United States Patent

Kugler

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[54] REGULATION OF PLASMA GENERATORS

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[52] **U.S. Cl.** **315/111**, 204/164, 204/323, 313/175, 313/231

[51] **Int. Cl.** **H05b 31/26**

[58] **Field of Search** ..... 315/108, 111; 313/231, 12, 313/175, 231; 219/121, 122, 121 P, 74, 75; 204/323–328

[56] **References Cited**

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Assistant Examiner—Marvin Nussbaum
Attorney—Brady, O'Boyle & Gates

[57] **ABSTRACT**

For regulating the flows in a liquid stabilizing plasma generator a constant amount of stabilizing liquid, which is independent of the flow resistant of the generator, is supplied through at least one stabilizing liquid supply duct to the generator. Various means are employed for keeping the supply constant.

12 Claims, 5 Drawing Figures

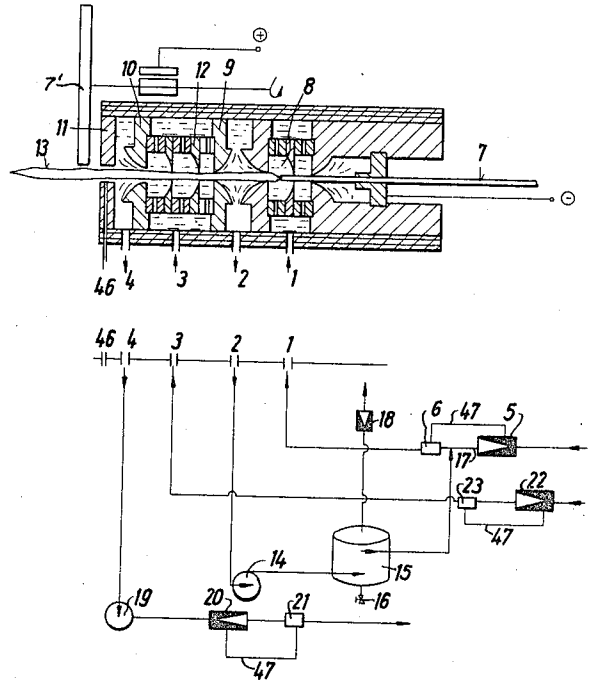

Fig.1

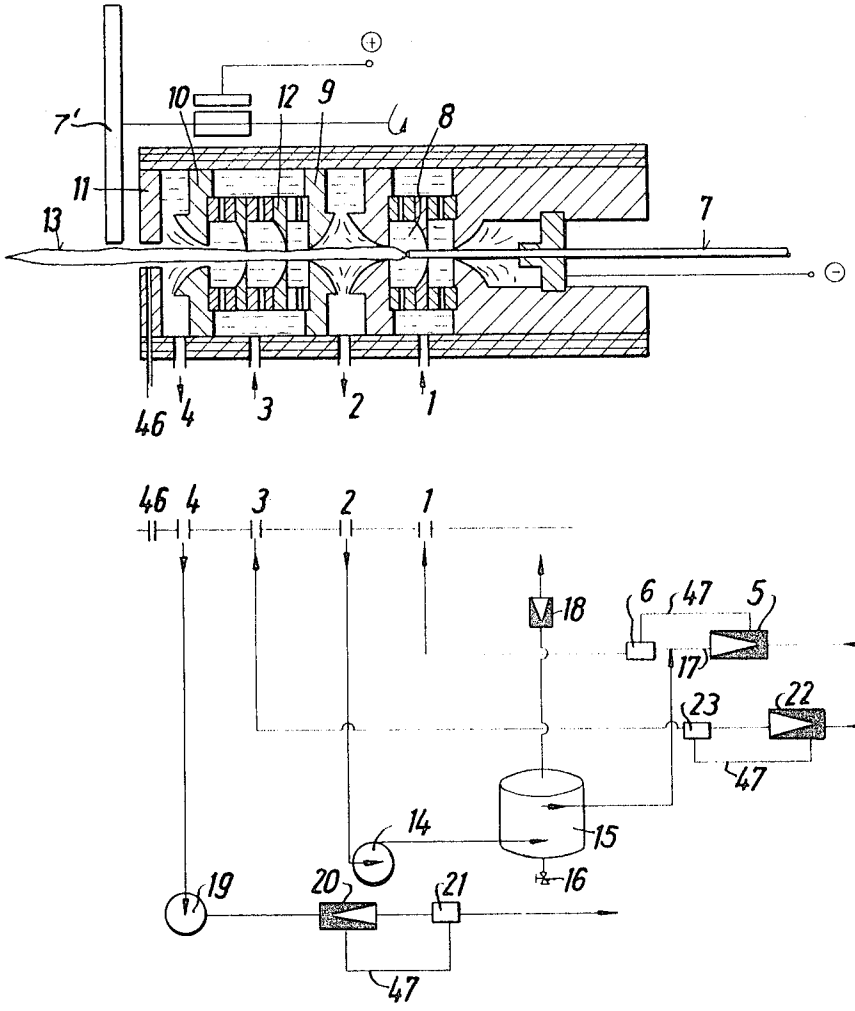

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Fig. 2

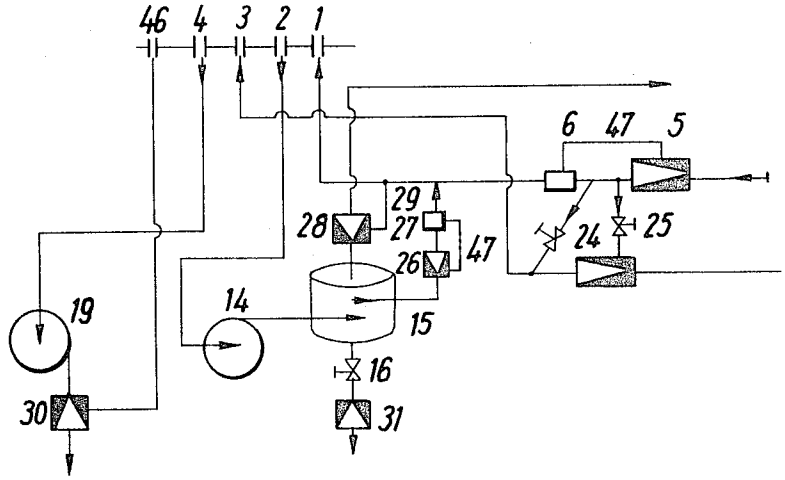

Fig. 3

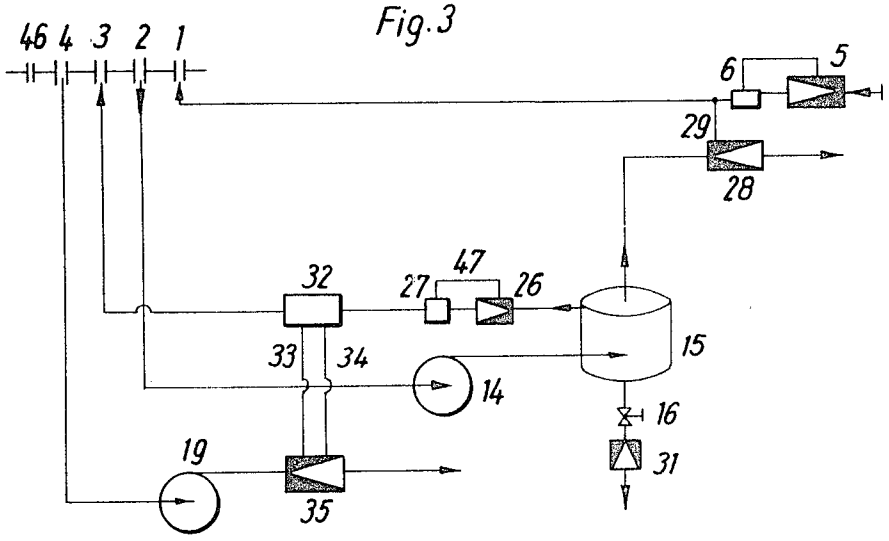

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Fig.4

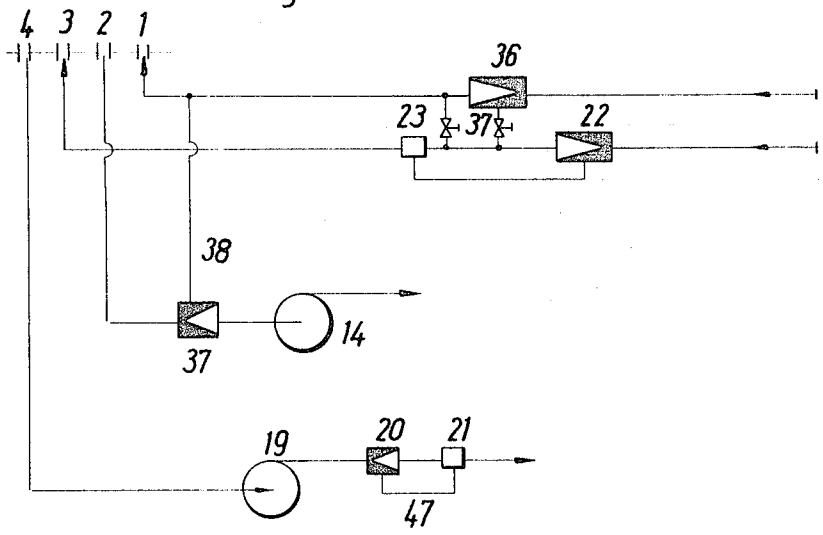
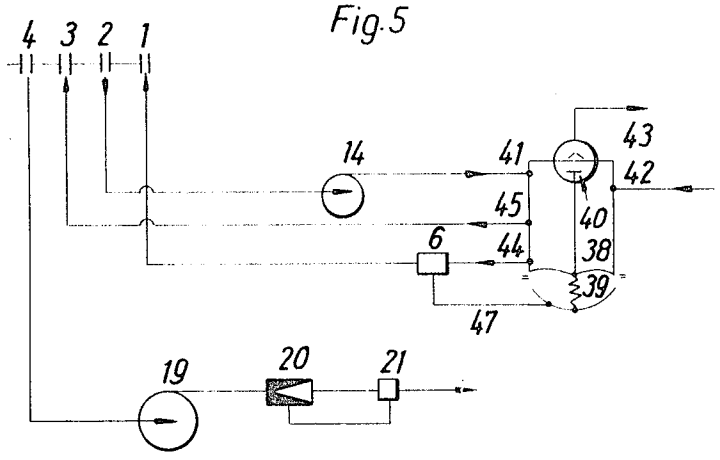


Fig.5



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REGULATION OF PLASMA GENERATORS

The present invention relates to regulating arrangements for fluid stabilized plasma generators.

Fluid stabilized plasma generators are known which comprise a stabilization channel for the arc column, the stabilization channel having a comparatively small channel diameter for the arc, and an electrode chamber with a larger diameter than that of the stabilization channel. In these plasma generators, the pressure of the plasma produced by the arc discharge acts directly on the free surface of the flowing stabilizing liquid. Since the pressure of the plasma alters with current intensity of the arc, a varying counter-pressure acts against the inflow of the stabilizing liquid. This counter-pressure increases as the intensity of the arc increases in a given plasma generator. As a result, too little stabilizing liquid is supplied in the liquid stabilized plasma generators known at present, and too much liquid-gas mixture is discharged at the discharge duct. This causes the cooling of the generator to be less as the load increases, and as the pressure increases more plasma gas is drawn from the electrode chamber, whereby the energy losses are increased. If there is an unobserved power reduction — for example caused by a small voltage drop— the plasma pressure is reduced and more stabilizing fluid is fed in, with the result that the electrode chamber is filled with liquid and the arc is extinguished.

Plasma generator constructions are also known in which there is provided at the outlet from the electrode chamber a throttle member which, after ignition of the arc, throttles the outflow. This arrangement also does not fulfill requirements, although the losses of plasma gas are reduced. Deterioration of the cooling cannot be avoided. This arrangement, moreover, can only be used for a predetermined small arc current and is subject, when the power drops, to the same dangers as mentioned above.

It is an object of the present invention to mitigate the disadvantages of prior plasma generators by regulation of the flows.

According to the present invention, a method of stabilizing the flows in a liquid stabilized plasma generator comprises supplying a constant amount of stabilizing liquid, independent of the flow resistance of the plasma generator, through at least one stabilizing liquid supply duct into the plasma generator.

Preferably, the amount of stabilizing liquid supplied is kept constant by a device measuring the amount flowing through, which device is connected through a pulse transmitter to a pressure regulator.

It has also been found to be expedient in addition to adjust the flow resistance (pressure) of the outflowing gas-containing stabilizing liquid in at least one of the outlet ducts in accordance with the pressure in the supply duct for the stabilizing liquid.

A further advantageous manner of performing the method according to the invention comprises regulating the flow resistance (pressure) in at least one of the outlet ducts for the liquid to be drawn off in dependence on the amount of flow in at least one of the supply ducts.

It is also possible to return a part of the discharged stabilizing liquid directly by a pump to the supply duct. This can advantageously be effected by drawing off the liquid to be discharged by a pump and feeding it under pressure into a flow divider. In the flow divider a part of the liquid can be bled off through a pressure regulator. The main part, or if desired, even the whole amount is metered into the supply duct. The metering can be effecting by including a metering duct between the measuring device and the pressure regulator in the supply duct. If a constant amount is fed back, the amount being kept constant by a measuring device coupled with a pressure regulator, then the amount fed back can be controlled at any point in the supply duct. If a plurality of supply ducts are used for the stabilizing liquid, it is often advantageous to couple at least two of them. In this way the pressure in the duct which is coupled with the duct supplying the constant amount into the plasma generator can be altered.

By the method according to the invention, the regulating impulse is obtained directly from the plasma pressure. The flow is also controlled in a suitable manner in dependence on the cause of the variation. The invention enables the flow ratio in the stabilization channel and in the electrode chamber to be controlled separately, and also enables the pressure and the flow, and also the temperature, of the circulating stabilizing liquid around the plasma arc and the edge region of the plasma arc to be adjusted. The discharge of uncondensed gasses, which can build up in the chambers, and any liquid or solid products formed by the effect of the plasma on the electrodes, can be readily discharged without interrupting the continuous operation of the generator.

The invention will be more readily understood from the following description of embodiments thereof given by way of example and diagrammatically illustrated in the accompanying drawings, in which:

FIG. 1 shows a plasma generator in longitudinal section with an associated schematic of a flow regulating system; and

FIGS. 2 to 5 are schematic diagrams of four different modifications of the flow regulating system arrangement of FIG. 1.

As shown in FIG. 1, a plasma generator having an cathode electrode chamber in which plasma arc 13 is established between anode electrode 7' and a rod-shaped electrode 7 is supplied with stabilizing liquid through supply ducts having inlets 1 and 3. The stabilizing liquid together with steaming gasses and any electrode products formed in the generator, leaves the electrode space through an annular space between restrictors 8 and 9 and through an outlet opening 2. The stabilizing liquid from the stabilization channel formed by restrictors 9, 10 and 12 is discharged through the annular space between the restrictors 10 and 11 and through an opening 4.

A predetermined amount of stabilizing liquid independent of the pressure in the generator is supplied to the electrode chamber through the inlet 1 by way of the supply duct connected thereto, which is provided with a measuring device 6 for measuring the through flow (e.g., a Venturi tube) coupled through a pulse transmitter 47, (e.g. a pressure duct) with a pressure regulator 5 that is connected to a supply source of liquid. For supplying a constant amount of stabilizing liquid into the stabilization channel, the amount of liquid at the inlet 3 is kept constant by a flow measuring device 23, a pulse transmitter 47 and a pressure regulator 22 that is connected to the supply source of liquid.

The stabilizing liquid flowing out from the electrode space through an opening 2, which is mixed with gas and steam, is drawn by a pump 14 and fed into a flow divider 15. The flow divider 15 is provided with an outlet duct 16 for periodic removal of solid or liquid products. From the flow divider 15 a part of the stabilizing liquid is fed back to a duct 17 between the measuring devices 6 and the pressure regulator 5. Another part of the liquid is fed through a regulator 18 from the flow divider. This part is suitably such that it contains the non-condensable products.

A suitable amount of the stabilizing liquid is removed from the stabilization space through an opening 4 by a pump 19 and passes through a pressure regulator 20 and flow measuring device 21, which are connected by a pulse transmitter 47.

If the pressure at the free surface of the stabilizing liquid alters in the plasma generator, e.g., in the electrode space, then the pressure at the inlet 1 also alters. The measuring device 6 then measures a very small change in the amount of through flow stabilizing liquid, indicates this very small amount to the pressure regulator 5 and the latter, by raising the pressure, ensures that the through flow amount of stabilizing liquid to inlet 1 remains constant.

By the arrangement of the inlet supply system 1, 6 and 5 in combination with outlets 2, 14, 15, 17 and 18, a constant pressure difference between the inlet ducts and the outlet ducts is ensured, independently of absolute pressure.

Referring now to FIG. 2, in this case the supply duct to the inlet 3 is connected to the supply duct to the inlet 1. At the

inlet 1 a constant amount of stabilizing liquid, regulated by the flow measuring device 6, pulse transmitter 47 and pressure regulator 5, is fed into the electrode space. The supply to the inlet 3 in the stabilization channel is controlled either by a pressure regulator 25 or by a connection 24. In the first case, the pressure is regulated in a predetermined relationship to the pressure prevailing in the duct to the inlet 1. In the second case the supply is ensured by the connection between the flow regulator 5 and the flow measuring device 6 with the same pressure as in the supply opening 1.

The discharge of the stabilizing liquid from the electrode space is effected through the opening 2, the pump 14, and the flow divider 15. Through a pressure regulator 28, which is controlled by the connection 29 to the pressure inlet duct to opening 1, the constant pressure difference between opening 2 and pressure regulator 25 is maintained independently of the pressure in the electrode chamber. The amount of (hot) liquid to be fed back is predetermined by the control arrangement (flow measuring device 27, pressure regulator 26 and pulse transmitter 47) and thereby the temperature of the liquid in the electrode chamber is regulated.

The discharge of the gas/steam/liquid mixture at the outlet 4 is controlled by a regulator 30, which maintains a constant pressure difference between the pressure in the mouth of the restrictor 11 and the outlet opening 4.

The discharge valve 16 of the flow divider 15 is controlled by a regulator 31 to provide a constant flow for an uninterrupted discharge of a part of the liquid coming from the electrode chamber.

In the modification shown in FIG. 3, a part of the stabilizing liquid coming from the opening 2 is fed back into the supply duct to the inlet 3 of the stabilization chamber. The stabilization chamber is thereby supplied with liquid which is preheated in the electrode chamber. This duct can be regulated either by the regulating arrangement comprising the flow measuring device 27, the pressure regulator 26 and the pulse transmitter 47, or can be regulated to a pressure which is proportional to the pressure in the duct to the opening 1 and which is controlled by the regulator 28 connected by the connection 29 to the duct 1. The liquid mixture (with gas and steam) flowing out from the opening 4 is controlled by a flow regulator 35, which obtains a pulse representing the flow to opening 3 from a control element (flow regulator 32).

In the modification shown in FIG. 4 the amount of flow to the stabilizing channel through the opening 3 is kept constant by the flow measuring device 23 and the pressure regulator 22. The pressure at the opening 1 is controlled either by a pressure regulator 36 or by a connection 37 between the regulating elements 23 and 22.

A regulator 38, which is provided before the inlet of the pump 14, ensures a constant pressure difference between the outflow from opening 2 and the inflow into opening 1 or 3.

In the embodiment shown in FIG. 5 only two regulating devices are employed. The regulation of the outflow from the opening 4 is effected as in FIGS. 1 and 4. The metering to the inlets 1 and 3 and the discharge from the opening 2 of the electrode chamber through the pump 14 takes place through a pressure enclosure 43. This enclosure performs the function of the pressure regulator 40 and of the flow divider. The amount of the supply to the inlet opening 1 is kept constant by the flow measuring device 6 co-operating with a spring 39 and a membrane 38 in the pressure regulator 40 (safety valve). The pressure before the pressure regulator 40 which is adjusted in accordance with the pressure prevailing in the electrode chamber, is equal for the supply to openings 1 and 3; likewise for the counter-pressure for the pump 14. In this way the pressure difference between the supply ducts and the discharge duct (opening 2) are kept constant.

For comparison a liquid stabilized plasma generator as shown in FIG. 1 was operated firstly without a regulating arrangement and then with a regulating arrangement according to FIGS. 1 to 5. In all cases, the stabilizing liquid leaving the system was calorimetrically examined. The inlet and outlet amounts of the stabilizing liquid were in all cases equal before the ignition of the arc 13, and likewise the temperature of the liquid, the current intensity and the arc voltage were measured in all cases. The current intensity was the same in all cases. At a current of about 500 amps during operation of the generator without a regulating device, the voltage at the arc was 320 volts, and the power supplied to the arc therefore amounted to 160 kilowatts. The cooling loss measured in the liquid leaving through the openings 2 and 4 was found to be 80 kilowatts. The consumption of the graphite cathodes, which had a diameter of 13 mm amounted to 27 mm/min, per minute.

In comparison thereto, during operation of the generator with the present regulating arrangements, the following results were obtained:

Regulating arrangement of figure	Arc voltage (v.)	Power supplied (kw.)	Cooling loss (kw.)	Electrode wear (mm./min.)
1	400	200	38	3
2	420	210	40	2.8
3	450	225	45	3.2
4	380	190	35	2.5
5	380	190	35	2.5

I claim:

1. A method of operating a liquid stabilized arc discharge plasma generator comprising,
continuously supplying stabilizing liquid to the plasma arc discharge space,
circulating the stabilizing liquid around the plasma arc discharge path,
establishing an arc discharge and stabilizing it with said circulating stabilizing liquid,
withdrawing circulated gaseous and liquid portions of the stabilizing liquid from the plasma arc discharge space, and
maintaining constant the rate of supply of the stabilizing liquid to the plasma arc discharge space independent of variations in the pressure applied by the plasma arc to the stabilizing liquid circulating around the plasma arc caused by variations in intensity of the plasma arc.

2. A method according to claim 1, wherein the amount of stabilizing liquid to be supplied is kept constant by measuring the amount of stabilizing liquid being supplied to the plasma arc discharge space, and controlling the input pressure of said stabilizing liquid with said measuring step.

3. The method as set forth in claim 2 in which the withdrawing step is accomplished through at least one outlet duct connected to the plasma arc discharge space, and including the step of adjusting the pressure of the withdrawn circulated gaseous and liquid portions of the stabilizing liquid in the at least one outlet duct in accordance with the inlet pressure of the stabilizing liquid being supplied to the plasma arc discharge space.

4. The method as set forth in claim 2 wherein the measuring step is accomplished in an inlet supply duct for supplying the stabilizing liquid to the plasma arc discharge space, the withdrawing step is accomplished through at least one outlet duct connected to the plasma arc discharge space, and including regulating the pressure of the gaseous and liquid portions of the stabilizing liquid in said at least one outlet duct in dependence on the amount of stabilizing liquid flowing into the plasma arc discharge space through said inlet supply duct.

5. The method as set forth in claim 3 wherein the withdrawing step includes recycling a part of the withdrawn liquid portion of the stabilizing liquid into the plasma arc discharge space in the step of continuously supplying stabilizing liquid thereto.

6. The method as set forth in claim 5 wherein an inlet supply duct connected to the plasma arc discharge space supplies a constant amount of stabilizing liquid to the plasma arc discharge space independent of the pressure applied by the plasma arc to the stabilizing liquid, a further supply duct connected for supplying stabilizing liquid to the plasma arc

discharge space, and altering the pressure of the stabilizing liquid in said further supply duct with the pressure of the stabilizing liquid in said inlet supply duct.

7. The method as set forth in claim 4 and including separating the gaseous and liquid portions of the stabilizing liquid withdrawn through the outlet duct, and supplying at least a part of the amount of the separated stabilizing liquid under pressure to the inlet supply duct to recycle the same to the plasma arc discharge space when the amount of stabilizing liquid in the continuously supplying step is not maintained constant by the step of controlling the input pressure of the stabilizing liquid in the inlet supply duct with said measuring step.

8. A liquid regulating system for a circulating liquid stabilized arc discharge plasma generator of the type having a pair of electrode means adapted to have a high current electric arc generated therebetween, means connected between said electrodes to circulate liquid around the electric arc to stabilize the arc, a plurality of restrictors arranged between said means and one of said electrode means forming a withdrawal chamber around the electric arc for circulated stabilizing liquid, a liquid inlet connected to said means, a liquid outlet connected to said withdrawal chamber, comprising a source of stabilizing liquid, at least one supply duct connected to supply stabilizing liquid from said source to said liquid inlet for circulation around the electric arc, a measuring device connected in said supply duct to measure the amount of stabilizing liquid flowing therethrough, pressure regulating means connected in said supply duct between said source and said measuring device, transmitting means connected between said measuring device and said pressure regulating means whereby said measuring device controls the pressure regulating means to control the pressure of the stabilizing liquid in said supply duct to maintain constant the rate of supply of said stabilizing liquid to said liquid inlet independent of variations in the pressure applied by the electric arc to the stabilizing liquid circulated around the electric arc by said means.

9. A liquid regulating system as set forth in claim 8 including a second pressure regulating means and a second measuring device for measuring the amount of stabilizing liquid to be withdrawn are connected in series in said liquid outlet, and second transmitting means connected between said second measuring device and said second pressure regulating means whereby said second measuring device controls the latter to control the flow of stabilizing liquid from said liquid outlet.

10. A liquid regulating system as set forth in claim 8 including a discharge duct connected to said liquid outlet, a pump connected in said discharge duct, at least one flow duct connected to said discharge duct on the opposite side of the pump from the liquid outlet, a pressure regulator connected in said flow duct, and a recycling duct having one end connected to the opposite side of the pump from the liquid outlet and the opposite end connected to said at least one supply duct between said measuring device and said pressure regulating means for recirculating circulated stabilizing liquid from said withdrawal chamber back into said means to circulate liquid around the electric arc.

11. A liquid regulating system as set forth in claim 8 including a discharge duct connected to said liquid outlet, a pump having an output connected in said discharge duct, a flow divider connected to the output of said pump, a feed-back duct connected between said flow divider and said supply duct, a second pressure regulating means and second measuring device connected in series in said feed-back duct and a second transmitting means connected between said second measuring device and said second pressure regulating means to control feed-back of a constant amount of circulated stabilizing liquid into said supply duct, and a third pressure regulating means connected to said flow divider and having a control connection with said supply duct for regulating the pressure of the circulated stabilizing liquid to be discharged from said liquid outlet in dependence on the pressure in said supply duct.

12. A regulating system as set forth in claim 8 including a pressure enclosure which serves as a flow divider, a second pressure regulating means connected to said pressure enclosure, a discharge duct connected to convey circulated stabilizing liquid from said liquid outlet to said pressure enclosure, and a pump connected in said discharge duct for pumping said circulated stabilizing liquid through said discharge duct.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,665,244 Dated May 23, 1972

Inventor(s) TIBOR KUGLER

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Following the line designated [21] add the following:

[30] Foreign Application Priority Data
June 5, 1969 Switzerland 8546/69

In the Abstract, line 1, change "stabilizing" to

--stabilized--;

line 3, change "resistant" to

--resistance--.

Signed and Sealed this

fourth Day of *May 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE
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