

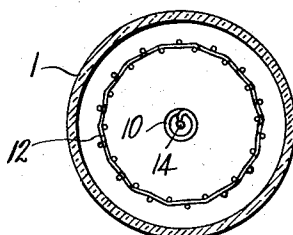
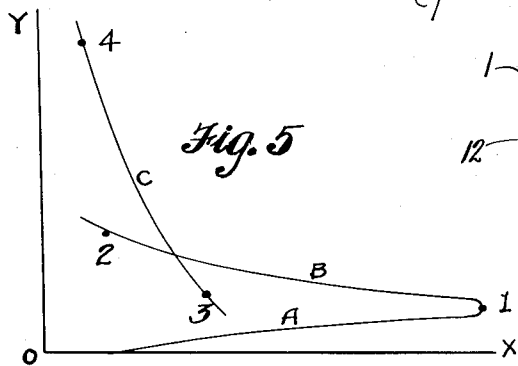
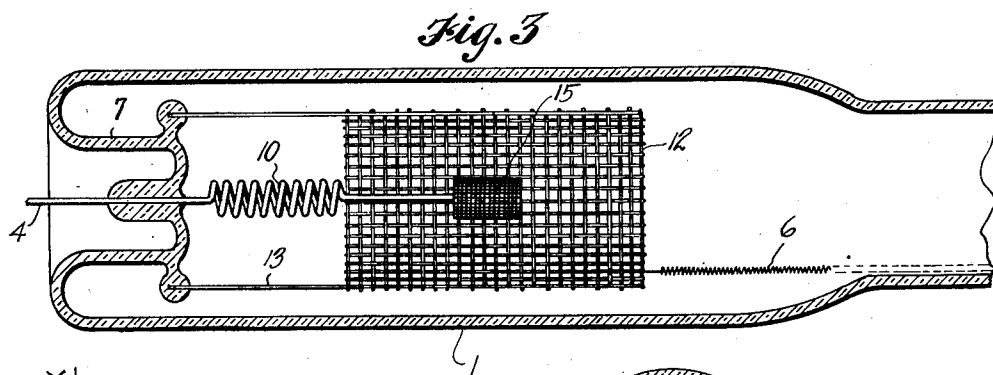
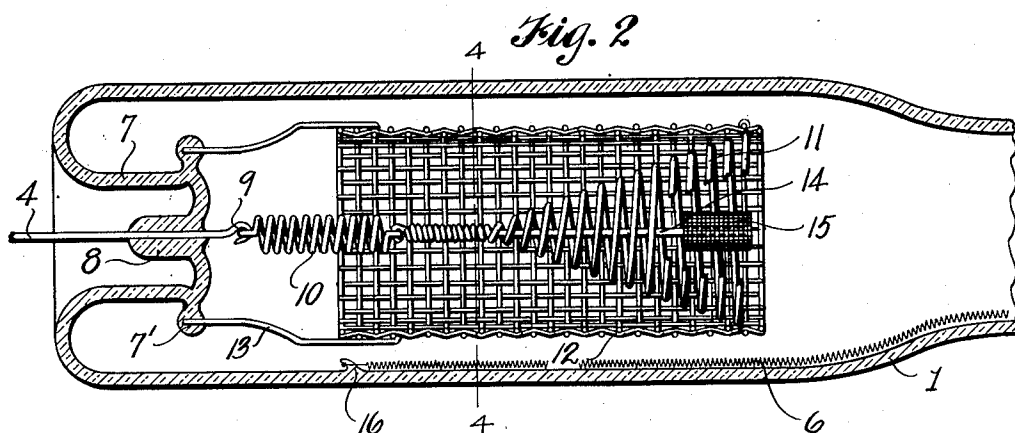
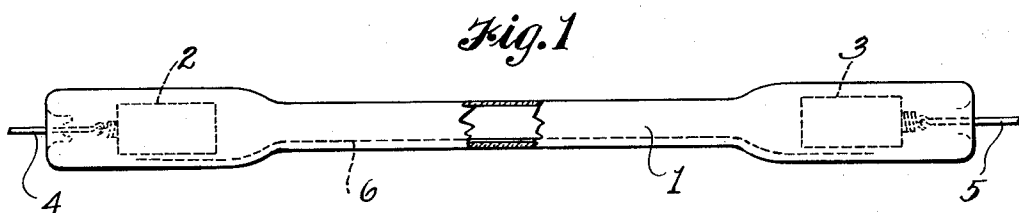
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LOW VOLTAGE GAS ARC LAMP

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LOW VOLTAGE GAS ARC LAMP

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This invention relates to the art of electrical illumination and it has reference particularly to gas arc lamps of low voltage suitable for purposes of general illumination as distinguished from what are commonly known as "corona lamps" or "glow lamps".

Before going into detailed explanation of the present invention it is thought advisable, for purposes of better explanation, and clearer understanding, to recite briefly the characteristics of corona lamps, glow lamps and arc lamps; also, a brief discussion of rare gas arc lamps as disclosed in the prior art.

It is a well known fact that any electrical circuit can give rise to the phenomenon known as corona provided that certain conditions are satisfied. Corona is descriptive of the leakage of electrical energy from the positive side of the circuit to the negative side, or vice versa, through an insulating medium when the potential gradient of the medium is sufficiently high to ionize said medium.

The potential gradient is proportional to the voltage between the parts of the circuit in question; the diameter of the electrical conductor, or the surface per unit length of the conductor; and to the dielectric characteristic of the medium. The dielectric characteristics include the density of the medium. A transmission line may not show corona near sea-level but sometimes shows considerable corona when passing over a mountain range. Therefore, the lower the density of the medium, the more readily corona appears. The surface condition of the conductor also has a bearing upon the readiness of formation of corona. A smooth conductor will give corona less readily than one with a rough surface or with points protruding. It may be stated, however, that corona does not appear unless the voltage of the circuit is sufficiently high to start ionization of the medium surrounding the conductor. This voltage is called "critical corona voltage". The "critical corona voltage" for a $\frac{3}{4}$ " diameter transmission line is approximately 175,000 volts.

When corona is formed in gaseous media, a glow of comparatively low intensity can be seen surrounding the conductor. This glow represents an electrical energy change to heat energy and is accompanied by a rise in temperature of the medium.

Rare gases, such as helium, neon, argon, xenon, etc., have a greater conductivity than air and hence they show corona at far lower voltage, especially when their density is considerably

lower relative to normal atmospheric pressure. Consequently, these gases lend themselves very readily to the manufacture of corona lamps, which consist mainly of a glass bulb containing a rare gas under very low pressure. This gas surrounds suitably spaced electrodes upon which a difference of electrical potential is impressed. Such lamps show a decided corona at very low voltages (120 volts and less) but this type of glow lamp has a very small luminous intensity so that it cannot be used for practical illumination.

As stated above, the amount of energy discharged from the electrical conductor, known as a corona discharge, is directly proportional to the voltage impressed. Consequently, the circuit may be said to have a positive resistance characteristic, by which is meant that the greater the voltage the greater is the current flow.

However, the corona phenomenon above described has a very important function in the invention herewith submitted as will appear later.

The term "glow lamp" is here applied only to bulbs or tubes containing a charge of rare gas, such as neon, helium, xenon, and others. It is well known that a transparent container charged with a rare gas and having two electrodes which are subjected to an electrical potential shows a glow from terminal to terminal if the impressed potential upon the terminals or electrodes is sufficiently high. Such tubes are well known today in the art of the electrical display-sign industry. The gases most commonly used in the art of luminous tube advertising are neon, helium, argon and mercury vapor. Each of these gases glows in its characteristic color when under electrical influence.

These glow tubes which have an internal diameter of approximately 15 millimeters or less operate under an electrical potential of approximately 1000 volts per meter. The current flow in these tubes is approximately 30 milliamperes. It is common practice in the manufacturing industry of display signs to connect several tubes in series so that the whole circuit of tubes will operate on a potential of about 16,000 volts. This comparatively high voltage is obtained by the use of a transformer, the primary of which is arranged to operate from a 120 volt circuit. An important feature of these tubes is the fact that they possess a negative resistance characteristic. By that is meant that, after the tubes are once functioning, the current therethrough has a tendency to rise rapidly to a large magnitude on the same voltage. In order to avoid this

rapid growth of current in these tubes the transformers are provided with a comparatively large leakage reactance so that, automatically, as the current begins to flow through the transformer the voltage of its terminals decreases to values which limit the current flow in the tube.

As a consequence of this relatively high internal leakage reactance of the transformer, the power factor of the circuit which carries these luminous tubes is in the neighborhood of 40%. Since a low power factor is undesirable from the standpoint of efficient transmission of electrical energy, it will be necessary to use condensers connected across the high potential side of the tube circuit in order to correct for this low power factor when the load taken by luminous signs becomes large enough to warrant such demands for the economic operation of the power system.

The luminous intensity from these tubes is rather low so that these tubes cannot be used for illuminating purposes in competition with the existing tungsten filament lamps. Furthermore, their use for internal illumination is objectionable because of the dangerously high potential required to operate them.

To summarize the above, the glow tube, although beautiful in appearance and highly decorative, cannot be used for illuminating purposes in competition with existing tungsten filament lamps. The tube circuit is costly because of the necessity of a high potential transformer. The electrical operating characteristics are undesirable from the standpoint of a low power factor, and their requirements for a very high potential for operation will limit them to installation outside of buildings in places which cannot be touched by human hands, or be safeguarded by other means.

The invention herewith submitted is related to the glow tube inasmuch as it contains all the elements of a glow tube and can be operated as such if its energizing current is properly limited. However, it contains additional features which produce glow at low voltage and change the glow to an arc for comparatively large current values.

If the electrodes in a closed glow tube are so shaped as to stimulate, either by material make-up or by special electrical circuit connection, the emission of electrons, the glow between electrodes changes to a distinct arc of extraordinary brilliancy. At the same time the voltage required to maintain this arc is far lower than the voltage required for the maintenance of the glow, so that an arc tube will operate at a voltage of 40 to 60 volts instead of 400 to 600 volts as required for the glow tube. The current consumption at the same time rises from 30 milliamperes to approximately 6, 7 and up to 10 amperes. This brilliant arc at once compares very favorably with the luminous intensity of the tungsten filament lamp from the standpoint of energy consumption and light emitted.

The arc tube, however, again has negative resistance characteristics, that is, the current has a tendency to grow as the voltage remains constant and in order to prevent a flash-over from terminal to terminal it is necessary to introduce a resistance or reactance element which automatically has a voltage drop comparable to the decrease in voltage required to maintain the arc, so that the terminal potential on which the tube is operating rises slightly as the current consumption of the tube increases.

The rare-gas arc lamps of the prior art differ

from the corona lamps and glow lamps inasmuch as they contain a means of stimulating electronic emission from the electrode; a means of starting the arc and a means of stabilizing the arc after it has been established.

The means of stimulating electronic emission consists either of a glowing filament or of a material such as an oxide of a metal. The glowing filament has long been known in the art of radio tubes for its characteristic of emitting a stream of electrons. Consequently, if a glowing filament is introduced into the vicinity of an electrode in a rare-gas glow tube, the cathode drop is considerably reduced by the electrons emitted, and an arc is readily established. It has also been known that some metallic oxides such as oxides of potassium, borium, strontium, etc. also readily emit electrons when under electrical stimulation. Therefore, the electrodes of some arc tubes of the prior art are made of this metallic oxide.

All low-voltage arc tubes of the prior art require a high voltage arc starting device. Although conditions may be satisfied to maintain a low-voltage arc, this arc does not kindle on that same low voltage on which the tube operates. The initial ionization of the gas between electrodes requires a high voltage such as is necessary for the glow tubes. The same effect, namely the stimulation of ionization, may be accomplished by a high-frequency, high-potential electrical discharge in the neighborhood of the tube. Consequently, the low-voltage tubes of the prior art are equipped with a high voltage "kicking coil" which is connected to the tube circuit only during the starting period of the arc; or they are exposed to the effect of a "Tesla coil" for the arc-starting period. The above starting means may not be the only means of starting an arc in a glow tube, but any sudden high potential impulse, such as the collapse of a magnetic field or of a dielectric field may also be used.

The stabilization of the arc is necessary because, as stated above, the arc in a glow tube has a negative resistance characteristic. By connecting a resistance in series with the glow tube, so that the total voltage of the tube circuit includes the voltage drop of the resistance, the circuit as a whole may be made to have a positive resistance characteristic. Similarly, a reactance drop may be utilized in the form of a reactance coil to provide automatically a voltage drop in excess of the negative drop of the arc, so that the ohmic drop of the whole tube circuit increases with the growth of the current in the circuit.

The above three requirements of the low voltage arc tubes of the prior art introduce special and costly materials in the make-up of the tube electrodes, necessitating the use of special circuits for cathode heating and of other auxiliary equipment for the proper functioning of the arc tube.

The present invention belongs to the class of low-voltage arc lamps and the object of the invention has been to provide a low voltage gas arc lamp suitable for purposes of general or special illumination, operating on either direct or alternating current, and being free from all external means or equipment for stimulating, starting or stabilizing the arc, that is, a lamp which within itself contains all of the necessary elements for kindling and maintaining a steady arc from a low but constant potential or direct current source of electrical energy.

It is also an object of this invention to produce a lamp in accordance with the above statement,

the life and efficiency of which, from an illuminating standpoint, are greater than the life and efficiency of all arc lamps of the prior art, and which can be produced economically in commercial quantities.

Other objects of the invention reside in the construction of the electrodes and in the provision and use of a special arc kindling means within the lamp.

In accomplishing these and other objects of the invention I have provided improved details of construction, the preferred forms of which are illustrated in the accompanying drawing, wherein—

Fig. 1 is a side view of a gas arc lamp embodying the present invention.

Fig. 2 is an enlarged sectional view of one of the terminal portions of the lamp and the electrode contained therein.

Fig. 3 is a longitudinal, sectional view illustrating an electrode of an alternative form of construction.

Fig. 4 is a cross section on line 4—4 in Fig. 2.

Fig. 5 is a graphic illustration in which curves have been plotted to illustrate current and voltage relationship of a rare gas lamp.

Referring more in detail to the drawing—

First, with reference to Fig. 5, this illustrates the current and voltage relation of a lamp filled with a rare gas, such as neon. When a difference of potential exists between the two electrodes of the lamp placed sufficiently close together and this difference of potential is made to rise from zero to larger values as read along the abscissa OX, a very small current is observed to flow. This current increases almost in proportion to the increase in voltage "E". A faint glow is observed to envelope the electrodes which is a visual indication of corona. As the voltage is increased to the critical value (abscissa of point 1) the gas between the electrodes becomes luminous and the current in the lamp increases while the voltage across the lamp terminals decreases. The lamp has changed its corona performance as depicted by curve A to glow performance shown by curve B. The glow of the lamp persists although its voltage may decrease to the value of abscissa of point 2. At the same time, the current in the lamp assumes considerable proportions as compared to the corona current. If this current is large enough to heat the electrode sufficiently for electronic emission, the glow changes to an arc. If this emission does not occur, the lamp will cease to function. When the arc strikes, the current changes instantly to a much larger value (ordinate of point 4) and the performance of the lamp is now described by curve C.

Not only does the electrical performance change very strikingly when the arc begins to function, but the luminous brilliancy also changes from a weak glow to a light of remarkable intensity. The lumens per watt emitted compare favorably with the tungsten filament lamp with the added advantage of a greatly decreased intrinsic brilliancy. That is, in the tungsten lamp, all the light flux emanates from a very small space so that direct visualization of it is painful and harmful to the human eye, whereas the light flux from the gaseous arc lamp emanates from all the space within the lamp. Consequently, a tungsten lamp necessitates the use of a dispersing shade which absorbs approximately 15% of the total emitted light flux, while all of the light flux from the arc lamp is available for direct illumination without disagreeable or harmful visual sensations.

The operation of the present lamp is similar

to that of the arc lamps above described when once the arc is started, but it differs from all arc lamps of the prior art inasmuch as the construction of its electrodes is fundamentally different. It is the particular arrangement and construction of the electrodes that makes it possible to operate the lamp free of all auxiliary equipment for kindling the arc and for maintaining it.

Fig. 1 shows one form of a low-voltage arc lamp consisting of an airtight, tubular, transparent vessel 1 which is provided at its opposite ends with terminal electrodes 2 and 3, connected with the terminals 4 and 5 which would lead to a suitable source of electrical energy. Contained within the tube, and extending from one terminal portion to the other, is the kindling element 6. In this illustration the electrodes 2 and 3 and the kindling element 6 have been shown in dotted lines.

The details of construction of a terminal portion of the tube of Fig. 1 and the electrode contained therein are illustrated in Fig. 2. The vessel 1, as seen in Fig. 2, is constricted at its electrode ends to smaller tubular portions 7 that project inwardly and preferably co-axially of the vessel to serve as supports for the terminal seals 8 and for the electrodes proper. Each of the metallic terminals 4 and 5, is provided on its extremity within the vessel, with a hook 9 to which one end of a resistance coil 10 is attached; this coil extends co-axially with the vessel and the inner end thereof is attached to the apex of a conically spiraled coil 11, the base of which is fastened to a cylindrical metallic screen 12. Each screen 12 is held in position concentrically within its end of the vessel, and in position to enclose the spiral 11 therein, by a plurality of supporting rods 13 which have ends firmly attached to the screen and have their other ends sealed into a peripheral flange 7' formed about the inner end of the adjacent tubular portion 7.

Contained co-axially within each of the spiral coils 11 is a metallic rod 14 which is fastened within the apex of the spiral at one end and, at its opposite end, which terminates substantially at the plane of the base of the spiral, carries an arc stimulating element such as a fine mesh screen sleeve 15, of a special metal of high emissivity, such as nickel.

The transparent vessel 1 is also provided with its terminal enlargements with protuberances 16 in hook form which serve as means of attachment and support for the opposite ends of the kindling element 6, which is here shown in the form of a long wire coil of small diameter, and its ends are in spaced relation to the screens 12.

The operation of the low voltage arc lamp of Figs. 1 and 2 is described as follows:

When the terminals 4 and 5 are connected to an alternating current circuit so that a difference of potential of approximately 120 volts exists between them, a current tends to flow from terminal 4 to 5 for one-half of the cycle and from 5 to 4 during the other half of the cycle. For greater simplicity one-half cycle will be described only, the other being merely a repetition of the first half in the reverse direction. The current tends to flow through terminal 4, thence through resistance coil 10, through spiral 11 and into screen 12. Here a gap in the circuit, namely the space between screen 12 and the kindling element 6, prevents the current from flowing to the other terminal 5. A similar gap exists between kindling element 6 and the electrode 3 at the other extremity of the lamp. Hence, no cur-

rent can flow through the lamp, as long as these two gaps offer sufficient resistance against the existing voltage between terminals 4 and 5.

However, when the vessel 1 is filled with a rare gas, such as neon, argon, krypton and others, at a pressure of approximately 10 mm. or less, a potential of 110 volts is sufficient to cause a small current to flow from screen 12 to the kindling element 6. This current is the corona current as previously described in the specification. If the vessel 1 be filled with neon, a deep orange glow is seen enveloping all the metal parts within the lamp, except that part of the kindling element 6 which is not in the close vicinity of screens 12. The lamp then operates as a corona lamp.

As the voltage of the terminals is gradually increased, the corona glow begins to creep along the kindling element 6 toward the center of the lamp, and as soon as the glow completely envelops the kindling element 6, the whole lamp flashes into a glow of deep red orange color, filling all the space between the electrodes 2 and 3. The lamp in this stage of operation has become a glow lamp. Its appearance is similar to the neon glow tubes of the prior art which are essentially high-potential tubes.

The glow of the tube does not persist very long. Since the glow tube has negative resistance characteristics, as explained in the specification, the current through the lamp rapidly increases to such proportions as to create a hot cathode spot somewhere on the surfaces of screen 12, spiral 11 or rod 14. The heat emanating from the surface of the electrode at once creates a condition which changes the glow performance of the lamp to arc performance. This change from glow to arc is powerfully stimulated by the electronic emission of the arc stimulating means 15 at the inner end of the rod 14. As the arc suddenly kindles, the brilliancy of the lamp increases manifold. At the same time, the current in the lamp also increases due to the practical elimination of the cathode drop which is considerably high during the glow performance. A rush of current into the lamp takes place which would increase indefinitely due to the negative resistance characteristics of the arc, if the ballast resistance 10 were not placed into the circuit. The resistance drop across coil 10 must, therefore, be such as to compensate for the drop in arc potential as the arc current increases. Coil 10 is designed so that its resistance drop with the normal arc current is slightly greater than 5% of the terminal voltage of the lamp. With two such resistors, one on each end of the lamp, the ballast resistance drop of the lamp is slightly greater than 10% of the terminal voltage.

The operation of the low voltage lamp as described above consists of three separate steps, namely corona, glow and arc, only if the terminal voltage is gradually and cautiously increased from about 100 volts to the final operating voltage of the lamp. If the lamp is suddenly connected to a 120 volt main, as for instance by the closing of a switch, the three progressive steps in performance follow each other so rapidly that it appears as though the arc were formed without preliminary corona or glow. But since in alternating current circuits the voltage rises gradually from zero to a maximum twice during each cycle, it is evident that all parts of the electrodes function successively twice per cycle, that is, the lamp changes from corona to glow and from glow

to arc and vice versa as the circuit potential rises and falls during the cycle.

In the construction illustrated in Fig. 3, the same results, as with the lamp of Fig. 2, can be obtained however, in this electrode the coil 11 has been eliminated and the kindling element 6 has been connected directly to the screen 12. This arrangement is possible by reason of the fact that the gas itself provides sufficient conductivity between the arc stimulating screen 15 and screen 12 to carry the corona current necessary for the kindling of the arc, provided that the element 15 be given sufficient area to produce corona when the circuit is closed.

The low voltage lamps above described also function when connected to a direct current source. However, the arc, once established, remains stable and does not have to be kindled periodically as is required for the alternating current arc. Since the direct current arc lamp operates with a continuous arc, its brilliancy is also greater than that of the alternating current lamp for the same voltage and current flow. The periodicity of the alternating current arc lamp introduces periods of absolute darkness, faint corona and glow of low intensity into every cycle, which makes the integration of the total lumens emitted less than for a continuous arc.

While Figs. 2 and 3 illustrate two different embodiments of the principles of my invention, however, it is evident that the principal design features which must be satisfied in these lamps or in modifications thereof are:

First, the lamp must have a conductor leading between the electrodes along which corona may be formed along the whole arc path at low voltages. For practical operation, this conductor, herein called kindling element, must have a potential gradient higher than the arc gradient along the arc path, and its resistance must be in the neighborhood of 100 ohms, or more, per foot of arc path. This kindling element should be within the lamp since its corona glow within the rare gas stimulates ionization in the arc path. Again, the required potential gradient of the kindling element is greater the higher the internal gas pressure, the smaller the diameter of the arc tube and varies with the material make-up of the gas or gases within the lamp. The exact quantitative relations of the above variables can be found by experiment without difficulty. The kindling element may be made of suitable resistance wire, or of a carbon filament, or of a conductive ribbon painted upon the inside surface of the glass container 1, or the vessel itself may be made sufficiently conductive for this purpose.

Second, the lamp electrode, as in the device of Fig. 2, must have sufficient metallic surface to facilitate the formation of corona. Screen 12 may be replaced by a solid cylinder or by rods in squirrel-cage arrangement; coil 11 may be made of a series of small cylindrical coils, tied together on one end to be fastened to coil 10; it may have a different shape than that of a cone, etc. But the principal function of coil 11 is to furnish a conductive path from coil 10 to screen 12 of sufficient resistance so that the arc will preferably strike from parts 14 and 15 rather than from screen 12, or from coil 11. It has been found that when the lamp is operating under glow conditions, the ions of the glow stream preferably emanate from the inside surface of a cylindrical or conical electrode, whereas the arc emanates with apparently equal ease from a solid rod or the outside of a hollow cylinder, but always prefers

to root itself to a hot spot wherever this spot may be located. Consequently, when during the period of glow performance a cathode spot forms, it tends to form on the inside surface of either screen 12 or coil 11. This cathode spot is unstable in location and shifts position constantly. When the glow changes to the arc, the latter roots preferably on the hot cathode spot, wherever that spot may happen to be. It is desirable, however, to limit the arc roots on the electrodes to that part of the electrode which is especially constructed to withstand the high temperatures involved. Hence, the lamp must be so constructed that the voltage available for the maintenance of the arc proper is greater per unit length of arc between the desired root points of the arc than between any other two surface points of the electrodes. By reference to Fig. 2, it is seen that, if the arc would root on one of the turns of spiral 11, the arc current would first have to flow from the apex of the cone through the spiral to the root point with a consequent voltage drop equal to the product of the current and the resistance of the length of spiral traversed by the current. The voltage available for the maintenance of the arc would then be the voltage between coils 10 of both electrodes reduced by the above mentioned resistance drop. However, the voltage between rods 14 and elements 15 of both electrodes is equal to the voltage between coils 10 since the resistance of rod 14 is negligible. At the same time, the arc when rooted to screens 15 has the shortest possible length. From the above, it is manifest that in the construction of the electrodes as shown in Fig. 2, the arc, when rooted to parts 14 and 15 has a greater available voltage per unit of its length.

In a lamp using terminal electrodes of the type shown in Fig. 3, the gas itself provides sufficient conductivity between rod 14 and screen 12 that the resistance coil 11 is not necessary. However the action is the same as described with reference to the electrode of Fig. 2.

Third there must be an introduction of ballast resistance into the interior of the lamp itself to create a considerable potential drop within the conductive gas in the lamp. The potential gradient in coil 10 must be smaller than that of the surrounding gas or the current would rather flow through the gas than through coil 10. In order to satisfy the requirement for a comparatively low potential gradient in coil 10 the gradient in the gas must be kept high. Hence the gas must not be exposed to electrical stimuli which would tend to ionize it and thus make it highly conductive. The arc would then root on hook 9 of terminal 4 rather than on parts 14 and 15. The result would be an unimpeded current flow into the lamp or a short circuit. It is necessary, therefore, to design the electrode so that the voltage drop of coil 10 is less than the voltage drop of a possible arc from hook 9 to screen 15 through the gas in the lamp.

The electrical circuit characteristics within the low voltage arc lamp are far more complicated than ordinary electrical circuits which may be readily analyzed by the application of Ohm's law. Since all the circuit constituents, comprising ballast resistance, screens, inter-screens, resistance and kindling element, are enveloped by a conductive medium, namely the rare gas in the lamp, there is a slight leakage of current from all parts of the metallic conductors from one point of the circuit to other points of different potential. This

phenomenon makes mathematical calculations of performance practically impossible and necessitates therefore, the evaluation of the circuit variables by experimentation. It is also apparent that the variables are many in number, as for instance, the kind of gas or gas mixtures for best operation; the gas pressure in the lamp; length and diameter of lamp; the geometric dimensions and relations of the different parts of the electrodes; the kind of materials best suited for the different parts of the electrodes, etc. Although the invention is based upon a great many of such experiments, it is expected that slight modifications of its present form and of its constituent parts will suggest themselves as experimental data accumulates in the near future. However, the basic principles of operation are now plainly recognized and are described above.

Having thus described my invention, what I claim as new therein and desire to secure by Letters Patent is—

1. In a gas arc lamp comprising a sealed vessel with terminals on which electrical potential may be impressed to energize the lamp, an electrode within a terminal portion of the lamp, a ballast resistance element connecting the electrode with its terminal; said electrode including an arc stimulator connected to the terminal through said ballast resistance, a corona producing member and a resistance element connecting the corona producing member with the ballast resistance through which current will flow to the corona producing surface to stimulate the formation of the arc but which has resistance characteristics which will confine the current to the arc stimulator after the arc is formed.

2. In a gas arc lamp comprising a sealed vessel with terminals on which electrical potential may be impressed to energize the lamp, an electrode within a terminal portion of the lamp comprising a ballast resistance element connecting the electrode with its terminal, an arc terminal connected to the ballast resistance, a sleeve enclosing the said arc terminal and a resistance connection between the sleeve and ballast resistance; said ballast resistance having a resistance drop which will compensate for any drop in arc potential and having a potential gradient less than that of the surrounding gas and said resistance connection having resistance characteristics which will confine the current to the arc terminal after the arc is formed.

3. In a gas arc lamp comprising a sealed, tubular vessel with circuit terminals sealed therein and on which electrical potential may be impressed to energize the lamp, an electrode comprising a ballast resistance coil connecting the electrode to the current terminal, a rod jointed with the ballast resistance and having arc stimulator at its inner end, a sleeve of screen like construction located about the rod and the arc stimulator, a resistance coil within the sleeve about the arc terminal and joining the sleeve with the circuit terminal through the ballast resistance; said sleeve, arc terminal and resistance coils being coaxial of the tube and said ballast resistance having a resistance drop which will compensate for any drop in arc potential and having a potential gradient less than that of the surrounding gas and said resistance connection having resistance characteristics which will confine the current to the arc terminal after the arc is formed.

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