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Plasma Stream Apparatus and Methods—*JTST* Historical Patent #32*

UNITED STATES PATENT OFFICE

2,922,869

Gabriel M. Giannini, Newport Reach, and Adriano C. Ducati, Corona Del Mar, Calif., assignors to Plasmadyne Corporation, Santa Ana, Calif., a corporation of California Continuation of Application 18 November, 1957, Serial No. 697,279, Patented January 26, 1960

This application 7 July, 1958, Serial No. 747,094
49 Claims. (Cl. 219-75)

Note: *Only a much abbreviated form of this 27-page patent is presented. The completed patent can be accessed through the TSS web site. http://www.asminternational.org/*

This invention relates to plasma stream apparatus a methods, and more particularly to plasma stream torches methods of creating and sustaining very high-temperature plasma streams or jets, and methods of using the same. The present application is a continuation of our co-pending application Serial No. 697,279, filed November 18, 1957, for Plasma Stream Apparatus and Methods. Said application is a continuation-in-part of our application Serial No. 649,461, filed March 29, 1957, und the same title, both now abandoned.

Streams of plasma (which has been defined as consisting of neutral gas, ions and electrons, at high temperatures) have been observed as physical phenomena for many years, for example in connection with electric arcs. Such streams have been employed to achieve very high temperatures for short periods of time. All known prior art activity in the very high-temperature field has, however, been theoretical in nature and has not been productive of practical apparatus and methods capable of commercial use in arts such as cutting, welding, metalizing, ceramic coating, surface treating, sintering, etc.

An important field of activity to which the pres application is directed is the field of workpiece heating, especially localized heating, now occupied largely by gas equipment and electric arc and other devices. Electric furnaces now operate in a relatively high-temperature range, up to about 10 000° F., as do solar furnaces and certain special cutting flames such as the oxy-aluminum and Thermit flames. The high current-density torch of the present invention, however, provides sustained pure heat and much higher temperatures. The present torch normally operates in the general range of 5000° F. to 30 000° F., and at atmospheric (or other) pressures. The upper portions of this temperature range, above 10 000° F., may be termed, for purposes of the present patent application, the very high-temperature range. Such terminology is employed despite an appreciation of the fact that much higher temperatures are present in certain instantaneous reactions, such as atomic explosions.

*This series of historical patents concerned with thermal spray technology has been compiled by C.C. Berndt (Stony Brook University, NY-USA) and K.A. Kowalsky (Flame Spray Industries, Inc., NY-USA).

In addition to temperature limitations, conventional gas and arc apparatus is subject to many other limitations and defects well known to the art. For example, in connection with conventional arc devices it is necessary that the work be made a component of the electrical circuit which eliminates this method of heating when the work is not electrically conductive. Furthermore, and very importantly, the necessity of connecting the work in the electrical circuit gives rise to numerous problems of current connection, mobility, and the like. In addition, the necessity of connecting the work in circuit makes it impractical or impossible to effect simultaneous cutting of a plate by the use of two arc devices disposed on opposite sides of the plate. The simultaneous cutting of a plate from both sides thereof is important not only in connection with cutting speed, but in connection with preventing formation of undesirable ridges along one side of the plate being cut.

Other limitations and problems with relation to conventional heating apparatus, especially as to temperature, are so numerous that it is impractical to specify them herein. Some such problems, and their solutions with the apparatus and methods of the present invention, will, however, be set forth in subsequent portions of this specification.

In view, of the above and other factors characteristic of conventional heating and related equipment, it is an object of the present invention to provide practical, commercial plasma stream apparatus and methods which are not subject to the above-specified, and other, limitations and defects.

Another object is to provide apparatus and methods for effecting dynamic constriction of an electric arc by means of gas, to produce a high current-density arc and a very high-temperature plasma stream.

A further object is to provide a sustained, very high temperature plasma stream through use of metal electrodes and with little or no contamination of the stream by electrode material.

A further object is to provide a plasma stream torch and methods in which the work need not be connected in the electrical circuit, and in which temperatures are produced which are greatly higher than those produced with conventional gas or arc equipment.

An additional object is to provide a practical and useful plasma stream torch for creating and maintaining very high temperatures, which torch has metal electrodes and will operate for relatively long periods without the necessity for replacement of parts and without loss of desirable operating characteristics.

Another object is to provide novel means and methods for protecting and cooling the electrodes of a very high temperature plasma stream torch, to prevent such electrodes from burning or deteriorating in a short time, and to result in a long-lasting torch which is practical and useful in construction and operation.

A further object is to provide novel means and methods for injecting substances into plasma streams.

Another object is to provide novel means and methods for constricting an electric arc in a plasma stream apparatus.

A further object is to provide apparatus and methods for producing a whirling or vortical flow of gas in a plasma stream torch in order to constrict the electric arc, and also to electrically insulate portions of the torch, protect such portions from deterioration, and effect protection of work being operated upon by the torch.

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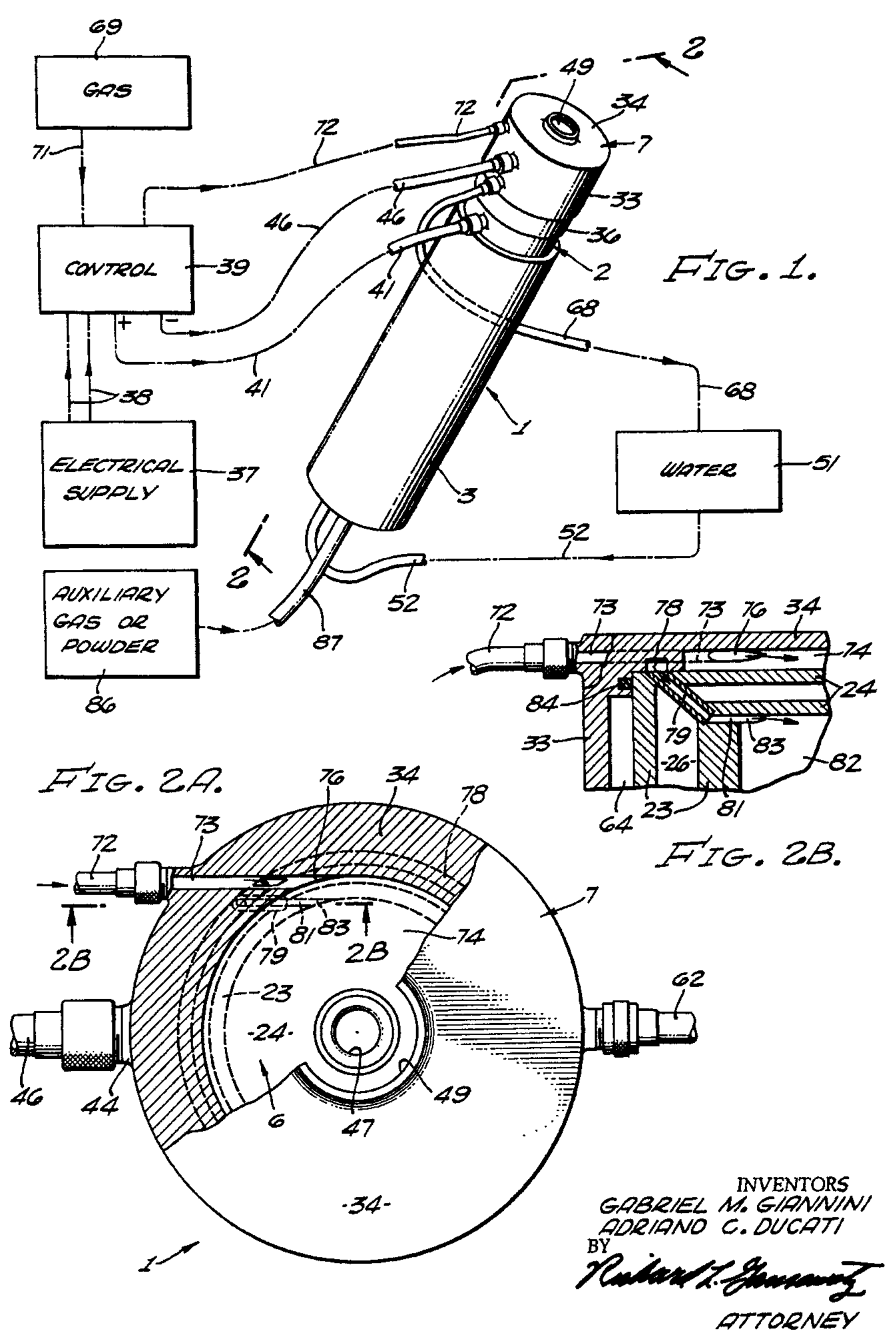
PLASMA STREAM APPARATUS AND METHODS

Original Filed Nov. 18, 1957 8 Sheets-Sheet 1



A further object is to produce high-density plasma streams with electrodes having a novel electrical polarity, such plasma streams having improved characteristics including greatly elevated temperatures as compared to prior art plasma streams.

A further object is to provide novel nozzle structures for plasma stream torches.

Another object is to provide means and methods for providing fluid cooling of the components of the plasma stream apparatus, and for producing the maximum cooling effect without placing fluid seals undesirably near the plasma stream.

An additional object is to provide means and methods for preventing power losses and other undesirable effects within a plasma jet torch, such effects resulting from undesired electrical discharges between portions of the electrodes.

A further object is to provide novel interchangeable electrodes for plasma stream torches.

An additional object comprises the provision of means and methods for cooling the periphery of the torch and both electrodes thereof with but one set of intake and return coolant conduits, and without resulting in electrolysis, power losses or other undesired effects.

An additional object is to prevent starting of an electric arc on the inside (relatively adjacent the back electrode or plate) of the opening in the nozzle electrode, and to protect such nozzle from oxidations and excessive deterioration.

Another object comprises the provision of apparatus and methods for feeding large amounts of current to the electrodes of plasma stream apparatus in a radial manner, to minimize heating and power losses.

Another object is to provide novel means and methods- for protecting the work being operated upon by plasma jet torches

An additional object is to provide a method of controlling the length and characteristics of a plasma jet by regulating gas flow in the nozzle electrode.

Other objects include the provision of novel methods of ceramic spraying or metalizing metals and non-metals, welding metals and non-metals with the work not in circuit, cutting' and drilling metals and non-metals with the work not in circuit, quick heating of metals and non-metals, localized and other hardening of metals, surface treating of metals and non-metals, sintering, shaping, ore refining, etc.

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

In the drawings:

Figure 1 is a view illustrating one form of plasma stream torch, constructed in accordance with the present invention, as associated with control and supply elements which are shown schematically;

Figure 2 is an enlarged longitudinal central sectional view of the torch, taken on line 2-2 of Figure 1;

Figure 2A is, a transverse view, half in section and half in end elevation, on the broken line 2A-2A of Figure 2;

Figure 2B is a fragmentary longitudinal sectional view on line 2B-2B of Figure 2A;

Figure 3 is a longitudinal central sectional view of a second and more commercially practical plasma stream torch, constructed in accordance with the present invention;

Figure 4 is a section on line 4-4 of Figure 3;

Figure 5 is a schematic view, in longitudinal central section, illustrating basic components of a plasma stream torch, and indicating the electrical polarity which is preferably employed in the torch;

Figure 6 is a schematic view corresponding generally to Figure 5, but illustrating the flattened electrodes permitting radial flow of current to or from the arcing points or regions;

Figure 7 illustrates in schematic form a basic means for effecting cooling of the electrodes of the torch, to provide the maximum cooling effect near the arcing portions of the nozzle and plate;

Figure 8 is a schematic view, in longitudinal central section, illustrating means for dynamically constricting the arc and for protecting, cooling and electrically insulating portions of the electrodes of a plasma stream torch;

Figures 8A, 8B, 8C and 8D are schematic views illustrating nozzle-arc relationships with different electrical polarities and gas flow conditions;

Figure 9 is a schematic view illustrating cooling not only of the electrodes but also of the casing of the torch;

Figure 10 is a schematic view which is generally similar to Figure 9, but which illustrates the provision of additional gas flow means in order to aid in protection of the work from oxidation, and in order to permit introduction of substances into the plasma stream at a point outside the arc chamber;

Figures 11-19 are fragmentary longitudinal central sectional views illustrating various forms of nozzle and plate electrodes, and various means for protecting, the same with electrically-conductive refractory substances;

Figure 20 is a schematic longitudinal central sectional view illustrating a preferred form of interchangeable nozzle electrode;

Figure 21 is a schematic longitudinal central sectional view illustrating an interchangeable nozzle electrode and an interchangeable plate electrode;

Figure 22 is a schematic longitudinal central sectional view illustrating another form of interchangeable electrode, characterized by centrifugal or vortical fluid cooling of the nozzle;

Figure 23 is a schematic longitudinal central sectional view illustrating formation of the arc passage or chamber with both gas and water;

Figure 24 corresponds somewhat to Figure 23, but illustrates the use of a wall or divider between the gas and water;

Figure 25 illustrates, in schematic form, a method of coating a workpiece with a substance such as ceramic, such substance being introduced into the gas which constricts the arc and insulates and protects the nozzle;

Figure 26 corresponds somewhat to Figure 25, but illustrates the introduction of a substance through a hole in the plate electrode;

Figure 27 illustrates a method of coating- a workpiece by use of -the very high-temperature plasma stream torch, the coating substance being introduced into the end of the plasma stream or jet in the form of a rod or wire;

Figure 28 illustrates an additional method of coating or metalizing by use of the plasma stream torch, the coating substance being introduced externally of the torch and in particulate form;

Figure 29 illustrates a method of shaping a workpiece with the very high-temperature plasma stream torch;

Figure 30 illustrates the use of the torch in hole punching, cutting and the like;

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PLASMA STREAM APPARATUS AND METHODS

Original Filed Nov. 18, 1957 8 Sheets-Sheet 2

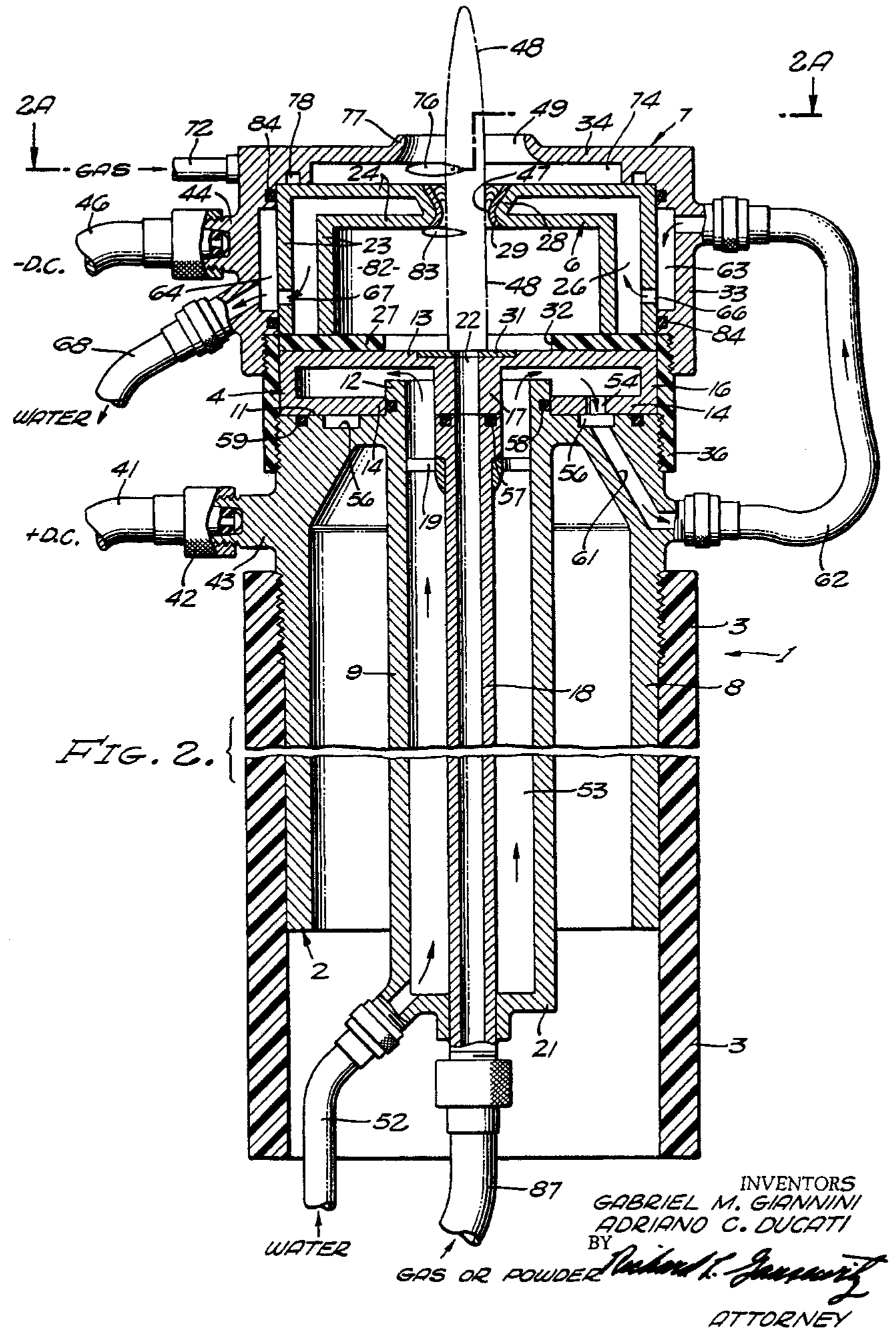

Figure 30A illustrates cutting of a plate. simultaneously from opposite sides thereof;

Figure 31 illustrates a method of welding with the torch; and

Figure 32 illustrates the use of the torch in surface treating, sintering, etc.

In the following specification there will first be described, in non-schematic form and for purposes of illustration and orientation, several embodiments (Figures 2-4) of plasma jet torches constructed in accordance with the present invention. Much of the theory and methods with relation to such very high-temperature torches will then be described, and with particular reference to schematic Figures 5-10. Thereafter, a number of forms of electrode structures will be described with reference to schematic Figures 11-19, and additional embodiments will be described with reference to the schematic showings of Figures 20-24. Methods of employing the torches are illustrated schematically in Figures 25-32, and will be described in connection therewith.

Referring first to Figures 1, 2, 2A and 2B, the very high-temperature plasma stream torch is indicated generally at **1**, and is illustrated to comprise a body **2**, a handle **3**, a plate or base (back) electrode **4**, a nozzle electrode **6**, and a cap **7**.

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