Dec. 16, 1952 W. D. BUCKINGHAM 2,622,223

ARC REGULATOR APPARATUS

Original Filed Aug. 10, 1949

FIG. 1

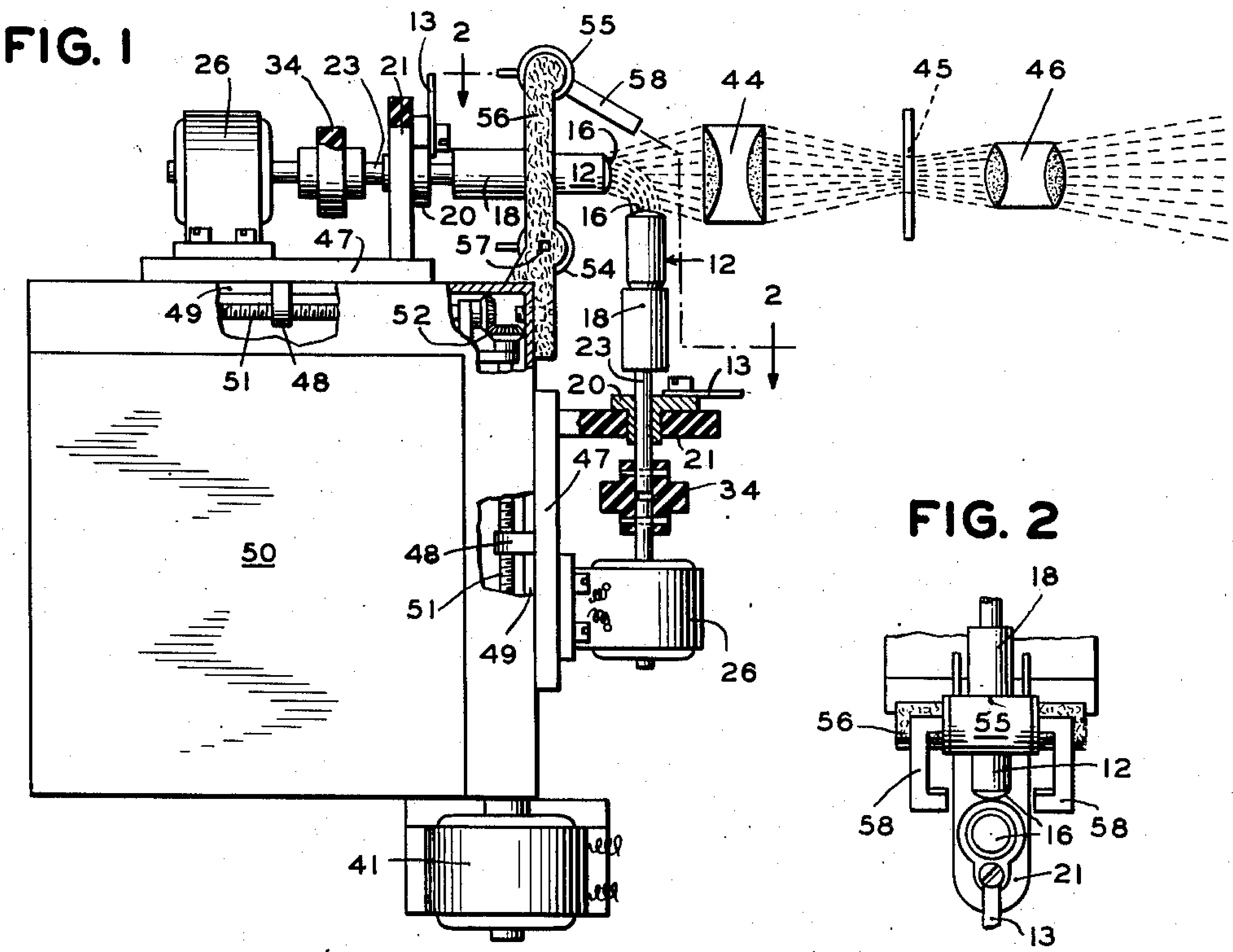
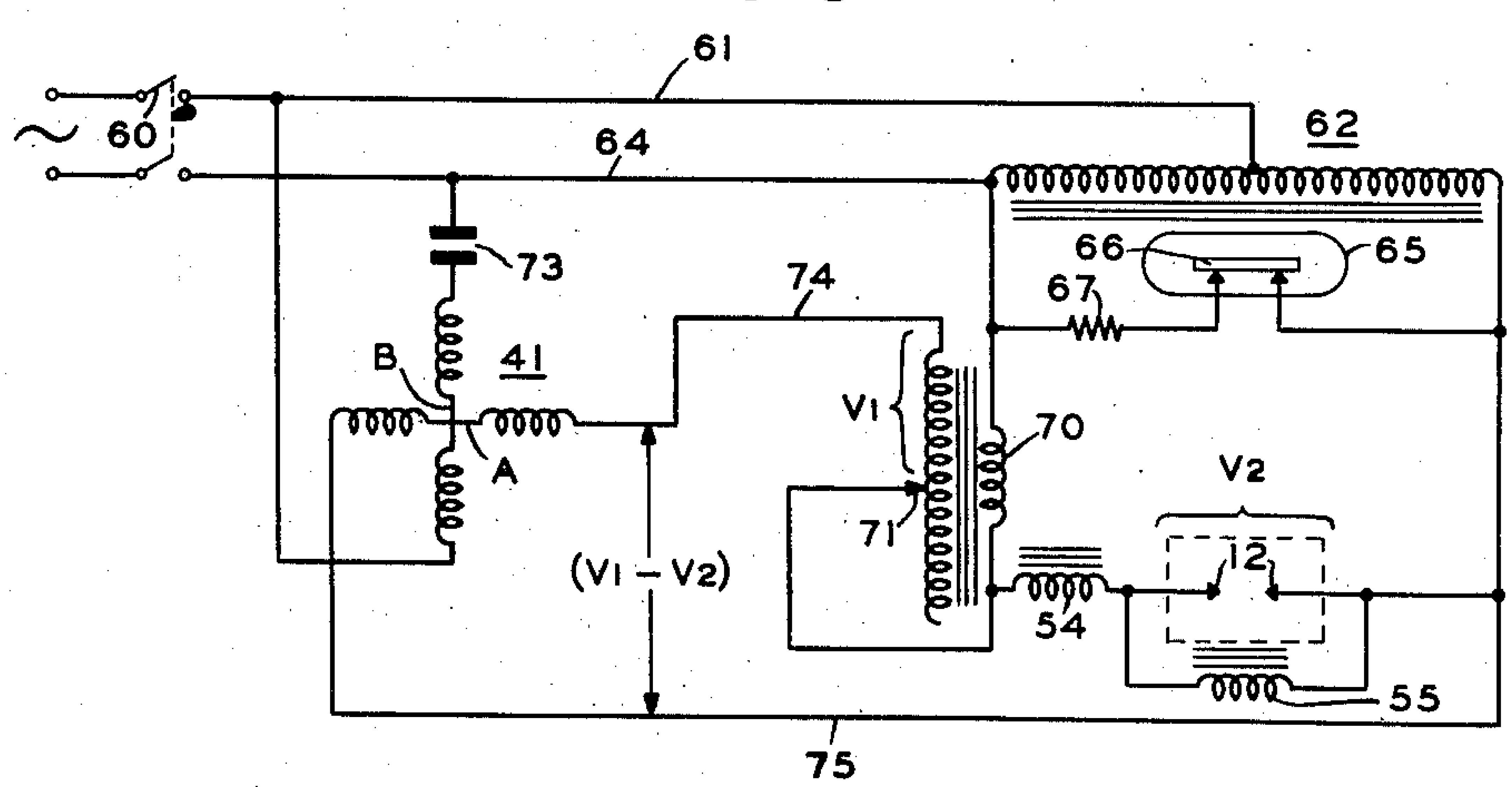


FIG. 2

FIG. 3



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ARC REGULATOR APPARATUS

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Original application August 10, 1949, Serial No. 109,456, now Patent No. 2,541,028, dated February 13, 1951. Divided and this application December 21, 1950, Serial No. 202,069

7 Claims. (Cl. 314—43)

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This invention relates generally to improved means for magnetically controlling arc discharge devices, and more particularly to suitable arc regulator apparatus for determining and maintaining a desired spacing between electrodes, and a desired positioning of the arc on the active surfaces of the electrodes, in concentrated arc discharge lamps of the type described in Buckingham and Deibert Patent No. 2,453,118, which operate with a highly concentrated arc discharge in contradistinction to a low pressure diffused or glow discharge, the disclosure of which patent is incorporated herein by reference thereto.

This application is a division of application Serial No. 109,456, filed August 10, 1949, now Patent No. 2,541,028, issued February 13, 1951.

With suitable construction, such as illustrated herein, a concentrated arc device of the foregoing type is particularly adapted for use in high wattage lamps, such as those used in flood lamps, search lights and the like, operating in the open air and powered from a source of alternating current supply. The lamp utilizes two electrodes, which in an alternating current type operate as anodes and cathodes during each cycle of the alternating current supply which may be the 110 volt, 60 cycle current commonly available. Each of the electrodes may comprise a generally cylindrical metal tube or shell that is closed at one end and is filled with the electrode material. The thin active surface film of the electrode material at the open end of the tube comprises a molten metal, such as zirconium or hafnium, when the lamp is in operation, and underlying this active surface film is an oxide of the metal. This oxide has a melting point much higher than that of the base metal which has high electron emissive properties at the very high temperature at which the device operates, but which is not a sufficiently good electron emitter at lower temperatures to cause the electrons to be emitted in sufficient quantity to support an arc of high current density until the metal has reached incandescent temperatures, well above the melting point of the metal.

Either zirconium or hafnium metal is a better electron emitter at high temperatures than is its oxide, and it also has a lower melting temperature; thus, under the intense ionic bombardment of the arc a very thin molten film of this metal is formed over the active surface area of the electrode, and as soon as it is formed the temperature of the electrode drops slightly and the underlying oxide solidifies and supports the film of molten metal on its surface. It is this thin

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film of molten metal that is the chief source of the visible radiation from the lamp. It is so thin that surface tension holds it to the oxide backing so that the lamps may be burned in any position.

An important feature of the electrode structure is that the lamp may be operated in the open air, and when thus operated the voltage drop across the lamp is within the range of 50 to 150 volts depending upon the magnitude of the current flowing through the lamp and the length of the arc gap, thereby substantially reducing the losses heretofore occasioned in ballast resistors of the size required with lamps having comparatively low voltage drops and operating from a 110 volt source of supply. In addition, the brightness of the lamp is greatly increased when operating in air; a zirconium metal lamp in air produces from 100 to 132 candles per square millimeter of active surface area, depending upon the size of the lamp, which is approximately twice the brightness of a zirconium oxide concentrated arc lamp operating in an envelope with a gas filling of argon and the like. The same effects and advantages are present with powdered hafnium metal as the electrode material and operating in air; a 25 watt lamp has a brilliance of 172 candles per square millimeter of active surface area, compared to 100 candles with hafnium oxide operating in argon.

The electrodes of the lamp slowly erode at their active ends during operation, but a portion of the zirconium or hafnium which is exposed to the arc oxidizes thereby to maintain the oxide layer which underlies and supports the film of molten metal on the surface of the electrodes. Each electrode may be as long as desired, for example, several inches long in the large size lamps, thereby to compensate for the burning of the active end of the electrode.

Although the rate of erosion of the electrodes is very low, it is desirable to provide means for automatically maintaining the adjacent active surfaces of the electrodes at their proper spacing during operation of the lamp, and also to automatically move the electrodes towards each other to facilitate starting of the lamp and to move them away from each other to the proper spacing as soon as the lamp has started. A suitable spacing between the adjacent ends of the electrodes generally is from one to two times the outside diameter of the electrode. It was attempted to employ balanced voltage-current solenoids for maintaining the correct distance between the electrodes, but the non-linear characteristics of the solenoids resulted in inaccurate control, and their massive armatures produced hunting problems which were difficult of solution. It is also desirable in certain instances to provide means for automatically rotating the electrodes about their longitudinal axes to insure proper centering of the light spots in their active surface areas.

One of the objects of the invention is the provision of more suitable means for automatically determining and maintaining a proper spacing between the adjacent ends of the electrodes of the arc discharge device, which means will automatically move the electrodes towards each other to facilitate starting the lamp and then move the electrodes away from each other to their proper spacing when the lamp has started.

Another object is to provide suitable control means for automatically maintaining a proper spacing between the electrodes, without having the control mechanism in the field of projection of the light.

A further object is to provide suitable means in combination with the automatic spacing means for automatically rotating the electrodes relative to each other about their longitudinal axes to insure proper centering of the light spots in their active surface areas.

Other objects and advantages of the invention will be apparent in the following detailed description of an illustrative embodiment thereof, taken in connection with the accompanying drawings in which:

Fig. 1 is a view, in elevation, of a high wattage open air lamp adapted to be powered from alternating current, in which the electrodes are mounted approximately at right angles to each other, with improved means for automatically determining and maintaining the correct distance between adjacent ends of the electrodes, the figure also showing means for rotating the electrodes about their longitudinal axes;

Fig. 2 is a fragmentary view, taken along the line **2—2** of Fig. 1; and

Fig. 3 shows a circuit arrangement for operating the alternating current lamp illustrated in Fig. 1 with means for automatically determining and maintaining the correct distance between the electrodes, and including means for automatically controlling the position of the arc stream.

Referring to Figs. 1 and 2 of the drawings, there is shown a construction adapted for use with high wattage lamps, capable of operating in the open air and powered from a source of alternating current supply. The lamp utilizes two electrodes **12**, which may be identical in construction if desired, and which alternately operate as anodes and cathodes during each cycle of the alternating current supply. The electrodes may be disposed in axial alignment with each other, or may be disposed at an angle of approximately ninety degrees to each other, as shown in Fig. 1, in order to provide an unobstructed light output from the lamp. The light, which principally comes from the active surfaces **16**, passes through a condenser lens **44** and thence through a light aperture **45** and projecting lens **46**.

The interior construction of each of the electrodes preferably is in accordance with that disclosed in the parent case of which this is a division.

The electrode material may comprise zirconium or hafnium metal powder with which is

mixed a material that protects all but the active end of the core from oxidation, whereby progressive oxidation of the zirconium or hafnium metal beneath the underlying oxide layer can be prevented.

A suitable powdered metal, such as nickel, in the proportion of about one part of nickel to three parts of zirconium metal powder, when zirconium is employed, has been found to produce a mixture which does not progressively oxidize throughout its entire volume as would be the case if zirconium alone was used. Such electrodes acquire only a thin cap of zirconium oxide at the active end, and the underlying conductive nickel and zirconium mixture remains to aid in starting the lamps.

Preferably there is also added to the zirconium-nickel mixture a small percentage of metallic substance, such as magnetite, which is an oxide of iron, the magnetite increasing the electrical conductivity through the fused oxide cap when the electrode is cold, and thus aids in starting.

The exact proportions of the metals and oxides in the whole mixture do not seem to be critical. However, if more than 40% of nickel is employed in the mixture, excessive smoking occurs and the electrode erodes away more quickly; if less than 5% of nickel is employed, the protective action of the nickel is not present. With respect to the conductive material, such as magnetite, from 2% to 15% may be employed.

As hereinbefore stated, each of the electrodes slowly erodes during operation of the lamp, and a portion of the zirconium which is exposed to the arc does oxidize thereby to maintain the underlying oxide layer, but further oxidation of the mass below the oxide layer does not take place to any substantial extent. The same effect is obtainable when hafnium metal powder is used instead of zirconium metal powder.

Each of the electrodes **12** is mounted in a holder **18** which is carried by a rotatable metal shaft **23**. Surrounding each shaft, and in good electrical contact therewith, is a metal collector block or collar **20** to which is secured, as by soldering or by screws, the external terminals **13** of the lamp. Each collector block is secured to an insulating block **21** that is mounted on a slidable block **47**, one of the blocks resting on the top surface of a cabinet or supporting frame **50**, and the other block **47** being mounted on a vertical side of the structure **50**. Each of the blocks carries a motor **26**, and the shaft of each motor is connected, by an electrically insulating coupling **34**, to the shaft **23** thereby to rotate the associated electrode **12** in the proper direction about its longitudinal axis. The motors **26** may be either direct or alternating current type, and the electrodes are thereby rotated at suitable speeds about their longitudinal axes in opposite directions relative to each other. This speed may be quite low, for example, one revolution per minute, and should not be so high as to cause appreciable centrifugal forces to be exerted on the active surfaces of the electrodes or to cause rotation of the arc spot. A symmetrical oxide bead is thus formed and maintained on each electrode and the position of the luminous spot on each electrode is stabilized.

Fig. 1 shows the improved means for automatically bringing the electrodes together for starting the arc and for maintaining them at a correct distance from each other during operation of the lamp. The proper electrode-spacing operation is based on a differential action between the arc voltage, i. e., the voltage drop across the arc, and the arc current flowing at any instant. A satisfactory control is obtained by the use of a small two-phase alternating current motor 41 as the balance detecting unit. Each of the blocks 47 has a lug 48 which passes through a slot 49 in the frame structure 50, the lug 48 being internally threaded and receiving a threaded shaft 51, and the shafts 51 are geared to each other through bevel gears 52. The shafts have right hand and left hand threads so that when the motor 41 turns in one direction, the blocks 47 and hence the electrodes will move towards each other, and when the motor reverses its direction the blocks and electrodes carried thereby will move away from each other. The motor advances the electrodes until they touch and the arc is struck by a high voltage starting pulse, and when the arc current is established the motor draws the electrodes apart to the proper operating distance and then stops. As hereinbefore stated, a suitable spacing between the electrodes is generally from one to two times the outside diameter of the electrode. As the electrodes slowly burn away, the control motor advances the electrodes to maintain their spacing and the relative positions of the luminous spots constant. The motor 41 is controlled in a manner hereinafter described in order to maintain the desired spacing between the electrodes.

It will be seen from Fig. 1 that when the electrodes are disposed at an angle to each other, the arc stream between the active surfaces 16 of the electrodes should follow a curved path, but sometimes the arc stream would tend to concentrate on the edges of the electrodes closest to each other, and at other times would tend to rise due to convection currents and also when the arc stream became too long. In order to prevent this there is provided an electromagnet comprising a coil 54 which is in series with the arc electrodes of the lamp, and an electromagnet 55 which is bridged across the electrodes, these magnets being mounted on an insulating support structure 56 which is secured to the casing 50. The magnet 54, which is the current coil, is wound around a straight core 57 of magnetizable material, and the coil 55 is wound around a U-shaped core of magnetizable material having projecting leg portions 58. The electromagnet 54, which is in series with the electrodes, may comprise for example 200 ampere turns for use with a 750 watt lamp, and the second electromagnet 55 which is connected across the electrodes may have for example 100 ampere turns. The current coil 54 is poled so that its external magnetic field tends to force the arc stream outwardly, whereas the voltage coil 55 is poled so that its external magnetic field tends to force the arc stream inwardly and keep the arc from rising. The resultant field maintained by the two electromagnets operates to keep the arc stream centered on each of the active surfaces 16 of the electrodes and cause it to follow the curved path indicated by the broken lines in Fig. 1. Since the magnetic effect of one of the windings is proportional to the current flowing in the arc stream and the magnetic effect of the oppositely poled winding is proportional to the voltage drop across the arc, the resultant effect of their magnetic fields tends to maintain the voltage-current relationship and hence the length of the arc constant. This feature relates to other divisible subject matter which is claimed in my copending application Serial No. 177,612, filed August 4, 1950, now Patent No. 2,608,675, issued August 26, 1952.

Fig. 3 shows a starting and running circuit for the lamp, with means for automatically maintaining the proper distance between the electrodes in accordance with the instant invention. When the line switch 60 is closed, current is applied over a circuit comprising conductors 61 and 64 to a high leakage reactance transformer 62 of the constant current type. The transformer shown is an auto-transformer, and conductor 61 is connected to the midpoint thereof so that if 110 volts of alternating current is applied to the primary part of the transformer, 220 volts will be generated across the secondary of the transformer. Bridged across the transformer is a vacuum switch 65, the switch being of the type in which the circuit is made and broken between solid contacts in a vacuum in response to a magnetic field, such a switch having been found to be very effective to provide the surge required in starting concentrated arc lamps of the type disclosed herein. The transformer 62 has an iron core and an open air gap and hence sets up a magnetic field which, when line switch 60 is closed, attracts the magnetizable bar or armature 66 of the vacuum switch, opening the circuit formerly through the switch contacts, the latter circuit including the electrodes 12 of the arc lamp. Various kinds of such switches are well known; one particularly suitable for the purpose is disclosed in my copending application Serial No. 35,928, filed June 29, 1948, now Patent No. 2,564,877, issued August 21, 1951, the structure of which enables the switch to be mounted in an aperture in the core of transformer 62. Opening the circuit of switch 65 causes a surge of from 1000 to 2000 volts to appear across the electrodes 12 of the lamp, the surge being due to collapse of the field in the transformer 62, this circuit including a resistor 67 and the winding of electromagnet 54 which is a current coil such as referred to in the foregoing description of Figs. 1 and 2. When the gap between the electrodes 12 breaks down due to the voltage surge, the current flowing through transformer 62 from the supply line 60 maintains the arc across the electrodes and also keeps the contacts of switch 65 open so long as the lamp is operating.

Connected between one end of the transformer 62 and the electrode terminals is a transformer 70 through which the arc current flows. The secondary winding of the transformer 70 has a variable tap connection 71, the upper end of the secondary winding being connected by means of a conductor 74 to one of the windings A of a two-phase motor, the other end of winding A being connected by a conductor 75 to the right-hand end of the transformer 62. The winding B of the two-phase motor 41 is connected across the supply conductors 61 and 64, a condenser 73 being connected in circuit therewith in order to give a phase displacement so that there will be a suitable phase difference between the currents in the two windings A and B of the motor to provide the necessary starting torque for the motor.

The adjustable contact 71 on the secondary winding of transformer 70 enables the voltage V1 developed across the winding to equal the voltage V2 across the lamp terminals at the proper spacing of the electrodes. When voltage V1 equals voltage V2, the two-phase motor 41 has no voltage on one phase represented by its winding A. When the supply current is applied to the lamp through transformer 62 and before the lamp has started, the voltage V2 is high and voltage V1 is substantially zero, and the motor 41 rotates in a direction to close the gap between the electrodes until they either touch each other or are sufficiently close to start the arc. The voltage V2 then drops rapidly, and the voltage V1 rises rapidly from zero and usually will be greater than V2. Under these conditions the motor 41 will operate to separate the electrodes to the correct spacing as previously determined by the adjustment of the contact 71.

If the arc spacing becomes too great, the voltage V2 increases, and the current through the arc decreases and hence voltage V1 decreases, so that there is a difference between V1 and V2 and this difference causes current to flow through winding A of the motor and causes the motor to rotate in a direction to bring the electrodes towards each other. If the arc spacing becomes too small, the voltage V2 decreases, and the current through the lamp and also the voltage V1 increases, and the current flow through winding A of the motor is opposite in phase to that in the previous case when the gap was too long, so that the motor will turn in a direction to increase the separation between the electrodes. The arrangement thus automatically causes the lamp to be started and to maintain the electrodes at their proper spacing during operation of the lamp. The arrangement has substantially linear characteristics which result in accurate control, and there are no overrunning or hunting difficulties involved.

The arc lamp of the instant invention may also be used with a direct current source of power, in which case one of the electrodes always operates an anode. The anode may comprise a plate, rod or other known anode construction and, in fact, may be a solid copper rod which is of such construction as to prevent overheating and vaporization at the point of arc contact.

While there is shown and described herein one illustrative embodiment of the invention, many other and varied forms and uses will present themselves to those versed in the art without departing from the invention, and the invention is therefore not limited either in structure or in use except as indicated by the scope of the appended claims.

What is claimed is:

1. An arc discharge device comprising electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the electrodes to assume the shape of a concentrated arc, and regulating means for automatically moving said electrodes towards and from each other to maintain a predetermined desired arc spacing between them during operation of the device, said regulating means comprising an alternating current reversible motor device rotatable to advance or retract the electrodes, said motor device having at least two windings with a phase difference between the currents flowing in the windings respectively, said windings being operatively connected to the arc circuit so that the torque produced by the windings is proportional to the difference between a voltage which is proportional to the current flowing in the arc stream and the voltage drop across the arc, the resultant torque causing the motor device to turn in a direction to maintain said predetermined desired arc spacing between the electrodes.

2. An arc discharge device comprising electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the electrodes to assume the shape of a concentrated arc, and regulating means for automatically moving said electrodes towards and away from each other to maintain a predetermined desired arc spacing between them during operation of the device, said regulating means comprising an alternating current two-phase reversible motor rotatable to advance or retract the electrodes, said motor having at least two windings with a phase difference between the currents flowing in the windings respectively, said motor windings being operatively connected to the arc circuit so that the torque produced by the windings is proportional to the difference between a voltage which is proportional to the current flowing in the arc stream and the voltage drop across the arc, the resultant torque causing the motor to turn in a direction to maintain said predetermined desired arc spacing between the electrodes.

3. An arc discharge device comprising electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the electrodes to assume the shape of a concentrated arc, and regulating means for automatically moving said electrodes towards and from each other to maintain a predetermined desired arc spacing between them during operation of the device, said regulating means comprising an alternating current reversible motor device rotatable to advance or retract the electrodes, said motor device having at least two windings with a phase difference between the currents flowing in the windings respectively, means for producing a first voltage which is proportional to the current flowing in the arc stream, and means for producing a second voltage which is proportional to the difference between said first voltage and the voltage drop across the arc and for applying said difference voltage to one of the windings of said motor device to cause it to rotate in a direction and to an extent to maintain said predetermined desired arc spacing between the electrodes.

4. An arc discharge device comprising electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the electrodes to assume the shape of a concentrated arc, and regulating means for automatically moving said electrodes towards and from each other to maintain a predetermined desired arc spacing between them during operation of the device, said regulating means comprising an alternating current reversible motor device rotatable to advance or retract the electrodes, said motor device having at least two windings with a phase difference between the currents flowing in the windings respectively, a source of alternating current power supply for the arc discharge, means for energizing one of said motor windings from said power supply, a transformer having a primary winding connected to said power supply and in series with the arc stream, means comprising the secondary winding of said transformer for producing a first voltage which is proportional to the current flowing in the arc stream, circuit connections for obtaining a voltage which represents the voltage drop

across the arc, and means including said circuit connections and the secondary winding of said transformer for producing a second voltage which is proportional to the difference between said first voltage and the voltage drop across the arc and for applying said difference voltage to a second winding of said motor device to cause it to rotate in a direction and to an extent to maintain said predetermined desired arc spacing between the electrodes.

5. An arc discharge device comprising electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the electrodes to assume the shape of a concentrated arc, and regulating means for automatically moving said electrodes towards and from each other to maintain a predetermined desired arc spacing between them during operation of the device, said regulating means comprising an alternating current reversible motor device rotatable to advance or retract the electrodes, said motor device having at least two windings with a phase difference between the currents flowing in the windings respectively, a source of alternating current power supply for the arc discharge, means for energizing one of said motor windings from said power supply, a transformer having a primary winding connected to said power supply and in series with the arc stream, means comprising the secondary winding of said transformer for producing a first voltage which is proportional to the current flowing in the arc stream, circuit means connecting one end of a predetermined portion of said secondary winding to one end of a second winding of said motor device and the other end of said portion of the secondary winding to one side of the arc, and circuit means connecting the other end of said second motor winding to the other side of the arc, said predetermined portion of the secondary transformer winding and said circuit means producing a second voltage which is proportional to the difference between said first voltage and the voltage drop across the arc and applying said difference voltage to said second winding of said motor device to cause it to rotate in a direction and to an extent to maintain said predetermined desired arc spacing between the electrodes.

6. An arc discharge device comprising longitudinally-extending electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the adjacent ends of the electrodes to assume the shape of a concentrated arc, regulating means for automatically moving said electrodes towards and from each other to maintain a predetermined desired arc spacing between said adjacent ends thereof during operation of the device, said regulating means comprising an alternating current reversible motor device rotatable to advance or retract the electrodes, said motor device having at least two windings with a phase difference between the currents flowing in the windings respectively, means for producing a first voltage which is proportional to the current flowing in the arc stream, and means for producing a second voltage which is proportional to the difference between said first voltage and the voltage drop across the arc and for applying said difference voltage to one of the windings of said motor device to cause it to rotate in a direction and to an extent to maintain said predetermined desired arc spacing between the electrodes, and means for automatically rotating the electrodes relative to each other about their longitudinal axes to insure proper centering of the arc stream in the active surface areas of the adjacent ends of the electrodes, said rate of rotation being lower than that which would cause appreciable centrifugal forces to be exerted on said active surface areas.

7. An arc discharge lamp comprising longitudinally-extending electrodes operating in a gaseous medium at a pressure sufficiently high to cause the discharge between the adjacent ends of the electrodes to assume the shape of a concentrated arc and produce highly incandescent light spots in the active surface areas of said adjacent ends, regulating means for automatically moving said electrodes towards and from each other to maintain a predetermined desired arc spacing between said adjacent ends thereof during operation of the lamp, said regulating means comprising an alternating current reversible motor device rotatable to advance or retract the electrodes, said motor device having at least two windings with a phase difference between the currents flowing in the windings respectively, means for producing a first voltage which is proportional to the current flowing in the arc stream, and means for producing a second voltage which is proportional to the difference between said first voltage and the voltage drop across the arc and for applying said difference voltage to one of the windings of said motor device to cause it to rotate in a direction and to an extent to maintain said predetermined desired arc spacing between the electrodes, and means for automatically rotating the electrodes in opposite directions relative to each other about their longitudinal axes to insure proper centering of the light spots in their active surface areas, said rate of rotation being lower than that which would cause appreciable centrifugal forces to be exerted on said active surface areas.

WILLIAM D. BUCKINGHAM.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,615,687	Eschholz	Jan. 25, 1927
2,329,127	Levy	Sept. 7, 1943
2,488,861	Gooch	Nov. 22, 1949