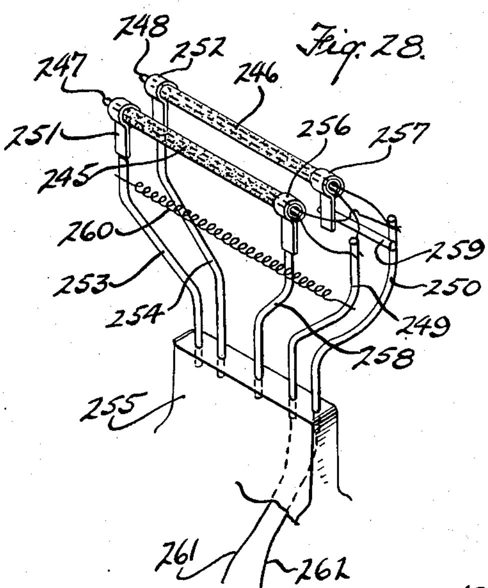
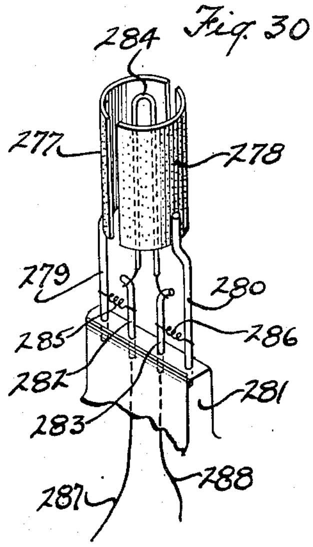


Fig. 30



INVENTOR

Patented July 9, 1935

2,007,923

UNITED STATES PATENT OFFICE

2,007,923

ELECTRIC DISCHARGE LAMP

Chester H. Braselton, New York, N. Y., assignor to Sirian Lamp Company, Newark, N. J., a corporation of Delaware

Application December 4, 1931, Serial No. 578,935

12 Claims. (Cl. 176—1)

This invention relates to a lamp or similar device for the radiation of energy, either luminous or non-luminous, and particularly to an improved device for utilizing the energy of an electric discharge of a gaseous medium for obtaining radiant energy.

An important object of the present invention is to provide an energy emitter of the type which utilizes an electric discharge in a gas and in which the energy of the discharge is confined to a relatively constricted area, so that the density of light emission is high.

Another object of the invention is to provide a type of electric discharge device wherein the discharge takes place between separated electrodes and in which the breakdown potential necessary to cause the discharge to be initiated between the electrodes is relatively low.

Another object of the invention is to provide an electric discharge device which has high utility when employed for purposes of illumination.

Still another object of the invention is to provide a gas discharge emitter which may be operated at the ordinary potentials of commercial lighting circuits as used in dwellings as distinguished from analogous devices requiring abnormal operating voltages.

Another object contemplated is to provide a device of the type indicated in which the diffusion of the arc about and intermediate the electrodes is automatically controlled.

An object also is to provide an electric discharge emitter in which there is no tendency for the localization of the discharge at any given points of the electrode surfaces but in which the discharge tends to proceed from the whole end surfaces of the electrodes, thus distributing the heat energy evolved and tending to prevent fusion of the electrode material.

Another object of the invention is to provide means for assembling a series of arcs so that there will be a minimum tendency for potential breakdown between the points separated by the highest potential.

Various other objects will appear on consideration of the following specification and of the accompanying drawings, in which:

Fig. 1 is a view in elevation of an embodiment of the invention which may be shown as the application to a single discharge unit;

Fig. 1*a* is a fragmentary view of a modified form of the construction of Fig. 1;

Fig. 2 is an enlarged detail of the electrodes and accompanying parts of Fig. 1 showing the heating coils;

Fig. 2*a* is similar to Fig. 2 but shows a modification thereof;

Fig. 3 is a view of the modified electrodes;

Figs. 4, 5, and 6 are views of three modifications of the electrode discharge device;

Fig. 7 is an elevation showing in part the series connection of the electric discharge units;

Fig. 8 is an enlarged detail of a modified construction for producing a plurality of discharges in series;

Figs. 9, 10, 11, 12, and 13 are fragmentary views of modified forms of the construction of Fig. 8;

Fig. 14 is a view of a plurality of the discharge gaps connected in parallel and electrically opposed to each other;

Fig. 15 is an enlarged detail of still another type of discharge unit;

Fig. 16 is a side elevational view of a single discharge unit but showing a different arrangement of the unit;

Fig. 17 is a perspective view of another embodiment of the invention showing a plurality of discharge units connected in series;

Fig. 18 is a front elevational view of a device embodying the invention in which the discharge occurs outside of the heater coil and spaced slightly therefrom;

Fig. 18*a* is a front elevational view of a modified form of the construction of Fig. 18;

Fig. 19 is an enlarged fragmentary sectional view of the electron emitting elements shown in Figs. 18 and 18*a*;

Fig. 20 is a front elevational view of a device somewhat similar to the construction of Fig. 18 but showing a different type of electrodes;

Fig. 21 is a front elevational view of an embodiment of the invention in which the electrodes operate similarly to those shown in Figs. 18 and 20 but surround the heating element;

Fig. 22 is a perspective view of another embodiment of the constructions shown in Figs. 18, 20 and 21;

Figs. 23, 24, and 25 are front elevational views of embodiments of the invention with electrodes connected to the electron emitting element and adapted to carry a portion of the current;

Figs. 26 and 27 are front elevational views of two embodiments of the invention wherein unipotential electron emitting cathodes are used;

Fig. 28 is a perspective view of the element structure of another embodiment of the invention wherein two unipotential cathodes are used;

Fig. 29 is a perspective view illustrating still another embodiment of the invention using two unipotential cathodes; and

Fig. 30 is a perspective view of the element structure of still another embodiment where two unipotential cathodes are used with a single heater.

In my co-pending application, Serial No. 459,048, filed June 3rd, 1930, I have described a type of energy emitter which utilizes the emission of a highly activated layer of ionized gases about a conductor in conjunction with a gas discharge between separated electrodes positioned adjacent the activated gas layer, both units being enclosed in a container which contains inert gases at a pressure reduced below atmospheric pressure. In accordance with said application, it has been found that with appropriate pressure conditions in the container and applied voltages on the mains, particularly when the density of electron emission from the conductor is intensified by the use of coating material which when heated emits electrons in profusion, a highly luminous layer of activated gases forms immediately adjacent the conductor. It has also been found, as stated in the above identified application, that if electrodes are connected in parallel with the conductor so that the external voltages are applied across the electrodes that when these electrodes are sufficiently heated a luminous discharge forms between. Should the distances between electrodes be properly selected in conjunction with the voltages employed the energy of the device may be concentrated in the discharge, although both elements of the discharge device may be made to function independently of each other. Preferably, the electrodes should be coated with electron emitting material so as to aid in overcoming the breakdown potential of the intervening gases.

In my co-pending application above referred to I have described specifically the method by which a conductor with a satisfactory electron emitting coating thereon may be prepared suitable for use in a radiating unit either alone or, if desired in conjunction with an electric discharge electrode. In accordance with the principles of the invention, a conductor is coated with electron emitting materials so as to increase the electron emissivity per unit area, and electric current passed through the conductor to heat the coating in the presence of an atmosphere of inert gases, such as neon, argon, krypton, and mercury and caesium vapors. With appropriate voltage, gas and pressure conditions, a layer of highly activated gases forms about the conductor which is a source of radiation, acting as such in conjunction with the conductor.

In forming a radiator of this type, a filament of appropriate resistance, such, for example, as 150 ohms, is coated with various alkaline oxides, such as the oxides of barium, strontium, calcium, or other materials which have been found to emit electrons densely when heated. The base filament is tungsten or tantalum wire, although other metal conductors may be used. It is not necessary ordinarily that the base material be highly refractory, as the operating temperatures may be relatively low, in many cases not being above that of low red heat.

The filament is preferably coiled and coated with materials as above mentioned, which may be initially in the proportions of 40 grams of barium carbonate, 40 grams of calcium carbonate, 8 grams of barium nitrate with a binder of sufficient nitrocellulose dissolved in amyl acetate to hold the coating on the wire, and the filament is then mounted on a stem support and sealed in the bulb of the envelope.

The exhaust pump is then connected to the bulb and an oven lowered thereupon to raise the temperature of the bulb and contents to about 400° C., or to as high a temperature as the envelope will stand without softening. Simultaneously, electric current is passed through the filament which is heated to red heat of approximately 600° C. The heat and exhausting process is continued until there is no fluorescence when the high tension current is directed against the wall of the bulb, or in other words, until there is practically no more gas inside of the bulb. A vacuum of about one-half of a micron is an approximate limiting value.

The current is then increased through the filament so that the temperature thereof is slowly raised until it is about 800 degrees, or a bright red color, the exhaust operation being continued until the newly emitted gases are removed. The oven is then raised from the bulb and the filament heated to about 1200° C., the pumping being continued until a high vacuum of one-half micron is again obtained.

The pump is then shut off, the current turned off, and about one-half mm. of neon gas admitted to the bulb. The filament current is then turned on and gradually increased until a diffused glow completely fills the bulb. When the discharge is uniform throughout the bulb, which usually takes less than ten minutes, the so-called activating process for the filament coating is completed. Should white discharge spots appear on the filament or support rods, it is an indication that the gases or vapors within the bulb have not been completely removed, and the bulb is again exhausted and the whole process of activation repeated. When the activating process is finally complete, the filament temperature is raised for a short interval to about 1400° C., and the pumping operation is again resumed to remove any undesirable gases which may have been thrown off during the activation process.

The filament circuit is then disconnected and the pump turned off and the appropriate amount of gas admitted to the bulb. In one form of my invention I utilize neon and argon gases in the relative amounts of 50 mm. of neon gas, and 150 mm. of argon. Other monatomic gases, such as krypton, helium, or metal vapors, such as those of mercury, caesium and rubidium may also be used. The bulb is then sealed off and a small quantity of magnesium flashed to absorb additional impurities, thus completing the process. The gases used should preferably be as pure as possible so that after completing the bulb the impurities in the gases do not exceed one per cent.

Referring to the drawings, I have illustrated the container 10 of glass or other material which is appropriately transparent to the type of radiation which is desired to be secured from the energy emitting unit. This container or envelope is gas-proof and one end is sealed to a support stem 11 which protrudes inwardly inside of the container and in which are mounted the inwardly projecting standards 12, 13, 14, and 15, which may be of nickel. Secured to the top of the standard 12 at right angles thereto is a length of tungsten wire 16, the end 17 of which forms one of the open electrodes of the electric discharge element. Similarly, to the standard 15 a length 18 of tungsten is welded or otherwise attached, the free end 19 of which being adjacent but separated from the end 17 of the tungsten electrode 16.

Wound about portions of the electrode rods 16 and 18 is a coil 20 of refractory wire such as tungsten, the coil bridging the gap between the electrodes 17 and 19 and continuing as above intimated on parts of the electrode rods 16 and 18. The ends 21 and 22 of the coil 20 are attached to corresponding standards 13 and 14. Lead-in wires 23, 24, 25, and 26 are connected to the corresponding standards 12, 13, 14, and 15, whereby electrical energy is transmitted to the electrodes 17 and 19 and to the coil 20 hereinabove described.

If desired the leads 23 and 24 may be connected together and also the leads 25 and 26, either inside or outside of the bulb, or the construction of Fig. 1*a* may be used where two of the support rods are entirely eliminated. Here the two uprights 12*a* and 15*a* support the electrodes 16 and 18 while the ends of the coil 20 are attached to short connectors 13*a* and 14*a* which are welded respectively to the uprights 12*a* and 15*a*.

As shown more clearly in Fig. 2 of the drawings, the electrodes 17 and 19 are coated by material 27 which when heated emits electrons densely, particularly when under the influence of a potential gradient and under appropriate gas pressure conditions. The coating material may be such as hereinabove described in connection with my copending application. The oxides of barium, strontium, and calcium, are found satisfactory as coating material for this particular use. The coating may be only on the opposing end surfaces of the electrodes, or it may be on the ends and also extend outwardly on the sides of the electrodes, or it may be entirely on the sides of the electrodes with the opposing end surfaces uncoated, or both electrodes may be left uncoated while the coil itself may be coated between them, as shown in Fig. 2*a*. In this latter case the coil may be coated either on the inside or the outside or the individual turns may be coated. The electrodes or coil may, in some instances, be made of a metal having electron emitting material incorporated therein such as the well known thoriated tungsten which is generally made by treating tungstic acid and thorium nitrate.

The type of emitting surface depends upon the particular uses intended for the device as well as upon the physical features involved, such as the pressure, density, or type of gases used and the extent of separation of the electrodes, and the material of the electrodes.

The coil 20, as shown, is wound about the electrode rods 16 and 18, the function of the coil being in part to heat the rods and bring the electrodes up to such a temperature that the coating will reach temperatures of dense electron emission. The portion or section 28 of the coil 20 intermediate the electrodes 17 and 19 may have additional functions in that it may serve to heat the gases intermediate the electrodes by convection or by electron bombardment, and also to weakly ionize the region included by its coil so that the discharge between the electrodes forms more rapidly than would otherwise be the case. The coil section 28 may also serve as a barrier to the discharge, offering a resistance to lateral discharge movement and tending to hold the discharge within restricted limits. The various elements mentioned, including the electrode rods 16 and 18 and the attached elements 17 and 19 of the coil 20, constitute, with their supporting and conducting circuits, an energy discharge unit generally referred to by the numeral 29.

The container 10 contains a gas or a plurality of gases which, as hereinabove referred to in connection with my co-pending case, has or have a relatively low breakdown potential, such gases including the monatomic or the inert gases of the type argon, neon, nitrogen, either alone or in combination with certain metallic vapors such as mercury, caesium, and rubidium. Helium gas may be employed in combination with other gases for certain types of radiators, particularly where heat conductivity is desirable. In the present instance I find a combination of argon and neon gives satisfactory results, these gases being in the proportion in accordance with pressures of practically three to one, that is, about 150 mm. of argon mixed with 50 mm. of neon, giving a total pressure of approximately 200 mm. of mercury.

The metal vapors may be introduced by providing a small container 12*a* of pressed metal having a pin hole therein and attached to one of the standards or support rods, as the rod 12, by means of the wire 13*a*. A small quantity of a salt such as a chloride of the desired metal is placed in the container together with a piece of magnesium or calcium and when the container is heated to a high enough temperature as by external bombardment the magnesium or calcium will combine with the salt forming magnesium or calcium chloride and liberating the free metal which is ejected through the pin hole and condenses on the walls of the bulb to be vaporized again when the device is heated in use.

In the operation of this embodiment of my invention, when electrical energy is applied to the leads 24 and 25 the coil 20 becomes heated throughout its entire length and by radiation and conduction transmits energy to the electrode rods 16 and 18 and to the electrodes 17 and 19. When the coatings 27 on the electrodes 17 and 19 become heated there is a tendency to break down the potential of the inter-electrode gases and when appropriate temperature conditions are reached an electric discharge forms between the electrodes. This discharge is intensely luminous, giving off illumination at the rate of approximately .5 watt per candle power, the type of discharge being very similar to that of the electric arc. At the same time the heating of the electron emitting material increases its conductivity so that portions of the coil contacting therewith become short circuited thus automatically reducing the resistance through the coil when the arc forms.

For a given pressure the potential across the electrodes may be varied, but I have found that a peak of illumination forms when the inter-electrode potential lies in the neighborhood of a range of 30 to 40 volts with a separation of electrodes approximately one-eighth of an inch. Under these conditions a current ranging from one-half ampere to two amperes may flow, thus indicating an ohmic resistance of approximately two ohms or under between the electrode terminals. Obviously, by modifying the physical dimensions of the device proportionately, the device may be changed to operate under any other desired potential, such as 110 volts. During the discharge the conductor section 28 appears to be at white heat with the discharge apparently within and without the same. The point of maximum light intensity appears to be when the discharge has approximately the same diameter as the heating coil. Due to the low resistance of the gas path between the electrodes only a small portion of the current appears to pass through the conductor 28.

It is to be noted that the discharge is not concentrated between definite points on the surface of the electrodes, but on the contrary, is spread over the entire surface. This is due, apparently, to the electron emitting coating which, being highly conductive, tends to spread the discharge emission area not only over the opposing ends of the electrodes but also over the coated portions, if any, which extend on the sides of the electrodes. This feature of the invention has utility in tending to prevent pitting and fusion of the electrode points, thus making possible a practical device of this type.

In Fig. 3 of the drawings I have illustrated an embodiment of the electrode terminals which instead of being in the shape of tungsten rods are fashioned as coils 30 and 31, the adjacent terminals 32 and 33 of which being formed in the shape of cones with coils of decreasing diameter. By this means, particularly where the coil material has a marked resistance, as, for example, tantalum, there is a potential gradient between the end points, as, for example, 34 and the rearwardly positioned point 35, so that when a discharge area forms intermediate the electrodes it will extend backwardly from the point 34 to the point 35, the point 35 having greater potential and hence functioning to force a discharge current through the longer path between the electrodes than is the condition between points 34. The electrode coils intermediate points 34 and 35 should be coated with electron emitting material, preferably as is the case as illustrated in the modification of Fig. 2.

A modification of the electrodes is illustrated in Fig. 4, in which the electrodes 40 and 41 are formed of a second class conductor, such as the oxides of cerium, calcium, and other combinations of oxides, such as the combination of the oxides of thorium and cerium, all of which when heated become conducting, although when conducting offering a greater resistance under equivalent conditions to the passage of electricity than that of metals. The potential gradient on electrodes of this type is relatively high so that the discharge may be readily diffused along a predetermined area, as intermediate the points 42 and 43. These electrodes may be coated on their terminals as at 44.

The modification of Fig. 5 illustrates electrodes 50 and 51 which may combine the features of the modification of Figs. 2 and 4 in that the discharge is spread over the electrode terminals not only by means of the electrode coating 52 but also by the use of high resistance material in the electrodes which may be of oxides or high resistance metal which serves to spread out the area of discharge.

A further modification is illustrated in Fig. 6 in which instead of solid electrodes coiled wire is used in the manner somewhat similar to the showing of Fig. 3, with the exception that the electrode is formed by placing a small section 60 of conducting coil on to the heating coil 20, this electrode coil 60 having a coating 61 of electron emitting material.

Heretofore I have described my invention as utilizing a single pair of electrodes as forming the unit 29 of Fig. 1. In order, however, to make use of higher potentials such as are available in private dwellings and elsewhere, it may be desirable to connect a number of these units in series. In Fig. 7 I have illustrated an arrangement of several units so connected that this device is usable under higher potential conditions than a single unit. In the container 10 is mounted on the support 11 two standards 70 and 71. The standard 71 is joined at its upper point 72 to a support bar 73. Also, there is mounted on the standard 71 a tubular insulating rod 74 and from a point 75 thereof connection is made to a supporting wire 76 welded or otherwise fastened at the end thereof to a length of tungsten or other refractory metal 77. Tungsten rods 78 and 79 are also attached respectively to the support wire 73 and standard 70 so that the open ends of the tungsten rods 78 and adjoining end of the rod 77 form opposing electrodes and the open end of the rod 79 and the adjacent end of the rod 77 also form opposing electrodes. A coil of wire 80 joins electrodes 79 and 77 and extends upon and around the same and is attached thereto. Similarly, a coil 81 connects the electrodes 78 and 77 and is wound about and attached to the same. Lead-in wires 82 and 83 respectively connect the standards 70 and 71 to a source of electric energy.

When an electric potential is applied to the lead-in wires 82 and 83, with gases of appropriate substances and pressure immersing the electrode elements and conductors, the current passes through the standard 71, support wire 73, and the various electrode and conductor elements 78, 81, 77, 80, 79, and 70, thus heating the conductors 80 and 81 and causing the electrode coatings 84 to ionize the inter-electrode gases and permit the formation of intensive gas discharges therebetween. Any number of discharge units of this type may be placed in series, provided each individual discharge is properly confined to its inter-electrode area. This may be done by proper control of the voltage conditions, by physical spacing of the electrodes, by proper pressure conditions of the gases, and by utilization of inter-unit barriers or conducting sections, such as described in my copending application hereinabove mentioned.

If desired the series arc produced by the construction of Fig. 7 may be formed by a construction as shown in Fig. 8. Here a pair of electrodes 85 and 86 corresponding to the electrodes 78 and 79 of Fig. 7 are connected by a single coil 87 which is provided inside thereof at substantially the central point with a solid short rod 88 of tungsten or other desired material. The rod 88 may be held in position by a slight deformation of the coil at the ends thereof and it may have its ends coated with electron emitting material. This construction breaks the discharge into two arcs which form between the electrode 85 and the rod 88 and between the rod 88 and the electrode 86. While I prefer to coat the ends of the rod 88 with the electron emitting material the rod may, of course, be coated on the sides as well although this may tend to cause the arc to jump outside of the coil.

In Fig. 9 a modified form is shown where, instead of a solid rod in the center of the coil, a sleeve 90 is provided which may be coated on the inside thereof with electron emitting material. In some instances it may be desirable to omit the sleeve 90 and coat the interior of the coil at the center thereof with the electron emitting material.

Figs. 10 and 11 are sectional views of still further modifications of the constructions of Figs. 8 and 9. Fig. 10 shows a solid member 91 which is half round and fills half the internal diameter thus providing an opening through the coil at this point. The ends of the member as well as the flat surface 92 may be coated with the electron emitting material. In Fig. 11 a ribbon of tungsten may have its sides coated with the electron emitting material and may be placed inside of the coil similarly to the other constructions. The ribbon is thin enough to leave a space on each side of it to permit the discharge to pass through the coil at this point.

In Fig. 12 a modification of the construction of Fig. 9 is shown in which a sleeve 94 is provided inside of the coil and having a somewhat larger diameter than the sleeve of Fig. 9 so that the inside diameter thereof is about the same as the inside diameter of the coil. The several turns 95 of the coil are larger in diameter so as to receive and hold the sleeve 94. The inside of the sleeve may be coated with electron emitting material similarly to the sleeve 90 of Fig. 9.

In Fig. 13 a still further modification of this construction is shown where a sleeve 96 is provided outside of the coil at the center thereof. The coil itself may be coated as at 97 with electron emitting material and the sleeve slipped over the coil and held in position thereon by slightly pressing the edges down over the turns as indicated.

A parallel arrangement of the discharge units is shown in Fig. 14 of the drawings. In this embodiment of my invention, the container, the included gases, and the coating material is similar to that utilized in previously described forms. On the support 11 are mounted three standards 98, 99, and 100, to each of which are connected lead-in wires 101, 102, and 103. To the standard 98 is secured the support wire 104, to the end of which the electrode rod 105 of tungsten is welded or otherwise attached. Similarly, to the end of the standard 99 is attached the tungsten electrode rod 106. Intermediate the adjacent ends of the electrode rods 105 and 106 is the electrode rod 107 which is held in place by the cross support wire 108 mounted upon the standard 100. The electrodes 105, 106, and 107 are mounted in line and are joined to each other by the coils 109 and 110, the coil 109 joining the electrode rods 105 and 107 and the coil 110 joining the electrode rods 106 and 107. These coils are fastened to the electrode rods and serve as bridging conductors intermediate the electrodes. They also serve to heat the electrode coatings 111.

The lead-in wires 101 and 102 are joined together either within or without the container so that when an electric potential is applied to the junction of these lead-in wires and also to the lead-in wire 103, current passes up through the standard 100, support wire 108, and divides, passing to electrodes 105 and 106 in opposite directions. This simultaneous opposite movement of the current in the adjacent discharge units tends to prevent a spilling over of the discharge between points of highest potential within the container, and hence affords a practical means of multiplying the number of units and increasing in this way the luminosity of the emitter.

Attention is directed to the support rod as a spacing element between the discharge units, tending to prevent "spilling over" between the units. As a conductor, the support absorbs radiation which breaks across.

In Fig. 15 a still further modification of the invention is shown. Here a pair of electrodes 85 and 86 similar to those shown in Fig. 8 are bridged by a coil 20 provided with a solid conductor 88 similar to the construction of Fig. 8 and having the ends thereof coated with electron emitting material. The conductor 88 is held in position by deforming the coil at the ends of the rod as already described in connection with Fig. 8. In this construction however I may employ an auxiliary coil 117 which is wound in a larger diameter than the coil 20 and is spaced from it being connected at its ends to additional support rods 118 and 119 as indicated. In this construction the two coils 20 and 117 are connected in parallel and are therefore both heated when a current flows through them. As the two coils are in parallel the resistance will be less and therefore more turns will be necessary to make the desired resistance. The outer coil tends to aid in keeping the discharge within bounds and prevent any tendency to "spill over" or arc between the high potential points of the lamp.

In Fig. 16 another modification of the construction shown in Figs. 1 to 6 inclusive is shown. Here a single coil 120 having a relatively long length may be supported at its lower end upon a support rod 121 and at its upper end upon a support rod 122 which extends horizontally and is bent downwardly to be sealed in the press 123 together with the support rod 121. Coated electrodes 124 and 125 are positioned in the ends of the coil as indicated and are welded to the support rods. A tube of insulating material 126 such as glass or quartz may be inserted over the rod 122 so as to insulate the rod from the surrounding gas as far up as the horizontal portion thereof. Additional support rods 127 of suitable metal may be sealed in the tube 126 and may extend outwardly having loops 128 at the ends thereof to hold the filament against lateral distortions.

In Fig. 17 a modification of the construction shown in Figs. 7, 14, and 15 is illustrated. In this construction a plurality of coils 130, 131, and 132 are mounted in parallel relation. The coil 130 is mounted between support rods 133 and 134 which are parallel with each other throughout a portion of the length thereof and then are bent inwardly to be sealed in the press 135. The coil 131 may be mounted upon support rods 136 and 137 which are similar to the support rods 133 and 134 and are also sealed in the press 135. Similarly the coil 132 may be mounted upon the support rods 138 and 139 which are also sealed in the press similarly to the others just described.

Electrodes 140 and 141 may be positioned within the coil 130 and attached respectively to the support rods 133 and 134, and similarly electrodes 142 and 143 may be positioned within the coil 131 and attached to the corresponding support rods and electrodes 144 and 145 may be positioned in the coil 132 and attached to its corresponding support rods. These electrodes may be coated at their ends as described in connection with the other figures and they may be spaced sufficiently apart to produce an arc between them when the coils are energized.

Leading-in wires 146 and 147 may be connected to the extreme support rods 133 and 139 while wires 148 and 149, connected to the support rods 134 and 136, may be connected together as indicated; also leading-in wires 150 and 151 may be connected respectively to the support rods 137 and 138 and may also be connected together. This connects all of the coils 130, 131, and 132 in series and inasmuch as there are three separate discharges the potential drop across each one is one-third of the total line voltage.

While constructions showing an enclosed discharge have been described it is also possible to make the discharge occur outside of the heating coil and such a construction is shown in Fig. 18. Here an electron emitting element 155 is connected between two support rods 156 and 157 which are mounted in the press 158. The ends of the support rods extend upwardly and are bent inwardly and closely wound coils 159 and 160 made of tungsten or other metal capable of standing high temperatures are welded respectively to the ends of the rods 156 and 157, there being a slight space between the two coils and between the coils and electron emitting element 155. The electron emitting element may comprise a coil 161 of wire (see Fig. 19) which is coated with electron emitting material 162. The wire may be refractory metal such as tungsten, molybdenum, nichrome, or tantalum, while the electron emitting coating may be any material used for that purpose such as the oxides of the alkali earth metal group or mixtures of such oxides held together with a suitable binder. The coils 159 and 160 should be near enough so as to be in the region of the discharge when the element is energized and are then heated by bombardment by the element whereupon the discharge takes place between the coils. The resistance along the coils is sufficient to spread out the discharge along the surface thereof instead of permitting a concentrated arc to form at the ends.

In Fig. 18*a* the coils 159*a* and 160*a* are similar to the coils 159 and 160 of Fig. 18 and the emitting element 155*a* is also similar to the element 155 of Fig. 18 but a bimetallic thermostat switch 155*b* is connected between the end of the element 155*a* and the support rod 156*a*, the thermostat and end of the element being mounted upon an auxiliary support rod 156*b*. When the temperature of the device is raised by the discharge high enough the thermostatic switch opens thus opening the circuit through the emitting element. The discharge between the coils 159*a* and 160*a* is then self-maintaining.

In the construction of Fig. 20 a similar electron emitting element 165 is used connected between similar support rods 156 and 157 and coils 163 and 164 of tungsten, somewhat similar to the coils 159 and 160 are connected respectively to the ends of the support rods 166 and 167, being spaced similarly to the coils in Fig. 18. These coils however are enclosed by tubes 165 and 166 of quartz or other insulating material which extends the full length of the coils leaving a space between them. When the discharge occurs in this construction it is confined in outside dimeneter by the quartz sleeves so that it takes place inside of the coils.

In Fig. 21 a construction is shown which combines the constructions of several previous figures into one. In this figure a coil of wire 167 is mounted between two support rods 168 and 169 which are sealed in a press 170. Electrodes 171 and 172 may be connected respectively to the ends of the support rods 168 and 169 and may extend a short distance inside of the coil 167, the inner ends of the electrodes 171 and 172 being coated with electron emitting material. Around each end of the coils 167 I have provided additional coil electrodes 173 and 174 which are attached to the support rods 168 and 169 respectively. These coils may also be coated with electron emitting material or not as desired. When the coil 167 is heated up the coils 173 and 174 heat by bombardment and a discharge will occur both inside of the coil 167 and outside of it between the coils 173 and 174.

In Fig. 22 a construction is shown in which the external discharge is at right angle to the electron emitting element and across it. The electron emitting element 175, similar to the elements already described, may be connected between two support rods 176 and 177 which are sealed in the press 178. A pair of tungsten electrodes 180 and 181 may be positioned in line with each other and at right angles to the element 175 with the inner ends spaced slightly from the element as indicated and supported respectively upon two support rods 182 and 183 which extend downwardly and are also sealed in the press 178. Leading-in wires 184 and 185 may be connected respectively to support rods 182 and 176 and may be connected together so as to connect the electrode 180 to the end of the filament connected to the support rod 176. Similarly two leading-in wires 186 and 187 may be connected respectively to the support rods 187 and 183 and may be connected together to connect the electrode 181 with the other end of the element 175.

In Fig. 23 a construction is shown in which the electrodes are at the end of the electron emitting element. In this case the electron emitting element 188 has a coil 189 attached to it in any desired manner and a coil 190 attached to the opposite end. The coils 189 and 190 are preferably somewhat larger in diameter than the coil of the element 188 and may be attached to the element 188 by a paste made by mixing powdered tungsten and tungsten paratungstate with a small amount of water, or the coils 189 and 190 may be made of a different metal than the coil 188 such as molybdenum, if the coil is made out of tungsten, and the ends of the wires welded together. The outer ends of the coils 189 and 190 may be connected respectively to support rods 191 and 192 which may be sealed in the press 193 similarly to the support rods described in the other figures.

In Fig. 24 an electron emitting element 194 is shown connected between two support rods 195 and 196 which are sealed in the press 197. Two coils 198 and 199 are positioned around the ends of the element being connected respectively to the support rods 195 and 196 at their outer ends while their inner ends may be connected respectively to two support rods 200 and 201 which are sealed in the press 197. In this case the discharge occurs between the coils 198 and 199 around the electron emitting element 194. Leading-in wires 202 and 203 may be connected to the support rods 200 and 201 and when the device is connected in a circuit the current flows through the leading-in wires 201 and 202, the support rod 200, the coil 198, the electron emitting element 194, the coil 199, the support rod 201, and out through the wire 203. It will thus be seen that the high potential ends of the coils 198 and 199 are nearest together so as to aid in starting the discharge.

A modification of this structure is shown in Fig. 25 where a pair of electron emitting elements 204 and 205 are mounted in line with each other and spaced apart and with their outer ends attached respectively to two support rods 206 and 207 which are mounted in the press 208. The inner ends of the emitting elements are attached respectively to the inner ends of two coils 209 and 210 which extend outwardly around the elements 204 and 205 and have their outer ends attached to two support rods 211 and 212 respectively which are also sealed in the press 208. Leading-in wires 213 and 214 are connected to the support rods 211 and 212 to form the leads for connecting to the external circuit while leading-in wires 215 and 216, connected respectively to the support rods 206 and 207 may be connected together as indicated so that the coils and emitting elements are connected in series but with the high potential ends of the coils 209 and 210 away from each other and a gap between the two units.

In Fig. 26 a modified form of the invention is shown in which two unipotential cathodes 217 and 218 coated with electron emitting material are mounted respectively upon two support rods 219 and 220 by means of short connectors 221 and 222. The cathodes 217 and 218 are positioned in alignment with each other but spaced apart a small distance and a heater 223 is provided extending through both cathodes and insulated therefrom by a coating 224 of insulating material. The heater is bent in the form of a hairpin and the ends thereof are welded one to the support rod 219 and the other to the additional support rod 225 which is also sealed in the press 226 with the other support rods 219 and 220. A ballast wire 227 may be connected between the support rod 220 and the support rod 225. This wire may be made of tungsten or other desirable resistance material which will preferably give some light when the device is operated. A pair of lead-in wires 228, 229 may be connected respectively to the support rods 225 and 219 and when these wires are connected to a source of energy the current will flow in through the wire 228, through the support rod 225, through the heater element 223, through the support rod 219 and out through the wire 229. This will raise the temperature of the heater and heat the cathodes 217 and 218 and when these have been raised to electron emitting temperature the discharge will appear between them and then additional current will flow in through the wire 228, through the support rod 225, through the ballast resistance 227, through the end portion of the support rod 220, the connector 222, the cathode 218, through the gaseous gap between the two cathodes, through the cathode 217, the connector 221, the support rod 227, and out through the wire 229. Inasmuch as the ballast wire 227 is in the cathode circuit there is no danger of an arc forming between the cathodes and concentrating at one point causing overheating of the parts or other damage.

In Fig. 27 a modification of the construction of Fig. 26 is shown in which the two cathodes 230 and 231 are mounted vertically within the bulb and in alignment with each other as in the previous structure. In order to space the cathodes close together but still insulate them electrically from each other I provide a disc 232 of mica or other insulating material which may be placed between the cathodes and in contact with the inner ends thereof. The lower cathode 230 may be mounted by means of a band 233 upon a support rod 234 which is sealed in the press 235. The upper cathode may be mounted by means of a band 236 surrounding the upper end of the cathode and welded to a support rod 237 which extends downwardly spaced from the cathode and inwardly to be sealed in the press 235. The heater filament 238, similar to the filament 223 of Fig. 26, extends through the cathode passing through holes provided for it in the insulation disc 232 and is supported at its lower ends by means of the support rods 239 and 240 which are sealed in the press 235. The support rod 240 may have its end bent outwardly and a ballast 241 of tungsten wire or other resistance material may be attached to it and may extend upwardly to be welded to the end of the support rod 237. Leading-in wires 242, 243, and 244 may be attached respectively to the support rods 234, 239, and 240. The two wires 242 and 243 may be connected together so as to connect the cathode 230 to one end of the heater 238 and when the wires are connected across the circuit current will flow in through the wire 243, through the support wire 249, through the heater element 238, through the support rod 240, and out through the lead-in wire 244. As in the previous figure the cathodes 230 and 231 will be heated to electron emitting temperature and a discharge will start between the cathodes which will cause current to flow through the leading-in wire 242, the support rod 234, the cathode 230, the space of ionized gas between the cathodes, the cathode 231, the band 236, the ballast resistance 241, the support rod 240, and out through the lead wire 244.

Another embodiment of this same construction is illustrated in Fig. 28 where a pair of cathodes 245 and 246 may be mounted parallel to each other and spaced apart and a pair of insulated heater elements 247 and 248 may be inserted in the cathodes, being connected at their ends to two support rods 249 and 250 in such a manner that the heaters are in parallel, but of course they may be connected so that they are in series if desired. The ends farthest away in the illustration may be surrounded by bands 251 and 252 which are connected respectively to support rods 253 and 254 sealed in the press 265 together with support rods 249 to 250. The nearest ends of the cathodes may be connected respectively by bands 256, 257 the former of which is attached to the support rod 258 sealed in the press 255 and the latter to a connector 259 which is welded to the support rod 250. A ballast wire 260 may be connected between the support rods 253 and 249. Leading-in wires 261 and 262 may be connected respectively to the support rods 249 and 250 and when the device is connected to a circuit the current will flow through the support rods 249 and 250 and through both of the heaters 247 and 248 and when the cathodes are raised to emitting temperature and a discharge occurs between them current will also flow through the connector 259, the cathode 246 and the cathode 245, and the ballast resistance 260, to the support rods so that the current through the cathode circuit must pass through the ballast as in the previous case to prevent any concentration of the arc at a localized point on the cathode.

A still further modification of this construction is illustrated in Fig. 29 in which the unipotential cathodes 263 and 264 are formed of small pieces of ribbon made of tungsten or other refractory metal and bent in the form of a V with the vertices of the V's adjacent each other and both in the same plane and on the same axis. The extreme ends of the V-cathode 263 may be attached to a connecting rod 265 which may be welded to a support rod 266 extending downwardly and sealed in the press 267 while the ends of the V-cathode 264 may be attached to a connecting rod 268 which is welded to a support rod 269 which also extends downwardly and is sealed in the press 267. Inside of the vertex of the cathode 263 I attach a heating filament 270 which may have its other end attached to a support rod 271 which extends down parallel to the support rod

266 and is also sealed in the press 267. In like manner the cathode 264 has a heating filament 272 connected at the vertex thereof and having its other end attached to a support rod 273 which is sealed in the press 267 alongside of the support rod 269. Between the support rods 271 and 273 I connect a ballast resistance 274. Lead-in wires 275 and 276 may be connected to the support rods 266 and 269 and when so connected current will flow when the device is connected in a circuit, through the lead wire 275, the support rod 266, the connecting rod 265, the cathode 263, the heating filament 270, the support rod 271, the ballast 274, the support rod 273, the heating filament 272, the cathode 264, the connecting rod 268, the support rod 269, and out through the lead wire 276. When the heating filaments 270 and 272 have raised the temperature of the cathodes 263 and 264 to electron emitting temperature a discharge will take place between the cathodes which will then flow through the space between them thus short circuiting the ballast 274 and the heating filament 270 and 272.

In Fig. 30 a modified form of the invention is shown in which two semi-cylindrical cathodes 277 and 278 are mounted concentrically and spaced slightly apart upon two support rods 279 and 280 which are sealed in the press 281. A pair of support rods 282 and 283 are also sealed in the press 281 and have connected to the ends thereof a heating filament 284 which is properly insulated by a suitable coating similar to those of Figs. 26, 27, and 28 and a pair of ballast resistances 285 and 286 are connected respectively between support rods 279 and 282, and 283 and 280. Leading-in wires 287 and 288 are connected respectively to the support rods 282 and 283 and when connected in a circuit the current flows through the leading-in wire 287, the support rod 282, the heater 284, the support rod 283, and the lead wire 288. The heater raises the temperature of the cathodes 277 and 278 to electron emitting temperature and a discharge occurs between the cathodes beginning at the edges thereof and being distributed over the surface of the cathodes. Current will then flow from the support rod 282 through the ballast resistance 285, support rod 279, the cathode 277, the space between the cathodes, the cathode 278, the support rod 280, and other ballast resistance 286, and through the support rod 283 again. In this construction as in the constructions of Figs. 26, 27, and 28 the ballast is in the cathode circuit so that no localized arc can be formed to overheat the parts thereof.

The dimensions of the heating coils, electrodes, the conductors between the units and multiple electrode units, the pressure and kind of the gases, the extent and type of coatings, and other values are obviously subject to considerable variation in accordance with the uses and demands of the apparatus. I have mentioned a voltage drop of definite ranges over a discharge path in the constructions of Figs. 1 to 15 inclusive over one-eighth of an inch as giving a maximum light intensity at a stated potential for the device as used for illuminating purposes. Other values might be mentioned, such as a diameter for the heating coil of approximately .04 inches. These values, however, may be changed considerably within limits without affecting the utility of the device. Various modifications of the arrangement of the unit, as well as of the arrangement of various units if multiple discharge devices are employed, may of course be readily made, and accordingly, I do not desire to be limited by the specific embodiments as shown otherwise than is required by the claims hereto appended.

Having thus described my invention, what I desire to claim is:

1. An electric discharge device comprising the combination of adjacent elongated electrically conducting electrodes mounted on a common axis, means for heating said electrodes including a relatively high resistance conductor between said electrodes, an ionizable gas surrounding said electrodes, said electrodes including material which when heated emits electrons in profusion, and a container for holding said gases about said electrodes, said gases having a pressure preferably exceeding 150 mm. of mercury and not exceeding 200 mm. of mercury.

2. An electric radiator the combination of a container, a support mounted therein, two opposing and separated electrodes mounted on said support along a common axis, a coating of electron emitting material on the adjacent ends of said electrodes, means for electrically heating said electrodes, said means constituting a coiled shunt conductor wound about said electrodes and extending in a straight line thereinbetween, and an inert, ionizable gas within said container.

3. An electric radiator comprising the combination of a container, a support mounted therein, two opposing and separated electrodes mounted on said support, a coating of electron emitting material on the adjacent ends of said electrodes, means for electrically heating said electrodes, said means constituting a coiled shunt conductor about said electrodes and coaxial with said electrodes, and an ionizable gas within said container, said electrodes being separated preferably in excess of one-eighth of an inch and the pressure of the gas not exceeding 200 mm. of mercury.

4. An electric emitting device comprising the combination of a container, a support mounted therein, two linearly extended electrodes mounted on said support having an end of each adjacent but separated from an end of the other, a coiled shunt heating conductor connected about said electrodes and coaxial therewith, an ionizable gas within the container, and a coating of electron emitting material on the adjacent end portions thereof, the resistance of said electrodes from their ends outwardly being sufficient to cause a pronounced potential gradient adjacent the discharge areas of the electrodes.

5. An electric radiating device comprising the combination of a container, a support therein, a conductor mounted on said support, said conductor having a section in the form of a coiled wire with a straight axis and having a less conductivity than the remaining portion of the conductor, a coating of electron emitting material on said conductor adjacent the ends of the section of less conductivity, and an ionizable gas immersing said conductor.

6. An electric radiating device comprising the combination of a container, a support therein, a conductor mounted on said support, said conductor having a section of less conductivity than the remaining portion of the conductor, a coating of electron emitting material on said conductor adjacent the ends of the section of less conductivity, and an ionizable gas immersing said conductors, the breakdown potential of said gas along a unit length of the axis of said conductor being less than the potential per unit length necessary to elevate the coating to electron emitting temperature, and the pressure of said gas within the

container preferably exceeding 100 mm. of mercury and not exceeding 200 mm. of mercury.

7. An electric radiating device comprising the combination of a transparent container, a support therein, a plurality of standards mounted on said support, lead-in wires connecting said standards to points external to the container, an electrode of refractory conducting metal mounted on each of two of said standards, said electrodes having adjacent separated points adapted to support an electric discharge therebetween, a coil of refractory metal wire connected between two of said standards and surrounding the adjacent end portions of said electrodes and extending along a straight line in the space intervening, a coating of electron emitting material including an alkaline oxide such as the oxides of barium, strontium, or calcium, on the ends of said electrodes, and an ionizable gas within said container.

8. An electric emitting device comprising the combination of a container, an ionizable gas within the container, a support within the container, a conductor mounted on said support, said conductor having connection to points external to said container, and coatings of electron emitting material at spaced intervals on said conductor, an electric discharge being adapted to form between the coated sections of the conductor when said sections are heated to electron emitting temperature by the passage of an electric current through the conductor, the length of said coatings along the conductor being less than the length of the spaced intervals between the coatings.

9. An electric emitting device comprising the combination of a container, a support mounted therein, an ionizable gas within the container, a conductor mounted on said support, said conductor being in the shape of a closely wound coil of refractory metal, spaced intermittent sections of coiled wire metal externally mounted on said conductor, and coatings of electron emitting material in contact with said conductor adjacent said external coiled sections.

10. An electric discharge device comprising a pair of spaced apart electrodes, electron emitting material coated upon portions of said electrodes, a conductor shunted between said electrodes and adapted to heat said electrodes when an electric current is passed therethrough, an auxilary electrode positioned between said first mentioned electrodes and electrically connected to substantially the mid-point of said conductor and an ionizable gas surrounding said electrodes said auxiliary electrode having electrical connection only with said conductor.

11. An electric discharge device comprising a pair of electrodes spaced apart, electron emitting material coated upon portions of said electrodes, a conductor wound in the form of a coil and shunted between said electrodes and enclosing them, and an auxiliary electrode within said coil and in contact therewith and positioned between said first mentioned electrodes, an electron emitting material upon portions of said last mentioned electrode, and an ionizable gas surrounding said electrodes.

12. An electric discharge device comprising a pair of spaced apart electrodes, a coating of electron emitting material upon portions of the surface of each of said electrodes, a coil of filamentary resistance wire shunted between said electrodes and enclosing them, a sleeve of metal within said coil at substantially the center thereof and providing spaced gaps between said sleeve and said electrodes, a coating of electron emitting material on the inner surface of said sleeve, and an ionizable gas surrounding said electrodes and sleeve.

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