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PROCESS FOR PLASMA FLAME FORMATION

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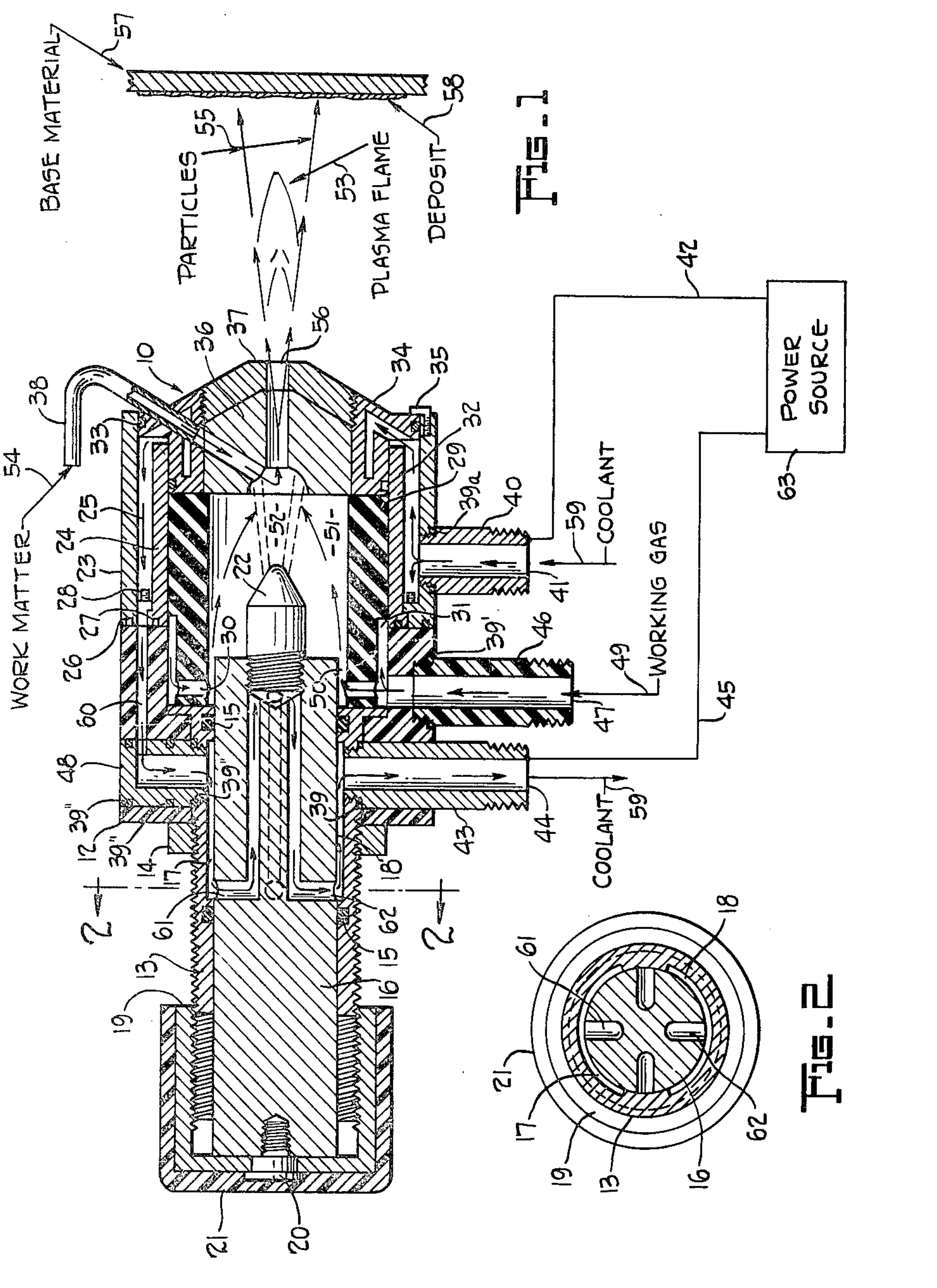

FIG. 1

FIG. 2

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PROCESS FOR PLASMA FLAME FORMATION

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Application Feb. 7, 1962, Ser. No. 174,344, now Patent No. 3,179,782, dated Apr. 20, 1965, which is a continuation of abandoned application Ser. No. 859,292, Dec. 14, 1959. Divided and this application Feb. 9, 1965, Ser. No. 431,270
The portion of the term of the patent subsequent to Apr. 21, 1982, has been disclaimed
2 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 division of my prior copending application Serial Number 174,344, filed February 7, 1962, now Patent No. 3,179,782, which was 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 D.C.S.P., D.C.R.P. or A.C.

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:

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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 draw 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 tthe 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 exotherimc, 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.S.P. 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 process for coating a surface with a predetermined material comprising the steps of creating an electric arc between axially spaced electrodes and across a chamber having an outlet orifice in axial alignment with said arc, introducing a working gas capable of ionic disassociation into said chamber rearwardly of said electrodes remote from said orifice, ionizing said working gas in a controlled, enclosed arc region in said chamber adjacent said orifice to form plasma and simultaneously introducing coating material into said arc region whereby to heat said coating material to a high temperature, and projecting said plasma and coating material through said orifice and onto said surface.

2. In a process for plasma jet spraying the step of ionizing a portion of a stream of working gas capable of ionic disassociation at a predetermined location in the flow of said gas and substantially simultaneously and no later introducing the matter to be sprayed into said stream of working gas at said location, without prior mixing of said working gas and matter to be sprayed.

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