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RADIAL TYPE ARC PLASMA GENERATOR

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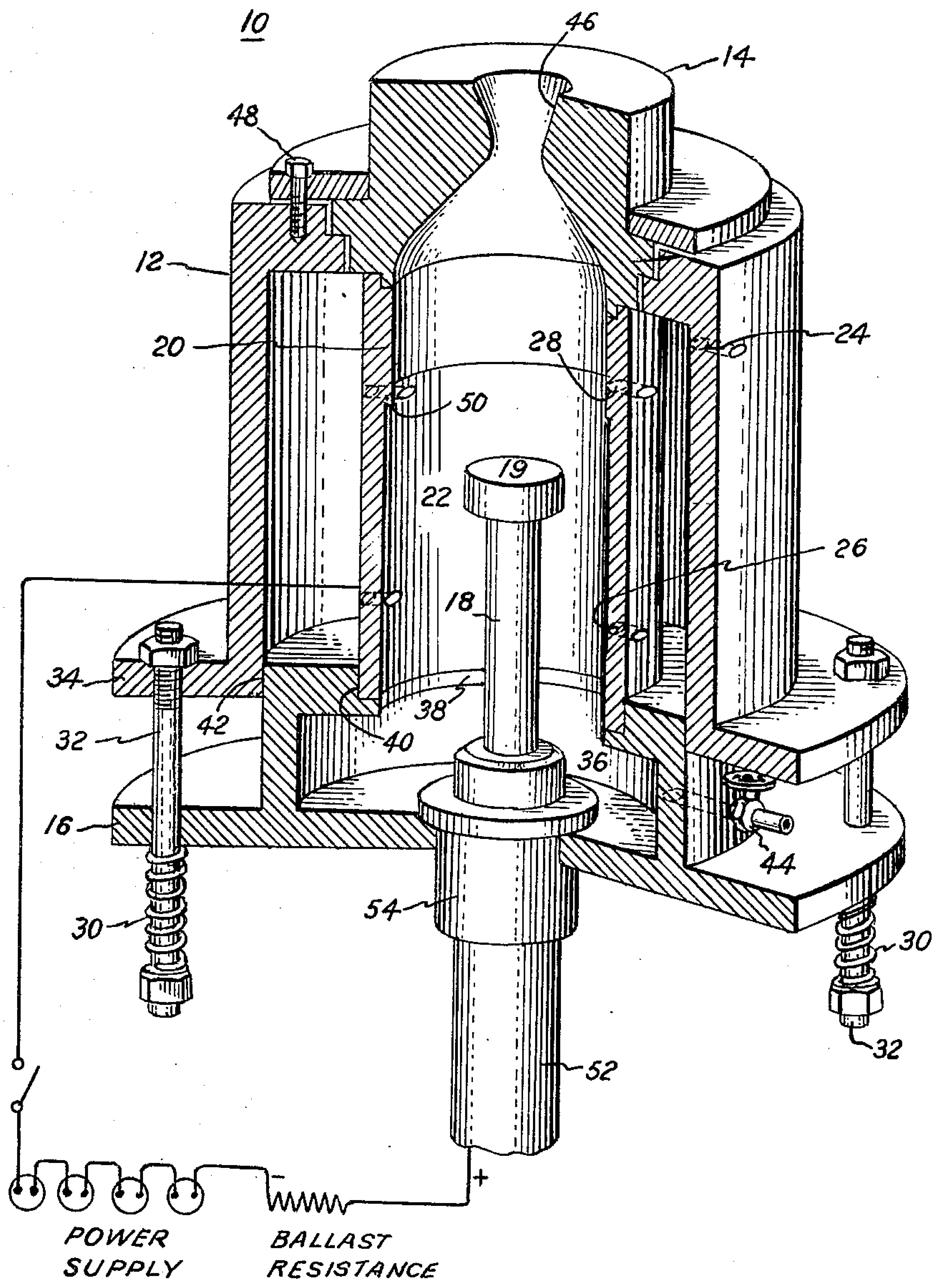

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RADIAL TYPE ARC PLASMA GENERATOR

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The present invention relates to a fluid stabilized electric arc device and more particularly to a fluid stabilized electric arc device having a radial type arc plasma generator.

In keeping with modern missile technology, it is quite desirable to develop components which will function satisfactorily when exposed to ultra high temperatures for short periods of time. Such components range from liners for uncooled rocket engines to surface structures of high speed vehicles which are subject to large heat fluxes as the result of aerodynamic heating. In these particular applications, and in many others, temperatures may range up to thousands of degrees fahrenheit for only a few seconds to minutes time of exposure.

In order to determine beforehand what material would be suitable for fabricating such high speed vehicle components, it would be desirable to test samples of prospective materials in an environment comparable to that in which they would be exposed in actual service. In this manner, tests can duplicate not only the high temperatures, but also structural loading, thermal shock and attack by the gaseous environment to be encountered by the component in actual operational service. A device which is useful for the rapid and economical evaluation of materials for resistance to high temperatures is the fluid stabilized electric arc.

Briefly, a fluid stabilized arc mechanism usable in high temperature component testing comprises an electric arc which is condensed or constricted into a smaller circular cross-section than would ordinarily exist in an open arc type device. This construction generates a very high temperature so that a superheated plasma working fluid may be ejected through a suitable nozzle structure and used in any desirable manner. The mass flow through the nozzle structure and the composition of the plasma is of prime concern in testing high speed vehicle components where a homogeneous and smooth flowing jet or working fluid is required.

In general, in a coaxial jet-electrode arc structure the intimate coupling between the plasma discharge and the flow of the fluid medium used to constrict the arc, particularly in the neighborhood of the exhaust electrode, gives rise to instabilities which greatly disturb the temperature and velocity field in the exhaust plasma. Interpretation of test data obtained under such circumstances is most hazardous. If the exhaust nozzle is made to approach the diameter of the opposing cylindrical electrode, the plasma discharge becomes erratic and cannot be satisfactorily maintained.

Consequently, the arc will usually blow-out within a second or two after commencement of operations. In most cases, another objection to a coaxial jet-electrode arc discharge arrangement is the rapid change in orifice geometry through erosion and burning.

The present invention provides a new type of arc discharge for a fluid stabilized arc generator which overcomes the above difficulties associated with the coaxial jet-electrode arc discharge arrangement and permits high pressure operation by utilizing a side burning or radial arc to generate the working plasma. An electrode rod is slidably adjustable with respect to a chamber wall electrode coaxial therewith, wherein the radial gap therebetween is much smaller than the distance of the end of the electrode rod from a nozzle assembly coaxially spaced

therefrom. A pressurized fluid medium is tangentially introduced in an arc chamber enclosing the electrodes to provide uniform circumferential burning therein and to flow through the struck arc to generate a plasma working fluid discharged through the nozzle assembly.

An object of the present invention is the provision of a fluid stabilized electric arc device permitting high pressure operation by utilizing radial arc generating means.

Another object is to provide a radial type arc plasma generator which produces a homogeneous and smooth flowing jet applicable for high speed vehicle component test purposes.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawing in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIGURE 1 is a cross-sectional view of a preferred embodiment of the invention.

Referring now to the drawing, there is illustrated a preferred embodiment **10** comprising a high pressure cylindrical housing **12** having a nozzle assembly **14** at one end thereof and a spring biased housing assembly **16** at the other end adjustably supporting thereon an axially slidable rod electrode **18** having an enlarged tip **19**. A hollow cylindrical wall electrode **20**, of such material as graphite, or the like, is suitably mounted within housing **12**. The inner walls of wall electrode **20** define arc chamber **22**. Rod electrode **18** is slidably mounted on housing assembly **16**, within arc chamber **22** so that the two electrodes are substantially coaxial; i.e., the longitudinal axis of wall electrode **20** and the longitudinal axis of rod electrode **18** are substantially coincident.

The high pressure cylindrical housing **12** is provided with a fluid medium inlet **24** having an axis tangential to the circumferential surface thereof and suitably coupled to a source of fluid medium under pressure, not shown. In this manner, the fluid medium flows tangentially into the housing **12** where a pressure build-up is experienced in the manner of a manifold device. A main inlet **26** is tangentially provided on the cylindrical surface of the wall electrode **20** near the base thereof and a smaller tangential auxiliary inlet **28** near the top portion thereof. In this manner, the fluid medium within the housing **12** will flow tangentially into the arc chamber **22** formed by the cylindrical wall electrode **20**.

The lower portion of the arc chamber **22** is enclosed by the sliding housing assembly **16** biased by a number of spring means **30** mounted on a plurality of rod means **32** fixed to a radial flange **34** integrally formed on the lower end of the high pressure cylindrical housing **12**. A cylindrical chamber **36** is provided within the housing assembly **16** with an opening **38** coaxially mating with the lower opening of the wall electrode **20**, as shown in the drawing. The opening **38** and the lower wall of electrode **20** are provided with a freely slidable coacting joint **40** to allow for the differential thermal expansion of the component parts of the preferred embodiment **10**.

As further seen from the drawing, the circumferential surface of the cylindrical chamber **36** slidably contacts the interior wall of the housing **12** at **42** to completely seal the lower end thereof, while permitting thermal expansion of the coacting structural components.

An adjustable relief valve **44** is provided on the wall of the housing assembly **16** opening into the chamber **36** and, in turn, into the arc chamber **22** to permit regulation therein of the desired chamber pressure and flow rate. The relief valve **44** is predeterminedly located below the main inlet **26** and sufficiently distant from the discharge region of the arc chamber so that the structural arrangement provides sufficient space for imparting a moderate angular velocity to the fluid medium within the arc chamber **22**, without forcing too large a fluid flow through the arc region. Briefly, the relief valve allows gas to be discharged from the cylindrical chamber **36** to thereby increase the total gas flow and increase the tangential velocity. Under some operating conditions, the preferred embodiment **10** may be possibly used with the valve **44** closed. For example, the valve would be closed when it is desirable to have all the gas discharge through the nozzle.

The nozzle assembly **14** is provided with a converging and diverging throat **46** of a predetermined design so that the cross-sectional area of the discharge region between the electrode **18** and the chamber wall electrode **20** will be predeterminedly smaller than the cross-sectional area of the throat to keep the arc from blowing downstream toward the nozzle assembly. The nozzle assembly is suitably attached, such as by bolt means **48**, to the high pressure cylindrical housing **12** and coacts with the cylindrical chamber **36** to axially support therebetween the interior cylindrical wall electrode **20** to prevent any relative radial movement except the differential thermal expansion of the respective structural components. As can be seen in the drawing, the wall electrode **20** is maintained fixed in a coaxial relationship with the housing **12**, the nozzle assembly **14**, and the electrode **18** by a compression force generated by the spring biased axially slidable housing **16** so that the direction of flow of the plasma produced within arc chamber **22** through throat **46** of nozzle assembly **14** is also coaxial, or aligned with the longitudinal axes of the wall electrode **20** and the rod electrode **18**.

To assist in anchoring the arc within the discharge region, a cylindrical wall step **50** is integrally provided on the interior of the wall electrode **20** between the nozzle assembly **14** and the tip **19** of the electrode. Further, the tip of the electrode **18** is provided with an integral enlarged tip **19** to predeterminedly reduce the cross-sectional area of the discharge region between the wall electrode **20** and the electrode rod to maintain the area smaller than the throat area **46** to prevent the arc from blowing downstream.

The electrode **18** is suitably mounted in an electrode holder **52** through collet means, not specifically shown, or by being threaded therein, or by any other well-known fastening or supporting means.

The electrode holder may be coupled to a remote controlled electrode actuating means, not shown, to axially slide the electrode, with respect to the sliding housing assembly **16**, in a predetermined manner within the arc chamber **22** to maintain the discharge region in a desired location with respect to the nozzle assembly. An insulating bushing **54** is coaxially provided between the housing **16** and the electrode **18**, or its electrode holder **52**, to insulate electrically the relative structural components from each other.

In the operation of the preferred embodiment **10**, prior to striking the arc, the interior portion of the high pressure cylindrical housing **12** is pressurized by injecting through the main inlet **24** a fluid medium under pressure. The fluid medium will, in turn, flow tangentially into the arc chamber **22** through the main inlet **26** and through the much smaller auxiliary inlet **28**. In the meanwhile, the relief valve **44** is predeterminedly adjusted for the desired chamber pressure and flow rate, parameters dictated by the particular application. In this manner, a moderate angular velocity is imparted to the gas without forcing too large an axial flow through the discharge region between the coacting electrode members.

Axially sliding the electrode **18** within the arc chamber **22** to electrically short the rod end-step **19** of the electrode with the wall electrode **20** will initially strike

an arc. If desirable the arc may be initiated by moving the electrode **18** forward so as to contact the nozzle and then withdrawing the electrode to the position shown and maintaining the arc, or by placing a small piece of fuse wire between the electrode and the wall. This wire will melt when power is applied and the arc will continue. After the arc is initiated the arc discharge will be maintained between the electrode **18** and the wall electrode **20** provided the radial gap therebetween is substantially smaller than the distance of the electrode tip **19** to the nozzle assembly end of the chamber. The tangential rotation of the fluid medium within the arc chamber **22**, will cause the arc between rod electrode **18** and the wall electrode **20** to rotate with the fluid medium within the discharge region substantially at right angles to the longitudinal axes of wall electrode **20** and rod electrode **18**, and the direction of flow of the plasma through throat **46**. In addition, fluid medium entering through the smaller auxiliary inlet **28** will provide a cooling layer to protect the nozzle assembly **14** from the hot plasma. In this manner, the maximum temperature obtainable will be that of the arc column itself, which would approximately equal 6,000° K. when air is utilized as the fluid medium.

As can be seen from FIGURE 1, the sliding housing **16** is suitably grounded while the wall electrode **20** is electrically coupled to a suitable power source, such as the D.C. power supply shown in the drawing. The circuit is completed by coupling the electrode **18** to the power source through a resistance element. The resistance is placed in the circuit so that approximately 50 percent of the available D.C. power is dissipated in the ballast resistance. This tends to stabilize the arc.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention and that it is intended to cover all changes and modifications of the example of the invention herein chosen for the purposes of the disclosure, which do not constitute departures from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An arc plasma generator comprising a high pressure cylindrical housing, a hollow cylindrical wall electrode within said housing, a rod electrode mounted within the cylindrical wall electrode, the longitudinal axes of said wall electrode and said rod electrode being substantially coincident, a nozzle assembly secured to said housing, inlet means for introducing a pressurized fluid medium within said wall electrode, means for connecting said wall electrode and said rod electrode to a source of unidirectional electrical current, the distance between the wall electrode and the rod electrode being such that arcs between said electrodes are substantially transverse to the longitudinal axes of the rod and wall electrodes.

2. An arc plasma generator comprising a housing assembly, a hollow substantially cylindrical wall electrode mounted within said housing assembly, a rod electrode mounted within said wall electrode and substantially coaxial therewith, means for connecting a source of electrical power to said rod and wall electrodes to establish an arc between them, tangential fluid inlet means in said housing assembly and said cylindrical wall electrode for introducing within the wall electrode pressurized fluid having a component of angular velocity about said rod electrode, nozzle means mounted on said housing assembly in substantial coaxial relationship with the rod electrode and the wall electrode to discharge the plasma produced within the wall electrode, the spacing between said rod electrode and said wall electrode and said nozzle means being such that arcs will be established only between the rod electrode and the wall electrode, and will be substantially transverse to the direction of flow of plasma through the nozzle means.

3. An arc plasma generator comprising a high pressure cylindrical housing, a hollow cylindrical wall elec-

trode within said housing, said wall electrode having a step in the inner wall portion thereof, a rod electrode having an enlarged tip mounted within the cylindrical wall electrode, the longitudinal axes of said wall electrode and said rod electrode being substantially coincident, a nozzle assembly mounted on said housing, inlet means for introducing a pressurized fluid within said wall electrode, said inlet means causing said fluid to rotate around said rod electrode, means for connecting said wall electrode and said rod electrode to a source of electrical power, the distance between said wall electrode and said rod electrode being such that arcs between said electrodes are substantially transverse to the longitudinal axes of the rod and wall electrodes and strike the wall electrode at or below the step.

4. An arc plasma generator comprising a high pressure cylindrical housing, a hollow cylindrical wall electrode within said housing, a rod electrode mounted within said wall electrode so that the longitudinal axes of said wall and rod electrodes are substantially coincident, a nozzle assembly having a central opening mounted in one end of said cylindrical housing, means for connecting a source of electrical energy between said wall and rod electrodes, said nozzle assembly providing an outlet for the plasma produced by arcs between the rod electrode and the wall electrode, the direction of flow of the plasma through the nozzle being substantially aligned with the longitudinal axes of the rod and wall electrodes, the wall and rod electrodes being so positioned that the electrical arcs between them are substantially at right angles to their longitudinal axes and transverse to the direction of flow of the plasma produced, through said nozzle, said arcs rotating substantially with the fluid introduced into said wall electrode.

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