Sept. 3, 1963 A. DE LA CUADRA ETAL 3,102,971

ELECTRIC IMPULSE GENERATING SYSTEM FOR SPECTRAL ANALYSIS WITH CONTROLLED ARC

Filed June 1, 1961 2 Sheets-Sheet 1

FIG. 1.

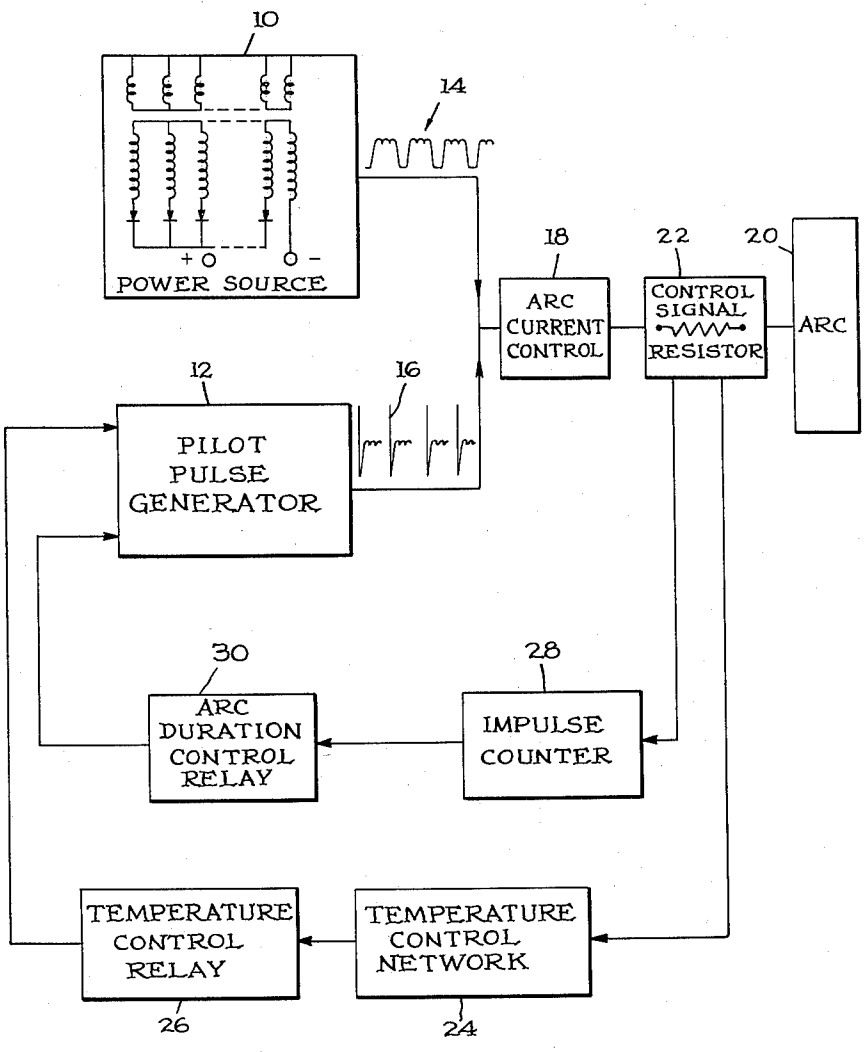

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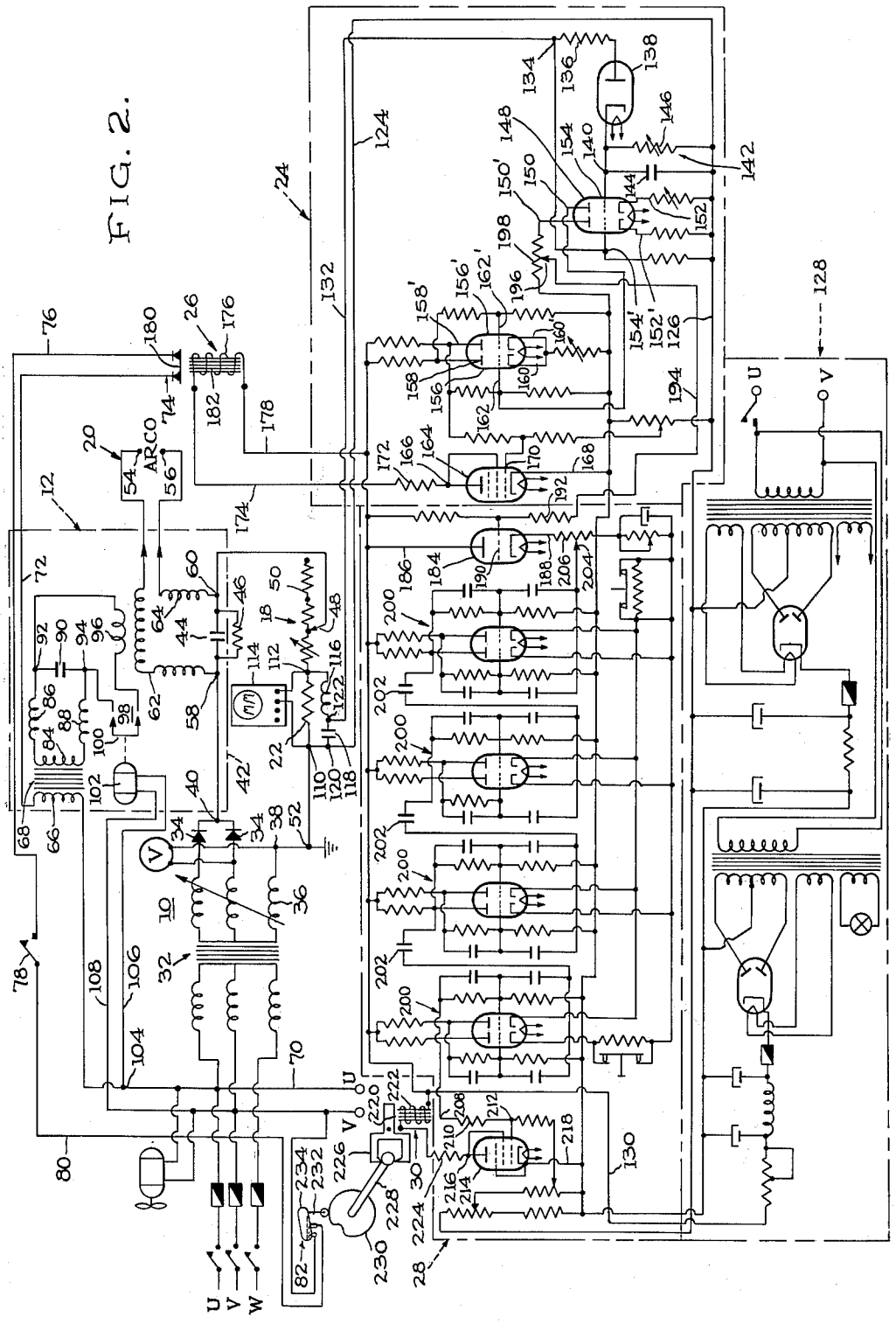
FIG. 2.



United States Patent Office 3,102,971 Patented Sept. 3, 1963

3,102,971

ELECTRIC IMPULSE GENERATING SYSTEM FOR SPECTRAL ANALYSIS WITH CONTROLLED ARC

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Filed June 1, 1961, Ser. No. 114,232
Claims priority, application Spain June 10, 1960
14 Claims. (Cl. 315—171)

The invention relates to electric impulse generating systems and more particularly to systems for generating an electric arc of controlled temperature, intensity, and duration for use in spectrochemical analysis and the like.

It is an object of this invention to provide an electric arc generating circuit for controlling the duration of an arc comprising a polyphase power supply, a polyphase rectifier for converting the voltage from the said power supply to a series of impulses, arc electrodes connected in circuit with said rectifier having an arc generated thereacross and fed by said impulses, and counting means for counting said impulses to thereby break said circuit between said rectifier and said arc electrodes to extinguish said arc after a predetermined number of impulses have passed through said arc.

Another object of this invention is to provide an electric arc generating circuit for controlling the duration of an arc comprising a pulsating voltage source for striking and feeding said arc, counting means to extinguish said arc after a predetermined number of voltage pulses therethrough and modulating means for extinguishing said arc, irrespective of said counting means, to control the temperature generated by said arc.

These and other objects of this invention will become apparent with reference to the following specification and drawings which relate to a preferred embodiment of the invention.

In the drawings:

FIGURE 1 is a block diagram of the system of the invention; and

FIGURE 2 is a schematic diagram of the system of the invention.

Referring in detail to the drawings and more particularly to FIGURE 1, the system of the subject invention is shown in block diagram as comprising a main power supply 10, generally indicated as a rectified polyphase source, and a pilot pulse generator 12 synchronized therewith such that the pulsed power output shown at 14 from the main power supply 10 and the pulsed pilot output shown at 16 from the pilot pulse generator 12 are locked in phase with one another.

Both of the outputs 14 and 16 are fed simultaneously to an arc current control circuit 18 for controlling the arc discharge across a set of arc electrodes generally indicated at 20.

The current impulses passing through the arc at the electrodes 20 is monitored by a control signal resistor 22 in series with the said arc electrodes and the arc current control circuit 18, the pulsed voltage drop across the control signal resistor 22 being used, as will be hereinafter described, as a control signal for actuating arc duration and electrode temperature control devices.

The pulsed voltage drop across the control signal resistor 22 is fed to an arc electrode temperature control circuit 24 which is shown as controlling a first or temperature control relay 26. The temperature control relay 26, in turn, acts to selectively energize or de-energize the pilot pulse generator 12 in response to the output of the said temperature control network 24.

The pulsed voltage drop across the control signal resistor 22 is also fed to an impulse counter circuit 28 which after a suitable number of input voltage impulses produces an output signal to energize a second or arc duration control relay 30. The arc duration control relay 30, in turn, acts to selectively energize the pilot pulse generator 12 in response to the output of the impulse counter circuit 28.

Referring now to FIGURE 2, a preferred embodiment of the system of the present invention will now be described in detail.

The polyphase power for the present system is brought in at phase leads U, V and W as shown. The main power source 10 is shown as comprising a Y-connected three phase transformer 32 having a pair of half wave rectifiers 34 located one in each of two of the three phase windings in the secondary of the transformer 32. The third phase winding 36 is connected to ground via a terminal 38.

The two rectifiers 34 are connected to a common node 40. The node 40 is connected via a lead 42 through a parallel R–C combination comprising a capacitor 44 and a resistor 46 to an adjustable tap 48 on the arc current control means 18 comprising a variable resistor 50 in a series with the control signal resistor 22. The control signal resistor 22 is in turn connected to ground via a terminal 52.

The arc electrodes 20 comprise an anode 54 and a cathode 56 connected to terminals 58 and 60, respectively, located one on either side of the capacitor 44, through a respective pair of inductances comprising a two-segment inductance 62 and an inductance 64.

The pilot pulse generator 12 derives its power from the primary winding 66 of a step-up transformer 68 connected across phase terminals U and V through a lead 70 extending from the terminal U through the said primary winding 66, lead 72, a first or temperature control relay operated switch 74, lead 76, manual switch 78, lead 80 and a second or arc duration control relay operated switch 82 to the terminal V.

The step-up transformer 68 includes a secondary winding 84 forming a part of an L–C ringing circuit comprising additional inductors 86 and 88 connected in a closed loop with a capacitor 90.

The ringing circuit includes a pair of output terminals 92 and 94 located one on either side of the capacitor 90. An output inductance 96 is connected between the terminal 92 and one stationary contact of a rotary intermittent switch means 98 comprising a motor driven shorting bar 100 driven by a synchronous motor 102 connected across the phase terminals U and V via leads 70, junction 104, lead 106 and lead 108, whereby the switch 98 is intermittently closed in synchronism with the power input to the main power source 10 and hence, with the main power source 10. The other fixed contact of the said rotary switch 98 is connected with the other output terminal 94 to the said ringing circuit.

The output inductance 96 is inductively coupled with at least one of the segments of the two-segment inductance 62 in the anode circuit of the arc electrodes 20 whereby pilot pulses generated in the said ringing circuit including frequency components determined by the parameters of the said ringing circuit, may be coupled to the arc electrodes 20 via the anode electrode 54, the pilot pulses being coupled to the said anode 54 in synchronism with the main power pulses from the main power source 10.

The pulsating current generated in the main power source 10 and passing through the arc current control 18 and the control signal resistor 22 cause a pulsating voltage drop to appear across the end terminals 110 and 112 of the said control signal resistor 22.

A cathode ray oscilloscope 114 or the like may be connected across the terminals 110 and 112 of the signal resistor 22 whereby a visual monitoring of the arc current pulses will be provided.

A control signal is derived from the pulsating voltage drop across the signal resistor 22 by way of an L–C series network connected across the terminals 110 and 112 including an inductance 116 and a capacitance 118, the capacitance having a pair of output terminals 120 and 122 located one on either side thereof across which the said control signal is taken.

One output terminal 120 is connected via a lead 124 to a first common bias reference lead 126 on one side of both the temperature control circuit 24 and the arc duration control circuit 30. The first common bias lead 126 is also connected with one side of a bias supply circuit generally indicated at 128. A second common bias lead 130 is provided and extends from the other side of the bias supply 128 and on the other side of the said temperature and arc duration control circuits 24 and 30, respectively.

The other output terminal 122 from the capacitor 118 in the control signal generating circuit is connected via a lead 132 to an input node 134 common to both the temperature control and arc duration control circuits 24 and 30, respectively.

Looking from the input node 134 the temperature control circuit 24 is shown as comprising a current limiting resistor 136 and a diode 138 in series between the input node 134 and one terminal 140 of a parallel R–C input network 142 comprising a capacitor 144 and a variable bleed resistor 146 both connected from the said one terminal 140 thereof to the common lead 126; a first amplifier stage comprising one-half of a twin triode 148 having anode, cathode, and grid terminals 150, 152 and 154, respectively, the said grid terminal 154 being connected with the said one terminal 140 of the R–C input network 142; a second amplifier stage comprising both halves of a twin triode 156—156′ having anode, cathode and grid terminals 158, 160 and 162 and 158′, 160′ and 162′, respectively, the grid terminal 162 of the first half 156 being connected with the anode 150 of the first amplifier stage through a suitable impedance and the grid terminal 162′ of the second half 156′ being connected with the anode 158 of the first half 156 through a suitable impedance; and a third and final amplifier stage comprising a pentode 164 including anode, cathode, and control grid electrodes 166, 168 and 170, respectively, the control grid terminal 170 of the said pentode 164 being connected with the anode 158′ of the said second half 156′ of the second amplifier stage.

When a sufficient number of pulses are transmitted through the said diode 138 to cause the capacitor 144 in the input network 142 to charge up to a predetermined value, the bias placed on the grid 154 of the first amplifier stage causes conduction of the first, second and third amplifier stages in the said temperature control circuit 24. The input network 142 thus functions as an integrating circuit.

The temperature control relay 26 is connected from the anode 166 of the third amplifier stage or pentode 164 of the temperature control circuit 24 via a resistor 172, lead 174, relay coil 176 and a lead 178 back to the common bias lead 130. Thus, in response to conduction in the pentode 164, the relay coil 176 in the temperature control relay is energized. This causes an armature 180 integral with the temperature control switch 74 in the pilot pulse generator circuit to be attracted toward the core 182 of the temperature control relay 26, opening the said switch 74 and de-energizing the pilot pulse generator. This causes the arc at the arc electrodes 20 to extinguish at the completion of the subsisting power pulse from the main power source 10.

The arc duration control circuit or impulse counter 28 comprises an input amplifier stage consisting of the remaining half of the twin triode 148 having anode, cathode and grid terminals 150′, 152′ and 154′, respectively, the grid terminal 154′ being connected with the common input node 134 so as to be biased to render the said input

stage conductive in response to each current pulse through the said signal resistor 22 reflected at the common input node 134 as hereinbefore described; a second amplifier stage including a triode 184 having anode, cathode and grid terminals 186, 188 and 190, respectively, connected at its grid terminal 190 to the anode 150′ of the said input stage via a suitable coupling impedance 192, lead 194, variable tap 196 and load resistor 198 at the said anode 150′; a plurality of flip-flop counter stages 200 coupled by capacitors 202 in a counting chain initially energized by the voltage drop sensed by the variable tap 204 on the cathode resistor 206 of the second triode 184 and fed via lead 208 to the right hand one of the flip-flops 200; and an output stage fed from the left hand or final counter stage 200 through a lead 208 and coupling resistor 210 to a control grid terminal 212 comprising a pentode 214 including anode and cathode terminals 216 and 218, respectively, in addition to the control grid terminal 212, the said pentode 214 being rendered conductive in response to an output signal from the said left hand or final counter stage 200.

The arc duration control relay 30 is shown as comprising a core 220 having a winding 222 thereon connected to the anode terminal 216 of the output pentode 214 of the counter 28 via a resistor 224 on one side thereof and to the common bias lead 132 on the other side thereof. The arc duration control relay includes a rocking armature 226 schematically shown which rotates a shaft 228 on which is fixedly mounted a cam 230 in response to the energization of the said winding 222 of the arc duration control relay 30.

A cam follower 232 on the pivoted mercury capsule 234 of the arc duration control switch 82 cooperates with an indentation or detent 236 on the cam 230 to tilt the said capsule 234 and open the said switch 82 in response to the rotation of the cam 230, whereby the pilot pulse generator circuit 12 is de-energized after a predetermined number of current pulses have passed between the said arc electrodes 20.

Operation

In operation, referring to both FIGURES 1 and 2, the main power source 10 will be assumed to be energized and the pilot pulse generator will be subsequently selectively energized by the manual switch 78. At this point it will also be assumed that both the arc duration control switch 82 and the temperature control switch 74 will be closed and that both the temperature control and counter circuits 24 and 28, respectively, are ready to begin their cycle of operation.

The switch 78 is now closed which energizes the pilot pulse generator causing the ringing circuit therein to produce oscillations reflected at the output terminals 92 and 94 on either side of the capacitor 90 of the said ringing circuit.

The motor 102 is running at a synchronous speed locked-in with the supply frequency of the main power source and thus makes and breaks the stationary contacts of the rotary switch 98 via the rotating shorting bar 100 driven thereby. This causes high frequency pilot pulses to be produced in the output inductor 96 and coupled to the anode terminal 54 of the arc electrodes 20 through the two-segment inductor 62. This causes a pilot spark, of an intensity much less than that of the main arc, to be generated across the arc electrodes 20 by virtue of the high voltage and high frequency components in the pilot pulses and the greater tendency of the high frequency to ionize the air in the gap between the electrodes 20.

Once the air breaks down into ions, the lower voltage higher current main arc will strike from anode 54 to cathode 56 and will be re-ignited for successive power pulses through the action of the pilot pulse generator 12.

After a predetermined number of current pulses through the main arc the electrodes 20 (anode 54 and cathode 56) become overheated and a break or delay in the sequence

of current pulses through the arc is necessary to effect cooling. The total energy through the arc is thus sensed by charging the capacitor 144, in the input network 142 of the temperature control circuit, in step-by-step fashion, by the signal pulses appearing across the signal resistor 22, via the lead 132, input node 134, resistor 136 and diode 138. After a number of pulses representative of the total energy having passed through the main arc electrodes 20, the capacitor 144 reaches a predetermined charge which biases the temperature control circuit amplifier stages into conduction, as hereinbefore described. Thus, the temperature control relay is energized to open the temperature control switch 74 to de-energize the pilot pulse generator 12 and temporarily extinguish the arc for a time sufficient to maintain the temperature of the arc electrodes 20 below a predetermined value. This time is controlled by adjusting the resistor 146 in the input network 142 of the temperature control circuit 24, whereby the charge on the capacitor is bled off at a desired rate to subsequently cut off the amplifier stages in the temperature control circuit to de-energize the temperature control relay 26, close the switch 74 and energize the pilot pulse generator 12 to re-ignite the arc.

The temperature control is superimposed on the arc duration control in the form of a modulation which temporarily extinguishes the main arc in response to the total energy consumed therein regardless of the number of power pulses which have passed through the arc.

The voltage pulses in the signal resistor 22 corresponding to the power pulses passing through the arc electrodes 20 are used to sequentially trigger the counter stages 200 of the impulse counter circuit 28 as hereinbefore described until a predetermined number of said pulses have occurred. At this point, the left hand or final counter stage 200 provides an output signal through lead 208 and resistor 210 to the grid terminal 212 of the pentode 214. This causes the pentode 214 to conduct, energize the arc duration control relay 30, and open the arc duration control switch 82 to de-energize the pilot pulse generator 12 and extinguish the main arc across the arc electrodes 20.

Thus, the duration and temperature of the arc are accurately controlled.

The intensity of the arc may be controlled by adjusting the value of the arc current control resistor 18.

As can be seen from the foregoing description and drawings this invention provides a new and novel arc generator and control circuit which produces a pulse direct current arc wherein the duration of the arc and the temperature of the arc electrodes is automatically controlled.

It is to be understood that the embodiments shown and described herein are for the purpose of example only and are not intended to limit the scope of the appended claims.

What is claimed is:

1. An arc generating and control system comprising an alternating current power supply, a rectifier for converting the alternating current energy from said power supply to a series of energy pulses, arc electrodes connected in circuit with said rectifier having an arc generated thereacross and fed by said energy pulses, and arc duration control means responsive to a predetermined number of energy pulses for extinguishing said arc after said predetermined number of energy pulses have passed therethrough.

2. An arc generating and control system comprising a power source generating a series of energy pulses, arc electrodes in circuit with said power source having an arc generated thereacross and fed by said energy pulses, a pilot pulse generator in circuit with said electrodes and synchronized with said power source producing a high frequency arc striking pilot pulse at the incidence of each of said energy pulses, and arc duration control means, including pulse counting means responsive to a predetermined number of energy pulses and connected in circuit with said arc electrodes and switch means in said pilot pulse generator controlled by said pulse counting means, for de-energizing said pilot pulse generator and thereby extinguishing said arc after said predetermined number of energy pulses have passed through said arc.

3. The invention defined in claim 2, wherein said system further includes a resistor in circuit with said arc electrodes having a pulsating series of control signals produced thereacross corresponding to a series of energy pulses passing through said arc, and circuit means connecting said series of control signals with said pulse counting means.

4. The invention defined in claim 3, wherein said pulse counting means comprises an input amplifier stage having an input and an output connected at its input with said circuit means, a series of cascaded counter stages having an input and an output, the input of said series of counter stages being connected with the output of said input amplifier stage, whereby the said series of counter stages is progressively energized by the said control signals via said input amplifier stage, and an output amplifier stage having an input and an output, connected at its input to the output of said series of counter stages, whereby said output amplifier stage is energized in response to a predetermined number of control signal pulses to said pulse counting means, the output of the said output amplifier stage being connected with said switch means to selectively energize or de-energize said switch means and said pilot pulse generator.

5. An arc generating and control system comprising an alternating current power supply, a rectifier for converting the alternating current energy from said power supply to a series of energy pulses, arc electrodes connected in circuit with said rectifier having an arc generated thereacross and fed by said energy pulses, and temperature control means, for preventing said arc electrodes from overheating responsive to a predetermined quantity of energy imparted to said arc by said power pulses for extinguishing said arc for a period sufficient to cool said electrodes after said predetermined quantity of energy has been imparted to said arc.

6. An arc generating and control system comprising a power source generating a series of energy pulses, arc electrodes in circuit with said power source having an arc generated thereacross and fed by said energy pulses, a pilot pulse generator in circuit with said electrodes and synchronized with said power source producing a high frequency arc striking pilot pulse at the incidence of each of said energy pulses, and temperature control means for preventing said arc electrodes from overheating, including integrating means connected in circuit with said arc electrodes responsive to a predetermined quantity of energy imparted to said arc and switch means in said pilot pulse generator controlled by said integrating means, for de-energizing said pilot pulse generator and thereby extinguishing said arc after said predetermined quantity of energy has been imparted to said arc.

7. The invention defined in claim 6 wherein said system further includes a resistor in circuit with said arc electrodes having a pulsating series of control signals produced thereacross corresponding to a series of energy pulses passing through said arc, and circuit means connecting said series of control signals with said integrating means.

8. The invention defined in claim 7, wherein said integrating means comprises an input amplifier stage having an input and an output, an input network connected at the input of said input stage and including a parallel connected capacitor and bleed resistor connected between said input of said input stage and a suitable reference source, said input of said input stage being also connected with said circuit means, and an output amplifier stage having an input and an output connected at its input to the output of said input stage, said capacitor being charged by said series of control signals until a predetermined charge is provided thereon representative of a predetermined quantity of energy imparted to said arc,

whereby said input stage and said output stage will be energized in response to said predetermined quantity of energy, the output of said output amplifier stage being connected with said switch means to selectively energize or de-energize said switch means and said pilot pulse generator.

9. An arc generating and control system comprising an alternating current power supply, a rectifier for converting the alternating current energy from said power supply to a series of energy pulses, arc electrodes connected in circuit with said rectifier having an arc generated thereacross and fed by said energy pulses, arc duration control means responsive to a predetermined number of energy pulses for extinguishing said arc after said predetermined number of energy pulses have passed therethrough and temperature control means acting independently of said arc duration control means, for preventing said arc electrodes from overheating, responsive to a predetermined quantity of energy imparted to said arc by said power pulses for extinguishing said arc for a period of time sufficient to cool said electrodes after said predetermined quantity of energy has been imparted to said arc.

10. An arc generating and control system comprising a power source generating a series of energy pulses, arc electrodes in circuit with said power source having an arc generated thereacross and fed by said energy pulses, a pilot pulse generator in circuit with said electrodes and synchronized with said power source producing a high frequency arc striking pilot pulse at the incidence of each of said energy pulses; arc duration control means, including pulse counting means responsive to a predetermined number of energy pulses and connected in circuit with said arc electrodes and a first switch means in said pilot pulse generator controlled by said pulse counting means, for de-energizing said pilot pulse generator and thereby extinguishing said arc after said predetermined number of energy pulses have passed through said arc; and temperature control means, acting independently of said arc duration control means, for preventing said arc electrodes from overheating, including integrating means connected in circuit with said arc electrodes responsive to a predetermined quantity of energy imparted to said arc and a second switch means in said pilot pulse generator controlled by said integrating means, for de-energizing said pilot pulse generator and thereby extinguishing said arc after said predetermined quantity of energy has been imparted to said arc; said temperature control means acting only to modulate the action of said arc duration control means and not to vary the total number of energy pulses imparted to said arc during a complete cycle of operation.

11. The invention defined in claim 10, wherein said system further includes a resistor in circuit with said arc electrodes having a pulsating series of control signals produced thereacross corresponding to a series of energy pulses passing through said arc, and circuit means connecting said series of control signals with said pulse counting means and said integrating means.

12. The invention defined in claim 11, wherein said pulse counting means comprises an input amplifier stage having an input and an output connected at its input with said circuit means, a series of cascaded counter stages having an input and an output, the input of said series of counter stages being connected with the output of said input amplifier stage, whereby the said series of counter stages is progressively energized by the said control signals via said input amplifier stage, and an output amplifier stage having an input and an output, connected at its input to the output of said series of counter stages, whereby said output amplifier stage is energized in response to a predetermined number of control signal pulses to said pulse counting means, the output of the said output amplifier stage being connected with said switch means to selectively energize or de-energize said switch means and said pilot pulse generator.

13. The invention defined in claim 11, wherein said integrating means comprises an input amplifier stage having an input and an output, an input network connected at the input of said input stage and including a parallel connected capacitor and bleed resistor connected between said input of said input stage and a suitable reference source, said input of said input stage being also connected with said circuit means, and an output amplifier stage having an input and an output connected at its input to the output of said input stage, said capacitor being charged by said series of control signals until a predetermined charge is provided thereon representative of a predetermined quantity of energy imparted to said arc, whereby said input stage and said output stage will be energized in response to said predetermined quantity of energy, the output of said output amplifier stage being connected with said switch means to selectively energize or de-energize said switch means and said pilot pulse generator.

14. The invention defined in claim 11, wherein said pulse counting means comprises an input amplifier stage having an input and an output connected at its input with said circuit means, a series of cascaded counter stages having an input and an output, the input of said series of counter stages being connected with the output of said input amplifier stage, whereby the said series of counter stages is progressively energized by the said control signals via said input amplifier stage, and an output amplifier stage having an input and an output, connected at its input to the output of said series of counter stages, whereby said output amplifier stage is energized in response to a predetermined number of control signal pulses to said pulse counting means, the output of the said output amplifier stage being connected with said first switch means to selectively energize or de-energize said first switch means and said pilot pulse generator; and wherein said integrating means comprises an input amplifier stage having an input and an output, an input network connected at the input of said input stage and including a parallel connected capacitor and bleed resistor connected between said input of said input stage and a suitable reference source, said input of said input stage being also connected with said circiut means, and an output amplifier stage having an input and an output connected at its input to the output of said input stage, said capacitor being charged by said series of control signals until a predetermined charge is provided thereon representative of a predetermined quantity of energy imparted to said arc, whereby said input stage and said output stage will be energized in response to said predetermined quantity of energy, the output of said output amplifier stage being connected with said second switch means to selectively energize or de-energize said second switch means and said pilot pulse generator.

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