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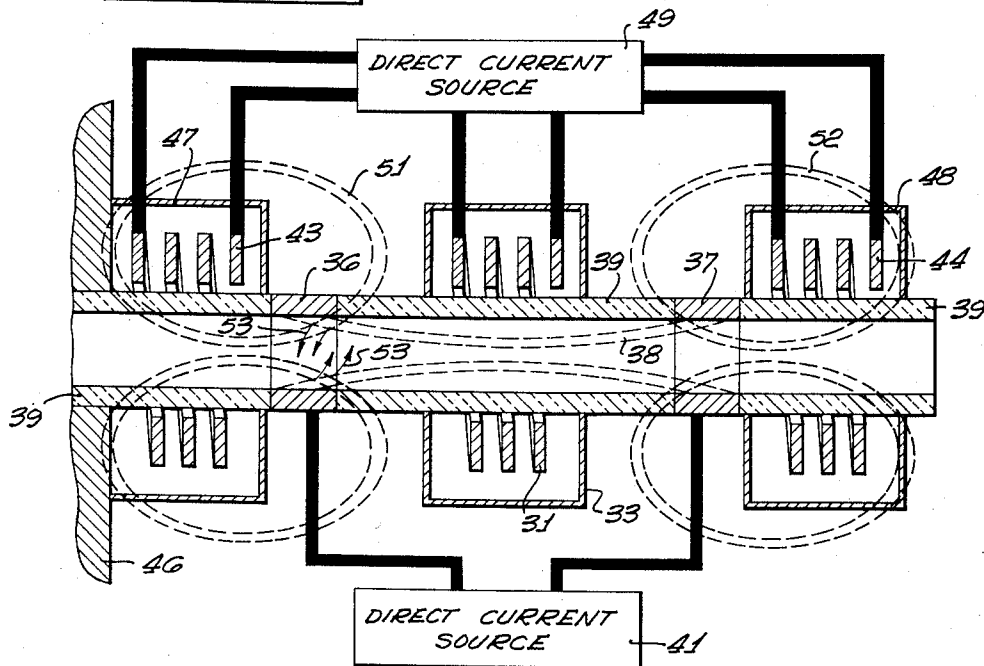
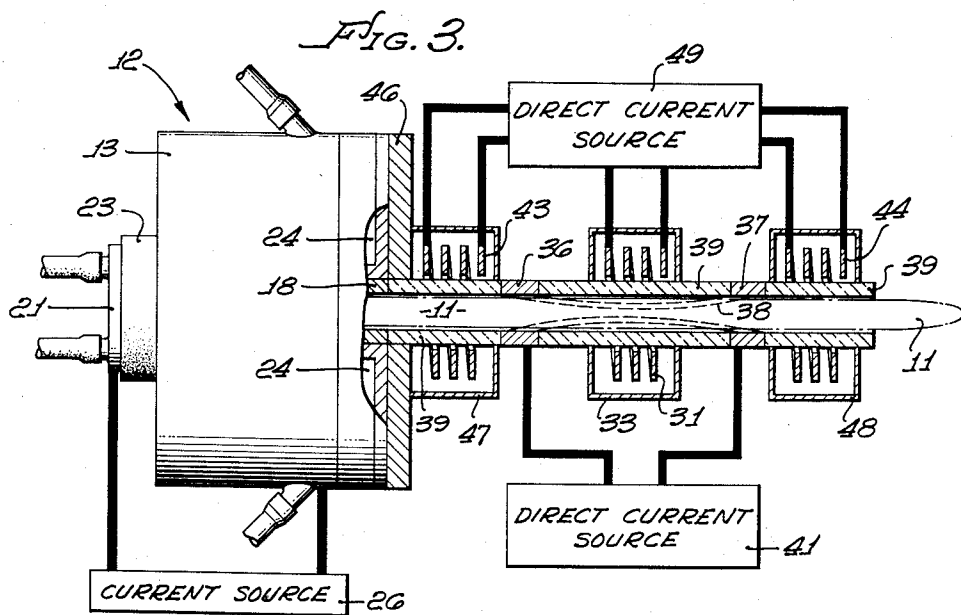
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STABILIZED MAGNETIC NOZZLE FOR PLASMA JETS

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This invention relates to stabilized magnetic nozzle means for an ionized gas flow, and also relates to an electrical plasma-jet torch incorporating auxiliary arcing means for purposes of stabilizing the jet and increasing the energy thereof.

An object of the present invention is to provide an electrical plasma-jet torch incorporating a magnetic nozzle means which is stabilized through use of an auxiliary electric arc.

Another object is to provide stabilizing means for ionized gas flows, and employing combination magnetic and electric-arc effects for stabilizing the flow, increasing the stagnation enthalpy thereof, and increasing the life of the electrodes.

A further object of the invention is to provide magnetic nozzle means stabilized by a longitudinally-directed electric arc, in combination with means for effecting rotation of the terminals of the arc in order to augment the stabilization effect and increase electrode life.

These and other objects and advantages of the invention will be set forth more fully in the following specification and claims, considered in connection with the attached drawings to which they relate.

In the drawings:

Figure 1 is a longitudinal sectional view illustrating schematically a first form of apparatus for stabilizing and adding energy to the ionized gas emanating from a plasma-jet torch;

Figure 2 is a transverse section taken on line 2-2 of Figure 1;

Figure 3 is a view, partially in longitudinal central section and partially in side elevation, illustrating a second embodiment of the invention in which magnetic means are provided to insure rotation of the terminal portions of the stabilizing arc and thereby provide desirable results including increased electrode life; and

Figure 4 is an enlarged view of the right portion of the showing of Figure 3, illustrating representative lines of magnetic force and also illustrating the stabilizing arc and the rotation thereof.

Referring first to the embodiment of Figures 1 and 2, a stabilized magnetic nozzle means 10 is illustrated as employed in stabilizing and adding energy to the plasma jet 11 (composed of neutral gas, ions and electrodes, at high temperatures) emanating from an electrical plasma-jet torch 12. The illustrated torch 12 comprises a generally cup-shaped metal nozzle electrode 13 having a generally disc-shaped metal back electrode 14 mounted therein in insulated relationship. Nozzle electrode 13 and back electrode 14 cooperate to define an annular gas-pressure chamber 16 which is coaxial with the nozzle opening 17 in the nozzle electrode. The wall of nozzle opening 17 is protected by a generally tubular refractory metal insert 18, formed of tungsten or the like, and the adjacent arcing portion of the back electrode is similarly provided with a disc-shaped tungsten insert 19.

A flanged metal base member 21 is disposed in surface engagement with the peripheral portion of back electrode

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14, such elements being maintained in surface engagement by means of a retaining ring 22 which is threaded into the nozzle electrode. Suitable insulation means 23 are provided to maintain the base member 21 and back electrode 14 electrically insulated from nozzle electrode 13. Cooling chambers 24 and 25 are formed, respectively, adjacent the arcing inserts 18 and 19 in the electrodes in order to effect cooling thereof. Water may be passed continuously through chambers 24 and 25 by means of the indicated passages and hoses.

A suitable current source 26 is electrically connected between base member 21 and nozzle electrode 13 in order to conduct current to the arcing inserts 18 and 19 of the nozzle and back electrodes. An arc may be initiated between such inserts in any suitable manner, as by momentarily impressing a high voltage therebetween. The arc effects heating of gas which is introduced into the gas-pressure chamber 16 from a suitable source 27 through a passage 28 which is tangential to the chamber 16. Gas enters chamber 16 at sufficient velocity and pressure to flow vortically therein and effect stabilization of the arc in the axial canal through the vortex. The gas is ionized and greatly heated by the arc, and discharges axially out nozzle opening 17 (in the form of jet 11) into the magnetic nozzle means 10 next to be described.

The magnetic nozzle means 10 comprises a relatively short helical current-conducting coil 31 mounted coaxially around the plasma jet 11 emanating from torch 12 and adapted, when supplied with a large current from a suitable direct current source 32, to generate a magnetic field having strong axial and radial components. Stated otherwise, the generated magnetic field is generally nozzle-shaped and provides a nozzle action with relation to the ionized plasma jet 11 passing coaxially there-through. Wall means 33 are shown provided around the coil 31 in order to define a cooling chamber through which water may be passed by means of conduits 34. The magnetic nozzle having strong axial and radial components is described in co-pending patent application Serial No. 775,973, filed November 24, 1958, for High-Intensity Electrical Plasma-Jet Torch Incorporating Magnetic Nozzle Means, inventors Gabriel M. Giannini and Vernon H. Blackman, and assigned to the assignee of the present invention.

Electrode elements 36 and 37 are mounted in mutually-insulated relationship around the plasma jet 11 at opposite ends of coil 31 in order to form an electric arc 38 passing through the jet. In the illustrated apparatus, each electrode 36 and 37 comprises a short metal tube which is mounted in flush relationship in an elongated insulating tube 39 which may be formed of quartz or the like. The inner end of tube 39 is flush with the outer end of insert 18, so that the plasma jet 11 is unimpeded as it leaves the torch 12 and passes through the tube 39 as well as the electrodes 36 and 37 interposed therein.

A direct current source 41 is connected to the electrodes 36 and 37 in order to supply current thereto so that the current may pass, in the form of an arc, between the electrodes 36 and 37 and longitudinally of the central portion of insulating tube 39. Arcing is enhanced because of the ionized condition of the plasma jet 11. In order to increase the arcing action, small metal protrusions may be provided on the internal surfaces of electrodes 36 and 37 at circumferentially spaced points.

In the operation of the embodiment of Figures 1 and 2, a strong direct current is fed from source 32 to winding 31 in order to generate the described magnetic field having strong axial and radial components. Direct current is also fed from source 41 to electrodes 36 and 37, and the arc 38 is initiated therebetween longitudinally

through the plasma jet and through the central portion of insulating tube 39.

The presence of the electric arc 38 within the magnetic nozzle formed by winding 31 eliminates or minimizes any tendency of the plasma 11 to become unstable because of the presence of disturbances along the surface of the flow, or other factors. The arc 38 also greatly increases the energy (stagnation enthalpy) of the plasma.

The stabilization indicated above is believed to result from a combination of the generally longitudinal magnetic field generated by winding 31 and the circumferential magnetic field generated by arc 38. These combine to produce a rotating magnetic field having the desired stabilizing characteristics. Such rotating magnetic field not only effects plasma stabilization, but also tends to rotate the terminal portions of the arc 38, at electrodes 36 and 37, thereby preventing the arc from burning into the electrodes and reducing the life thereof.

Embodiment of Figures 3 and 4

Referring next to the second embodiment of the invention, illustrated in Figures 3 and 4, the plasma torch 12 may be the same as in the previous embodiment and has been given the same reference numerals. The quartz tube 39, electrodes 36 and 37, current sources 26 and 41, and winding 31 are also employed in the embodiment of Figures 3 and 4.

In the present embodiment, two additional helical coils or windings 43 and 44 are mounted coaxially around the inner and outer sections of insulating tube 39 and on opposite sides of electrodes 36 and 37 from winding 31. A shield 46, formed of soft iron or other magnetizable material, is mounted adjacent the forward wall of torch 12 in order to prevent entrance of lines of magnetic force into the body of the torch. Suitable wall means 47 and 48 are provided around windings 43 and 44 to form water chambers through which water may be passed by means of passages, not shown. A direct current source 49 is employed to pass current through the windings 31, 43 and 44.

In the operation of the embodiment of Figures 3 and 4, current is fed from source 49 to the three magnetizing coils 31, 43 and 44 in order to generate the previously-described magnetic fields having portions disposed in the tube 39 and in electrodes 36 and 37. Representative lines of force in the magnetic fields generated by coils 43 and 44 are indicated at 51 and 52 in Figure 4. The lines of force generated by the winding 31 are not illustrated, in order to prevent confusion with the representation 38 of the electric arc between electrodes 36 and 37.

In normal operation, a relatively high current is fed to the central winding 31 in order to provide a strong magnetic nozzle effect. The plasma passing through such magnetic nozzle is stabilized, as described above, by means of the electric arc 38 extending longitudinally of tube 39 between electrodes 36 and 37.

The windings 43 and 44 are normally supplied with smaller currents than winding 31, but such smaller currents are adequate to insure that the terminal portions of arc 38 will rotate around the common axis of electrodes 36 and 37 in order to provide a current-sheet effect or at least prevent burning in of the terminal arc portions and consequent reduction in electrode life. The polarities of windings 43 and 44 are preferably so selected that the terminal arc portions rotate in the same direction, that is to say both clockwise or both counterclockwise as viewed from the right in Figure 4. The arrows 53 in Figure 4 indicate a clockwise rotation as viewed from the right, such rotation resulting from the combination of the circumferential magnetic field generated by arc 38 and the generally longitudinal magnetic field generated by coil 43.

If desired, the currents fed through windings 43 and 44 may be as strong or stronger than the current fed to winding 31, to provide three magnetic nozzles in series relationship.

Various embodiments of the present invention, in addition to what has been illustrated and described in detail, may be employed without departing from the scope of the accompanying claims.

I claim:

1. Stabilized magnetic nozzle means for a substantially arc-free stream of ionized gas, which comprises means to create a magnetic field through which said stream passes, and means to maintain an electric arc in said stream adjacent said magnetic field.

2. Stabilized magnetic nozzle means for a jet of plasma, which comprises means to create around said jet a nozzle-shaped magnetic field, and means to maintain an electric arc through said jet at said field, said electric arc co-operating with said field to stabilize said jet.

3. Stabilized magnetic nozzle means for an external jet of plasma from a plasma generator, which comprises a magnetizing winding mounted relatively closely around said jet and adapted when supplied with direct current to form a magnetic field having strong components axially and radially of said jet, first and second electrodes provided in mutually insulated relationship at longitudinal points along said jet and on opposite sides of said winding, and means to maintain an electric arc between said electrodes and longitudinally through said jet.

4. Stabilized magnetic nozzle means for an external jet of plasma from a plasma generator, which comprises a magnetizing winding mounted relatively closely around said jet and adapted when supplied with direct current to form a magnetic field having strong components axially and radially of said jet, first and second electrodes provided in mutually insulated relationship at longitudinal points along said jet and on opposite sides of said winding, means to maintain an electric arc between said electrodes and longitudinally through said jet, and means to effect continuous movement of the terminal portions of said arc relative to said electrodes to thereby prevent said terminal portions from burning into said electrodes and reducing the life thereof.

5. An electrical plasma-jet torch apparatus, which comprises means to generate a high-temperature jet of ionized gas, conduit means to confine said jet, first and second generally annular electrodes provided at spaced points along said conduit means generally coaxially with said jet, means to supply direct current to said electrodes to effect arcing therebetween through said jet, and means to generate a magnetic field adapted to effect rotation of the terminal portions of said arc around said electrodes.

6. An electrical plasma-jet torch apparatus, which comprises means to generate a high-temperature jet of ionized gas, conduit means to confine said jet, first and second electrodes provided at spaced points along said conduit means, means to supply current to said electrodes to effect arcing therebetween through said jet, a magnetizing winding mounted around said conduit means generally coaxially of said jet and between said electrodes, and means to supply current to said winding to thereby generate a magnetic field through which said jet must pass.

7. An electrical apparatus, which comprises means to generate a high-temperature jet or stream of ionized gas, first and second generally annular electrodes provided at spaced points along said jet generally coaxially therewith, means to supply current to said electrodes to effect arcing therebetween through said jet, and magnetizing means mounted around said jet adjacent said electrodes and adapted upon supply of current thereto to create magnetic nozzles for said jet and insure rotation of the terminal portions of the arc around said electrodes.

8. An electrical plasma-jet torch apparatus, comprising a nozzle electrode having a nozzle opening therein, a back electrode spaced and insulated from said nozzle electrode, means to define an annular gas-pressure chamber between said electrodes and coaxial with said opening,

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means to introduce gas tangentially into said chamber for vortical flow therein and subsequent discharge through said opening, means to maintain an electric arc between said electrodes and in the vicinity of said opening in order to heat said gas and effect discharge of a jet of plasma out said opening, first and second electrodes mounted adjacent said jet in spaced and mutually insulated relationship, means to maintain an electric arc through said jet between said electrodes, a relatively short helical magnetizing coil mounted coaxially around said jet between said electrodes, and means to supply a strong direct current to said coil to effect generation in said jet of a magnetic field having strong axial and radial components.

9. An electrical plasma-jet torch apparatus, comprising a nozzle electrode having a nozzle opening therein, a back electrode spaced and insulated from said nozzle electrode, means to define a gas-pressure chamber between said electrodes and coaxial with said opening, means to introduce gas into said chamber for discharge through said opening, means to maintain an electric arc between said electrodes and in the vicinity of said opening in order to heat said gas and effect discharge of a high-temperature jet of plasma out said opening, conduit means disposed on the side of said nozzle opening remote from said back electrode to confine said jet of plasma, first and second annular electrodes mounted in

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said conduit means coaxially thereof in longitudinally spaced and mutually insulated relationship, means to maintain an electric arc between said annular electrodes and longitudinally through said conduit means, a relatively short helical magnetizing coil mounted coaxially around said conduit means between said annular electrodes, and means to supply a strong direct current to said coil to effect generation in said conduit means of a magnetic field having strong axial and radial components.

10. The invention as claimed in claim 9, in which second and third coils are mounted coaxially around said conduit means respectively adjacent said annular electrodes, and means are provided to supply direct current to said second and third coils to effect generation of magnetic fields in said conduit means and effect rotation of the terminal portions of said arc around said annular electrodes.

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