United States Patent [19]

Towlson

[11] **3,767,922**

[45] **Oct. 23, 1973**

[54] **ELECTRIC ARCS**

[76] Inventor: **Peter G. Towlson,** 40 Old Gate Rd., Davington Ct., Favesham, England

[22] Filed: **Apr. 27, 1972**

[21] Appl. No.: **248,292**

[30] **Foreign Application Priority Data**

May 3, 1971 Great Britain 12,638/71

[52] **U.S. Cl** **250/340,** 250/85, 313/8, 313/146

[51] **Int. Cl.** .... **G21h** , H01j 61/96

[58] **Field of Search** .... 250/83.3 H, 85; 313/8, 146; 328/2

[56] **References Cited**

UNITED STATES PATENTS

2,724,790	11/1955	Embshoff et al.	250/85
3,694,624	9/1972	Buchta	250/85
2,270.099	1/1942	Womer	250/85
2,952,762	9/1960	Williams et al.	250/85
934,796	/1907	Davies	313/8

Primary Examiner—Harold A. Dixon
Attorney—Stevens, Davis, Miller & Mosher

[57] **ABSTRACT**

A source of electromagnetic radiation comprises two electrodes, means for connecting a voltage across the electrodes sufficient to maintain an arc discharge between them, and means responsive to a property of the discharge across the electrodes to adjust the separation of the electrodes to a value below that at which a mathematic minimum occurs in the voltage/separation curve.

12 Claims, 5 Drawing Figures

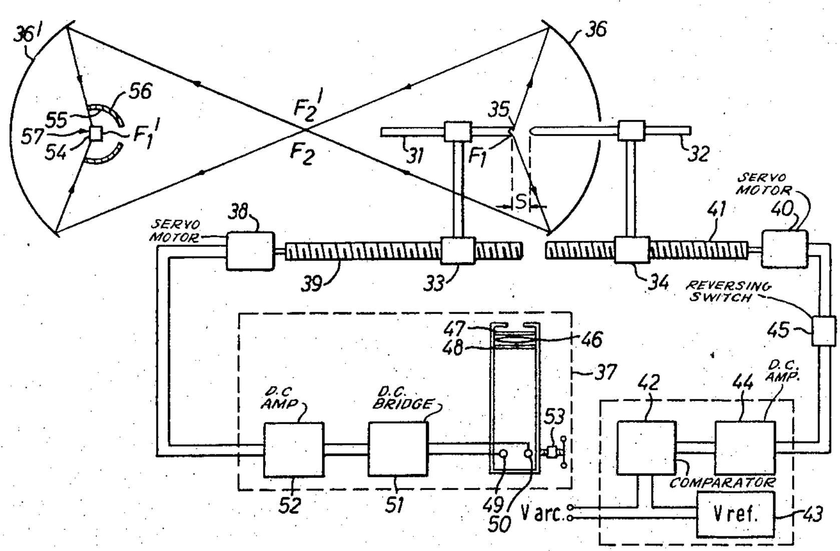


FIG. 1A

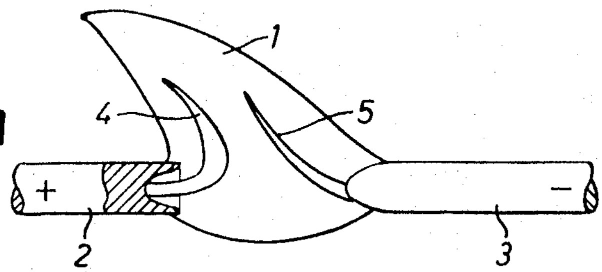
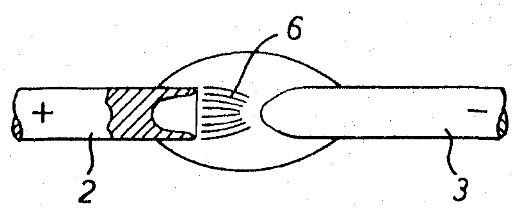


FIG. 1B



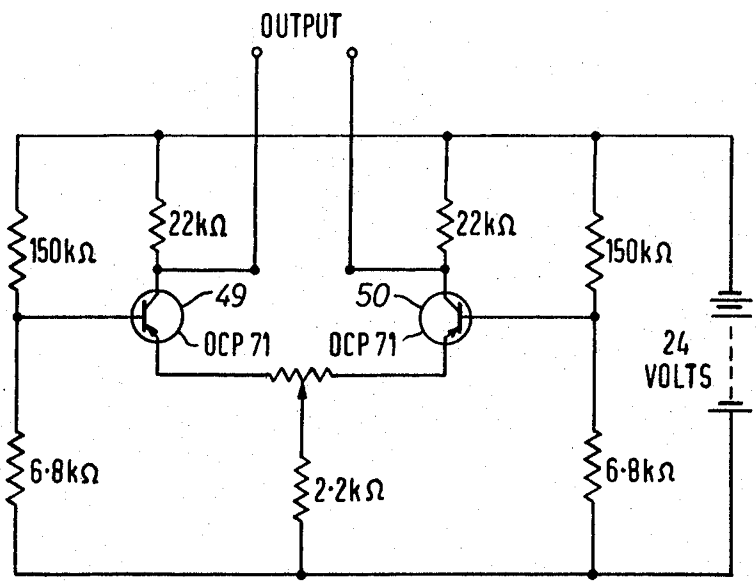
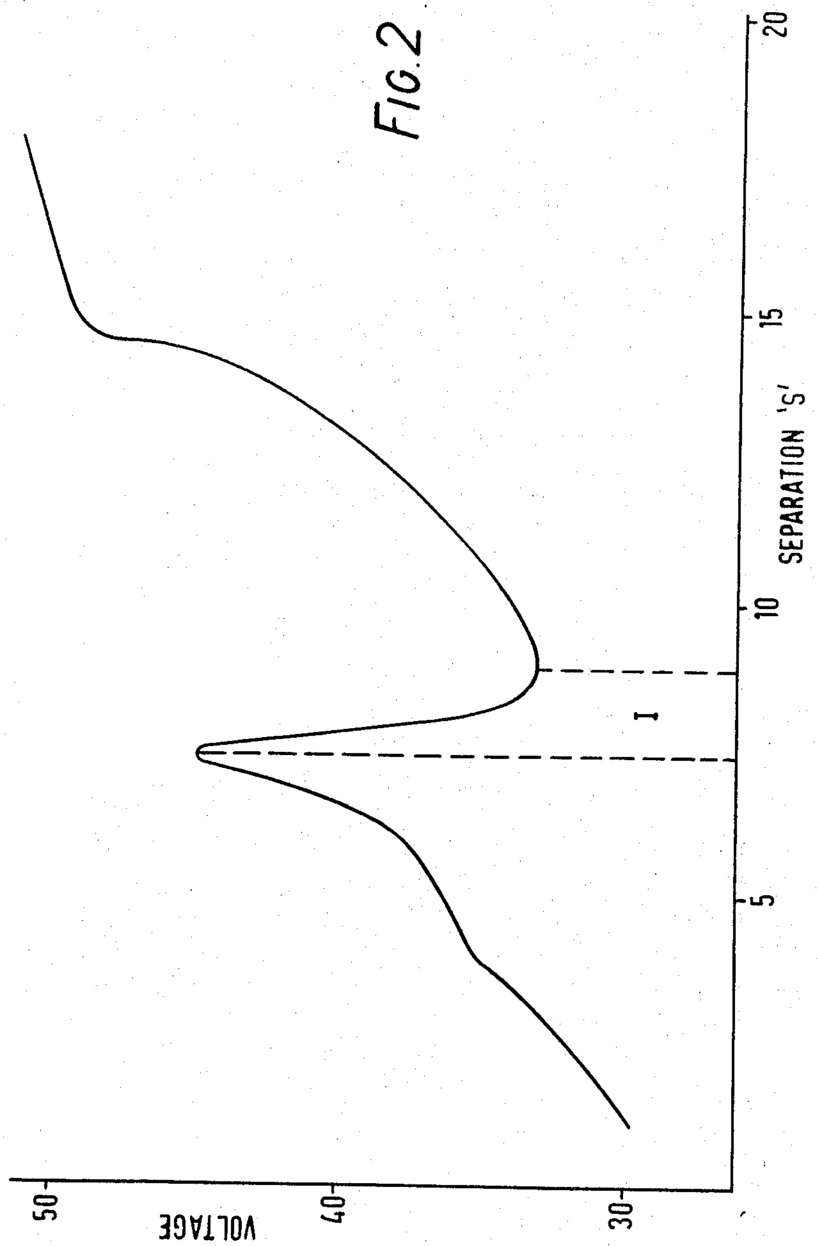


FIG. 4

FIG. 2



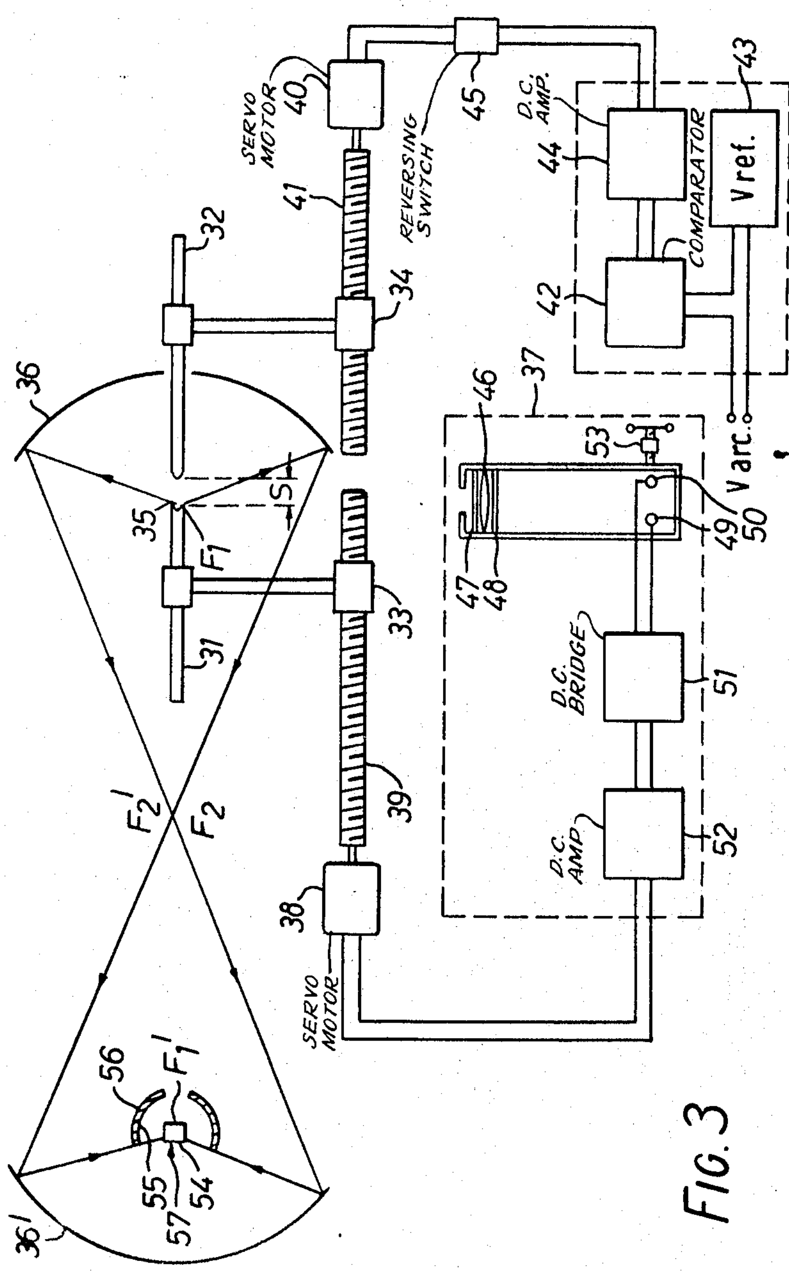

SERVO MOTOR
REVERSING SWITCH
D.C. AMP.
COMPARATOR
Vref.
D.C. BRIDGE
D.C. AMP
SERVO MOTOR
Varc.

FIG. 3

ELECTRIC ARCS

This invention relates to sources of electromagnetic radiation using an electrical discharge between two electrodes.

Earlier radiation sources of this type include the carbon-arc radiation source in which the carbon electrodes are initially brought together and then allowed to spring apart as the arc strikes between the electrodes. The arc is usually connected in series with a ballast resistance across a supply source, and the arc separation and the ballast resistance value are chosen to give arc currents and voltages which provide maximum light radiation. This conventional arc is known as the high intensity arc. The present invention is concerned with increasing the generation of heat.

In investigating how to modify the carbon arc discharge to provide large amounts of heat radiation, not necessarily accompanied by as large amounts of light radiation as formerly, I have provided control apparatus for the arc discharge which causes the electrode separation to be smaller than that previously used with similar conditions (such as electrode size) for the high intensity arc. Higher efficiencies of heat generation are thereby obtained.

According to one aspect of this invention, there is provided a source of electromagnetic radiation comprising two electrodes, means for connecting a voltage across the electrodes sufficient to maintain an arc discharge between them, and means responsive to a property of the discharge across the electrodes to adjust the separation of the electrodes to a value below that at which a mathematic minimum occurs in the voltage/-separation curve.

According to another aspect of the invention, there is provided a method of generating the electromagnetic radiation comprising connecting a voltage across two electrodes sufficient to maintain an arc discharge between them and adjusting the separation of the electrodes in response to a property of the discharge to a value below that at which a mathematic minimum occurs in the voltage/separation curve.

An example of the invention will now be described with reference to the accompanying drawings in which:

FIG. 1A and 1B are a representation of a conventional arc together with a representation of an arc produced according to the invention;

FIG. 2 shows a voltage/electrode separation characteristic of an arc;

FIG. 3 is a diagrammatic representation of an image furnace incorporating the invention; and

FIG. 4 is a circuit diagram of a component of the image furnace of FIG. 3.

The conventional D.C. high intensity arc has a shape as shown in FIG. 1 of the accompanying drawings with an elongated "tail flame" 1 that extends over the anode 2 and points away from the cathode 3. Also within the "tail flame" 1 are two bright areas or columns 4 and 5 that emanate from the electrodes 2 and 3 and are known as the anode and cathode columns respectively.

It has been now found that if the electrode separation is decreased, a point is reached at which the tail flame 1 together with the anode and cathode columns 4 and 5, respectively, disappears and is replaced by a bright conical flame or "fireball" 6 extending from the anode 2 towards the cathode 3 as also shown in FIG. 1.

FIG. 2 represents the relationship of the voltage across the arc to the separation between the electrodes. The high intensity arc operates on the rising right hand part of the curve. As the separation increases in this region, the voltage increases, passing a knee and then rising more slowly until the arc is extinguished when the separation becomes too great. There is a mathematical minimum in the curve for the smallest separation in the high intensity region, and for separations below this point the voltage rises with decreasing separation to a maximum (which is below the maximum voltage in the high intensity region), after which the voltage again decreases with decreasing separation. In FIG. 2, the mathematical minimum refers to the point on the curve at the right-hand end of region I at which the voltage is less than the voltage at immediately adjacent points on the curve for greater and smaller separations. The arc is again extinguished when the separation between the electrodes becomes too small to support the arc discharge. By means of highspeed photographic techniques it has been ascertained that the fireball 6 consists of particles of material that have been torn from the anode and are transferred to the cathode. Hence this form of arc is known as a "transferred arc." The particles of matter torn from the anode are heated by the action of the arc and emit thermal radiation.

The heat radiation from the arc is measured by means of a black body radiation colorimeter in which radiation is absorbed by the blackened interior of a water cooled spherical cavity. Radiation from the arc is focussed on a small hole in the cavity housing. Thermo couples measure the temperature rise of the cooling water passing through a tube soldered to the exterior of the cavity housing. Measurements taken from the same electrodes operated in the falling and rising portions of the voltage/separation curve have shown that the efficiency rises to a higher maximum when operating the arc in the falling region of the curve.

One application of arc radiation sources of this type is in the arc image furnace, in which an image of the arc is focussed onto a sample to be heated. The discharge of FIG. 1 with a large tail flame and with anode and cathode columns which may all be unstable in position is not suitable for this purpose since the source of radiation is not concentrated, and is not fixed in position. The discharge according to the present invention shown in the lower part of FIG. 1 is more suitable for the arc image furnace. It has been proposed to concentrate the radiation source to the area between the electrodes by means of air jets discharged around the anode electrode towards the cathode, so that the radiation sources illustrated in the conventional high intensity arc in FIG. 1 are prevented from rising above the region immediately between the electrodes. By operating the arc as shown in the lower part of FIG. 1, the source is contained without the need for air jets by operating in the falling voltage/separation region in the curve of FIG. 2.

Referring to FIG. 3, two carbon electrodes 31 and 32 are mounted coaxially in holders 33 and 34 so as to be separated by a distance *s*. Potentials are applied to the electrodes 31 and 32 so as to cause them to become the anode and cathode respectively of an electric arc struck between them. The operating potential is applied to the electrodes 31 and 32 by means of a conventional D.C. power supply which is not shown. The anode **31** is positioned with one end **35** at one focus F_1 of an ellipsoidal mirror **36.** The cathode **32** projects through the pole of the mirror **36** to the vicinity of the end **35** of the anode **31.** The anode **31** is maintained at its desired position by means of an infra-red sensing unit **37,** to be described more fully later, that senses the position of the most intense part of the arc between the electrodes **31** and **32,** and operates to maintain this part of the arc at the first focus of the mirror **36** by means of a servo motor **38** and a lead screw **39** upon which the holder **33** works.

The anode locating system **37** comprises a lens **46** that is positioned between two infra-red filters **47** and **48,** and is so arranged as to form an image of the anode region of the arc at a point between two infra-red sensitive photo-transistors **49** and **50.** The photo-transistors **49** and **50** are connected in a d.c. bridge network **51,** the circuit diagram of which is shown in FIG. **4.** Any movement of the end **35** of the anode **31** from the first focal point F_1 of the mirror **36** will cause a change in the position of the image formed by the lens **46** and result in an out-of-balance voltage being developed by the bridge **51** which is amplified by the d.c. amplifier **52** and caused to operate the servo motor **38** and lead-screw **39** so as to hold the end **35** of the anode **31** in its proper position. The initial setting of the anode locating system **37** is by means of a hand wheel **53** and by a zero setting control (not shown) of the bridge **51,** reference being made to a sighting system of cross-wires (also not shown) trained upon the known position of the focus F_1 of the mirror **36.** A more sensitive control of the motors **38** and **40** can be achieved by frequency modulating the outputs of amplifiers **44** and **52,** and applying the variable frequency signals to stopping motors. Such motors advance by a predetermined amount for each cycle of their variable frequency input.

The position of the cathode **32** is controlled to maintain the separation *s* of the anode **31** and cathode **32** at a desired value so that the arc will operate in a regime of its voltage/separation characteristic below that at which a mathematical minimum occurs, the preferred region being shown as I in FIG. **2,** by a servo motor **40** and lead screw **41** similar to the servo motor **38** and lead screw **39.** The cathode adjusting servo-mechanism is operated by means of an error voltage V_e that is developed by means of a comparator circuit **42** that compares the voltage V_a across the arc with a reference potential V_{ref} generated by a reference potential source **43,** the error voltage V_e is amplified by means of a d.c. amplifier **44.** The arrangement is such that the direction and magnitude of the rotation of the servo motor **40** depends upon the slope of the voltage/separation characteristic and tends to maintain the arc in the region I of FIG. **2** having a negative slope. A reversing switch **45** is fitted to the input of the servo-motor **40** in case it should be desired to operate the arc out of the negative slope region.

The cathode position, however, may be controlled in a similar manner to that used for the anode.

In use, the arc is first struck manually and the separation of the electrodes **31** and **32** is adjusted by hand until the desired operating conditions are achieved. If the desired operating conditions correspond to a point on the negative slope region of the curve in FIG. **2,** the reversing switch is left unactuated, and the servo-mechanisms are brought into operation to maintain the desired conditions at that point on the curve. If the desired conditions relate to a point on the positive slope portion of the curve in FIG. **2** at separations below those of the negative slope region, the reversing switch **45** is actuated and the servo-mechanisms are brought into operation to maintain the operation of the arc in that positive slope region. It is also possible to operate the arc in the positive slope region of the curve in FIG. **2** at separations above the region I by adjusting the separation of the electrodes by hand to the appropriate value, actuating the reversing switch and bringing the servo-mechanism into operation; This region is however outside the scope of the present invention.

Care should be taken when operating the servo-mechanisms with a desired condition close to the maximum voltage point occuring at the lowest separation in the region I, as a transient may cause the conditions to move past the peak in the curve after which the control circuit will be unstable.

As an alternative to the manual arc formation method, an automatic mechanical device may be used in which the high current flowing between the electrodes in contact is used to operate a relay which operates a motor to separate the electrodes to the required distance. A further arc formation method is to apply a high frequency electric field to the region between separated electrodes. Another method of arc formation is to place a resistive body between the electrodes adjusted approximately to their working separation and to apply the current so that the current passing through the resistive body causes it to melt and evaporate, the vapour thereby assisting the striking of the arc. A ball of silver paper is a suitable resistive body.

Infra-red radiation proceeding from the mirror **36** passes through the second focus F_2 of the mirror **36,** which is arranged in conventional fashion to be the second focus F_2' of a second ellipsoidal mirror **36'**. A work piece **54** to be heated is arranged to be positioned at the first focus F_1' of the mirror **36'**. The mirrors are pure ellipsoids as the source has its position accurately controlled by the circuits described above and there is no need to allow for variation of the arc position by designing the mirrors in a non-ellipsoid shape. The work piece **54** is surrounded by a hollow part-spherical radiation shield **55** made of a glass with a layer **56** of gold upon its outer surface. The work piece **54** is arranged at the geometric centre of the radiation shield **55,** and the aperture **57** of the radiation shield **55** is such as to accept all the radiation reflected from the mirror **36'** towards the workpiece **54.** As the workpiece **54** is at the centre of the radiation shield **55,** radiation from the workpiece **54** will be reflected back to the workpiece **54.** The gold coating is itself provided with a protective coating, for example of silicon monoxide.

An alternative method of focussing the radiation from the arc includes the use of a lens system formed of material with very low absorption of infra-red radiation. Such a material is quartz which is substantially free of water and hydroxyl radicals. The lens system may be a single lens, or a number of thin lenses through which the radiation passes in succession. The lenses are suitably coated to prevent loss of efficiency by spurious reflections at their surfaces. Although the lens system absorbs some of the infra-red radiation, it has been found possible to use them continuously for up to twenty minutes with a beam of about 1 kilowatt without destruction of the lenses.

When it is required that the optical axis of the lens system should be parallel to the electrodes of the arc, the anode is arranged to be fed through a hole extending along the optical axis of the lens system in order to provide a compact optical layout.

The invention has application to conventional metallurgical processes such as welding, brazing, cutting, forging, freeforming and other purposes such as the deposition of metal coatings, crystal formation, and research into high temperature generally.

What I claim is:

1. A source of electromagnetic radiation comprising two electrodes, means for connecting a voltage across the electrodes sufficient to maintain an arc discharge between them, and means responsive to a property of the discharge across the electrodes to adjust the separation of the electrodes to a value below that at which a mathematical voltage minimum occurs in the voltage/-separation curve.

2. A source as claimed in claim **1** wherein the responsive means is responsive to the infra-red radiation from the discharge.

3. A source as claimed in claim **1** wherein the responsive means includes means responsive to the voltage across the arc.

4. A source as claimed in claim **1** comprising means to focus an image of the arc discharge at a remote point, said means comprising a reflector of gold coated upon a supporting substrate.

5. A source as claimed in claim **1** comprising means to focus the arc discharge at a remote point, said means comprising a lens of water-free and hydroxyl-free material.

6. A source as claimed in claim **5** wherein the means to form an image of the arc discharge is formed with a hole through which one of said electrodes extends.

7. A method of generating electromagnetic radiation comprising connecting a voltage across two electrodes sufficient to maintain an arc discharge between them and adjusting the separation of the electrodes in response to a property of the discharge to a value below that at which a mathematical voltage minimum occurs in a voltage/separation curve.

8. A method as claimed in claim **7**, wherein the property of the discharge is infra-red radiation from the discharge.

9. A method as claimed in claim **7** wherein the property of the discharge is the voltage between the electrodes.

10. A method as claimed in claim **7** comprising focusing an image of the arc discharge at a remote point by refracting the radiation from the arc discharge through a lens of water-free and hydroxyl-free material.

11. A method as claimed in claim **7** comprising focusing an image of the arc discharge onto a remote point by reflecting radiation from the arc discharge onto said point by means of a reflector of gold coated upon a substrate.

12. A method as claimed in claim **11** comprising feeding one of the electrodes through an aperture formed in the device for focusing the image of the arc discharge at a remote point.

* * * * *