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PLASMA FLAME JET SPRAY GUN WITH A CONTROLLED ARC REGION

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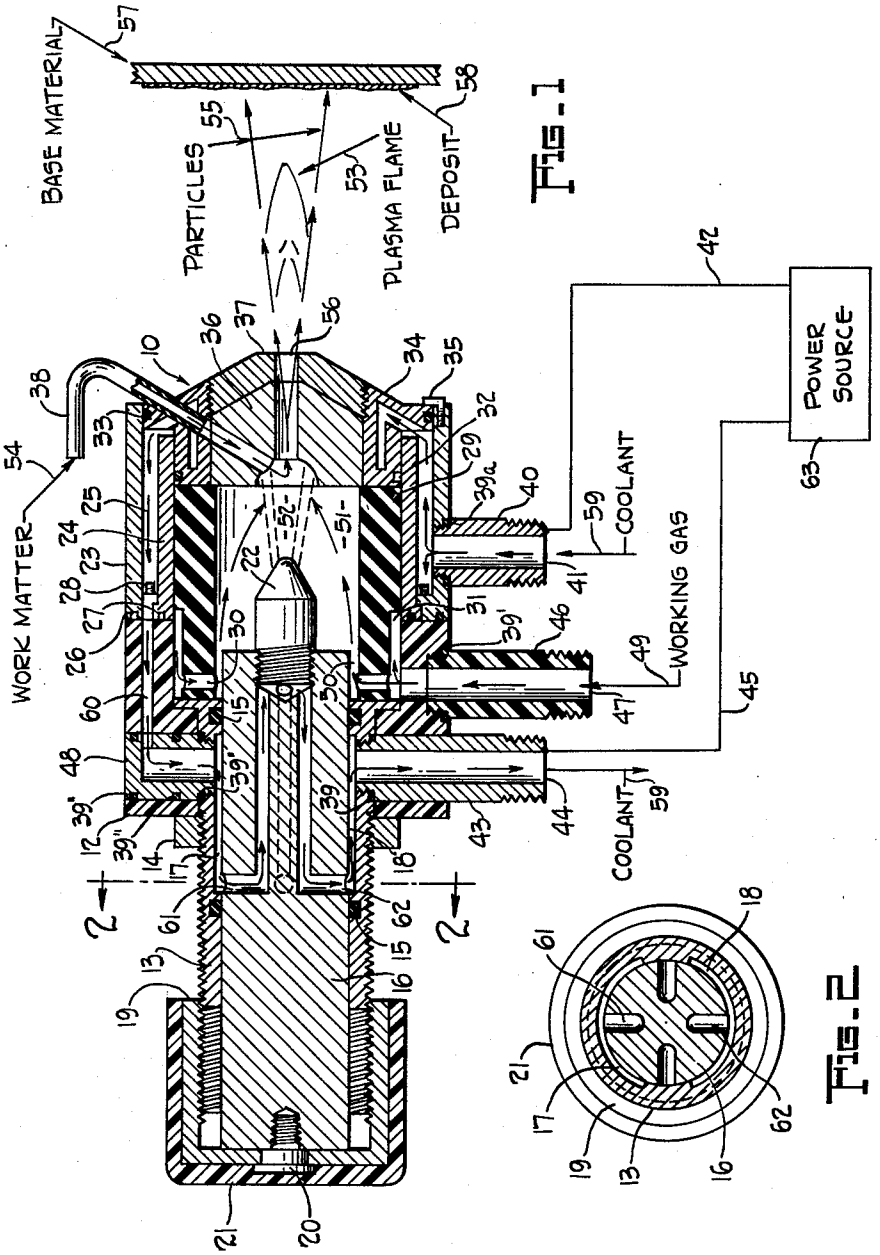


FIG. 1

FIG. 2

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PLASMA FLAME JET SPRAY GUN WITH A CONTROLLED ARC REGION

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Continuation of abandoned application Ser. No. 859,292, Dec. 14, 1959. This application Feb. 7, 1962, Ser. No. 174,344

21 Claims. (Cl. 219—76)

This invention relates to plasma flame apparatus and more particularly to a plasma flame jet spray gun with an enclosed arc region that is also a controlled arc region for receiving at controlled amounts and pressures working gas to be turned into plasma and at controlled amounts work matter that is to be heated to a very high temperature to be sprayed as particles to form a high density deposit upon the base material.

This application is a continuation of my prior copending application, Serial Number 859,292, filed December 14, 1959, now abandoned.

It is an object of the present invention to provide a high-temperature or hyperthermal plasma flame apparatus wherein the work matter, in any suitable form, is introduced into the arc in a controlled arc region and at or just prior to the point at which the working gas is ionized by the arc.

Another object of the present invention is to provide a plasma flame device where all of the work matter goes directly into the controlled arc region and all of the work matter is turned into molten, gaseous vapor or atomic particles, hereinafter called particles, and further all of the particles go directly out the orifice to be deposited upon the base material.

Still a further object of the present invention is to provide a plasma flame device which deposits a uniform high density deposit having good adhesion, cohesion, bonding, sealing, plating or cladding qualities.

Still another object of the present invention is to provide a plasma flame device that prevents globs of cooled work matter from building up inside the plasma flame jet spray gun and causing clogging, spattering and sputtering.

Still a further object of the present invention is to provide a plasma flame device that heats the work matter uniformly throughout to predetermined temperatures over a wide range, from a few hundred to thirty thousand or more degrees Fahrenheit.

Still another object of the present invention is to provide a plasma flame device where both electrodes are effectively and sufficiently cooled to make it possible to operate the device on DCSP, DCRP or AC.

Still a further object of the present invention is to provide a plasma flame device where the electrodes have a large cross section area to carry a high electrical current.

Still another object of the present invention is to provide a plasma flame device capable of propelling the particles at supersonic velocity to impinge them into or upon the base material.

Still a further object of the present invention is to provide a plasma flame jet spray gun which can be produced, packaged, and sold in large quantities at a comparatively low cost, and which can be conveniently utilized wherever needed.

Still additional objects, benefits, and advantages of this invention will become evident from a study of the following detailed description taken in conjunction with the accompanying drawing, in which:

FIGURE 1 is a partly schematic, sectional view taken along the axial centerline of plasma flame apparatus embodying a preferred form of this invention.

FIGURE 2 is a cross section view taken along line 2—2 of FIGURE 1 showing interior arrangement of the

coolant flow in the semiannular cavities between the draw screw and electrode chuck.

Referring now specifically to the drawing, a plasma flame jet spray gun **10** made in accordance with the present invention preferably comprises a hollow cylindrical plastic body **12** into which draw screw **13** is inserted.

The draw screw **13** is held firmly in place and axially aligned in the plastic body **12** by the draw nut **14**.

Two O-ring seals **15**, preferably of silicone rubber, are disposed in suitable grooves in draw screw **13** for purposes to be hereinafter more fully explained. Next the electrode chuck **16** is inserted into the draw screw **13** forming upper and lower semiannular cavities **17** and **18**, respectively.

Adjustment nut **19** is attached to the electrode chuck **16** by the idler screw **20**. As the adjustment nut **19** is screwed along its mating threads on the draw screw **13** the electrode chuck **16** is forced in or out along the axial centerline of the plasma flame jet spray gun **10**.

Plastic cover **21** is press fitted over the adjustment nut **19**.

The rod electrode **22** is supported in axial alignment as by a pipe thread which engages a mating self sealing taper pipe thread in the electrode chuck **16**.

The hollow cylindrical outer jacket **23** is slipped over the hollow cylindrical arc chamber jacket **24** and they are respectively axially aligned to each other by the inward flange of the outer jacket **23** and the outward flange of the arc chamber jacket **24**, thus forming the annular coolant cavity **25**.

Two silicone rubber seals, O-rings **26** and **27**, are located in suitable grooves in the outer jacket **23** and arc chamber jacket **24**, respectively. Then the outer jacket **23** and the arc chamber jacket **24** are attached as a unit, to the plastic body **12** by anchor screws **28**. Screws extend through the plastic body **12** into threaded mating holes in the outer jacket inward flange.

Next the hollow cylindrical electrical insulator **29**, having radial holes **30**, is inserted into the arc chamber jacket **24** in axial alignment to form an annular gas cavity **31**.

Two silicone rubber seals, O-rings **32** and **33**, are located in suitable grooves in the outer orifice **34**. The smaller O-ring **32** forms a seal between outer orifice **34** and the inside surface of the arc chamber jacket **24** and larger O-ring **33** forms a seal between outer orifice **34** and the inside surface of the outer jacket **23** thereby extending the length of the annular coolant cavity **25** into the outer orifice **34**.

The outer orifice **34** is held in place by half head screws **35**.

The washer electrode **36** is inserted into the outer orifice **34** to butt up against the electrical insulator **29** and is held firmly in place in axial alignment with the rod electrode **22** by screwing the inner orifice **37** into a mating threaded hole in the outer orifice **34**.

The Pitot tubes **38**, one shown, are located to deliver work matter **54** to the critical point in the controlled arc region **52**.

Rubber seal, O-ring **39***a*, is located in a suitable groove in the adapter nipple **40**. The adapter nipple **40** is screwed into a threaded mating hole in the outer jacket **23** to act as both the coolant inlet **41** and electrical conductor **42** connection terminal for supplying electrical current to the washer electrode **36**.

Rubber seal, O-ring **39**, is located in a suitable groove in the adapter nipple **43**. The adapter nipple **43** has a central bore providing a passageway therethrough and is disposed in a suitable aperture in draw screw **13** with its bore in communication with lower cavity **18**. The adapter nipple **43** acts as both the coolant outlet **44** and electrical conductor **45** connection terminal for supplying electrical current to the rod electrode **22**.

Rubber seal, O-ring 39', is located in a suitable groove in the plastic adapter nipple 46. The plastic adapter nipple 46 is then screwed into a threaded mating hole in the plastic body 12. The plastic adapter nipple 46 has a central bore which comprises the working gas inlet 47.

Three rubber seals, O-rings 39'', are located in suitable respective grooves in the hollow cylindrical coolant passage 48. The hollow cylindrical coolant passage 48 has a passageway therethrough and is disposed in a suitable aperture in draw screw 13 with its passageway in communication with upper cavity 17.

The operation of this device will now be readily understood. Under controlled pressure gases such as argon, helium, hydrogen, nitrogen or other gases, hereinafter called working gas 49, enter the plasma flame jet spray gun 10 at working gas inlet 47. The working gas 49 flows through the plastic adapter nipple 46 into the annular gas cavity 31. The working gas 49 circulates in the annular gas cavity 31 acting as both a coolant and thermal barrier to the surfaces of the plastic body 12, draw screw 13, and electrical insulator 29.

The working gas 49 leaves the annular gas cavity 31 through the radial holes 30 and passes into the inner annular gas cavity 50. The working gas 49 circulates in the inner annular gas cavity 50 acting as both a coolant and thermal barrier to the surfaces of the screw 13, electrode chuck 16, and electrical insulator 29.

The working gas 49 flows through the arc chamber 51 into and through the controlled arc region 52. As the working gas 49 passes through the controlled arc region 52, the space between the rod electrode 22 and the washer electrode 36, the electrical energy is transformed into heat and a portion of the working gas 49 becomes ionized and the working gas becomes a plasma flame 53.

Also at this point, the controlled arc region 52, at the same instant or a fraction of a second before the portion of the working gas 49 becomes ionized, a controlled amount of work matter 54 in any desired suitable form is introduced into the controlled arc region 52 through the Pitot tubes 38.

Under the controlled arc region arrangement all of the work matter 54 enters directly into the controlled arc region 52, the same instant the working gas 49 becomes ionized and the work matter 54 is immediately heated to a temperature as high as 30,000° F. At this high temperature the work matter 54 may be changed to molten, gaseous vapor or atomic particles indicated generally at 55. While in the controlled arc region 52, the heating of all work matter 54 to particles 55 is uniform throughout.

From this point in the controlled arc region 52 all of the particles 55 are turned directly out through the orifice 56 by the plasma flame 53 and conveyed to the base material 57 at sonic or supersonic velocity and form a high density deposit 58 by adhesion, cohesion, bonding, plating or cladding.

The controlled arc region arrangement was arrived at after a number of tests and experiments. Examples of two of the most informative tests and experiments follow:

Example 1

First it was attempted to introduce the work matter 54 into the plasma flame 53 outside the plasma flame jet spray gun 10. The results were very poor because the work matter 54 would not intermix into the plasma flame 53 but would merely skirt around the plasma flame 53. Only a few random work matter 54, particles 55 would enter the plasma flame 53 to be sprayed as deposit 58, very poorly deposited, upon the base material 57.

Example 2

In another attempt the work matter 54 was mixed with the working gas 49; the work matter 54 being tangentially swirled in the arc chamber 51. This resulted in good particle 55 spraying of a deposit 58 upon the base material 57. But here again only random work matter

54, particles 55 would be carried out the orifice 56 and the rest of the work matter 54 would be heated inside the arc chamber 51 forming globs that would cause the gun to spatter and sputter and clog at the orifice 56.

In apparatus embodying this invention the work matter 54, whether it be metal or non-metal, is introduced neutral into the controlled arc region 52 at the same instant as the neutral working gas 49 is becoming electrically charged plasma flame 53. Thus all are exposed to the thermionic bombardment together while still in their neutral states of matter.

The working gas 49 is heated to a very high temperature and part of it becomes a plasma flame 53 and the work matter 54 is heated to a very high temperature and becomes particles 55. The temperature to which the working gas 49, plasma flame 53 and the work matter 54, particles 55 are raised is dependent upon a number of physical, chemical and electrical factors.

The physical factors are such things as the space or gap between the rod electrode 22 and the washer electrode 36 which determine the electrical arc jump distance and, therefore, the impedance. The size of the hole in the washer electrode 36 controls the amount of constriction upon the flow of working gas 49. The smaller the hole diameter in the washer electrode 36 the more the flow of working gas 49 is constricted and the more the concentration of heat and electrical energy is increased.

The chemical factors include, inter alia, the nature of the atomic or molecular structure of the work matter 54 and working gas 49; whether or not a catalytic action or chemical reaction occurs and, if so, whether it is endothermic or exothermic, whether the work matter is metallic or non-metallic; and whether the work matter is magnetic, electrically charged or neutral. These chemical and physical chemical factors in themselves determine whether the plasma flame jet spray gun 10 will develop temperatures of only a few hundred degrees or temperatures as high as thirty thousand degrees Fahrenheit or even higher.

The electrical factors are such things as the amount of current used and whether the electrical current used is D.C.S.P., D.C.R.P. or A.C.

When a D.C.SP circuit is used the electron flow, kinetic energy, is from the negatively charged electrode to the positively charged electrode and the negatively charged electrode will remain relatively cool in comparison to the hot positively charged electrode Therefore in a D.C.S.P. circuit the positively charged electrode requires cooling in some manner. However, when a D.C.R.P. or A.C. circuit is used both electrodes must be effectively and sufficiently cooled to keep them from melting and spattering because of the high temperature concentration upon their surface and within them.

The coolant 59 as a liquid or gas enters the plasma flame jet spray gun 10 at the coolant inlet 41 and flows through the adapter nipple 40 into the annular coolant cavity 25, cooling and carrying heat away from the washer electrode 36, inner orifice 37, outer orifice 34 and arc chamber jacket 24.

The coolant 59 then flows from the annular coolant cavity 25 through the coolant passage 60 in the plastic body 12 down the hollow cylindrical coolant passage 48 into the upper cavity 17 in the draw screw 13.

As best seen in FIGURE 2, the coolant 59 cannot pass around the electrode chuck 16 because of the semiannular cavity construction, upper cavity 17 and lower cavity 18, in the draw screw 13. Rather the coolant 59 flows from the upper cavity 17 into the electrode chuck coolant passage 61 where the coolant 59 comes directly in contact with the rod electrode 22 to cool and carry heat away from it. Then the coolant 59 flows out through the electrode chuck coolant passage 62 to the lower cavity 18 and then out through the adapter nipple 43 to the coolant outlet 44.

The electric current is supplied to the plasma flame jet spray gun 10 by way of the electric conductors 42 and 45. The power source 63 may be an electric arc welder generator or transformer.

The arc region is enclosed and controlled so that the working gas is introduced therein at controlled pressures and volumes and the work matter, as a gas, liquid, slurry, powder or wire, is introduced into the controlled arc region, through the Pitot tubes, at the instant, or fraction of a second before, a portion of the working gas becomes ionized thereby ensuring the proper heating and dispersal of the work matter.

Additionally, both electrodes are effectively and sufficiently cooled so that it is possible to operate the plasma flame jet spray gun, embodying this invention, on D.C.S.P., D.C.R.P. or A.C. and are preferably of relatively large cross sectional area so that a high electric current may be used in the gun.

The working gas circulating in the annular cavities 31 and within the arc chamber 51 adjacent the interior wall of the insulator 29 acts as both a coolant and a thermal barrier for the surfaces and chamber exposed to its circulation effect.

The electrode chuck 16 has a positive flow cooling system running through it which is controlled by simply rotating the chuck within the draw screw 13 so as to constantly, effectively and sufficiently cool and carry heat away from the electrode chuck and from the rod electrode 22.

The washer electrode 36 is easily and quickly changed or replaced without requiring removal of the outer orifice 34, by merely screwing the inner orifice 37 out of the outer orifice, thereby avoiding disturbing the O-ring coolant seals.

Rod electrode 22 is easily and quickly changed or replaced by merely unscrewing and replacing it. A self sealing taper pipe thread is preferably used for rod electrode 22 so as to eliminate the need of gaskets and other materials which lose their effectiveness at high temperatures.

Because the adjustment nut 19 is supported on the idler screw 20, the electrode chuck does not turn as it is adjusted longitudinally by turning the nut 19.

With a plasma gun embodying this invention the base material need not be heated above its temper or heat treatment critical temperature to obtain good adhesion, cohesion, bonding, sealing, plating or cladding qualities.

The work matter may, for example, comprise such materials as aluminum, aluminum oxide, ammonia, beryllium, beryllium oxide, boron carbide, calcium zirconate, chromium, chromium boride, hydrocarbons, magnesium oxide, molybdenum, nickel, niobium carbide, propane, Pyrex, stainless steel, Stellite #1, tantalum carbide, thorium, thorium oxide, titanium carbide, tungsten, tungsten carbide, uranium oxide, zinc, zirconium boride, zirconium carbide, zirconium oxide and others.

The particles of work matter are propelled or conveyed at sonic or supersonic velocity to the base material, impinging thereon to form a high density deposit.

The structure and shape of the arc chamber 51 and the disposition of rod electrode 22 therein is such that the surface material is not blown off the rod electrode. This is because the working gas flow is controlled by the internal configuration of the arc chamber and electrode chuck so that the working gas merely flows gently over the rod electrode.

Thermionic bombardment may proceed in either direction between the electrodes.

All oppositely charged electric current carrying parts are so assembled in the plasma flame jet spray gun that they are at all times further apart from each other than the electrodes are from each other, when the gun is in operation.

The draw screw, outer orifice, inner orifice and arc chamber jacket are preferably made from copper or other high thermal conductive material so that heat transfer is always from a part having a smaller relative rate of thermal conductivity to a part having a larger relative rate of thermal conductivity thus providing good cooling throughout the unit with no undesirable temperature build-up or thermal barriers arising between different parts in a direction outwardly from chamber 51.

While this invention has been described with particular reference to the construction shown in the drawing it shall be understood that changes may be made thereto within the spirit and scope of the present invention, which is defined by the appended claims.

I claim:

1. A plasma jet spray gun comprising a body member of electrical insulating material having a cylindrical bore therein with a shoulder intermediate its length, a hollow cylindrical draw screw of electrically conductive material disposed in said body and having a flange engaging said shoulder, said draw screw extending rearwardly from said body member in a direction away from the direction said shoulder faces, said draw screw having an end with external threads remote from said flange, a nut on said threads and engaging said body member to hold said draw screw in position, an electrode chuck, of electrically conductive material, having ends and being disposed within said draw screw, an adjustment nut rotatably secured to said electrode chuck, encircling one said end thereof and engaging said threads of said draw screw for selective coaction therewith, whereby to advance and retract said electrode chuck in said draw screw, upper and lower axially aligned, circumferentially spaced, internal arcuate grooves or cavities in said draw screw, said grooves cooperating with the exterior of said electrode chuck to form coolant passages, a rod electrode detachably secured to the end of said electrode chuck remote from said adjustment nut, a coolant passage in said electrode chuck providing communication for coolant between said upper and lower cavities via said electrode; a hollow cylindrical outer jacket of electrically conductive material secured to said body member and extending forwardly therefrom, a hollow cylindrical inner jacket of electrically conductive material disposed in said outer jacket and defining an annular coolant passage therewith and therebetween, a hollow cylindrical insulator member of electrically non-conductive material disposed in said inner jacket and defining the lateral walls of an arc chamber, an outer orifice member of electrically conductive material and having a central bore secured to said outer jacket and retaining said insulator member in position, said outer orifice member having an internal bore and internal threads remote from said insulator, a cylindrical washer electrode disposed in said orifice member bore and abutting said insulator member, an inner orifice member having external threads engaging said internal threads of said outer orifice member and retaining said washer electrode in position, said washer electrode having a central bore, in axial alignment with said rod electrode and providing an orifice from said arc chamber, and an axially aligned hemispheric arc region cavity facing said arc chamber and defining an enclosed, controlled arc region, a plurality of radially spaced Pitot tubes in communication with said arc cavity and extending through said washer electrode and outer orifice member to provide means to conduct work matter to said arc region, a bore through said inner orifice member in communication with said washer electrode bore, an annular groove in said insulator member a plurality of arcuately spaced radial passages in said insulator member remote from said washer electrode and in communication with said arc chamber, and said annular groove means for conducting working gas to said insulator member groove, coolant passage in said outer orifice and communicating with said annular coolant passage, means interconnecting said annular coolant passage and said upper cavity, means for conducting coolant to said annular coolant passage, means to conduct coolant from

said lower cavity, and means connecting said draw screw and said outer jacket, respectively, with a power source whereby to cause an arc between said rod and washer electrodes.

2. A plasma jet spray gun comprising a body member of electrical insulating material having a bore therein a hollow draw screw of electrically conductive material disposed in said body bore and having an end extending rearwardly therefrom with threads thereon, an electrode chuck of electrically conductive material, said electrode chuck having ends and being disposed within said draw screw, an adjustment nut mounted on said electrode chuck and engaging said threads of said draw screw for selective co-action therewith, whereby to advance and retract said electrode chuck in said draw screw, upper and lower axially aligned, circumferentially spaced, internal arcuate grooves or cavities in said draw screw, said grooves cooperating with the exterior of said electrode chuck to form coolant passages, a rod electrode detachably secured to the end of said electrode chuck remote from said adjustment nut, a coolant passage in said electrode chuck proving comunication for coolant between said upper and lower cavities via said rod electrode; a hollow cylindrical outer jacket of electrically conductive material secured to said body member and extending forwardly therefrom, a hollow cylindrical inner jack of electrically conductive material disposed in said outer jacket and defining an annular coolant passage therewith, a hollow cylindrical insulator member of electrically nonconductive material disposed in said inner jacket and defining the lateral walls of an arc chamber, an outer orifice member of electrically conductive material, said outer orifice member having a central bore and being secured to said outer jacket and retaining said insulator member in position, said outer orifice member also having an internal bore and threads remote from said insulator, a cylindrical washer electrode disposed in said orifice member bore and abutting said insulator member, an inner orifice member having threads engaging said threads of said outer orifice member and retaining said washer electrode in position, said washer electrode having a central bore in axial alignment with said rod electrode and providing an orifice from said arc chamber, an axially aligned, hemispheric arc region cavity facing said arc chamber and defining an enclosed, controlled arc region, a plurality of radially spaced Pitot tubes in communication with said arc region cavity and extending through said washer electrode and outer orifice member to provide means to conduct work matter to said arc region, a bore through said inner orifice member in communication with said washer electrode bore, an annular groove in said insulator member, a plurailty of arcuately spaced, radial passages in said insulator member remote from said washer electrode and in communication with said arc chamber, and said annular groove for conducting working gas to said arc chamber, coolant passages in said outer orifice and communicating with said annular coolant passage, means interconnecting said annular coolant passage and a said draw screw cavity, means for conducting coolant to said annular coolant passage, means conducting coolant from the other said draw screw cavity, and means connecting said draw screw and said outer jacket, respectively, with a power source whereby to cause an arc between said rod and washer electrodes.

3. A plasma jet spray gun comprising a body member having a bore therein, a hollow draw screw disposed in said body and having an end extending rearwardly therefrom, an electrode chuck disposed within said draw screw and having means co-acting therewith whereby said electrode chuck is advanced and retracted in said draw screw, said draw screw and electrode chuck defining internal arcuate upper and lower coolant cavities, a rod electrode detachably secured to said electrode chuck, a coolant passage in said electrode chuck providing communication for coolant between said upper and lower cavities via said electrode jacket means secured to said body member and

extending forwardly therefrom, a hollow cylindrical insulation member of electrically non-conductive material disposed in said jacket means and defining the lateral walls of an arc chamber, an outer orifice member secured to said jacket means and retaining said insulator member in position, said outer orifice member having an internal bore, a washer electrode disposed in said outer orifice member bore and abutting said insulator member, an inner orifice member engaging said outer orifice member and retaining said washer electrode in position, said washer electrode having a central bore in axial alignment with said rod electrode and providing an orifice from said arc chamber, an axially aligned arc region cavity facing said arc chamber and defining an enclosed, controlled arc region, a plurality of radially spaced Pitot tubes in communication with said arc cavity and extending through said washer electrode and outer orifice member to provide means to conduct work matter to said arc region, a bore through said inner orifice member in communication with said washer electrode bore, a plurality of arcuately spaced radial passages in said insulator member remote from said washer electrode and in communication with said arc chamber, means for conducting working gas to said insulator member passages, mutually communicating coolant passages in said outer jacket, outer orifice and body member and in communication with one said coolant cavity, means for circulating coolant through said coolant passages and cavities and means for connecting said rod and washer electrodes, respectively, with a power source whereby to cause an arc therebetween.

4. A plasma jet spray gun comprising housing means having a bore therein, an electrode chuck of electrically conductive material disposed within said bore and having means co-acting with said housing means for selective advancement and retraction of said electrode chuck relative to said housing means, a rod electrode detachably secured to said electrode chuck, a coolant passage in said electrode chuck and adapted to cool said rod electrode, a hollow, cylindrical insulator member of electrically nonconductive material disposed in said housing means and defining the lateral walls of an arc chamber, said rod electrode extending into said arc chamber, a washer electrode disposed in said housing means, said washer electrode being electrically insulated from said electrode chuck and being longitudinally spaced from said rod electrode, said washer electrode having a central bore in axial alignment with said rod electrode and providing an exit orifice from said arc chamber, said washer electrode also having an axially aligned hemispheric arc region cavity opening into said arc chamber and defining an enclosed, controlled arc region, a plurality of radially spaced Pitot tubes in communication with said arc cavity and extending through said washer electrode to provide means to communicate work matter to said arc region, a pluraility of arcuately spaced radial passages in said insulator member remote from said washer electrode and providing communication with said arc chamber, means for conducting working gas to said insulator member passages, means for conducting coolant to said coolant passage, and means connecting said electrodes, respectively, with a power source whereby to cause an arc therebetween.

5. A plasma jet spray gun comprising housing means, an electrode chuck of electrically conductive material disposed within said housing means and having means coacting therewith for selective advancing and retracting said electrode chuck within said housing means, a rod electrode carried by said electrode chuck, a coolant passage in said electrode chuck and adapted to cool said rod electrode, said housing means including electrically nonconductive means defining the lateral walls of an arc chamber, disposed in said housing means, said rod electrode extending into said arc chamber, a washer electrode disposed in said housing means, said washer electrode being insulated electrically from said electrode chuck and

being spaced across said arc chamber from said rod electrode, said washer electrode having a central bore in axial alignment with said rod electrode and providing an exit orifice from said arc chamber, said washer electrode also having an axially aligned hemispheric arc region cavity opening into said arc chamber and defining an enclosed, controlled arc region, at least one Pitot tube in communication with said arc cavity and extending through said washer electrode to provide means to communicate work matter to said arc region, means opening into said arc chamber remote from said washer electrode for conducting working gas to said arc chamber, means for conducting coolant to said coolant passage, and means connecting said electrodes, respectively, with a power source whereby to cause an arc therebetween.

6. A plasma jet spray gun comprising housing means defining an arc chamber having electrically nonconductive walls, rod electrode means of electrically conductive material disposed within said housing means and mounted for selective advancement and retraction relative thereto, said rod electrode means extending into said arc chamber, a washer electrode disposed in said housing means, said washer electrode being electrically insulated from said rod electrode means and spaced across said arc chamber from said rod electrode means, said washer electrode having a substantially flat face adjacent said arc chamber and a central bore in axial alignment with said rod electrode means and providing an exit orifice from said arc chamber, said washer electrode also having an axially aligned hemispheric arc region cavity in said face and opening into said arc chamber and defining an enclosed, controlled arc region, means to communicate work matter to said arc region, means opening into said arc chamber remote from said washer electrode for conducting working gas to said arc chamber, and means connecting said rod electrode means and said washer electrode, respectively, with a power source whereby to cause an arc therebetween to ionize said working gas, said work matter being added to said working gas in said arc region substantially simultaneously with, but not after, the ionization thereof.

7. A plasma jet spray gun comprising housing means defining an arc chamber, electrically conductive rod electrode means disposed within said arc chamber, said arc chamber having electrically non-conductive side walls laterally spaced from said rod electrode means, washer electrode means disposed in said housing means, said washer electrode means having a substantially flat face at one end of said arc chamber and being insulated electrically from said rod electrode means and being spaced across said chamber from said rod electrode means, said washer electrode means having an axially aligned hemispheric arc region cavity in said flat face and opening into said arc chamber and defining an enlosed, controlled arc region, said washer electrode means also having a bore extending from said arc region cavity and providing an orifice from said arc chamber, means to communicate work matter directly into said arc region, means opening into said arc chamber remote from said washer electrode means for conducting working gas into said arc chamber, and means connecting said electrode means, respectively, with a power source whereby to cause an arc therebetween to ionize said working gas.

8. A plasma jet spray gun comprising housing means defining an arc chamber, electrically conductive first and second electrode means in said arc chamber, said electrode means being electrically insulated from each other and being spaced apart across at least a part of said arc chamber, said arc chamber having electrically non-conductive side walls laterally spaced from said first electrode means, said second electrode means having a hemispheric arc region cavity opening toward and in axial alignment with said first electrode means and defining an enclosed, controlled arc region, a bore in communication with said cavity and providing an exit from said chamber, means to communicate work matter directly into said arc region, a plurality of arcuately spaced passages in said housing means remote from said first electrode means and providing communication with said arc chamber, means for conducting working gas to said passages, and means for connecting said electrode means, respectively, with a power source to cause an arc between said electrode means to ionize said working gas.

9. A plasma jet spray gun comprising housing means defining an arc chamber, electrically conductive first and second electrode means in said arc chamber, said electrode means being electrically insulated from each other and being spaced apart across at least a part of said arc chamber, said arc chamber having electrically non-conductive walls laterally spaced from said first electrode means said second electrode means having a hemispheric arc region cavity opening toward and in axial alignment with said first electrode means and defining an enclosed, controlled arc region, means communicating with said arc region to provide an exit from said chamber for work matter carrying plasma flame, means to communicate work matter directly into said arc region, means for introducing working gas into said chamber, and means for connecting said electrode means, respectively, to a power source.

10. The plasma jet spray gun according to claim 11 wherein said means to introduce working gas is disposed more remotely from said second electrode means than the nearest portion of said first electrode means.

11. A plasma jet spray gun comprising housing means defining an arc chamber, electrically conductive first and second electrode means in said arc chamber, said electrode means being electrically insulated from each other and being spaced apart across at least a part of said arc chamber, said second electrode means having an arc region cavity opening toward and in axial alignment with said first electrode means and defining an enclosed, controlled arc region, means communicating with said arc region and providing an exit from said chamber, means to communicate work matter directly into said arc region, means for introducing working gas into said chamber, and means for connecting said electrode means, respectively, to a power source to cause an arc between said electrode means and ionize said working gas in said arc region.

12. A plasma jet spray gun comprising housing means defining an arc chamber, electrically conductive first and second electrode means in said arc chamber, said electrode means being electrically insulated from each other and being spaced apart across at least a part of said arc chamber, said second electrode means having a hemispheric arc region cavity opening toward and in axial alignment with said first electrode means and defining an enclosed, controlled arc region, means communicating with said cavity and providing an exit from said chamber, means to communicate work matter through said second electrode means directly into said arc region, said first electrode extending into said arc chamber, means for introducing working gas into said chamber more remote from said second electrode means than the nearest portion of said first electrode means, and means for connecting said electrode means, respectively, to a power source to cause an arc between said electrode means to ionize said working gas in said arc region.

13. A plasma jet spray gun comprising housing means defining an arc chamber having nonconductive walls, electrically conductive first and second electrode means in said chamber, said electrode means being spaced apart across at least a part of said chamber and being electrically insulated from each other; means for connecting said electrode means, respectively, to a power source to cause an arc having an axis extending between said electrode means, means to introduce working gas into said chamber and thence into said arc, said arc ionizing said working gas into plasma, means in axial alignment with

said arc axis and providing an exit orifice, and means for introducing work matter directly into said arc without otherwise entering into said chamber substantially at the point of plasma formation and immediately upstream of said exit means.

14. A plasma jet spray gun comprising housing means defining an arc chamber having electrically nonconductive walls, electrically conductive first and second electrode means in said arc chamber, said electrode means being electrically insulated from each other and being spaced apart across at least a part of said arc chamber, said second electrode means having an arc region cavity opening toward and in axial alignment with said first electrode means and defining an enclosed, controlled arc region, means providing an exit from said chamber through said arc region, means to communicate work matter to said arc region, means for introducing working gas into said chamber, and means for connecting said electrode means, respectively, to a power source, said working gas flowing through said arc region and exit in a predetermined direction, and said means to communicate work matter introducing the work matter into said arc region at an acute angle with and in the opposite direction of said direction of flow.

15. The plasma jet spray gun, according to claim 20, in which said power source is supplied with alternating current.

16. The plasma jet spray gun of claim 18 in which said aperture and electrode have mating, self-sealing, tapered threads.

17. The plasma jet spray gun according to claim 21 in which said housing means has threads thereon, said carrier is restrained against rotation about its own axis, and a threaded adjustment nut rotatably mounted on said carrier and engaging said housing means threads whereby said carrier is advanced and withdrawn without rotation about its own axis to maintain thel ateral ends of said passages and said grooves in respective communication.

18. In a plasma jet spray gun comprising housing means defining an arc chamber, the improvement that said chamber has non-conductive walls, washer electrode means having an orifice in one wall and rod electrode means spaced across said chamber from said washer electrode means and being insulated therefrom and extending into said chamber; said rod electrode means including a carrier mounted for selective advancement and withdrawal relative to said chamber and having an end in said chamber, an aperture in said end of said carrier and opening toward said washer electrode means, an electrode removably disposed in said aperture, passage means in said carrier providing communication with said aperture, and means for circulating coolant to said aperture and against said electrode.

19. In a plasma jet spray gun comprising housing means defining an arc chamber, the improvement that said chamber has non-conductive walls, washer electrode means having an exit orifice in one wall, and rod electrode means extending into said chamber, said rod electrode means including a carrier mounted for selective advancement and withdrawal relative to said chamber, a portion of said carrier extending into said chamber and having an end spaced across said chamber from said washer electrode means, a rod electrode carried by said end of said carrier, said washer electrode means being electrically insulated from said rod electrode means across said arc chamber from said rod electrode means, a plurality of equally and arcuately spaced passages in said housing means, said passages opening radially into said arc chamber opposite said portion of said carrier whereby means are provided for conducting working gas to said passages, and thence into said arc chamber, and means for connecting said electrode means, respectively, with a power source to cause an arc between said electrode means to ionize said working gas intermediate said electrode means.

20. The plasma gun according to claim 18 with additional passages to interconnect with said first mentioned passages to conduct said cooling means to cool said washer electrode means; and means connecting said electrode means with a power source for causing an arc therebetween.

21. In a plasma jet spray gun comprising housing means defining an arc chamber the improvement of rod electrode means extending into said chamber, said rod electrode means including a carrier mounted for selective advancement and withdrawal relative to said chamber and having an end in said chamber with an electrode carried by said end of said carrier, a plurality of passage means in said carrier for circulating coolant to and from said electrode, the ends of said passage means remote from said aperture extending laterally in said carrier toward said housing means, longitudinally extending grooves in the surface of said housing means, one said groove being in communication with the lateral ends of each said passage means said grooves and passage means maintaining communication respectively as said rod electrode means is advanced and withdrawn, and means to circulate coolant to and from said grooves, respectively.

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