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9-16-75 XR SR 3,906,289

United States Patent [19]

Lepp et al.

[11] **3,906,289**

[45] **Sept. 16, 1975**

[54] **METHOD OF COMPRESSING AN ARC DISCHARGE**

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[22] Filed: **Jan. 10, 1974**

[21] Appl. No.: **432,333**

[52] **U.S. Cl.** ..... **315/111;** 219/121 P; 219/131 R; 315/127; 315/246; 315/340

[51] **Int. Cl.**[2] **H05B 7/148;** H05B 7/20

[58] **Field of Search** ..... 315/119, 127, 246, 267, 315/340, DIG. 7, 111; 219/121 EB, 121 P, 122, 131 R, 131 F

[56] **References Cited**

UNITED STATES PATENTS

3,313,707	4/1967	Amsler	315/111 X
3,590,317	6/1971	Sennowitz	315/127 X

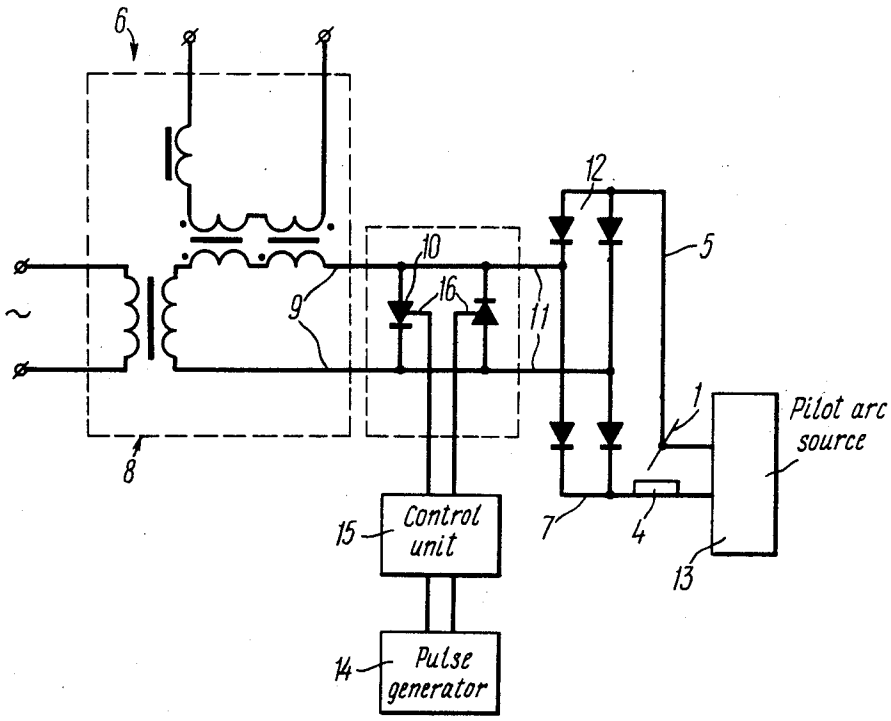
Primary Examiner—James W. Lawrence
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[57] **ABSTRACT**

The present invention relates to methods for compressing an arc discharge and is characterized by feeding current pulses to the arc gap, the duration of the current pulses being less than the arc-dicharge column expansion time.

The employment of the proposed method results in an increased power density in the arc gap and, consequently, a higher concentration of heat therein. The proposed method can be realized dispensing with special mechanical devices and additional means for forming a cooling gas stream.

2 Claims, 5 Drawing Figures



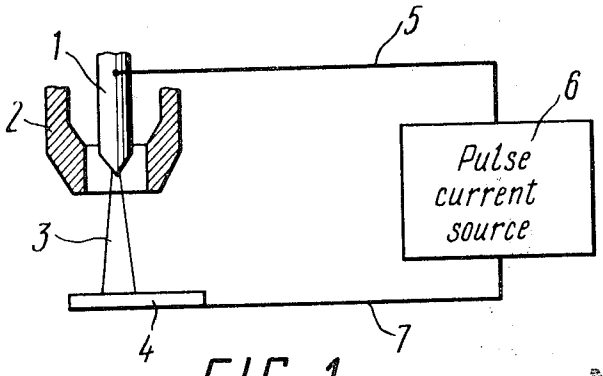


FIG. 1

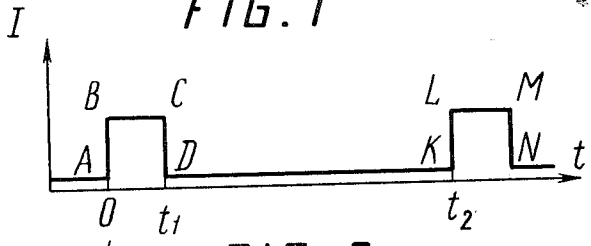


FIG. 3



FIG. 4

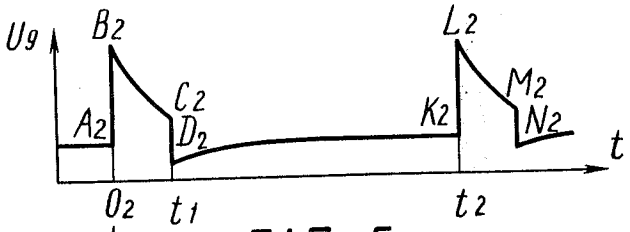


FIG. 5

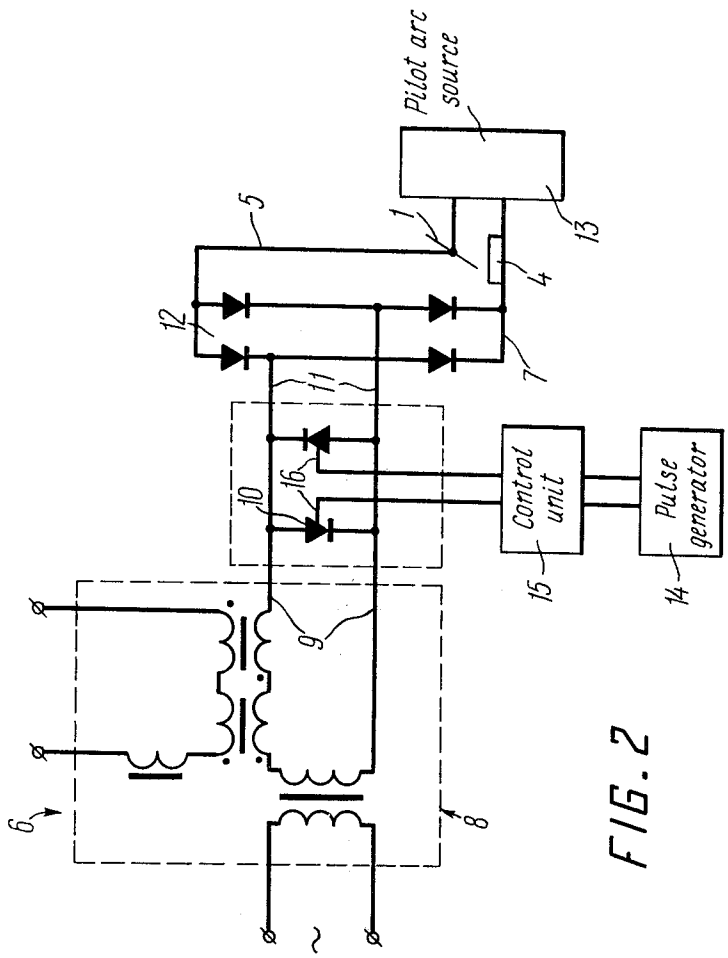

Pilot arc source
5
1
13
4
12
7
11
10
16
Control unit
Pulse generator
15
14
9
6
8
~

FIG. 2

METHOD OF COMPRESSING AN ARC DISCHARGE

The present invention relates to gas-shielded arc processes, and more particularly to methods for increasing heat concentration in an arc discharge by compressing the arc-discharge column.

The invention can advantageously be used, for example, in arc welding, cutting and spattering, in spectrography, in obtaining a high-temperature plasma and in electric-arc melting furnances.

For a better understanding of the present invention, given below are explanations of some terms used in the specification.

By compression of an arc-discharge column is meant the reduction of the cross-sectional area thereof.

Taken as the cross-sectional area of an arc-discharge column is that of an ionized gas column confined between electrodes and capable of conducting electric current.

Known in the art are a number of methods for compressing an arc-discharge column, particularly:

by superposing a magnetic field on the arc coaxially with the arc-discharge column;

by forced cooling of the arc-discharge column, for example, by intensively blowing it with a stream of a gaseous or liquid medium;

by mechanically compressing the arc-discharge column with a stream of a gaseous or liquid medium (cf. Amsler, U.S. Pat. No. **3,313,707**).

A method for compressing an arc-discharge column is known whereby a magnetic field, set up by specially designed electromagnets, is superposed on the arc coaxially with the arc-discharge column. To provide for a maximum intensity of the magnetic field in the arc-discharge column, the electromagnets should be arranged in direct proximity to the arc-discharge column.

The realization of this method requires special equipment which is to be arranged proximate to the arc-discharge zone. As a rule, the electromagnets setting up the coaxial magnetic field are too cumbersome and complicated and require additional cooling, which makes the whole arrangement too sophisticated and costly. Placing the electromagnets close to the arc-discharge zone renders the access thereto difficult.

Another method for compressing an arc-discharge column is known which consists in forced cooling of the arc-discharge column with a gas stream. This method necessitates special mechanical devices for forming a cooling gas stream so directed with respect to the arc-discharge column that an intensive abstraction of heat takes place from the periphery thereof without the latter's being expanded.

A disadvantage of this method lies in that some elements of the special mechanical devices indispensable for forming a cooling gas stream are arranged too close to the arc, which, in turn, necessitates their cooling whereby the construction of the whole apparatus becomes still more complicated. Said method is also disadvantageous in that it involves a higher consumption of the gaseous medium and an alteration of the configuration of the liquid metal bath when the arc discharge is used as a source of heat in welding, thus impairing the quality of the welding joint.

The method for compressing an arc-discharge column according to U.S. Pat. No. **3,313,707** consists in that a stream of the heated working medium is applied,

under a pressure of **100** kg/cm^2, to an arc discharge struck between electrodes, through an annular nozzle surrounding the arc discharge.

As a result, the arc discharge is cooled and pinched causing the current density to be increased therein, and the arc loses more energy. At the instant, when the amount of energy being lost exceeds that being introduced, the arc discharge discontinues. The duration of the compressed arc discharge is equal to $10 \cdot 10^{-3}$ sec. If necessary, the process is repeated.

The process of compressing an arc-discharge column according to this method requires the use of complicated equipment, namely apparatus for building up high pressure indispensable for compressing the arc discharge. Moreover, use should also be made of a means for cooling the annular nozzle surrounding the arc discharge, which renders access thereto more difficult and complicates the maintenance of the whole apparatus.

The complexity of the equipment and the necessity to cool the nozzle render the above method costly and the apparatus for carrying it out difficult in service.

It is, therefore, an object of the present invention to provide a method for compressing an arc-discharge column, which will make it possible to increase heat concentration in the arc-discharge zone dispensing with complicated mechanical devices and additional means for forming a cooling gas stream.

Another object of the invention is to provide a method ensuring easy access to the arc-discharge zone, which is an essential factor in controlling the arc discharge.

Still another object of the invention is to provide a method wherein the heat concentration in the arc-discharge zone can be increased only by using external arc sources.

Yet another object of the invention is to provide a method which will make it possible to save gas.

A further object of the invention is to improve the quality of welded joints when the proposed method is used in fusion welding.

With these objects in view, a method for compressing an acr-discharge column is proposed comprising the following steps: spacing electrodes at a distance sufficient to form an arc gap; supplying shielding gas to said electrodes; applying to said electrodes current pulses having a duration less than the time period during which the arc-discharge column expands to a steady-state value; ceasing to apply current pulses to said electrodes for a time period sufficient to bring the arc-discharge column to the initial state; alternately applying said current pulses to said electrodes to be followed by a discontinuance thereof.

In accordance with the invention, when the proposed method is used in welding, applied to gas-shielded non-consumable electrodes spaced at a distance sufficient to form an arc gap are current pulses having a duration less than $500 \cdot 10^{-6}$, and the time ratio between the pulse spacing and the duration of a pulse is chosen equal to no less than **5**.

As is well known, at the moment of striking any arc discharge, arcing takes place at an elevated voltage due to the fact that the arc gap is cold, the cross-sectional area of the arc-discharge column is small, while the resistance thereof is high, i.e. at the moment of striking an arc discharge, the current density in the arc is substantially higher than in an arc which is established

after a transient is over. By a transient is here meant the time interval during which the cross section of the arc-discharge column varies. This effect accompanies any type of gas-arc welding at the moment of applying a current pulse and is not dependent either on the shape of the electrodes, or the spacing therebetween, or their mutual arrangement. The proposed method is suitable for any electrodes, namely electrodes used in welding or melting of metals, striking arcs used in spectral analysis and the like. The same holds true for the spacing between electrodes and their mutual arrangement: there is no need to arrange electrodes in a particular manner for the proposed method to be effective.

To carry out the proposed method use can be made of any arc sources provided they can send current pulses of the required duration and amplitude to electrodes.

Since during striking an arc discharge the time required for the gas enveloping the arc-discharge column to be heated is insignificantly short, no more than **2** or **3** milliseconds, the arc-discharge column rapidly expands, its resistance, current density and arcing voltage drop, and, as a result, the arc temperature drops, too. If the duration of the current pulses applied to the arc gap exceeds the arc-discharge column expansion time, the mean values of the arcing voltage, current density in the column and arc temperature decrease and the effect of increasing heat concentration in the arc discharge cannot be achieved. On the other hand, reducing the pulse duration permits of increasing heat concentration in the arc discharge for it is precisely at the moment of striking the arc that the voltage across the arc is maximum as well as the concentration of thermal energy in the arc gap.

It is precisely for this reason that the pulse duration has been selected less than the arc-discharge column expansion time, whereby a thermal balance is established between the thermal energies introduced into the air gap and given up to the arc atmosphere.

In order to create, during the application of each subsequent current pulse to the arc gap, conditions favorable for the compression of the arc discharge and an increase therein of heat concentration, the interval between pulses should be long enough for the arc-discharge column to cool down and compress accordingly.

This is why the optimum time ratio between the pulse spacing and the duration of a pulse has been selected equal to no less than **5.**

During the interval between current pulses, natural cooling and compression of the arc-discharge column take place without the use of any diaphragms or intensive blasting of the arc gap with gas.

As a result, the arrival of each subsequent current pulse brings about an increase in the current density in the arc, a higher arc power and, consequently, a higher concentration of heat in the arc discharge.

Thus, the essence of the proposed method resides in that the timing of supplying current pulses to the arc gap has been selected such that the cross-sectional area of the arc-discharge column is always in a dynamic state with maximum possible heat release therein at minimum mean cross section. The proposed method is based on the time difference between the application of electric energy to the arc gap and the establishment of thermal balance between the arc and the surrounding medium.

Under varying conditions such as varying arc atmosphere, gas pressure, applied power, etc., the duration of current pulses as expressed in absolute values may be different, but at any rate it should not exceed the arc-discharge column expansion time.

The degree of arc-discharge column compression may also vary according to the shape and arrangement of electrodes, composition of the arc atmosphere and other factors, but the compression will take place irrespective of all this provided the proposed time ratio between the pulse spacing and the duration of a pulse is strictly observed, i.e. if said ratio is maintained equal to no less than **5.**

In the proposed method, to increase heat concentration in an arc discharge use only is made of the necessary components, such as electrodes and gas atmosphere, and no special mechanical devices and additional means for producing a cooling gas stream are required, whereby the apparatus for carrying out the method of the present invention is rendered simpler, cheaper and easy in service. The employment of this method keeps the gas consumption to a minimum.

Besides, the method of the present invention ensures free access to the arc-discharge zone, which is essential in observing and controlling an arc discharge.

When the proposed method is used in welding, the configuration of the liquid metal bath remains unchanged when acted upon by a gas stream, which substantially improves the quality of the welded joint.

Thus, the employment of the proposed method permits a higher concentration of heat in an arc-discharge column when the latter is compressed without using special mechanical devices and additional means for cooling the arc-discharge column.

The nature of the invention will be clear from the following detailed description of a specific embodiment thereof, for example in welding, with reference to the accompanying drawings, wherein:

FIG. **1** is a schematic representation of an apparatus for carrying out the method for compressing an arc-discharge column, according to the invention;

FIG. **2** shows schematically a source of pulsed constant currents according to the invention;

FIG. **3** is a graph representing current pulses versus time;

FIG. **4** is a graph representing the cross section of an arc-discharge column versus time;

FIG. **5** is a graph representing the arc-discharge voltage versus time.

Referring now to FIG. **1,** the welding apparatus for carrying out the method of the present invention comprises a tungsten electrode **1** disposed in a nozzle **2** wherethrough shielding gas is supplied to the zone of an arc-discharge column **3** confined between the electrode **1** and a workpiece **4** which serves as the second electrode. The electrode **1** is electrically connected to a terminal **5** of a pulse current source **6** using a magnetic amplifier operating in forced magnetization conditions. Another terminal **7** of the pulse current source **6** is connected to the workpiece **4.** The electrodes used to realize the herein-disclosed method may be of any shape and the pulse current source may be of any known design.

Turning now to FIG. **2,** the pulse current source comprises a magnetic amplifier **8** operating in forced magnetization conditions having a lead **9** connected with its terminals **11,** via a thyristor switch **10,** to a rectifier **12**

the terminals 5 and 7 whereof are, in turn, connected to the electrode 1 and the workpiece 4, respectively. Also connected to the electrode 1 and the workpiece 4 is a pilot arc source 13.

The thyristor switch 10 is controlled by a pulse generator 14 electrically connected, via a control unit 15, to control electrodes 16 of the thyristor switch 10.

The proposed method is realized as follows.

The tungsten electrode 1 is placed in the nozzle 2 and the workpiece 4, which serves as the second electrode, is spaced at a distance sufficient to form the arc-discharge column 3. Supplied to the electrodes 1 and 4 through the nozzle 2 is a shielding gas such as argon.

When the pilot arc source 13 is energized, a low-current arc discharge is struck between the electrode 1 and the workpiece 4. The magnetic amplifier 8 is dead and the switch 10 is in the "off" state.

Then, the magnetic amplifier 8 is energized, and a constant current is applied therefrom, at an instant t_0 (FIG. 3), through the leads 9, thyristor switch 10, terminals 11, rectifier 12 and terminals 5 and 7 to the electrode 1 and workpiece 4, the amplitude of said current corresponding to the bias current of the magnetic amplifier 8, as is shown in FIG. 3 (AB).

At the instant t_0, the cross section of the arc-discharge column 3 is minimum (FIG. 4, A_1) and, consequently, its resistance is maximum, which is manifested by a voltage surge on across the arc discharge and corresponds to line A_2B_2 (FIG. 5).

Current J flows through the arc-discharge column 3 during a time period from the instant t_0 to an instant t_1, which corresponds to line BC (FIG. 3).

Therewith, the cross sectional area of the arc-discharge column 3 expands, which is illustrated by curve A_1C_1 of FIG. 4, while the voltage U_g thereacross drops, which corresponds to curve B_2C_2 of FIG. 5.

The time period during which current is supplied to the electrodes 1 and 4 (from t_0 to t_1) is less than that during which the arc-discharge column 3 expands, as a result of supplying current to said electrodes, to a steady-state value corresponding to $500 \cdot 10^{-6}$ sec.

At the instant t_1, when the arc-discharge column 3 has not yet expanded to the steady-state value, control pulses are applied from the pulse generator 14 via the control unit 15 to the control electrodes 16 of the thyristor switch 10, the latter operates shorting the output of the magnetic amplifier 8, thus cutting off the supply of current to the electrodes 1 and 4, which current is reduced by a value corresponding to line CD of FIG. 3.

As a result of said electrodes being de-energized at the instant t_1 and the pilot-arc current flowing through the arc-discharge column 3 which has not yet had time to be compressed, which corresponds to point C_1 of FIG. 4, the voltage across the arc-discharge column 3 drops (line C_2D_2, FIG. 5). At the instant t_1, the arc-discharge column starts to liberate heat to the surrounding medium, cools down and is compressed with its cross section being reduced, which corresponds to curve C_1K_1 of FIG. 4, and the resistance of the arc-discharge column grows with a voltage being established there-across corresponding to the thermal equilibrium state, which is illustrated by curve D_2K_2 of FIG. 5. The supply of current, corresponding to curve DK of FIG. 3, is ceased for a time period sufficient for the arc-discharge column 3 to return to its initial state.

At an instant t_2, the pulse generator 14 stops sending control pulses to the thyristor switch 10. The switch 10 is thus brought to the "off" state and current is supplied again via the electrodes 1 and 4 to the already cooled arc-discharge column 3, which brings about an increased liberation of energy and, consequently, a higher concentration of heat in the discharge, as illustrated by FIGS. 3, 4 and 5. Then, the cycle is repeated.

As this takes place, the time ratio between the current pulse spacing and the duration of a pulse is chosen equal to no less than 5.

Thus, supplying current pulses to the arc-discharge column 3 results in an expansion of the latter when current is fed thereto and narrowing thereof when current discontinues.

When current pulses are fed to the arc-discharge column 3 with the time period during which current is supplied thereto being less then that during which the arc-discharge column 3 expands and with the interval between pulses being sufficient for the arc-discharge column 3 to return to its initial state, transient processes in the arc discharge are still under way, and the whole amount of the electric energy is liberated in the arc-discharge column 3 which has not yet had time to expand. Therewith, the current density in the arc discharge, hence the heat concentration therein, increases. The effect of heat concentration in an arc discharge is attained, according to the present invention, without using any additional means and solely due to feeding the arc discharge with current pulses of particular duration and intervals therebetween.

Comparative analysis has been performed of electric arc discharges with square current pulses having an amplitude of 200 A being supplied thereto, the time ratio between their spacing and the duration of a pulse being equal to 8.5, and the duration of each pulse being equal to $120 \cdot 10^{-6}$ and $120 \cdot 10^{-3}$ sec.

It has been revealed that the power density in an arc used in welding with pulses having a duration of $120 \cdot 10^{-6}$ sec. is 2.43 times higher than with pulses having a duration of $120 \cdot 10^{-3}$ sec.

Thus, experimental data indicate that welding with current pulses the duration whereof is less than the arc-discharge column expansion time results in a higher power density in the arc-discharge column and, consequently, in a higher heat concentration therein without using any mechanical devices and additional means for forming a gas stream for cooling the arc-discharge column.

Increasing heat concentration in an arc discharge by the proposed method can be advantageously used in a number of technological processes. For example, in arc welding of metals, this method will permit the welding of refractory materials keeping, at the same time, the total heating of the welded article within reasonable limits. When used in plasma generating devices, the method of the present invention may provide for an additional increase in temperature.

Modern research methods allow an engineer working on the application of arc discharges in research or industry to determine the time of a transient occurring during striking an arc in each particular case depending on the composition of the arc atmosphere and construction of the plasmatron and thereby find an optimum pulse duration for each particular technological process.

It should be borne in mind that the embodiment of the present invention as disclosed above with reference to the accompanying drawings is only exemplary and

preferable, for a number of other embodiments are possible as regards the shape, size and arrangement of individual components of the system. The components described above and illustrated in the drawings can be replaced by other, similar ones and their arrangement may be different provided all these variations remain within the scope of the present invention as set forth in the claims.

What is claimed is:

1. A method for compressing an arc-discharge column, comprising the following steps: spacing electrodes at a distance sufficient to form an arc gap; supplying shielding gas to said electrodes; applying to said electrodes current pulses having a duration less than the time period during which the arc-discharge column expands to a steady-state value; ceasing to apply current pulses to said electrodes for a time period sufficient to bring the arc-discharge column to the initial state; alternately applying said current pulses to said electrodes to be followed by a discontinuation thereof.

2. A method for compressing an arc-discharge column as claimed in claim **1**, wherein current pulses having a duration of no more than $500 \cdot 10^{-6}$ sec are applied to gas-shielded non-consumable electrodes and a welded article spaced at a distance sufficient to form an arc gap, and the time ratio between the pulse spacing and the duration of a pulse is chosen to be equal to no less than **5**.

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