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PROCESS OF AND APPARATUS FOR THE STABILIZATION OF HIGH-FREQUENCY GAS AND GLOW DISCHARGES

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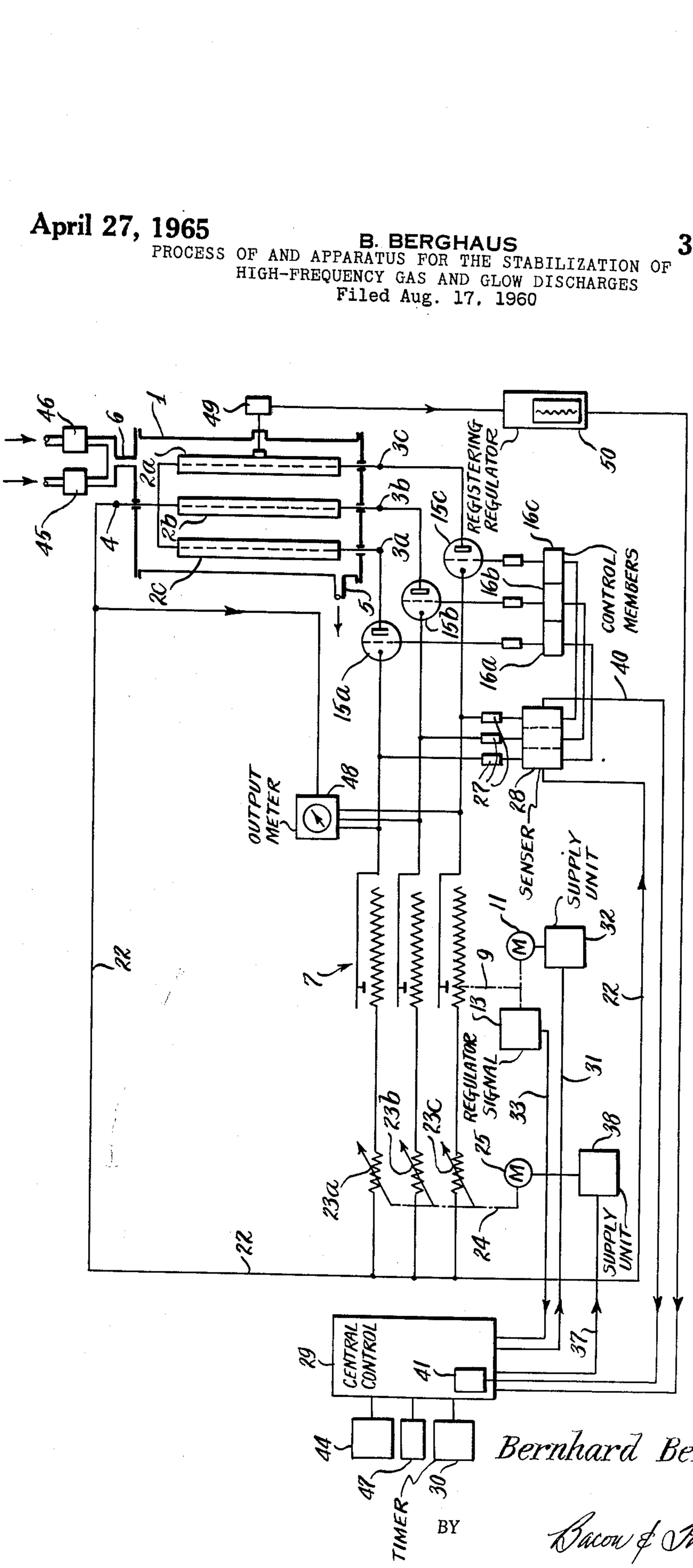

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PROCESS OF AND APPARATUS FOR THE STABILIZATION OF HIGH-FREQUENCY GAS AND GLOW DISCHARGES

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This invention relates to the initiation, maintenance and operation of high-frequency gas and glow discharges in a discharge vessel, particularly to a process of and an apparatus for the stabilization of such discharges.

During the operation of high-frequency gas and glow discharges, particularly during the initial time after the current for such discharges in a discharge vessel is switched on, it is known that measures must be provided in order to reduce possibilities for a glow discharge turning into an arc discharge between the parts to which a voltage is applied, as such arc discharges or spark discharges usually cause more or less serious combustion phenomena on the surfaces of the respective parts to which a voltage is applied. The tendency of a glow discharge to a transition into an arc discharge is particularly strong during the so-called starting period of the discharge process, thus during the initial time following the closing of the circuit of such a discharge section. Especially in the case of metallurgical processes which are carried out by means of a gas or glow discharge and for which a relatively high operating temperature must be maintained, these tendencies towards such undesirable arc discharges are observed quite frequently. Impurities on the respective work pieces or strongly emitting spots thereon, or enclosed gas remnants suddenly bursting out from metal surfaces or liquefied material, and the like, are chief causes favoring the transition from a glow discharge into an arc discharge. After a certain operation time at a prescribed temperature for the respective process, the tendencies towards such undesirable phenomena are known to become considerably less strong, and a rather steady operating condition is obtained on the discharge path. However, even with normal operation, safety measures must be provided to eliminate any detrimental action of such possible arc discharges in the case of a sudden outburst of gas from the heated surfaces or in the case of a momentary tendency towards a transition into an arc discharge which may appear from any other reasons.

Various suggestions have already been made for the protection against the detrimental action of such arc discharges which may occur during the starting period and operation of high-frequency glow discharges. A so-called starting process is for instance described in Patent No. 2,884,511 which reduces already considerably the tendency of the discharge towards a transition into an arc discharge. Moreover, the short reduction of the operating voltage at the discharge vessel is described in this patent application, this reduction being made in order to limit the current, i.e. to suppress any flash-over about to appear in such cases where an adjustable maximum current is exceeded or where an adjustable minimum voltage is underpassed. Also in Patent No. 2,884,511, dated April 28, 1959 suitable measures are described for switching off the current when flash-overs appear.

With the use of all the devices known to this day for switching off the current when flash-overs occur, an arc flash-over is supposed to take place first, if only for a short time, in order to put the switch device into operation and to reduce the operating voltage at the discharge vessel which extinguishes the arc. But this means that the electric arc which should be eliminated altogether, exists at least for a short time. Experience, however, has shown that if an arc appears, though only for a short time, undesirable consequences are inevitable, for instance, so-called burning spots appear on the surface of polished metal parts.

It is accordingly an object of this invention to suppress an arc about to be formed early enough so that the undesirable electric arc or spark flash-over actually does not take place.

The process according to this invention for the stabilization of high-frequency gas and glow discharges in a discharge vessel by reducing the operating voltage at the moment of sudden changes of an operation quantity of the discharge is characterized by the fact that the necessary time for reducing the voltage following the formation and flashover of a spark or arc discharge in the discharge vessel is made shorter than heretofore.

This invention relates moreover to a device for carrying out the process with a switch member designed to reduce the operating voltage, being controlled by a sensing member which reacts to sudden changes of an operation quantity characterized by the fact that the action time for both the sensing member and the switch member is made shorter than the time of build-up and flash-over for a spark or arc discharge in the discharge vessel.

This invention is described hereafter in an embodiment illustrated by way of example in the hereto attached wiring diagram of an installation for high-frequency electric glow discharges.

The simplified wiring diagram, which embodies in large part the structure shown and described in Patent No. 2,884,511, represents an installation for carrying out the process and especially for such case wherein, by means of a glow discharge, the nitriding of three steel tubes 2*a*, 2*b*, 2*c* takes place. The tubes 2*a*, 2*b*, 2*c* are each combined with the connections 3*a*, 3*b*, 3*c* over an insulated current lead-in. Inside of each tube and insulated therefrom, an internal lead is arranged consisting, for instance, of a 7 mm. wide steel wire. All the internal leads in the receptacle have parallel connections and are connected with the terminal 4 over an insulated current lead-in. Connected to a pump (not shown) is an exhaust line 5 as well as a gas lead-in 6 with the control valves 45 and 46.

The current supply is, as an example, a parallelly connected three-phase A.C. current over a three-phase variable voltage transformer 7 and three rectifying tubes 15*a*, 15*b*, 15*c* which feed the terminals 3*a*, 3*b*, 3*c* so that the tubes 2*a*, 2*b*, 2*c* act as cathodes against the internal lead. The variable voltage transformer 7 is shown only with its secondary windings. The primary windings may be connected to the polyphase main by means of a star or delta-connection. The variable voltage transformer 7 is provided with a mutual regulating mechanism 9 for all the three taps at the windings, wherein, by means of the reversible motor 11, it can be adjusted to higher or lower secondary voltages. The regulating mechanism 9 is moreover provided with a scale 13 which, for the initial and end adjustment, is controlled by a contact which, if so desired, may be arranged for signalling intermediary adjustments.

The three secondary windings of the variable voltage transformer 7 are interconnected to the connections 3*a*, 3*b*, 3*c*, respectively, over the cumulative grid rectifying tube 15*a*, 15*b*, 15*c*, respectively, which may be disconnected independently one from the other over the control members 16*a*, 16*b*, 16*c*, respectively.

The secondary windings of the variable voltage transformer 7 are operated in star-connection, however, an impedance coil 23*a*, 23*b*, 23*c*, respectively, is connected in the intermediate line from the neutral conductor 22 to the three secondary windings. All the three impedance

coils are adjustable and provided with a common regulating mechanism 24 which is operated reversibly by the motor 25. With the embodiment in question, the impedance value of the coils 23 is gradually adjustable, i.e. there are provided four steps with the impedances 30, 15, 5, and 1 ohm, respectively.

The neutral line 22 is moreover connected to the checking or sensing member 28 which is also connected to the three secondary phase voltages over the three impedances 27. This checking or sensing member 28 reacts to all voltage changes exceeding an adjustable minimum value between the neutral line 22 and the three phases, and that in dependance on their actual sequence which will be explained hereinbelow. The sensing member 28 is connected to a line each by the three control members 16*a*, 16*b*, 16*c*.

The whole installation is controlled by a central control device 29 to which a cadence tapper or timer 30 is connected. The control member 29 is connected, via the control line 31, to the supply unit 32 of the adjusting motor 11 of the variable voltage transformer 7 and receives the revertive communication of the scale 13 over the line 33. Moreover, the supply unit 38 for the adjusting motor 25 of the chokes 23 is activated in one or the other direction over the control line 37.

The functional sequence of the control device 29 is provided with suitable relays, step-by-step selectors or electronic means in such a manner that the necessary control steps follow one another, the next step being introduced, however, only in the moment when the previous step is signalled back to the control device 29 to have taken place. If, therefore, the just passing step is stopped by a checking member independent from the control device 29, the next step cannot take place unless the stopped control step is freed and terminated by the checking member and the revertive signal received by the control device 29. Such a control member is represented by the sensing member 28 which, when being activated over the control device 29, influences in a suitable manner the supply units 32 and 38 for the adjusting motors of the variable voltage transformer 7.

The embodiment of this installation according to the described principal diagram is provided for an all-automatic program control at the setting into working order of the discharge vessel 1 as well as for the automatic control of the tubes to be treated 2*a*, 2*b*, and 2*c* during the whole treating time as regards the temperature, the latter being checked on the one hand by an output meter 48 and on the other hand, attached to the tube 2*a*, by a thermoelectric element 49 with the registering and regulating device 50 which, for its part, influences the control device 29. If the control device 29 is suitably designed, a predetermined voltage may be set to the rectifier tubes 15*a*, 15*b*, and 15*c* and also to the terminals 3*a*, 3*b*, and 3*c* by means of the regulating motor 11 and the voltage taps 9 at the secondary windings of the transformer 7. It is unnecessary to describe herein in detail the functions of the control device 29 as a similar installation is shown and explained in full in the above-mentioned Patent No. 2,884,511, wherein the parts 41, 44 and 47 are shown as parts 141, 144 and 147.

For the present process of stabilizing the operation of the glow discharge in the vessel 1, the sensing device 28 is of importance. This checking device contains a control connection each for the time-sequence of the voltages which are supplied to the rectifier tubes 15*a*, 15*b*, and 15*c*, by the secondary windings of the transformer 7. These checking connections are designed in order not to be influenced by a phase voltage changing at the same time with the frequency of the supply voltage. On the other hand, the respective checking connection is influenced if the respective phase voltage changes considerably quicker as this is the case if at any spot of the tube connected to this phase a tendency for the formation of an arc discharge arises. The three checking connections provided

in the sensing member 28 are connected individually with each of the three control members 16*a*, 16*b*, and 16*c* which provide the grid control of the rectifier tubes 15*a*, 15*b*, and 15*c* connected to this phase. The design of the respective checking connections and the operation of the control devices for blocking the respective rectifier tubes is generally known in pulse control engineering so that a detailed description is superfluous.

It is, however, important for the present process that the actuating time required by the checking connections and the grid control devices for the blocking of the respective rectifier tube may be made practically of any desired short duration. For carrying out the present process, the whole actuating time required for the operation of the checking members in the sensing device 28 and of the control members 16*a*, 16*b*, and 16*c*, and the parent rectifier tubes 15*a*, 15*b*, and 15*c*, must be made shorter than the production and flash-over time needed for a spark or arc discharge to be formed in the discharge vessel. If this rule is observed, it will be possible to suppress an incipient arc discharge already during its formation so that, in any case, an arc or spark flash-over between the tubes 2*a*, 2*b*, and 2*c*, and the parent inner electrodes can be suppressed.

The present process was made possible when, by physical tests on the mechanism of the transition from an electric glow discharge into an arc discharge, it was established that already before the arc discharge actually takes place which is known to cause a reduction of the operating voltage of the glow discharge to about 20 to 50 v., the build-up of the arc takes place, though within a short but measurable time. This time interval preceding the arc flash-over is already combined with a voltage reduction and may be established by sufficiently sensitive sensing members in the current supply line to the respective discharge path. These sensing members must be so designed as to make the difference between these short-lived voltage reductions taking place very rapidly and the usual voltage fluctuations produced, for instance, in connection with the frequency of the alternating voltage with A.C. operation. But this is not very difficult to find out when operating with 50 cycles A.C. because the time interval necessary for the formation of an arc flash-over is much shorter than the duration of a half cycle of an A.C. voltage.

After establishing by the sensing member an arc discharge about to be formed, care must be taken during the remaining time interval until the actual flash-over of the arc that such an arc does not actually take place at all. Thus, with the described embodiment, the operating voltage at the respective tube is suddenly reduced strongly or disconnected altogether, for which purpose electronic connecting members working practically without moments of inertia must be used. This kind of connecting member is generally known today and may be operated within microseconds. The duration of disconnection of the operating voltage may be relatively short, since the respective arc discharge has been interrupted already during the interval of its formation so that there is no strong ionization and local concentration to be feared. It has been shown that disconnections ranging within a few milliseconds may be sufficient to eliminate a new arc to be formed suddenly at the same spot after reconnection of the current.

Instead of the operating voltage being controlled at the three phases hinted thereto in the described embodiment, the current power in the three supply lines may also be checked. With rectifier operation, as described in this embodiment and as experience shows, alternating voltages deviating from the sinusoidal form are often to be observed at such spots to which the sensing connections are applied via the impedances 27. The sensing connections must then be adjusted so as not to be actuated in spite of such distorted voltage curves being produced. The carrying out of the present process will naturally be much easier if the respective discharge path

is operated with direct current of a constant voltage. In this case, the respective sensing connection may be designed in such a manner that, practically, any short-lived voltage fluctuation will cause this connection to actuate, and a short reduction of the voltage or disconnection of the voltage to be obtained. As a connecting member, a grid controlled tube or a controllable semi-conductor diode with a respective efficiency may also be employed. In view of the short time intervals at disposal from the first appearance of signs of a formation of an arc discharge to shortly before the actual arc flash-over takes place, mechanical or electro-mechanical connecting members cannot be used for this process. On the contrary, the short voltage reduction needed for the suppression of the arc flash-over may not only be obtained by disconnecting the current supply but also by a respective short bridging of the connections at the discharge vessel, a protective impedance being provided in the bridging current circuit which permits the elimination of an increase of the charge of the current supply beyond an admissible top value during the bridging interval. For such bridging, already known in arc and gas discharge engineering, there exist special electronic connecting devices which are well known and need no detailed description.

Special attention is drawn to the fact that the process as described above is not only suited for the treatment of work pieces in an electric glow discharge, as outlined in the embodiment, but it can also be used with advantage for the so-called jet discharges as described in detail, for instance, in Patent No. 2,884,511. The control of the current supply circuit for establishing an incipient formation of an arc discharge may be substituted by

optic checking of the discharge path between the electrodes to which a voltage is applied, for instance, by means of electric photocells. It has been experienced that the incipient formation of an arc can be established by this means and be used for the operation of respective connecting members.

I claim:

1. The method of stabilizing a high current glow discharge between electrodes in a vessel and wherein operating voltage is impressed on said electrodes, comprising the steps of: sensing the commencement of changes in the character of said discharge, which changes presage formation of an arc; and, in response to said changes, reducing the operating voltage on said electrodes, completing said voltage reducing step in a time interval following said sensing step which is less than the time necessary for formation of an arc.

2. The method of stabilizing a high current glow discharge between electrodes in a vessel and wherein operating voltage is impressed on said electrodes, comprising the steps of: sensing the commencement of changes in the character of said discharge, which changes presage formation of an arc; and, in response to said changes, reducing the operating voltage on said electrodes, completing said voltage reducing step in a time interval of the order of a few milliseconds and to a value below the ignition voltage for an arc discharge.

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