March 7, 1933. D. McF. MOORE 1,900,578

GASEOUS DISCHARGE DEVICE

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Fig. 2.

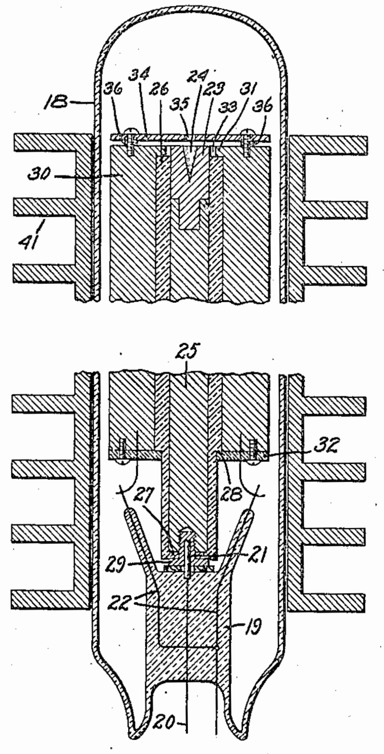

Fig. 1.

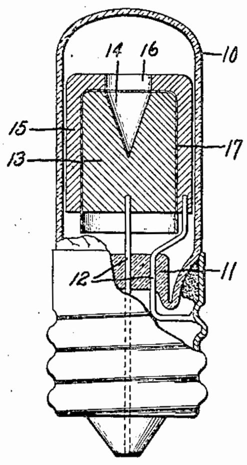

Fig. 4.

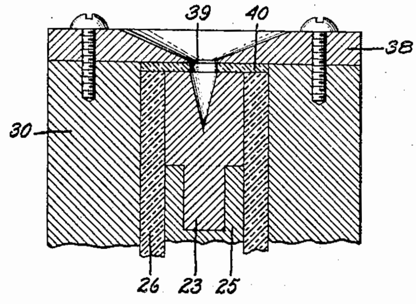

Fig. 3.

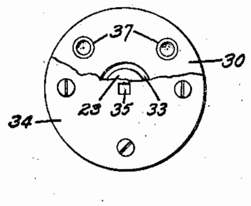

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Fig. 5.

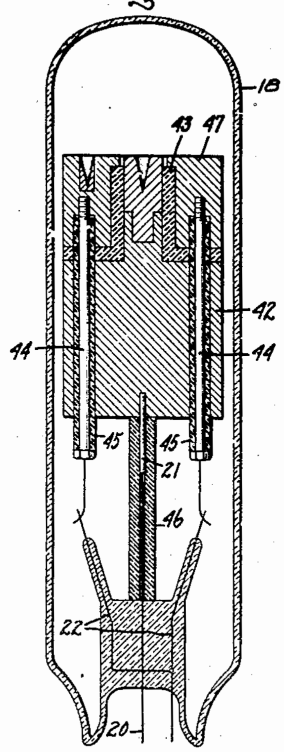


Fig. 6.

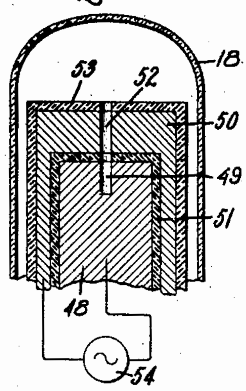


Fig. 7.

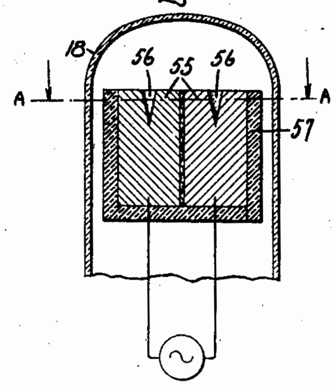


Fig. 9.

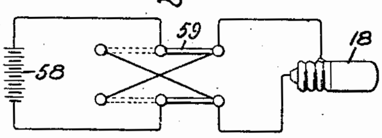


Fig. 8.

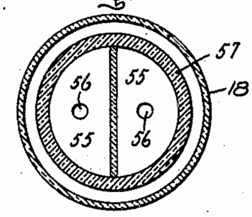


Fig. 10.

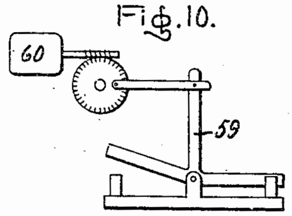
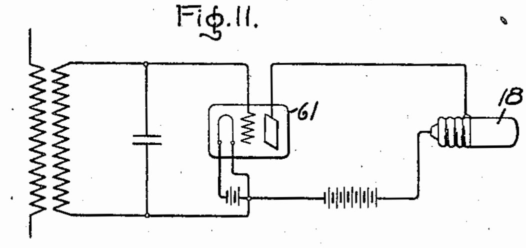


Fig. 11.



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Patented Mar. 7, 1933 1,900,578

UNITED STATES PATENT OFFICE

DANIEL McFARLAN MOORE, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

GASEOUS DISCHARGE DEVICE

Application filed March 31, 1930. Serial No. 440,178.

My invention relates to gaseous discharge devices, such as gaseous conduction lamps and more particularly to the type of gaseous conduction lamps described in my prior Patent 1,316,967 of September 23, 1919 and in my Patent 1,816,690 in which the light is produced by an electrical discharge, such as a negative glow discharge, which varies in brilliancy with the current passed through the lamp and which responds without appreciable time lag to current variations of high frequency such as those of the order of radio frequency. Such lamps are particularly useful as the light source for fac-simile receiving apparatus by which fac-similes or photographs of pictures, documents and similar objects may be obtained by wire or by radio; as the light source of the receiver or reproducer in television apparatus by which moving pictures are transmitted; for signalling and for many other purposes requiring a light source which varies in brilliancy with the current passed through it and which is accurately responsive to high frequency current variations.

This application is in part a continuation of my application for U. S. patent for gaseous conduction lamps, Serial No. 292,223, filed July 12, 1928.

One object of my invention is to provide a lamp which modulates or varies the amount of light emitted substantially in accordance with variations in the amount of voltage impressed on it or in the amount of current flowing through it, even though such variations are of a frequency as high as those of the order of radio frequency, and which will modulate well at much higher currents and with a luminous discharge of much greater intrinsic brilliancy than was feasible in lamps of this type heretofore used.

Another object is to provide a lamp for producing a very brilliant spot of light which varies in brilliancy with variations in the impressed voltage or in the current flowing through it, and which has sharply defined edges and is free from halo.

A further object is to provide a lamp of this general type which will operate on alternating current to produce a bright spot of light useful for signs, signaling and similar purposes.

Still another object is to improve the construction of such lamps so that they will be simple and rugged, commercially useful, and capable of economical manufacture on a commercial scale.

My present invention is an improvement in the device of my prior application Serial No. 748,346 (on which Patent 1,816,690 is to be issued July 28, 1931) which embodies a concentrated light source well adapted for use as the variable light source in certain types of television and facsimile apparatus, the negative electrode or cathode being provided with a cavity or crater in which the entire luminous discharge is concentrated to produce a small but bright spot of light which varies in intrinsic brilliancy with the amount of current flowing through the lamp, and responds to high frequency current variations.

As described in another prior application Serial No. 292,223, filed July 12, 1928, the crater in the cathode may be made conical, like a deep funnel of rather small bore with its depth greater than its maximum diameter. As shown in application Serial No. 748,346 the crater may be a cylindrical hole with parallel walls. For television and fac-simile purposes it may have a diameter of about three hundredths to six hundredths of an inch and a depth of about twenty-five one-hundreds of an inch. Good modulation with a much higher current and a luminous discharge of much greater intrinsic brilliancy than heretofore feasible is obtained with a cathode of a material such as tungsten, tungsten steel, cold rolled steel, or similar metal.

In accordance with one of the features of my present application this crater cathode is mounted inside an anode which forms a kind of cap over the cathode and has in it a window in alignment with the crater in the cathode so that the luminous discharge between the anode and the cathode is concentrated in the crater and the light from the luminous discharge in the crater can escape through the window in the anode. The shape of this window determines the shape of the spot of light produced by the lamp. The anode and the cathode may conveniently be mounted on and connected at the rear to a stem such as is commonly used in incandescent lamps or radio tubes and a base on the end of the lamp adjacent the stem permits the lamp to be connected in circuit while the other end of the bulb over the active surface of the cathode is left unobstructed. Such a based lamp is a very simple and rugged device well adapted for commercial use and capable of being manufactured economically on a large scale. The anode is set immediately over and in such relation to the cathode that no luminous discharge can occur between the anode and the surface of the cathode outside the crater, hence the luminous discharge is confined to the crater and a bright spot of light with sharply defined edges free from halo is obtained.

In accordance with another of the features of my invention I construct the lamp so that the deleterious gases which remain in the bulb after the usual method of exhaust and after the bulb has been charged with the conducting atmosphere can be cleaned up and rendered harmless by an aging process in which the normal electrical connections are reversed, thereby rendering the anode negative, and passing sufficient current to cause an intense glow discharge to appear in a crater formed in a material such as magnesium which is on the anode and has a clean up or getter action. I have found it convenient in aging the lamp in this way to reverse the electrical connections of the anode and the cathode many times, which can conveniently be done by a pole changing switch actuated by a motor. Since the mechanical spacing of the electrodes is important I prefer to construct the lamp so that the anode and cathode constitute a self-contained unitary structure with very definitely determined spacing and thereby avoid any change in the spacing of the electrodes during assembly in the bulb. This may conveniently be done by clamping the electrodes to the insulation and to each other in the desired relation before the tube is assembled.

For use with alternating current I construct the lamp so that each electrode has a crater in it. The electrodes may be side by side, or arranged so that the craters are in tandem.

In the accompanying drawings I have shown for purposes of illustration some of the various forms in which my invention may be embodied, and in which Fig. 1 is a longitudinal section of a lamp embodying one form of my invention and in which a cathode with a funnel shaped crater is covered by an anode having in it a window to permit light from the crater to escape; Fig. 2 is a similar view on an enlarged scale and with the middle part broken away of an improved form of such a lamp; Fig. 3 is an end view of the lamp shown in Fig. 2 with a portion of the cap plate on the anode broken away to show the clean up craters in the anode; Fig. 4 is a longitudinal section of the crater end of a lamp with modified form of the anode; Fig. 5 is a longitudinal section of a modified form of lamp in which the lower end of the cathode is enlarged to form a heat radiating member. Fig. 6 is a longitudinal section of a part of a form of lamp for alternating current and having craters in the cathode and anode in tandem; Fig. 7 is a longitudinal section of an alternating current lamp having crater electrodes side by side; Fig. 8 is a sectional view taken on line A—A of Fig. 7; Fig. 9 is a diagram of a circuit for changing the connections of the electrodes to age the lamp and clean up the deleterious gases, Fig. 10 shows a motor driven pole changing switch for use in the circuit shown in Fig. 9; and Fig. 11 is a diagram of a circuit in which the lamp may be used.

The particular form of lamp shown in Fig. 1 comprises a sealed bulb 10, preferably of the cylindrical form often referred to as a tubular bulb, into which there is sealed at one end a stem 11 of the usual construction with two leads 12 which supply current to the electrodes and in this form of lamp also support them. The bulb contains a filling of gas of good conductivity such as neon at a pressure of about 30 mm. of mercury. The neon may be purified before it is introduced into the tube, although for many purposes commercial neon which contains from 20 to 25% of helium, or mixtures of the various monatomic gases may be used, and I find it advantageous to add a small amount of argon, such as about one-half per cent, to the neon. For some purposes a gas filling which contains a greater percentage of argon, or of helium, or a gas filling of pure helium, or of practically pure argon may be used, but for most purposes a gas filling which is predominately neon is preferable.

The lamps are preferably made with a tubular anode and a cylindrical cathode mounted concentric with or in the bore of the anode, but spaced from it by a very narrow gap and also insulated from it. I may use between the electrodes a very thin spacer or partition of good insulating material, such as mica, but prefer to use some refractory material such as lava or the ceramic material commercially known as "isolantite", and to shape the electrodes so that the gap between them at a predetermined point is much less than the thickness of the insulation which lines the anode and permits the cathode to be fitted into the anode so firmly as to be held in place. To maintain the electrodes at low temperature during the operation of the lamp the anode is preferably of considerable mass with enough heat-radiating surface to maintain the electrodes at the desired temperature during operation, and the cathode may also be so made that it has considerable heat-radiating surface. Such a lamp with a comparatively massive anode in which the cathode is firmly fitted may be made mechanically rugged by fitting the annular anode into the lamp bulb with such clearance that objectionable movement of the electrodes transversely of the bulb is prevented.

In the particular form shown in Fig. 1 the cathode 13 is cylindrical and may be made of magnesium or aluminum for many purposes, or of other metals such as iron or tungsten for other purposes. It has in its front end a crater 14 in the form of a deep funnel of comparatively small bore. This tapering crater or funnel may, for example, be about one-tenth of an inch in diameter at the large end, tapers to a point at the bottom, and has a depth considerably in excess of the diameter at the large end. I place this cathode concentric with and inside the anode 15, which has the shape of an inverted cup, fits over the cathode and has in its bottom an outlet or window 16 in registry with the crater 14. The anode and cathode are insulated from each other by the lining or partition 17, preferably of thin mica about one-one-hundredth of an inch thick, which lines the bore of the anode and covers the sides and front end of the cathode except where perforated in registry with the crater 14 and the window 16 to permit free flow of current at that point. The insulating partition 17 encircles the cathode, and at the rear this insulating sleeve or cylinder of mica may project far enough, for example a quarter of an inch, to form an insulating sleeve or barrier to prevent the discharge occurring at undesired places, and to assist in preventing discharge between the leads. Under normal operating conditions of the lamp the glow discharge occurs in the crater, since by adjusting the gas pressure and the voltage applied to the lamp all the luminous cathode glow can be confined to the crater. The cylindrical anode 15 is preferably tubular and may fit with rather slight clearance, into the cylindrical bulb 10, so as to limit the movement of the electrodes transversely of the bulb, although considerable space may be left between the electrodes and the walls of the bulb if the electrodes are supported on the stem by leads heavy enough to carry the electrodes or by support wires embedded in the stem, such as are commonly used in radio tubes. The anode is rather massive so as to remain cool during operation, and has a length considerably greater than the thickness of its walls. It is preferably made of aluminum or magnesium, although it may be made of iron, copper, nickel or other metal, particularly if treated to clean it and free it of gas.

The modified form of lamp shown in Fig. 2 produces with a luminous negative glow a sharply defined spot of light free from halo and of much greater intrinsic brilliancy than has heretofore been obtainable, yet modulates well when used as a light source for television and fac-simile apparatus, and will successfully handle several times the current which could be passed through the lamps of this type heretofore used. This particular form of lamp comprises a bulb 18 containing a rarefied gas of good conductivity and having a stem 19 with a cathode lead 20, preferably terminating in a stud or projection 21 for positioning the cathode on the stem, and a pair of anode leads 22 which are preferably coated with vitreous insulation over the greater part of their length inside the bulb.

The cathode 23 is preferably made of some metal such as tungsten, tungsten iron alloys, cold rolled steel, or similar metals which vaporizes very slightly even at high temperatures, and practically not at all at red heat at the pressure existing in the lamp. The cathode has a crater 24, preferably tapering or funnel shaped, which for most purposes has a diameter of about four-hundredths to six-hundredths of an inch and depth of about one-quarter of an inch. When constituted of tungsten the cathode is conveniently made of tungsten powder sintered by heating it to a temperature of about 1700° C., which makes it coherent but slightly porous, and produces metal capable of being worked mechanically. It may be heated as high as possible without melting it, or up to about 3000° C., if a very dense metal is desired. As a matter of convenience the tungsten cathode is firmly mounted, preferably by tight mechanical contact or by brazing or welding on the end of a cathode stem 25 of some metal, such as iron or copper which is a good heat conductor, so that the composite cathode has an active end of tungsten and a stem of some other metal. It can be made entirely of tungsten, if desired, but the composite form of cathode is cheap and is more easily made to exact dimensions.

The cathode is firmly anchored in a tubular insulator 26 preferably of the ceramic material commercially known as "isolantite", which is molded to the desired form and fired until it is a hard vitreous mass much like porcelain. This tubular insulator has the general form of a very deep cup with a bottom 27 having a central hole, and has comparatively thick walls. It is reduced in diameter at the lower end to form a shoulder 28. The cathode fits snugly in the bore of the insulator with its lower end resting on the bottom 27 and clamped to the bottom by a set screw 29 which has a recess for receiving the stud 21 on the end of the cathode lead. This stud positions the cathode on the stem and also makes an electrical connection to the cathode.

A tubular anode 30, preferably rather massive and with thick walls, encircles the cathode. The anode has at the upper end an inwardly projecting lip or flange 31. The tubular insulator 26 fits snugly into the bore of the anode with its end against the lip 31, and is held firmly in place by a washer 32 of isolantite, which engages the shoulder 28 on the insulator and is secured to the rear end of the anode by screws. As a result the electrodes are firmly clamped to the insulator and hence to each other to form a self-contained unitary structure, which can be handled during an assembling of the lamp without altering the spacing of the electrodes.

A very narrow gap between the adjacent ends of the anode and of the cathode is desirable, as the lamp seems to modulate better with such a gap. The use of a very thin layer of insulation, such as mica, between the electrodes to obtain this narrow gap has some disadvantages, particularly from a manufacturing standpoint. In accordance with my invention I separate the electrodes by a comparatively thick insulator, and so shape the electrodes that their active ends are closer together than the thickness of the insulation, and hence the desirable narrow gap between the electrodes is obtained while the use of a very thin sheet of insulation is avoided.

In the lamp shown in Fig. 2 the exposed end of the cylindrical cathode 23 is flush with the end of the anode, and the inwardly projecting flange 31 has a bore only slightly larger than the cathode, leaving a narrow gap or moat 33 between the cathode and the anode. The bottom of this moat is formed by the end of the tubular insulator 26 which has a wall thickness much greater than the width of the moat 33. A very bright spot of light with sharply defined edges is obtained by so constructing the lamp that there is no luminous discharge between the anode and the surface of its cathode outside the crater.

The exposed end of the cathode is flush with the end of the thick walls of the tubular anode, but is covered by a cap plate 34 which has an aperture 35, in registry with the crater 24 and which is mounted on and electrically connected to the anode, so that it is in effect the bottom of an inverted cup anode with thick walls. This cap plate mounted on and in electric connection with the anode, and having its window in registry with the crater in the cathode, is so placed that the gap between it and the exposed end of the cathode is no greater than the thickness of the non-luminous discharge of the Crookes dark space of the gaseous conduction discharge which takes place in the lamp. Hence no luminous discharge can occur under operating conditions of the lamp between the anode and the cathode at points other than the walls of the crater. Since there is no luminous discharge outside the crater the lamp will project on a screen a spot of light which has no halo around it and which has sharply defined edges. The shape of the spot of light is determined by the shape of the hole 35 in the cap plate, and for picture projection this hole may to advantage be square. The cap plate may be secured to the anode by screws, and spaced away from it very accurately by metal spacers 36.

I have obtained good results with a lamp constructed as shown in Fig. 2, and made with a bulb about $1\frac{3}{8}''$ in diameter and about $6''$ long, an annular anode about $2\frac{1}{2}''$ long with an outside diameter of about $1\frac{1}{32}''$, and a bore of about $\frac{1}{2}''$ and a tubular insulator which fills the bore of the anode and is made of isolantite with walls about $\frac{3}{32}''$ thick, a cathode filling the bore of the insulator and having in its front end a conical crater 24 about $\frac{1}{4}''$ deep and a maximum diameter of from four-hundredths to six-hundredths of an inch, the gas being at a pressure of about 30 mm. of mercury and consisting primarily of neon, but containing about $\frac{3}{8}\%$ of argon. The diameter of the hole 35 in the cap plate 34 is about four one-hundredths of an inch, the spacing between the cap plate of the anode and the exposed end of the crater cathode is about one-thirty-second of an inch or less, and the moat 33 is about one one-hundredths of an inch wide and about one-thirty-second of an inch deep.

The lamp is exhausted in the usual way to as high a vacuum as can conveniently be obtained by good vacuum pumps such as are used in the incandescent lamp industry. I find it convenient, but not necessary, to use mercury condensation pumps to obtain a high vacuum. During the exhaust the bulb of the lamp is heated as hot as possible and in some cases the metal in the bulb may to advantage be heated during exhaust by a high frequency induction coil. The exhausted bulb is then charged with the conducting gas and usually the bulb may to advantage be charged with this gas and exhausted several times so as to wash out the bulb with the gas. The lamp is then charged with the gas to a pressure of about 30 mm. of mercury and sealed. The lamp is then aged by reversing the electrical connections to clean up and remove deleterious gases by the aid of clean up craters 37 in the anode, as best shown in Fig. 3. These clean up craters are of about the dimensions of the crater 24, and are made in masses of magnesium or similar metal set into the upper or active end of the anode. When the electrical connections of the lamp are reversed and sufficient potential applied to cause enough current to flow through the lamp a glow discharge appears in the clean-up craters, and the deleterious gases are quickly cleaned up and removed.

In the modification shown in Fig. 4, I use instead of the apertured cap plate 34 a ring 38 with a central opening 39 in registry with the cathode crater and electrically and mechanically connected to the active end of the anode. This ring 38 is spaced away from the end of the cathode by an insulating washer 40 of a thickness, for example, one-thirty-second of an inch, such that there is no glow on the cathode except in the crater and hence no luminous discharge outside the crater to cause halo around or at the edges of the spot of light projected on a screen by the lamp.

Where high currents are to be used I prefer to make the electrodes of the lamp relatively massive so that they will remain comparatively cool during the operation of the lamp. I may make the electrodes so that they have an extended heat radiating surface, or I may provide cooling means, such as a cooling jacket for the lamp, to keep down the temperature of the metal parts inside the bulb during operation. In my copending application Serial No. 505,846, filed December 31, 1930, I have described and claimed various forms of gaseous conduction lamps having artificially cooled cathodes.

For example, I may provide a ribbed cooling jacket 41 which fits snugly over the bulb, as shown in Fig. 2, or I may as shown in Fig. 5, make the cathode stem with an enlarged head 42 which substantially fills the bulb below the anode and radiates the heat which is conducted to the cathode stem from the cathode.

In the construction illustrated by Fig. 5 the cathode and anode are separated by insulator 43, and are rigidly held in proper relation to each other by stud bolts 44 which extend through the cathode head into the anode. These bolts are insulated from the cathode by insulating tubes 45, and also electrically connect the anode to the anode leads 22. An insulating tube 46 around the stud 21 of the cathode lead supports the cathode on the stem. The electrodes are held in place on the stem and in proper relation by joining the anode leads to the bolts 44, preferably by electric welding. This lamp is constructed much like that shown in Fig. 2 except that the cap plate 34 is omitted, and hence the spot of light from the crater is not quite as sharply defined. The spot of light from the crater can be made quite sharp and substantially free from halo by providing the ends of the electrode with a cover which may be a diaphragm with a central aperture in registry with the crater, such as a sheet of insulation like mica or lava, or a sheet of metal insulated from the electrode. The diaphragm may be mounted on the anode like the cup plate 34, but insulated from it instead of being electrically connected to it. I may also use a coating 47 applied directly to the ends of the electrodes, of some material such as zirconium oxide with a binder of water glass or finely divided graphite, such as the colloidal graphite commonly known as "aquadag" which forms a very black coating.

The alternating current lamp, partly shown in Fig. 6, is constructed with two craters in tandem. The electrodes are mounted in the lamp in much the same way as the electrodes shown in Fig. 1. One electrode 48, resembling the cathode 13, has a crater 49. The other electrode 50 resembling the anode is separated from the electrode 48 by an insulation 51 and has a tubular aperture 52 which acts as a crater when this electrode is negative. The electrode 50 may to advantage be covered with an insulating shield 53. The electrodes are connected to an alternating current source indicated at 54. During the half cycle when the electrode 48 is negative the glow is in the crater 49, and during the other half cycle it is in the tubular crater 52.

Another form of alternating current lamp with the electrodes side by side is shown in Figs. 7 and 8; the two semi-cylindrical electrodes 55, each with a crater 56 in the end, are mounted with their flat sides adjoining, and are spaced apart about one-thirty-second of an inch. The electrodes are preferably placed in an insulating cup 57, and are connected to the alternating current source 54. During one-half cycle the glow is in one crater, and during the other half cycle it is in the other crater.

A convenient circuit connection for aging the lamp is shown diagrammatically in Fig. 9 in which direct current is supplied from a direct current source 58 through a pole changing switch 59 connected to the leads of the lamp, as indicated in Fig. 10, and actuated by a motor 60 so that the polarity of the electrical connections to the lamp may be reversed as often as desired until the deleterious gases in the lamp are cleaned up by an intense glow discharge in the clean up craters in the anode. For example, I have obtained good results by reversing the connections at the rate of 50 to 100 times a minute, with a current several times that of normal operation until the color of the discharge indicates absence of the deleterious gases and the resistance of the lamp decreases until it is constant.

Lamps constructed in accordance with my invention may be used in many different kinds of circuits and for many purposes, but merely for illustration one of the forms of circuit in which the lamp is useful is indicated diagrammatically in Fig. 11, which is essentially a circuit commonly used in the receiving sets for television and fac-simile apparatus and which comprises a three-electrode vacuum tube 61 with its grid circuit connected to receive the incoming signals and its output circuit connected to the leads of the lamp. The current in the output circuit of the tube 60 varies in accordance with the strength of the incoming signals, and causes corresponding variations in the brilliancy of the glow discharge in the crater of the cathode.

The color of the light emitted by the lamp can be varied by selecting the material for the cathode as it is dependent not only on the gas but also on the material of the cathode. For example, with neon a nickel or tungsten cathode gives a very reddish light; with a magnesium or cold rolled steel cathode a light less reddish; with a cathode of tungsten steel with 17% of tungsten a lighter color, almost yellowish; and with a cathode of an alloy containing iron and cerium and commercially known as ferrometal the hue is still further away from red, and is pinkish or purplish. With helium and a magnesium cathode the light is decidedly whitish, much like daylight. These variations can be obtained not only with crater cathodes but with electrodes in the form of plates, such as are sometimes used.

Metals of the alkali or alkaline earth groups, such as caesium, sodium, barium, and the like, may be added to the lamp to reduce the starting voltage and to obtain other advantages. The additive metal may be incorporated in or mixed with the cathode so made as to be porous, or a compound of the additive metal, such as barium azide which decomposes during the operation of the lamp and thus produces the pure metal, may be used. The walls of the crater 24 may, for example, be coated with the compound to obtain a crater lined with the alkali or alkaline earth metal.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A gaseous conduction lamp comprising a sealed vessel containing a gas at cathode glow pressure, a thick walled cup-shaped anode having a partially closed end, a layer of insulation lining said anode, and a cathode fitted into said cup-shaped anode with one end adjacent the partially closed end thereof and having in said end a conical cavity with a depth greater than its maximum diameter said cavity being in registry with the opening in the partially closed end of said cup-shaped anode.

2. A gaseous conduction lamp comprising a sealed vessel containing a gas at cathode glow pressure, a thick walled cup-shaped anode having an opening in the bottom and lined on its inner walls with thin insulation and a cathode fitted into said cup-shaped anode and having a conical cavity with its base in registry with said opening in said anode and of a depth greater than the diameter of its base.

3. A gaseous conduction lamp comprising a sealed vessel containing a cathode having at one end a crater of a depth greater than its diameter, a tubular anode mounted concentric with said cathode with one end overhanging the crater end of said cathode, while permitting egress of light from said crater, said anode being spaced closely adjacent said cathode and a gas in said vessel at a pressure at which a cathode glow will appear in said crater at operating potentials.

4. A gaseous conduction lamp comprising a sealed vessel containing a rarified gas of good conductivity, a tubular electrode having a flange projecting at one end inwardly toward the bore of said electrode, a tubular insulator fitting into the bore of said electrode with its end resting on said flange and with a wall slightly thicker than the depth of said flange, and a solid electrode fitted into the bore of said insulator with one end exposed and substantially flush with the flanged end of said tubular electrode to leave between said solid electrode and the inner wall of said flange a gap with a width less than the wall thickness of said insulator, said electrodes being so spaced that at the normal operating potential a luminous discharge consisting solely of the negative glow appears on the cathode.

5. A gaseous conduction lamp comprising a sealed vessel containing a solid electrode having in one end a tapering crater of a depth greater than its greatest diameter, a hollow electrode mounted to embrace said solid electrode with one end overlying the end of said solid electrode outside of said crater, and a gas in said vessel at such pressure that at the operating potential of the lamp a negative glow appears solely in said crater.

6. A gaseous conduction lamp comprising a sealed vessel containing a solid electrode having in one end a tapering crater of a depth greater than its diameter, a tubular electrode surrounding but insulated from said solid electrode, a metal plate mounted on and electrically connected to one end of said tubular electrode to overlie the end of said solid electrode outside of said crater and having a window in registry with said crater, and a gas of good conductivity in said vessel at such pressure that at the operating potential of the lamp a negative glow appears solely in said crater.

7. A gaseous conduction lamp comprising a sealed vessel containing a solid cathode having in one end a crater of a depth greater than its diameter, an anode mounted out of alignment with said crater and so spaced with reference to said cathode that at the operating potential of the lamp a luminous negative glow appears in said crater, a mass of magnesium in said anode and having in it a crater in which a luminous glow discharge appears when the polarity of the lamp is

reversed whereby the deleterious residual gases are cleaned up, and a charge of monatomic gas in said vessel.

8. A gaseous conduction lamp comprising a sealed vessel containing a tubular electrode, an insulator in the bore of said tubular electrode, a solid electrode having two cylindrical portions of different diameter, one fitted into said insulator inside said anode with its end exposed and substantially flush with the adjacent end of said tubular electrode and the other of a diameter substantially that of the outside diameter of said tubular electrode, an electrical connection insulated from and extending through said larger portion to said tubular electrode, and a gas in said vessel at such pressure that at the normal operating potential a luminous discharge consisting solely of the negative glow appears at the exposed ends of said solid electrode.

9. A gaseous conduction lamp for alternating current comprising a sealed vessel containing an insulating cup, two semi-cylindrical electrodes mounted side by side in said cup with their flat sides adjoining and insulated from each other, each of said electrodes having in its exposed end a crater with a depth greater than the diameter, and a gas in said vessel at such pressure that at normal operating potential a luminous negative glow discharge appears in said craters.

10. A gaseous conduction lamp for alternating current comprising a sealed vessel containing a solid electrode having in one end a crater with a depth greater than its diameter, insulation surrounding said electrode but exposing said crater, a tubular electrode surrounding said insulation and having an end which overhangs the crater end of said solid electrode and which has a passage of a diameter substantially like that of the crater and in registry with said crater, and a gas in said vessel at such pressure that at normal operating potential a luminous negative glow appears in said crater during one half cycle and in said passage during the other half cycle of the alternating current supplied to the lamp.

11. A gaseous conduction lamp comprising a sealed vessel containing a tubular electrode, an insulator fitting into the bore of said electrode and having the shape of a deep cup the end wall of which has a window, a solid electrode fitted into said insulator, means for clamping said solid electrode in a position exposing a portion thereof at said window, and a rarified gas of good conductivity in said vessel at such pressure that at operating potentials negative glow appears at the exposed end of said solid electrode.

12. A gaseous conduction lamp comprising a sealed vessel containing a tubular electrode, a flanged insulator having a tubular portion fitted into the bore of said tubular electrode, a solid electrode having portions of different diameters, a portion of lesser diameter being fitted into the tubular portion of said insulator, the end of said portion being exposed and substantially flush with the adjacent end of said tubular electrode, and the portion of larger diameter bearing against the flanged portion of said insulator, and a gas in said vessel at such pressure that at operating voltage negative glow appears at the exposed end of said solid electrode.

In witness whereof, I have hereunto set my hand this 28th day of March, 1930.

DANIEL McFARLAN MOORE.