Sept. 8, 1964 G. A. JENSEN 3,148,263

PLASMA-JET TORCH APPARATUS AND METHOD RELATING TO INCREASING THE LIFE OF THE DOWNSTREAM ELECTRODE

Filed Aug. 2, 1961

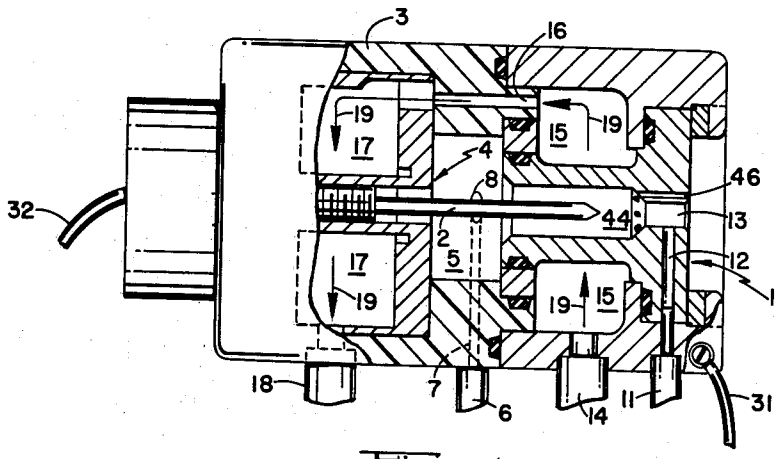


Fig 1

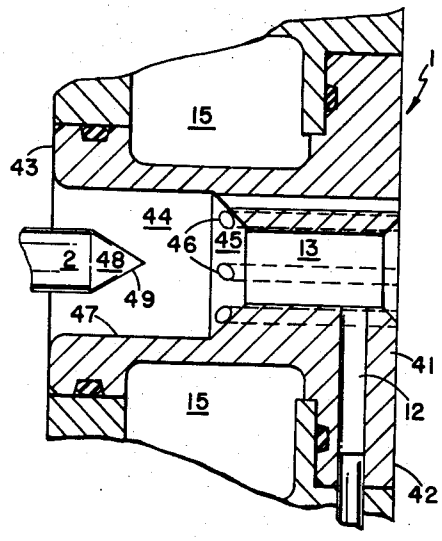


Fig 2

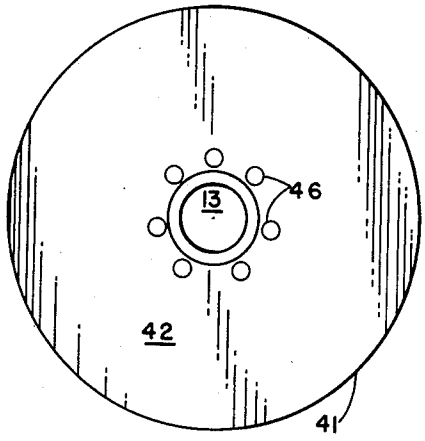


Fig 3

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PLASMA-JET TORCH APPARATUS AND METHOD RELATING TO INCREASING THE LIFE OF THE DOWNSTREAM ELECTRODE

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19 Claims. (Cl. 219—75)

This invention relates to plasma-jet torch apparatus incorporating means to increase the life of the downstream or front electrode and to a method of, inter alia, effecting such increase. Torch apparatus of the type here concerned is suitable for cutting operations or spraying a material such as metal which is melted or vaporized in an electric arc.

The general method of operation of plasma-jet torch apparatus includes producing an electric arc between an upstream electrode, usually referred to as the cathode, and a hollow downstream electrode, generally referred to as the anode. An elastic fluid, such as air, gas, or vapor, is passed through or around the arc struck between the electrodes and directed on a workpiece.

As used herein, the term arc is defined as a self-sustaining gas discharge in the pressure range above $\frac{1}{20}$ of an atmosphere and generally in the current range of several to thousands of amperes. Cobine, on pages 290 and 326 of Gaseous Conductors (1958), calls a discharge having the above-defined characteristics a high pressure arc.

The term plasma, as used herein, is defined as an electrically neutral mass of fluid, usually gas, which contains free electrons and ions created by the dissociation of the fluid, in addition to neutral atoms and/or molecules of the fluid. Plasma, when associated with an electric arc as defined above, exhibits intense chemical activity; regions of the plasma are at extremely high temperatures, often in the range of 10,000 to 30,000° F.

Plasma is created by the interaction of a gas and an arc flowing through the gas. Phrased differently, the gas acts as the conductor for the arc current. An energy transfer occurs between the electric arc and the gas through which the arc is flowing. As a result of energy transfer, the gas is heated to extremely high temperatures. Portions of the gas dissociate into electrons and ions and establish a plasma.

Plasmal derived from arcs as discussed above is used in welding implements and plasma cutting tools as well as plasma generating devices that generate high temperature plasma effluents. To distinguish between the working gas within plasma-jet apparatus and the highly heated gas leaving the apparatus the latter is referred to herein as an effluent. An excellent example of a plasma generating device is shown in the Rava Patent 2,768,279. An arc plasma device for cutting is described in the Cresswell et al. Patent 2,908, 798.

In plasma generators and arc welding equipments erosion of the electrodes is a major problem and limitation in the reliability and usefulness of these equipments. In order to generate the extremely high temperatures desired in arc equipments, the downstream electrode, typically the anode, is required to conduct extremely high currents, in the order of 1,000 amperes. Accordingly, the electrodes are required to operate in extremely high temperature environments generated by the arc and by the power dissipated internally. Heretofore, the life of prior art electrodes was quite short, in the order of 2 to 3 hours of continuous operation, and frequent replacement accompanied by costly down time was required. Because of structural limitations and the like for some applications, such as, for example, small devices, high current operation is impossible because of erosion of the downstream electrode. Where the arc device is used as a research tool the erosion of the electrodes has been found to be detrimental. The eroding material is deposited on the specimen being subjected to the plasma, thus creating nonhomogenous surfaces. In addition, the electrode material often reacts with the specimen being tested to the detriment of the test results.

In industrial coating procedures, the eroding material tends to contaminate the coating unless, of course, the electrode material is the same as the coating material. It is quite obvious, however, that this condition limits the scope of the arc coating apparatus.

A third important limitation of arc devices incorporating electrodes which readily erode is the variation in spacing between the anode and cathode electrode brought about by the steady erosion of the electrode material. As is well known, an arc current and potential and temperature generated by the arc vary with the spacing between the electrodes. The current supplied to the arc must therefore be closely regulated to compensate for the variation in spacing to maintain a constant arc environment.

An important limitation of plasma-jet devices is the tendency of the arc to run off one side of the upstream electrode. This resutls in erosion of the electrodes, nonuniform heating of the gas, and as a result thereof an effluent core that only partially fills the nozzle.

Accordingly, it is an object of the present invention to provide plasma-jet torch methods and apparatus that avoid the disadvantages and limitations of prior art devices of the type described hereinabove.

It is another object of the present invention to provide an improved arc electrode.

It is still another object of the present invention to provide a plasma-jet torch in which both the downstream electrode and the upstream or back electrode have a long life, despite passage therethrough of extremely high currents with consequently greatly elevated temperatures.

A still further object of the present invention is the provision of plasma-jet torch methods and apparatus which permit the passage of relatively high currents through the torch at high current-densities and temperatures, without resulting in destruction of the electrodes until expiration of long periods of time.

Another object of the present invention is the provision in plasma-jet torch apparatus of a hollow downstream electrode that provides an effluent having an improved configuration.

Other objects of the present invention are to provide:

(1) A high temperature electrode that is relatively simple in construction;

(2) A hollow arc electrode which has a relatively long life;

(3) A hollow arc electrode that permits operation at high current-densities; and

(4) An arc electrode having a main central passage and at least one secondary passage adjacent the main passage.

Briefly stated, in accordance with a preferred embodiment of the present invention there is provided a plasma-jet torch apparatus and particularly a nozzle assembly comprising a nozzle block acting as a first electrode and having a main central passage or orifice. The nozzle block cooperates with a second axial electrode upstream of the first electrode to form an arc, the electrodes being spaced one from another to form between them a region for introducing to the arc a fluid to be heated. Additionally provided in the nozzle block adjacent the main central passage is at least one and preferably a plurality of secondary passages extending through the nozzle block. The secondary passages are spaced adjacent to and around the main central passage and communicate with the region

between the electrodes and the outer surface of the nozzle block. The inlet portions of the secondary passages are located such that the temperature of the gas passing therethrough is less than that of the effluent, i.e., for all practical purposes, effluent does not issue from the secondary passages.

The novel features that are considered characteristic of the present invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in conjunction with the accompanying drawings, in which:

FIGURE 1 is a side elevation partly in cross section illustrating a plasma-jet torch constructed in accordance with the present invention;

FIGURE 2 is a fragmentary view of the electrodes in relative position one with another; and

FIGURE 3 is a front view of the downstream electrode illustrating the relative position of the main central passage and secondary passages.

Referring first to FIGURE 1, the torch is illustrated as comprising a nozzle or downstream electrode 1, an upstream electrode 2 spaced and insulated from the downstream electrode 1 by a nonconductive spacer 3 forming a part of the body of the torch, means for supplying an elastic fluid body, such as air, gas or a vapor, to the downstream electrode, means for maintaining an arcing potential between the electrodes, and means for cooling the electrodes. As shown in FIGURE 1, the downstream electrode 1 is spaced from the upstream electrode assembly, indicated generally by the numeral 4, to form a plenum chamber 5 into which is tangentially injected a gas, such as, for example, argon. The gas is supplied through pipe 6 and enters the plenum chamber tangentially through passage 7 and port 8. Pipe 11 and passage 12 are provided for the injection of a powdered metal or the like into the main central passage 13 of the downstream electrode 1. Because of heat generated by the electric arc produced between the upstream and downstream electrodes, it is necessary that these electrodes be cooled. Thus, a coolant, such as water, is first supplied to the downstream electrode 1 through pipe 14 and chamber 15. The coolant flows through pipe 14 and into chamber 15 which surrounds the middle portion of the downstream electrode 1 wherein the arc is located. The coolant then flows out of chamber 15 through passages 16 (only one of which is shown) and into a second chamber 17 which surrounds the middle portion of the upstream electrode assembly 4. Thereafter, the coolant flows out of the second chamber 17 through pipe 18. The flow of coolant is indicated by arrows 19.

The downstream and upstream electrodes 1 and 2 are connected with, respectively, conductors 31 and 32, to allow a D.C. electric potential from a source (not shown) to be impressed between them. The downstream electrode 1 may be connected, for example, to a positive connection and the upstream electrode 2 may be connected to a negative connection to achieve a straight polarity connection.

Proceeding now to a discussion of the downstream electrode 1 and adjacent elements best illustrated in FIGURES 2 and 3, this comprises an annular nozzle block 41 which gives direction to melted, vaporized, or ionized material and its carrying fluid which combine to form an effluent sprayed from the torch. The nozzle block 41 is formed of a highly conductive metal, such as copper, and is provided with a cylindrical central main bore or passage 13 from which effluent issues from the torch. The diameter of the main passage 13 of the nozzle block 41 is less than that at the rear surface 43 of the nozzle block. This may be accomplished as illustrated, for example, by providing a main central passage 13 and a counterbore 44 for receiving the upstream electrode 2,

thereby providing a forwardly inclined arcing surface 45 which joins the main central passage 13 and counterbore 44. The arcing surface 45 may have an included angle of 118°. A plurality of secondary passages 46 (seven as illustrated) are provided adjacent to and around the main central passage 13. The secondary passages 46 provide communication between the front surface 42 of the nozzle block and the outer periphery of the arcing surface 45, i.e., the inner surface 47 of the counterbore 44. The total cross sectional area of the passages 46 is less than that of the main central passage 13. As will become clear hereinafter, the arcing surface 45 intermediate the secondary passages 46 and the main central passage 13 preferably function as the arcing surface of the downstream electrode 1.

A pencil-shaped upstream electrode 2 comprised, for example, of thoriated tungsten is axially supported in the counterbore 44 and maintained in adjustable, spaced, and insulated relation to arcing surface 45. The forward end 48 of the upstream electrode 2 is pointed to provide an arcing surface 49. The arcing surface 49 preferably has an included angle of about less than 90°. When the included angle is about 90° or more, the arc does not tend to run uniformly off the extreme tip of the upstream electrode. However, when the included angle is, for example, in the vicinity of 45°, the arc runs uniformly off the extreme tip of the upstream electrode and appears to fan out and thereby uniformly fill the main central passage 13 with effluent. The upstream electrode 2 is preferably spaced a sufficient distance from arcing surface 45 that the arc formed therebetween contacts these elements at arcing surface 49 of the upstream electrode and the arcing surface 45 of the downstream electrode.

In operation of a plasma-jet torch incorporating the present invention argon is preferably first supplied to the plenum chamber 5 and because of its tangential injection therein is provided with a tangential velocity as it passes from the upstream electrode 2 to and through the counterbore 44 and central passage 13 of the downstream electrode 1. The arc may thereafter be struck in any conventional manner. Once the arc has been struck and gas is flowing around the upstream electrode 2 a material to be sprayed, such as a powder, may be fed through passage 12 of the downstream electrode 1. Effluent issues from the main central passage 13, and in normal operation very little, if any, effluent issues from the secondary passages 46 surrounding the main central passage 13. Of course, abnormal conditions may possibly cause effluent to issue from the secondary passages 46, but such a result is not intended nor will it occur under normal operating conditions, an example of which is given hereinafter in Table I.

The existence and function of the passages 46 or their equivalent are essential to the present invention, and therefore, will be discussed in detail. As has been indicated above, for the embodiment illustrated the upstream electrode 2 is adjusted such that the arc preferably forms between arcing surfaces 45 and 49. Thus, as the working gas approaches the arcing surface 45 of the downstream electrode 1 the portion of the gas which issues from the secondary passages 46 does not come into intimate contact with the arc and, hence, is heated only indirectly by the action of the arc. Under practical operating conditions the temperature of the gas which issues from the secondary passages 46 is heated to only a slight degree as compared to that of the effluent which issues from the main central passage 13. This results because the downstream portion of the arc attaches to the arcing surface 45 intermediate the main central passage 13 and secondary passages 46. Even when the arc is struck upstream of arcing surface 45, the gas that issues from the secondary passages 46 does not appear to be an effluent. This may be due to the fact that the gas comprising the boundary layer, which therefore is cooler than the effluent, issues from the secondary passages. Further, because the

secondary passages communicate with the outer periphery of the arcing surface **45** of the downstream electrode, they function to bleed the boundary layer disposed between the inner wall **47** of the counterbore **44** and the working gas contained therein. As used herein, "bleeding the boundary layer" means permitting at least a portion of the gas comprising the boundary layer to be removed or issue from the downstream electrode through means other than the main central passage. As used herein, the term "boundary layer" means that portion of the gas within the device in contact with gas confining surfaces in the vicinity of the arc and extending inwardly therefrom a distance that is small as compared to the distance between opposed points on the surfaces.

Bleeding of the boundary layer permits material injected through passage **12** to penetrate a greater distance into the effluent in the main central passage **13** than if the secondary passages **46** were not present. This in turn results in a greater transfer of heat to the material. The advantages of such an arrangement will be apparent when it is noted that the working gas, and hence the effluent, has a tangential velocity which tends to resist injection of a material into the effluent and that a relatively high tangential velocity is desirable to improve the characteristics of the arc.

In fact, it has been observed that in a nozzle of the type illustrated herein but without the secondary passages **46** wherein an effluent with a high tangential velocity was used it was impossible to inject a powdered metal to any significant degree into the effluent. Observations indicated that the existence of the boundary layer substantially prevented penetration of the particles comprising the powder into the effluent. Consequently, the centrifugal force exerted on the particles which were, therefore, at the periphery of the effluent, and the large mass of the particles as compared to that of the effluent, caused the particles to be thrown out of the effluent before they could be effectively heated to any appreciable extent.

As may now be obvious, bleeding of the boundary layer results in improved mixing of the effluent and material injected into the main central passage **13**.

The present invention has other advantages, characteristics, and improved benefits which are of equal if not greater importance. One benefit is that the present invention provides an effluent core having a longer and more pointed configuration than has heretofore been observed. Whereas a torch having an electrode of conventional configuration will generally have an effluent core configuration that is short and that has a relatively constant cross section as compared to the present invention, the present invention provides an effluent having an inner core that is longer, generally brighter, and that has an observable decreasing cross section.

Such an effluent configuration is beneficial in spraying operations. Thus, as compared to comparable prior art devices, for a given gas flow and power level, the effluent is longer, and as a result the residence time of the material injected into the effluent is longer, thereby resulting in greater heating and/or melting of the injected material. If greater heating of a material injected into the effluent occurs as a result of increased residence time of the material in the effluent, it also follows that as compared to given operating conditions for a comparable torch that does not incorporate the present invention, lower power levels may be utilized to accomplish substantially the same results.

Another benefit that has been observed is that the arc spot or root appears to fan out and to be more uniformly distributed over the circumference of the main central passage **13**.

As a result of this divergent arc envelope, it has been observed that under normal operating conditions the effluent uniformly fills the main central passage **13**, whereas in other prior art plasma-jet devices only part of the nozzle normally appears to be filled with effluent.

Thus, an important characteristic of the present invention is a divergent arc envelope which does not extend to any appreciable extent into the main central passage. This has been physically exemplified by actual tests wherein only the tip of the upstream electrode was uniformly discolored by the upstream arc root. Further, such erosion as occurred on the downstream arc roots occurred at and around the inner periphery of the arcing surface **45** intermediate the counterbore **44** and the main central passage **13**. As many as six downstream arc roots have been visually observed.

Still another and perhaps the most important benefit is the striking increase in useful operating time of the downstream electrode and power levels that may be achieved with the present invention. This may be most clearly and vividly seen by comparing the test results of a plasma-jet torch in accordance with the presenct invention and a torch that does not incorporate the present invention but is otherwise identical.

The increased power levels and electrode life provided by the present invention are demonstrated in the following data, Table I, giving the important operational and constructional data of a plasma-jet torch (No. 1) incorporating the present invention, and a plasma-jet torch (No. 2) otherwise identical, but not provided with passages around the central main passage.

Table I

	Torch No. 1 (Improved Torch)	Torch No. 2 (Conventional Torch)
Gas:		
Working gas	Argon	Argon.
Gas flow	86 cu. ft./min.	86 cu. ft./min.
Anode Geometry:		
Central main passage diam.	.242 in.	.242 in.
Central main passage length	.250 in.	.250 in.
Secondary passage diam.	.062 in.	
No. of secondary passages	7	0.
Bolt circle diam. of secondary passages	.375 in.	
Included angle and downstream electrode arcing surface	118°	118°.
Counterbore diam.	.453 in.	.453 in.
Distance from downstream electrode front surface to tip of upstream electrode arcing surface	.469 in.	.469 in.
Arc gap distance measured from tip of upstream electrode arcing surface to forward edge of downstream electrode arcing surface.	.179 in.	.179 in.
Upstream electrode diam.	.250 in.	.250 in.
Composition of upstream electrode.	Thoriated tungsten.	Thoriated tungsten.
Composition of downstream electrode.	Copper.	Copper.
D.C. Electrical Power:		
Voltage	40 volts	40 volts.
Current	Gradual increase to 1,000 amps.	Gradual increase to 700 amps.
Running Time	10 hours	5 min.
Erosion	Moderate but still serviceable.	Extreme—not serviceable.

As may be readily surmised from the preceding data, the conventional torch cannot be operated at a power level of 40 kw. under any circumstances. At the end of the test it was estimated that torch No. 1, the improved torch, still had a serviceable life of as much as 20 hours more of continuous use. Heretofore, operation of a torch comparable to torch No. 2 at the power level indicated for torch No. 1 was not possible.

Although a specific embodiment of the present invention has been shown and described, it is to be understood that the present invention is not so limited. For example, the inner surface of the downstream electrode may be formed otherwise than as shown. For different applications, a continuous and smooth surface having a generally increasing diameter from front to back or a generally decreasing-increasing diameter from front to back may be desirable as dictated, for example, by the gas being used, the purpose for which the torch is used, the upstream

electrode location and configuration and the like. Additionally, the downstream electrode may be in the form of a flat, annular disc rather than elongated as shown. Still further, the number of secondary passages may be increased or decreased and they may be skewed, for example, or a substantially continuous annular space may be substituted for the secondary passages. Additionally, where secondary passages are used they need not necessarily be circular and, for example, may be rectangular, elliptical and the like.

Still further, the means for bleeding the boundary layer, such as, for example, passages as shown and described herein, may be divergent with respect to the main central passage.

With the above understanding of the operations by means of which the present invention may be practiced, those skilled in the art will understand how to adapt existing apparatus and/or to build other devices to carry out the method aspects of the present invention.

The various features and advantages of the present invention are thought to be clear from the foregoing description.

Various other features and advantages not specifically enumerated will undoubtedly occur to those versed in the art, as likewise will many variations and modifications of the preferred embodiment illustrated, all of which may be achieved without departing from the spirit and scope of the invention as defined by the following claims.

I claim:

1. In combination with an electrical plasma-jet torch having an upstream electrode, a downstream electrode having a bore substantially coaxial with said upstream electrode for receiving a fluid having a boundary layer and means for bleeding said boundary layer.

2. In combination with an electrical plasma-jet torch having an upstream electrode arcing surface, a downstream electrode having a bore substantially coaxial with said upstream electrode arcing surface for receiving a fluid having a boundary layer and means adjacent said bore for bleeding at least a part of said boundary layer.

3. In combination with an electrical plasma-jet torch having an upstream electrode, a downstream electrode having an exterior surface, a bore substantially coaxial with said upstream electrode and at least one passage adjacent said bore, said passage having one opening upstream of said bore and one opening in said exterior surface of said downstream electrode to provide communication between the medium surrounding said upstream electrode and the ambient atmosphere exterior of said downstream electrode.

4. The combination as defined in claim 3 wherein said passage substantially surrounds said bore and said upstream electrode has a pointed arcing surface, said arcing surface, having an included angle of about less than 90°.

5. In combination with an electrical plasma-jet torch having an upstream electrode, a downstream electrode having an exterior surface, a bore substantially coaxial with said upstream electrode and a plurality of passages spaced adjacent to and around at least a portion of said bore, said passages having one opening upstream of said bore and one opening in said exterior surface of said downstream electrode to provide communication between the medium surrounding said upstream electrode and the ambient atmosphere exterior of said downstream electrode.

6. In combination with an electrical plasma-jet torch having an upstream electrode, a downstream electrode having an exterior surface, a bore substantially coaxial with said upstream electrode and a plurality of passages spaced adjacent to and around at least a portion of said bore and providing an arcing surface therebetween, said passages each having one opening upstream of said bore and one opening in said exterior surface of said downstream electrode to provide communication between the medium surrounding said upstream electrode and the ambient atmosphere exterior of said downstream electrode, said upstream electrode having a pointed arcing surface, said arcing surface having an included angle of about less than 90°.

7. In combination with an electrical plasma-jet torch having an upstream electrode, a downstream electrode having a central main bore substantially coaxial with said upstream electrode and a plurality of openings spaced adjacent to and around a portion of said bore providing an arcing surface therebetween, said downstream electrode having an outer surface and an inner surface, said bore and openings providing communication between said outer and inner surfaces whereby when an arc is maintained between said upstream electrode and said arcing surface and a gas is passed from said upstream electrode to and through said bore an effluent issues from said bore but substantially not from said openings.

8. The combination as defined in claim 7 wherein the total cross sectional area of said openings is less than that of said bore.

9. A downstream nozzle electrode for use in a plasma-jet torch comprising: a nozzle block having a front surface and a rear surface, said nozzle block having a central main bore communicating with said front and rear surface, an arcing surface surrounding said bore and at least exposed to said rear surface, and said nozzle block having a plurality of passages surrounding at least a portion of said bore and communicating with said front surface and the outer periphery of said arcing surface.

10. The combination as defined in claim 9 wherein said central main bore is comprised of a front portion and a rear portion having a diameter greater than said front portion, and said arcing surface is disposed between said front and rear portions.

11. The combination as defined in claim 10 wherein the total cross sectional area of said passages is small compared to the smallest cross sectional area of said bore.

12. In an electrical plasma-jet torch the combination comprising: an upstream electrode having a first arcing surface; a downstream electrode comprising a nozzle block having a front surface and a rear surface, said nozzle block having a central main bore communicating with said front and rear surfaces and generally coaxial with said first arcing surface, a second arcing surface forming a part of said bore, said nozzle block having a plurality of passages surrounding at least a portion of said bore and communicating with said front surface and the outer periphery of said second arcing surface; means for maintaining an electric arc between said arcing surfaces; and means for vortically passing a gas from said upstream electrode to and through said main bore whereby an effluent will issue from said main bore but substantially not from said passages.

13. The process of forming, concentrating and directing an effluent from an electric-arc torch having an upstream electrode axially spaced from a downstream electrode having an annular main passage, which comprises: inducing a gas flow having a boundary layer across the axial space from said upstream electrode to and through said downstream electrode; maintaining an arcing potential between said electrodes whereby an effluent issues from said annular main passage; and bleeding a portion of said boundary layer.

14. The process of forming, concentrating and directing an effluent from an electric-arc torch having an upstream electrode axially spaced from a downstream electrode having an annular main passage, which comprises: inducing a gas flow across the axial space from said upstream electrode to and through said annular main passage; maintaining an arcing potential between said electrodes whereby an effluent issues from said annular main passage; and passing a portion of said gas in said axial space through said downstream electrode adjacent said annular main passage whereby said portion of said

gas substantially does not issue from said downstream electrode as an effluent.

15. The process of forming, concentrating and directing an effluent from an electric-arc-torch having an upstream electrode axially spaced from a downstream electrode having an annular main passage, which comprises: inducing a gas flow across the axial space from said upstream electrode to and through said main passage; maintaining an arcing potential between said electrodes whereby an effluent issues from said main passage; and passing discrete portions of said gas through said downstream electrode adjacent said main passage.

16. The process of forming, concentrating and directing an effluent from an electric-arc torch having an upstream electrode axially spaced from a downstream electrode having an annular main passage, which comprises: inducing a gas flow across the axial space from said upstream electrode to and through said main passage; maintaining an arcing potential between said electrodes whereby an effluent issues from said main passage; and passing discrete portions of said gas through said downstream electrode adjacent to and around at least a portion of said main passage, said discrete portions of said gas being only indirectly heated by the action of the arc resulting from said arcing potential.

17. The process of forming, concentrating and directing an effluent from an electric arc torch having an upstream electrode axially spaced from a downstream electrode having an annular main passage, which comprises: inducing a flow of argon having a tangential velocity across the axial space from said upstream electrode to and through said main passage; maintaining an arcing potential between said electrodes whereby an effluent issues from said main passage; and passing a small portion of said gas in said axial space through said downstream electrode adjacent to and around at least a portion of said main passage but not substantially through the arc resulting from said arcing potential.

18. The process of maintaining a high temperature effluent and of prolonging the electrode life in a torch generating said effluent, which comprises: providing a downstream nozzle electrode having a central main passage and at least one secondary passage disposed generally around said main passage; providing an upstream electrode spaced and insulated from said downstream electrode; maintaining an electric arc between said upstream electrode and said downstream electrode; and passing gas from said upstream electrode to and through the main passage of said downstream electrode whereby an effluent issues from said main passage but substantially not from said secondary passage.

19. The process of maintaining a high temperature effluent and of prolonging the electrode life in a torch generating said effluent, which comprises: providing a downstream nozzle electrode having a central main passage and a plurality of secondary passages disposed generally around and adjacent said main passage; providing an upstream electrode spaced and insulated from said downstream electrode; providing a pointed arcing surface on said upstream electrode having an included angle of about less than 90°; maintaining an electric arc between said upstream electrode and the portion of said downstream electrode located between said main passage and said secondary passages; and passing argon vortically from said upstream electrode to and through the main passage of said downstream electrode whereby an effluent issues from said main passage but substantially not from said second passages.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,148,263 September 8, 1964

Gerald A. Jensen

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 71, for "are" read -- arc --; column 10, line 30, for "second" read -- secondary --.

Signed and sealed this 19th day of January 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

UNITED STATES PATENT OFFICE

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