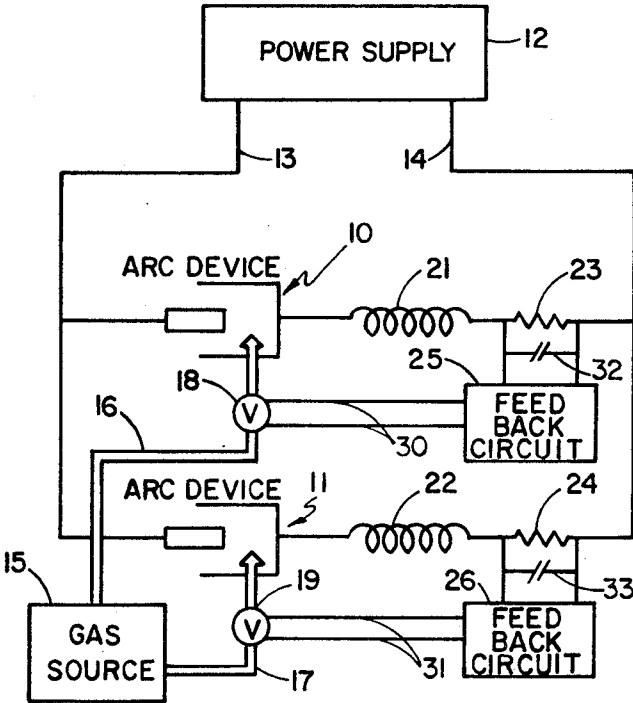


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[54] **MEANS FOR AND METHOD OF STABILIZING A PLURALITY OF GASEOUS ELECTRIC ARC DISCHARGE DEVICES**
15 Claims, 2 Drawing Figs.
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219/121, 219/131; 315/297
[51] Int. Cl. **H01j 7/24**
[50] Field of Search..... 219/74, 75,
121, 131, 133; 315/110, 111, 291, 294, 307, 308,
297; 313/231

ABSTRACT: A method of and apparatus for providing stabilization of gaseous electric arc devices by effecting suitable changes in the voltage-versus-current (V-I) characteristics of such arc devices. Stable V-I characteristics of such electric arc devices are obtained by controlling the rate of gas flow through each electric arc device as a function of the arc current. The rate of gas flow through each arc is controlled by deriving for each such arc a control signal from its arc current and actuating a valve in its gas supply means via feedback circuit means to cause the gas flowing there through to vary as a linear function of its arc current.



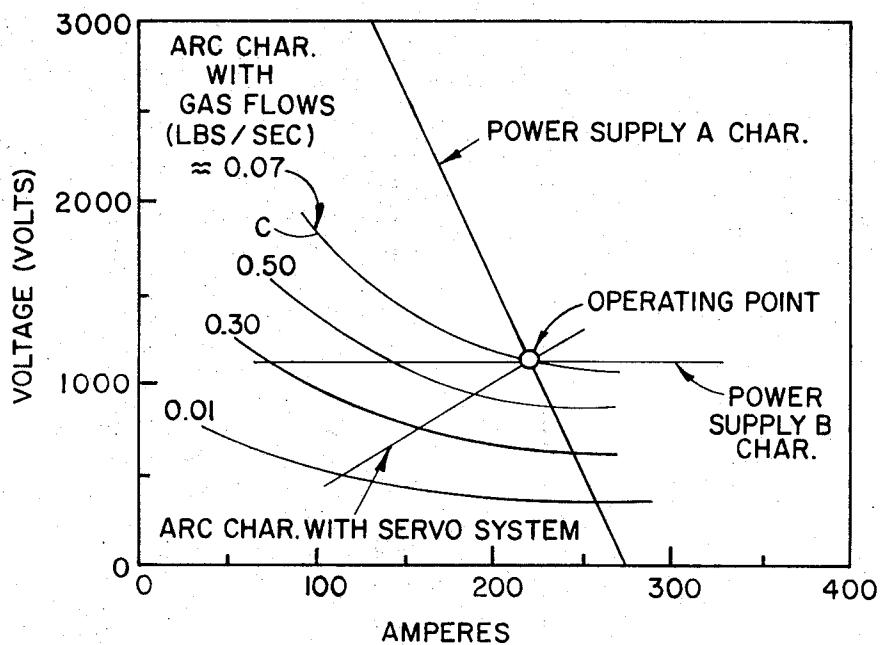


FIG 1

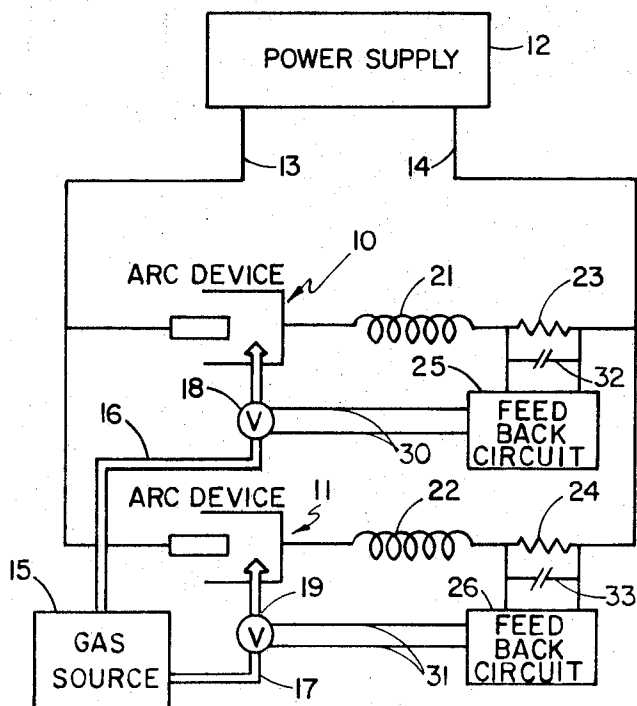


FIG 2

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MEANS FOR AND METHOD OF STABILIZING A PLURALITY OF GASEOUS ELECTRIC ARC DISCHARGE DEVICES

The present invention generally relates to gaseous electric arc devices and operation of same and more particularly to means for and a method of stabilization of gaseous electric arc devices.

In the past, stable operation of gaseous electric arc devices has been achieved by the use of ballast resistors electrically connected in series with the arc. Single arc devices as well as arc devices connected in parallel or series can be stably operated in this way, the main disadvantage with this technique being that often a large amount of energy is dissipated in the ballast resistors, and this greatly reduces the efficiency of the system. Another property of the ballast technique is that it tends to keep the arc gas chamber pressure constant rather than the gas enthalpy constant.

Unstable operation of gaseous arc devices such as electric arc heaters, high intensity electric arc light sources and the like arises when the operating V-I characteristics of the arc has a smaller slope than the power supply at the arc operating point as illustrated, for example, by the curve for the power source B and curve C for the arc shown in FIG. 1. If a positive current disturbance occurs in such an arc system wherein the arc was initially operating at its indicated operating point, the voltage of the power supply will exceed that required by the arc, and, hence, the arc current will increase without limit until failure of some component occurs. If a negative current disturbance occurs, however, the voltage across the arc will be less than the arc requires and thereby cause the arc current to decrease away from the aforementioned operating point. From the above, it will be seen that the operating point as shown, for example, in FIG. 1 will not be stable if the power supply for the arc possesses a characteristic such as for that shown for power supply B. However, with a different power supply having a characteristic as shown for power supply A in FIG. 1, the arc can be operated stably since a disturbance whether negative or positive will cause a system reaction which will ultimately terminate at the operating point. However, in a system utilizing a parallel connection of electric arc devices, it can be shown that even with a power supply having a characteristic as shown for power supply A in FIG. 1, the operation of two will be unstable. In summary, an operating point for one or more arcs in a series connection is stable if at that point the V-I characteristic of the arc combination has a greater slope than the power supply. For a parallel connection of arcs, a positive sloping arc characteristic is required for stability independent of the slope of the power supply characteristic.

Contrary to prior art techniques which tend to keep the arc gas chamber pressure constant, broadly, the present invention tends to keep the gas enthalpy constant.

It is therefore an object of the present invention to provide means for and a method of controlling and providing stable operation of gaseous electric arc devices.

It is a further object of the present invention to provide a simple, positive acting and sensitive apparatus for controlling and providing stable operation of gaseous electric arc devices.

Another object of the present invention is the provision of means for and a method of stabilizing a plurality of gaseous electric arc devices that do not require ballast resistors.

A still further object of the present invention is the provision of means for and a method of stabilizing the operation of one or more gaseous electric arc devices by changing the arc's characteristics.

The novel features that are considered characteristic of the invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a graphic representation showing voltage current characteristics of a gaseous electric arc device and power supplies therefore; and

FIG. 2 is a schematic representation of apparatus in accordance with the present invention.

Stabilization of gaseous electric arc devices is obtained in accordance with the present invention by suitable changes in the V-I characteristic of the arc device or devices. Broadly, the present invention accomplishes this by the use of a conventional servo system or systems which effects control of the gas flow through the arc or arcs. In this way, a stable V-I arc characteristic is obtained by causing the gas flow rate through the arc device to vary for instance as a linear function of the arc current.

Directing attention to FIG. 2, there is shown by way of example two conventional gaseous electric arc devices 10 and 11 connected in parallel across a power supply source 12 by conductors 13 and 14. Each arc device may be supplied with a suitable gas such as nitrogen or air from a gas source 15 via respectively pipes 16 and 17 and servovalves 18 and 19.

Connected in series with the electrodes of each gaseous electric arc device are inductances 21 and 22 and shunt resistors 23 and 24. The shunt resistors function in conventional manner to provide a shunt voltage which is a substantially linear function of the arc current. The shunt voltage is supplied to respectively conventional feedback circuit 25 and 26 for operating the servovalves 18 and 19. The shunt or control voltage developed across resistors 23 and 24 may be of the order of millivolts whereas the voltages supplied to valves 18 and 19 via conductors 30 and 31 generally must be about 1 volt or more. Suitable filter means, represented by capacitors 32 and 33, may be connected across respectively shunt resistors 23 and 24 to provide a relatively clean control signal in the event the arc current contains a lot of hash. During normal operation of the arc devices, each servovalve is most conveniently caused to vary linearly with the electrical input thereto derived from its feedback circuit to in turn cause the gas supply to each arc device to vary in the same manner as the aforementioned electrical input signal to the servovalves to provide a stable V-I arc characteristic. Thus, the operating characteristic of a plurality of arcs in accordance with the invention may be provided with a characteristic having a positive slope as shown by way of example in FIG. 1. Such an arc when comprising part of a plurality of parallel connected arcs will be efficiently stabilized for substantially all disturbances and in particular will not require ballast resistors and their inherent losses. Further, a single or multiple connection of arcs in accordance with the invention will also operate stably with a power supply having an otherwise undesirable characteristic such as that shown for power supply B in FIG. 1.

Means such as inductances 21 and 22 should be of a size sufficient to slow down the growth of a disturbance for a time sufficient that the proper adjustment in gas flow rate and therefore arc voltage can be made by the servovalves.

Servovalves 18 and 19 may comprise, for example, a plunger containing ferromagnetic material, such as iron or iron rods, the lower end of which is formed to engage a valve seat to adjustably open and close pipes 16 and 17 when the valve is actuated. The valve may be surrounded by an electromagnetic coil which upon energization lifts the plunger from the valve seat a distance depending on the degree of energization, thus allowing the rate of gas flow to the arc devices to be controlled.

As previously indicated, it has been found that variation of the gas flow in gaseous electric discharge devices provides a very sensitive way of changing the arc characteristic and in accordance with the invention this property is utilized to effect stabilization thereof. Thus, variations in arc current cause corresponding variations in the voltage developed across means such as shunt resistors 23 and 24. Alternately, where appropriate transformers may for example be used if desired. The aforementioned variations and voltage developed across the shunt resistor (control voltage) is suitably amplified and

provides in conventional manner the necessary power required to actuate the electromagnetic servovalves which effect the necessary variations in gas flow. Further, in conventional manner, a suitable potentiometer, bucking voltage or the like may be provided in each feedback circuit to afford, for example, adjustment of the level at which the solenoid valves operate to permit variation of each arc's operating point.

Two 250 kw. high voltage direct current arc heaters connected in accordance with the invention in parallel across the output terminals of a magnetohydrodynamic generator have been stably operated. The connections were as shown in FIG. 2 wherein servovalves type 72-242 manufactured by Moog, Inc. East Aurora, New York controlled the rate of supply of air to the arcs with a 0.35 henry inductor connected in series with each arc. The main components of the feedback circuit were a shunt resistor to supply the control signal, a high frequency filter having a cut off frequency of about 500-1000 cps, a variable voltage DC power supply and diode in series with the terminals of the servovalve, and a diode and second variable voltage DC power supply connected across the terminals of the servovalve. With this arrangement which was developed solely to provide full flexibility for experimental purpose, the arc characteristics could be changed as desired. The aforementioned power supplies were provided to permit not only adjustment of the arcs' operating points, but to also insure a minimum gas flow. The output power of the magnetohydrodynamic generator was varied to vary the voltage across and current through each arc from respectively about 700 to 1000 volts and about 110 to 180 amperes. Stable operation of both arcs was achieved with this arrangement.

As previously mentioned, FIG. 2 illustrates a parallel connection. However, it is to be understood that the invention is equally applicable to a plurality of series connected arc devices. In series connected arrangements, at least all but one of the arc devices must be arranged and adapted as shown and described herein.

For a more thorough discussion of gaseous electric arc devices suitable for use with this invention, reference is made to U.S. Pat. No. 3,296,479 relating to electric arc heaters; U.S. Pat. No. 3,064,153 relating to high intensity light sources; and U.S. Pat. No. 3,004,189 relating to electric plasma-jet torches.

The various features and advantages of the invention are thought to be clear from the foregoing description. Various other features and advantages not specifically enumerated will undoubtedly occur to those versed in the art, as likewise will many variations and modifications of the preferred embodiment illustrated, all of which may be achieved without departing from the spirit and scope of the invention as defined by the following claims:

I claim:

1. In apparatus for stabilizing a gaseous electric arc device comprising a gas inlet and outlet means through which gas may be passed through a gas chamber and electrode means for maintaining an electric arc in said chamber and heating said gas passing through said chamber, the combination comprising: means including valve means to effect variation of gas flow through said gas chamber as a function of electric arc current.

2. In apparatus for stabilizing a gaseous electric arc device comprising gas inlet and outlet means through which gas may be passed through a gas chamber and electrode means for maintaining an electric arc in said chamber and heating said gas passing through said chamber, the combination comprising:

- a. means for providing a control signal that varies as a function of the arc current; and
- b. means including valve means actuated by said control signal to effect variation of gas flow through said gas chamber as a function of said arc current.

3. The combination as defined in claim 2 and additionally including means connected in series with electrode means for preventing a change in arc current at a rate greater than the rate at which said gas flow is varied.

4. In apparatus for stabilizing a gaseous electric arc device comprising gas inlet and outlet means through which gas may be passed through a gas chamber and electrode means for maintaining an electric arc in said chamber and heating said gas passing through said chamber, the combination comprising:

- a. means for deriving from the arc current flowing between said electrodes an electrical control signal that varies linearly with said arc current;
- b. valve means for varying the rate of gas flow through said chamber; and
- c. feedback means actuated by said control signal and coupled to said valve means to effect control of said valve means and cause gas flow through said chamber to vary linearly with said control signal.

5. The combination as defined in claim 4 and additionally including inductance means connected in series with said electrode means.

6. The combination as defined in claim 4 and additionally including means for preventing a change in said arc current at a rate greater than the rate at which said gas flow through said chamber can be varied.

7. The combination as defined in claim 6 wherein said feedback means additionally includes filter means to remove noise from said control signal.

8. In apparatus for simultaneously increasing the enthalpy of a gas at two or more spaced points, the combination comprising:

- a. a gaseous electric arc device disposed at each said point, each said device comprising electrode means for maintaining an electric arc and means for flowing a gas past said electrode means whereby said gas is heated at each said point by said electric arc;
- b. a source of electrical current;
- c. means coupling the electrode means of each said device to said source of current;
- d. means coupled to respectively at least all but one of said devices for deriving from the arc current thereof a control signal that varies linearly as a function of said arc current; and
- e. feedback means including gas control means coupled to and actuated by each said control signal and effecting variation of gas flow to each of said devices as a linear function of the arc current flowing in each said device.

9. In apparatus for simultaneously increasing the enthalpy of a gas at two or more spaced points, the combination comprising:

- a. a gaseous electric arc device disposed at each said point, each said device comprising electrode means for maintaining an electric arc and means for flowing a gas past said electrode means whereby said gas is heated at each said point by said electric arc;
- b. a source of electrical current;
- c. means coupling the electrode means of each said device in series and to said source of current;
- d. means coupled to respectively at least all but one of said devices for deriving from the arc current thereof a control signal that varies linearly as a function of said arc current; and
- e. feedback means including gas control means coupled to and actuated by each said control signal and effecting variation of gas flow to each of said devices as a linear function of the arc current flowing in each said device.

10. In apparatus for simultaneously increasing the enthalpy of a gas at two or more spaced points, the combination comprising:

- a. a gaseous electric arc device disposed at each said point, each said device comprising electrode means for maintaining an electric arc and means for flowing a gas past said electrode means whereby said gas is heated at each said point by said electric arc;
- b. a source of electrical current;
- c. means coupling the electrode means of each said device in parallel and to said source of current;

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d. means coupled to each said device for deriving from the arc current thereof a control signal that varies linearly as a function of said arc current; and

e. feedback means including gas control means coupled to and actuated by each said control signal and effecting variation of gas flow to each of said devices as a linear function of the arc current flowing in each said device.

11. The combination as defined in claim 10 and additionally including inductance means connected in series with each of said electrode means for preventing a change in arc current at a rate greater than the rate at which said gas flow to each said device is varied, and said feedback means additionally includes filter means to remove noise from said control signal.

12. In the method of stabilizing a gaseous electric arc device, the steps comprising:

a. striking an electric arc between two electrodes and establishing a flow of arc current;

b. passing a gas through said electric arc;

c. deriving from said arc current a control signal that varies substantially linearly with said arc current; and

d. causing the flow of said gas through said arc to vary substantially linearly with said control signal and maintain the operation operating point of said arc substantially constant.

13. The method as defined in claim 12 additionally includ-

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ing supplying said control signal to and actuating a feedback circuit including valve means; and preventing the arc current from changing at a rate faster than said valve means changes the rate of gas flow.

14. The method as defined in claim 13 and additionally including the step of filtering said control signal before it is supplied to said feedback circuit.

15. In the method of simultaneously providing stable operation of a plurality of gaseous electric arc devices each having spaced electrodes for providing an electric arc and means for passing a gas through said arc, the steps comprising:

a. connecting the electrodes of said device in a parallel to a source of electrical power;

b. providing a control signal that varies substantially linearly as a function of respectively the arc current of each said device;

c. supplying the control signal of each device to feedback and gas control means associated with each said device to regulate the gas flow thereto as a linear function of each said control signal; and

d. preventing a change in arc current in each device from changing at a rate faster than the said gas control means of said device changes the rate of gas flow thereto.

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