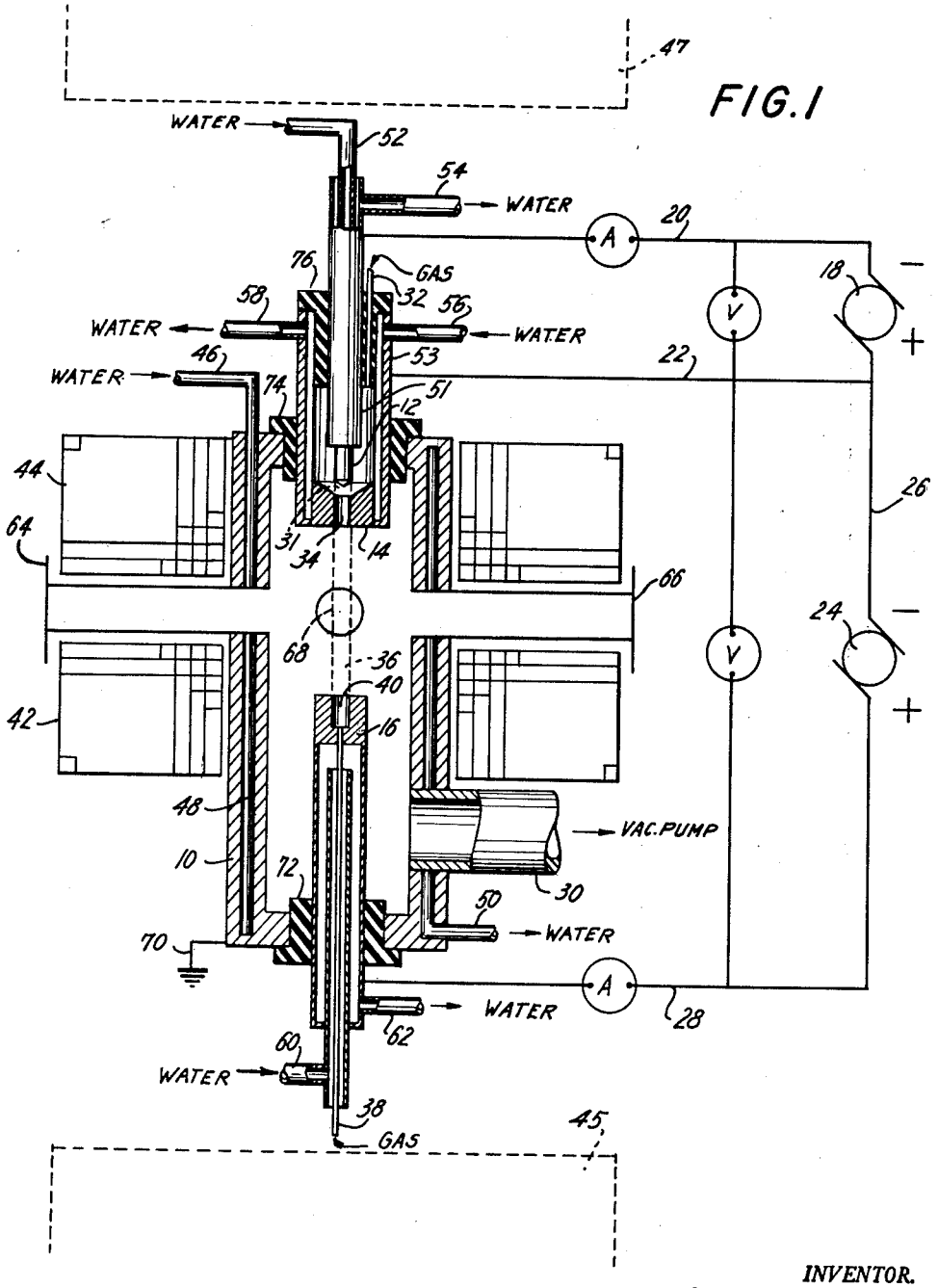
March 31, 1964 C. K. McLANE 3,127,536

MAGNETICALLY-STABILIZED LOW PRESSURE ARC APPARATUS AND METHOD OF OPERATION

Filed Dec. 23, 1960 2 Sheets-Sheet 1

FIG. 1



INVENTOR.
CHARLES K. McLANE

BY William F. Meisinger
ATTORNEY

March 31, 1964 C. K. McLANE 3,127,536

MAGNETICALLY-STABILIZED LOW PRESSURE ARC APPARATUS AND METHOD OF OPERATION

Filed Dec. 23, 1960 2 Sheets-Sheet 2

FIG. 2

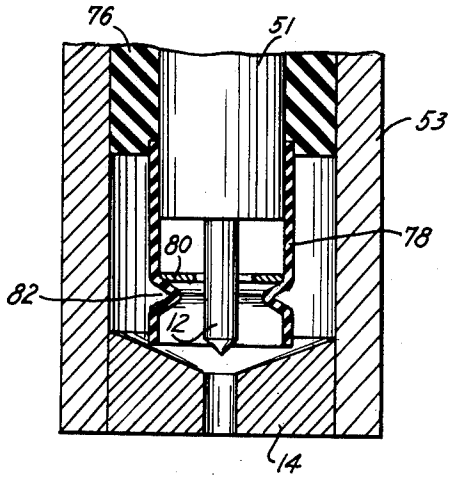
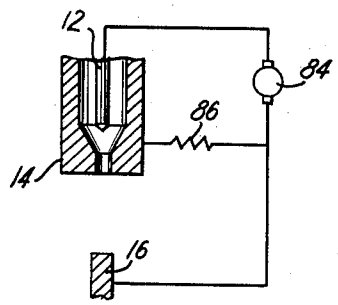


FIG. 3



INVENTOR.
CHARLES K. McLANE

BY William F. Mesinger
ATTORNEY

United States Patent Office 3,127,536 Patented Mar. 31, 1964

3,127,536

MAGNETICALLY-STABILIZED LOW PRESSURE ARC APPARATUS AND METHOD OF OPERATION

Charles K. McLane, Indianapolis, Ind., assignor to Union Carbide Corporation, a corporation of New York

Filed Dec. 23, 1960, Ser. No. 78,039
12 Claims. (Cl. 313—162)

This invention relates to magnetically stabilized low pressure arcs and more particularly to apparatus for producing a very stable low pressure arc for use in the fields of metal melting and refining, crystal growth, welding and chemical reaction promotion.

With conventional arcs, that is those operated at atmospheric or higher pressure, the anode terminal of the arc remains relatively fixed while the cathode terminal may wander over a small area. With decreasing pressure the area of cathode wander increases and also the anode terminal of the arc becomes positionally unstable, tending to follow the ever wandering cathode terminal until the entire arc discharge is able to move many inches away from the position intended. Many attempts have been made to stabilize these low pressure arcs. One method for stabilizing such arcs includes the use of a magnetic field.

It is a main object of this invention to provide novel apparatus for magnetically stabilizing low pressure arcs.

It is another object to provide an improved process of operating a low pressure arc whereby increased arc stability is realized.

These and other objects and advantages will be apparent from a consideration of the following detailed specification and the accompanying drawings wherein:

FIG. 1 shows one form of the novel apparatus of the invention;

FIG. 2 shows a preferred form of cathode structure; and

FIG. 3 shows an alternate form of power supply circuitry.

The process of the invention comprises the general steps of initiating an arc between a cathode and anode, uniformly heating the cathode by means of a secondary arc, maintaining the cathode region of the arc at a pressure of about 1 millimeter mercury absolute or above, maintaining the remaining portion of the arc at a pressure below about 100 microns mercury absolute and preferably about 1–10 microns mercury absolute, and collimating and stabilizing the arc by means of a magnetic field positioned around and parallel to the arc, such field having a strength of greater than 50 gauss and preferably above 1000 gauss.

As shown in FIG. 1, the arc chamber 10 contains a cathode 12, preferably in elongated or stick form, a nozzle secondary anode 14 and a primary anode 16 which is preferably cup-shaped as shown. Power supply 18 is connected between cathode 12 and secondary anode 14 by leads 20 and 22 respectively, while power supply 24 is connected in series with power supply 18 from cathode 12 to primary anode 16 through leads 26 and 28. In operation, chamber 10 is evacuated to an initial pressure of less than about 10 millimeters mercury absolute and preferably about 0.3 millimeter mercury absolute by connecting a vacuum pump (not shown) through the evacuation line 30. A small quantity stream of gas such as argon, nitrogen, helium or hydrogen is introduced through passage 32 and passes around cathode 12 and out through passage 34 in secondary anode 14. A secondary arc 31 is then initiated by suitable means between cathode 12 and secondary nozzle anode 14. When a high frequency discharge is employed to initiate arc 31, it is preferred to

initially use argon and then switch to the desired torch gas (if other than argon) once the arc becomes operable. The chamber pressure is then reduced to less than 100 microns mercury absolute and preferably to about 50 microns mercury absolute. As the pressure is reduced, the stream of hot, ionized gas emerging from the secondary nozzle anode will tend to lengthen until it impinges upon the primary anode. This extended plasma helps to initiate and maintain a primary arc 36 between cathode 12 and anode 16. Once primary arc 36 is established, the cathode gas stream can be stopped, but it is preferable to maintain it during operation in order to improve arc stability.

Finally, the chamber pressure is preferably reduced to an operating pressure of about 1–10 microns mercury absolute. If auxiliary starting means, such as a high frequency discharge, are employed, it may be possible to reduce the chamber pressure to 1–10 microns before initiating the primary arc 36. The above described procedure for arc initiation is the presently preferred process, however.

An anode gas stream using gases of the same type mentioned above is introduced through passage 38 and exits through the cup portion 40 of primary anode 16. This anode gas stream has been found to be necessary in order to reduce anode damage and maintain long operating life. If no anode gas stream is used, the arc in the region adjacent to the anode will become deficient in ions and will build up a space charge. This causes the electrons travelling from arc to anode to be accelerated, and energy delivered to anode to become so high that eventually anode materials will vaporize to form the required ions for continuous operation. The continuous presence of a small amount of ionizable gas will supply ions to neutralize the space charge and will thus retard anode damage. The gas that is introduced to the arc chamber through both the cathode and anode streams is continuously removed through evacuation line 30 and therefore the system stabilizes at a constant low pressure determined by gas flow rate and the rate of evacuation. The primary anode is cup-shaped so as to allow the introduced gas stream to become highly ionized before contacting the main portion of the arc 36.

If the present invention is used as a heat source to melt metals, for example, wherein the primary anode is maintained with a molten surface, such primary anode need not be cup-shaped and the anode gas stream can be eliminated. Vapors of the anode material or gases evolved by the anode material can be used for space-charge neutralization.

The cathode 12, nozzle secondary anode 14 and cup-shaped primary anode 16 are preferably constructed from refractory metals, such as tungsten or tantalum. The anodes could, if desired, be fabricated from copper provided that the water-cooling is adequate to prevent melting.

The primary arc 36 is stabilized in a substantially constant diameter collimated arc by means of a strong magnetic field maintained through the arc chamber in a direction parallel to the arc axis. It is desirable that the magnetic field be substantially uniform in cross-section through the arc chamber. As shown in FIG. 1, this magnetic field is conveniently obtained by means of a multiplicity of electromagnetic field coils surrounding the chamber 10. Coils 42 and 44 are shown for illustrative purposes. The magnetic field strength parallel to the arc should be greater than about 50 gauss and preferably above about 100 gauss. Alternatively, the field could be obtained from field magnets 45 and 47 placed at the upper and lower ends of the apparatus as shown in dotted lines in FIG. 1.

In order to prevent melting of the apparatus due to arc

heat, various items are water-cooled. Arc chamber **10** is cooled by introducing water to inlet **46**, then passing it through passage **48** and through outlet **50**. The cathode holder **51** is cooled by means of water flowing through passages **52** and **54**. Nozzle secondary anode holder **53** is water-cooled by means of passages **56** and **58**. The cup-shaped primary anode has cooling passages **60** and **62**.

Observations of the arc during operation can be made through viewing ports **64**, **66** and **68**. Arc chamber **10** is maintained at ground potential through connection **70**. The primary and secondary anodes are electrically separated from arc chamber **10** through insulator members **72** and **74** respectively. Cathode holder **51** is electrically separated from the nozzle anode member by means of insulator **76**.

Arc **36** is designated as the primary arc since it is the arc that can be used as a heat source or a generator of high-frequency radiation. The secondary arc **31** is maintained entirely within the cathode **12**-nozzle anode **14** structure. The designations of "primary arc" and "secondary arc" refer only to portions of a single arc column which originates at the cathode **12**. For most stable operation with relatively long primary arc lengths it is desirable that most of the current pass between cathode **12** and secondary nozzle anode **14** while a smaller portion of the current continues to the primary anode **16**. Typical operating currents for relatively small scale operation are 100 amperes for the secondary arc, 70 amperes nozzle anode current, and 30 amperes for the primary arc. The function of the secondary arc is to maintain the cathode uniformly hot and to keep the nozzle passage **34** filled with plasma so that the cathode may operate in a region of higher pressure than the primary external arc column. The arc cathode operates more efficiently and stably at pressures above about 1 millimeter mercury absolute.

The following example typifies operation of the improved apparatus.

The apparatus was similar to that shown in FIG. 1 and consisted of a ⅛ inch diameter thoriated tungsten cathode 2 inches long, a ⅛ inch diameter tungsten nozzle secondary anode ½ inch long and a tungsten primary anode having a center cup portion 3/16 inch diameter and ⅜ inch deep. This primary anode had a central gas passage 1/16 inch diameter. The arcing tip of the cathode was positioned ½ inch from the inlet to the secondary anode nozzle while the primary anode was spaced 7 inches from the outlet face of the nozzle anode. Argon gas at 2.9 cc./min. passed around the cathode and out through the nozzle passage while argon gas at 3.4 cc./min. was introduced through the primary anode passage. The electrodes were positioned within a sealed chamber and the external arc region between secondary and primary anodes was maintained at a pressure of 1.2 microns mercury absolute. An arc of 29 volts and 70 amperes was operated between the cathode and secondary anodes while a primary arc of 58 volts and 30 amperes was operated between the cathode and primary anode. The magnetic field parallel to the arc was 915 gauss. Under these conditions the primary arc was observed to be collimated, stable and to be operated for relatively long periods of time without fluctuations in operating conditions. Magnetohydrodynamic waves generated in this collimated arc were also detected by means of probes placed in the vicinity of the primary arc.

While the collimated arc obtained by this apparatus can be widely used as the heat source for welding, metal melting, crystal growth, chemical reaction promotion and other thermal processes, it is believed that important commercial utility may also be found as a generator of magnetohydrodynamic oscillations and other types of plasma oscillations, such as electron and ion plasma oscillations, which could be employed in communications or other high frequency equipment. It has been found that the present invention produces sinusoidal oscillations which are exponentially damped. Frequencies from about 100 to about 950 kilocycles per second have been observed. The frequency of these oscillations was found to depend linearly on the reciprocal of the length of the primary arc column, indicating a standing wave phenomenon. The exponential decay time for these oscillations was under some circumstances, found to be proportional to the square of the primary arc length. This indicates either a torsional oscillation or a transverse oscillation of the arc column after the fashion of a plucked string. It is believed that the oscillations could be excited continuously or in controlled pulses by some external means.

When a cathode structure of the type shown in FIG. 1 is used, there is a tendency for ions from the secondary arc to migrate up near the insulator **76** and cause a breakdown in insulation between cathode holder **51** and nozzle anode structure **53**. This is prevented in two ways as shown in FIG. 2. An insulator sleeve **78** constructed of material such as quartz can be positioned around cathode holder **51** and extend down along the cathode **12**. This increases the overall insulation in the arc gas region between cathode **12** and nozzle holder **53**. A high melting point material disc **80** such as molybdenum is then positioned around cathode **12** in order to prevent the passage of ions from nozzle anode **14** up to the cathode holder **51** and thus cause damage. Disc **80** which is spaced from electrode **12** and is electrically "floating" is conveniently supported by peripheral groove **82** in sleeve **78**. Alternatively, a multiplicity of indentations **82** could be used. This apparatus combination has extended cathode holder life at least by a factor of 10. While the combination of insulator sleeve **78** and disc **80** is preferred, it is understood that either one could be used alone and improved results could be obtained.

The electrical circuit shown in FIG. 1 employed two separate power supplies. This is generally desirable for increased arc stability. However, an alternative circuit of the type shown in FIG. 3 might be employed. In this modified circuit a single power supply **84** is connected between cathode **12** and primary anode **16** while secondary anode **14** is connected to the power supply through dropping resistor **86**.

This invention has been described by way of illustration rather than limitations. It is to be understood that certain modifications may be made to the invention without departing from the spirit and scope thereof.

What is claimed is:

1. A device for producing a very stable low pressure primary arc which comprises a leak-tight arc chamber; means for establishing a magnetic field within said chamber in a direction parallel to the axis of said primary arc, a primary anode mounted within said chamber, a cathode structure consisting of a cathode and cathode holder mounted within said chamber in spaced relation to said primary anode and in axial alignment therewith, a cooled secondary anode mounted within said chamber and surrounding the tip of said cathode and electrically insulated therefrom, a power supply means connected in a first circuit with said secondary anode and said cathode so as to maintain a secondary arc therebetween and said power supply means connected in a second circuit with said primary anode and said cathode so as to maintain a low-pressure primary arc therebetween, evacuating means connected to said chamber to maintain the pressure therein at a selected low pressure, means for feeding gas from a source thereof around said cathode and through said secondary arc, and means for cooling said cathode holder and secondary anode.

2. A device as claimed in claim 1 wherein said primary anode is cup-shaped and has a gas passage means therein for introducing gas from a source thereof through said primary anode to said primary arc region.

3. A device as claimed in claim 1 wherein the cathode, the secondary anode and the primary anode are constructed from refractory metals.

4. A device as claimed in claim 3 wherein said refractory metal is tungsten.

5. A device as claimed in claim 3 wherein said refractory metal is tantalum.

6. Apparatus for producing a very stable low pressure primary arc which comprises a leak-tight arc chamber, means for establishing a magnetic field within said chamber oriented parallel to the longitudinal axis of said low pressure primary arc, a primary anode mounted within said chamber, a cathode structure consisting of a stick cathode and cathode holder mounted within said chamber in spaced relation to said primary anode and in axial alignment therewith, a cooled secondary anode mounted within said chamber and surrounding the tip of said stick cathode and electrically insulated therefrom, a first power supply connected in circuit relation with said stick cathode and said secondary anode so as to maintain a secondary arc therebetween, a second power supply connected in circuit relation with said first power supply, said stick cathode and said primary anode for maintaining said lower pressure primary arc, evacuating means connected to said chamber to maintain the pressure therein at a selected low pressure, means for feeding gas from a source thereof around said stick cathode and through said secondary arc and means for cooling said cathode holder and secondary anode.

7. A device as claimed in claim 6 wherein said primary anode is cup-shaped and has a gas passage means therein for introducing gas from a source thereof through said primary anode to said primary arc region.

8. A device according to claim 1 including a resistor connected in circuit relation with said power supply and said secondary anode.

9. Apparatus for producing a very stable low pressure primary arc which comprises a leak-tight arc chamber, means for establishing a magnetic field within said chamber oriented parallel to the longitudinal axis of said primary arc; a primary anode mounted within said chamber; a cathode structure mounted within said chamber consisting of a cathode holder, a stick cathode held by and depending from said cathode holder, said stick cathode being in spaced relation to said primary anode and in axial alignment therewith, an insulator sleeve positioned around

said cathode holder and extending down beyond such holder around said stick cathode, an apertured disc located within said insulator sleeve and below said cathode holder such that said stick cathode may extend through the aperture in said apertured disc; a cooled secondary anode mounted within said chamber and surrounding the tip of said stick cathode and electrically insulated therefrom, a power supply means connected in a first circuit with said secondary anode and said stick cathode so as to maintain a secondary arc therebetween and said power supply connected in a second circuit with said primary anode and said stick cathode so as to maintain a low pressure primary arc therebetween evacuating means connected to said chamber to maintain the pressure therein at a selected low pressure, means for feeding gas from a source thereof around said stick cathode and through said secondary arc, and means for cooling said cathode holder and secondary anode.

10. An improved process for operating a low pressure primary arc comprising initiating a secondary arc between a cathode and a secondary anode; uniformly heating said cathode with said secondary arc; initiating said low pressure primary arc between said cathode and a primary anode; maintaining the secondary arc in the region of said cathode at a pressure of at least about 1 millimeter of mercury; maintaining the primary arc at a pressure below about 100 microns mercury absolute and providing a magnetic field having a strength greater than 50 gauss positioned around and parallel to the longitudinal axis of said primary arc to collimate and stabilize said low pressure primary arc.

11. Process according to claim 10 wherein the primary arc is maintained at a pressure of from about 1 to about 10 microns mercury absolute.

12. Process according to claim 10 wherein the strength of the magnetic field is above about 1000 gauss.

References Cited in the file of this patent

UNITED STATES PATENTS

2,040,215	Rava	May 12, 1936
2,574,562	Hansell	Nov. 12, 1951
2,884,550	Lafferty	Apr. 28, 1959
2,920,236	Chambers	Jan. 5, 1960