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2,862,099 1/1958 Gage 219/74
 2,906,858 9/1959 Morton, Jr. 219/121
 3,082,314 3/1963 Arata et al. 219/75

FOREIGN PATENTS

195,299 6/1967 U.S.S.R. 219/121

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[54] **PLASMA ARC CUTTING TORCH**
7 Claims, 1 Drawing Fig.

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 219/75

[51] Int. Cl. B23k 9/00

[50] Field of Search 219/74, 75,
 121; 313/231

[56] **References Cited**
UNITED STATES PATENTS

2,819,423 1/1958 Clark 313/231

ABSTRACT: Water introduced to a plasma jet near its base dissociates into hydrogen and oxygen, adding material and force to the jet and tending to make it more straight-sided and stable. Near the tip of the plasma jet, the hydrogen and oxygen recombine, affording heat. Materials difficult to cut with a torch using known methods, such as inch-thick plates of stainless steel or high-speed tool steel, may be cut at substantially higher traverse rates. Moreover, the kerf is straight-sided and lustrous, rather than being concave and having a dull, oxidized appearance.

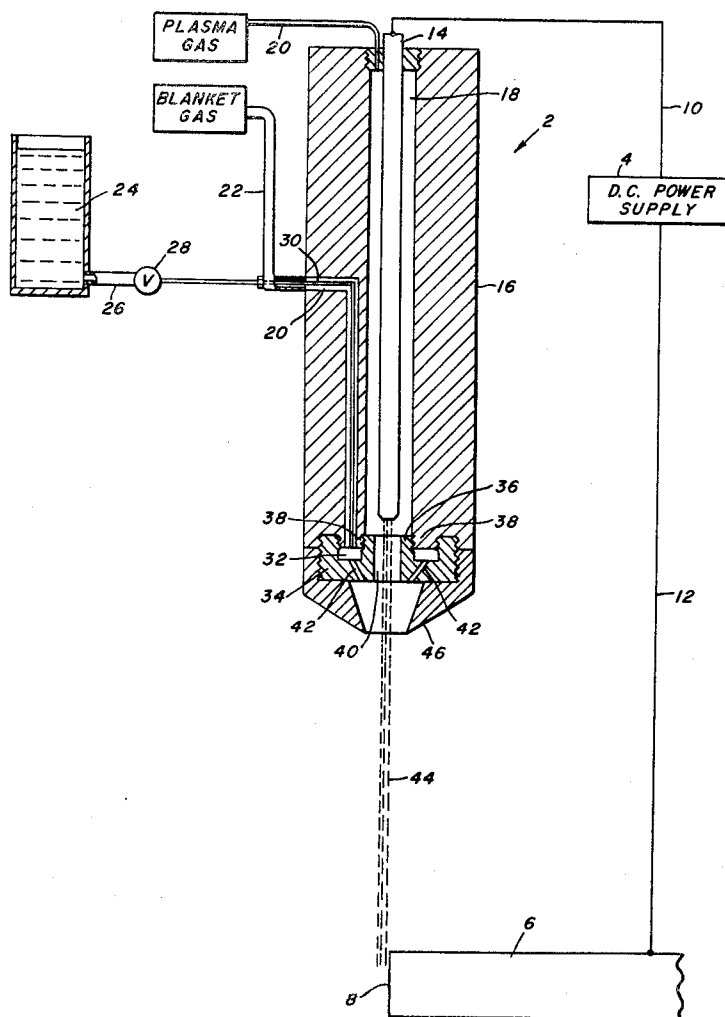


FIG. 1.

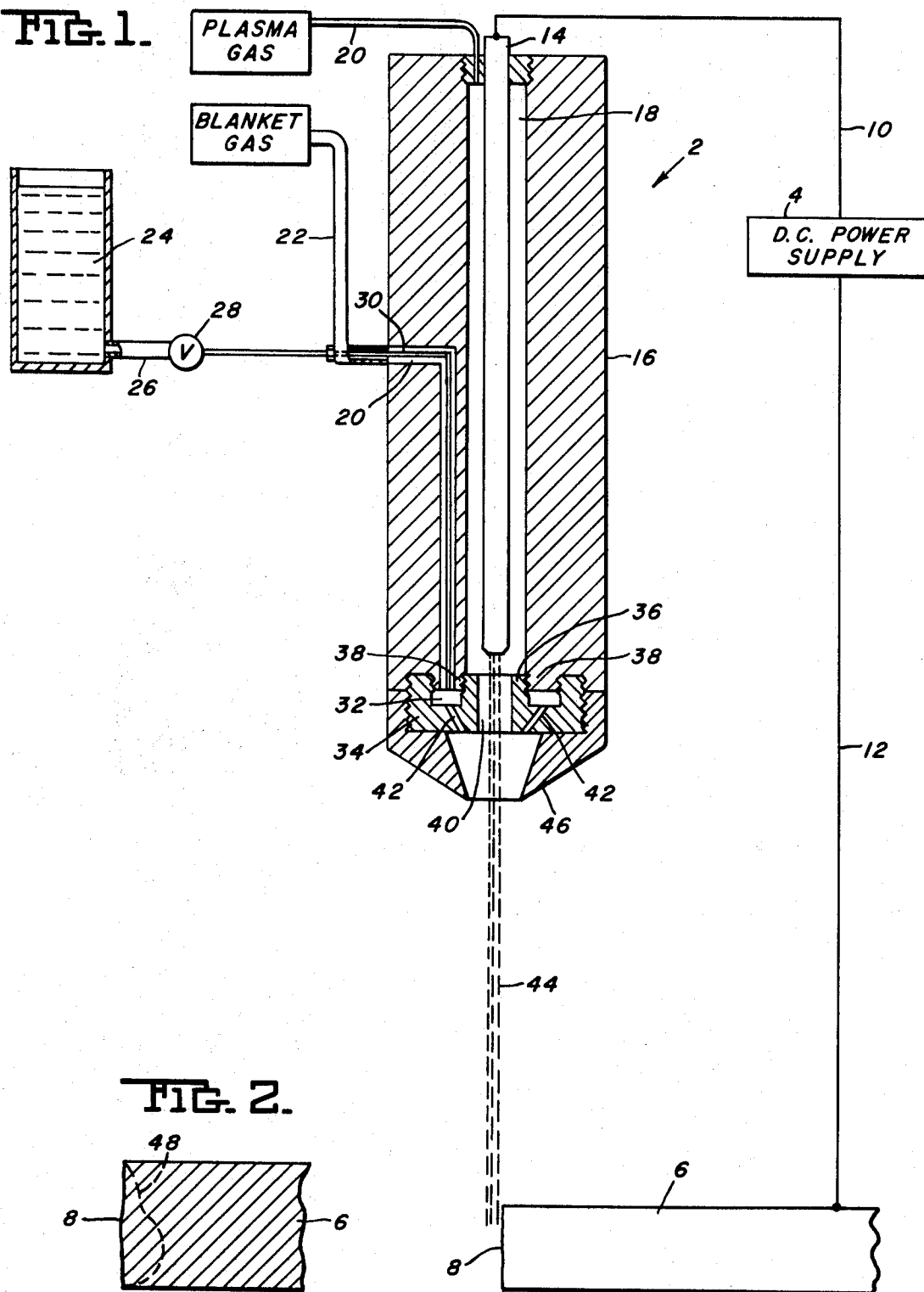
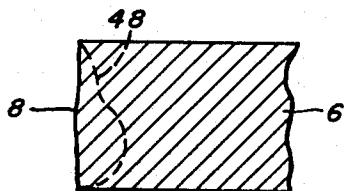


FIG. 2.



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PLASMA ARC CUTTING TORCH

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to plasma jets composed of material heated to a high temperature, such as about 15,000 to 60,000° F. by the action of a direct current arc of about 50–200 kilowatts. It relates more particularly to cutting torches that sever pieces of material of substantial thickness, such as one-fourth inch or more, with the use of a plasma jet of such material, and to methods of torch-cutting difficult-to-cut materials in substantial cross section thicknesses by means of such torches.

2. Description of the Prior Art

In the last 20 years, increasing attention has been paid to the properties and uses of matter at elevated temperatures such as 15,000–60,000° F. It is recognized by physicists that at such high temperatures, matter has properties distinctly different from those which it exhibits in the more familiar solid, liquid and gaseous states. At the high temperatures mentioned above, chemical compounds are unknown. Even at temperatures substantially lower, such as about 5,000° F., most compounds decompose or dissociate into ions of individual elements. For example, at temperatures above 5,072° F., the dissociation of water is complete.

Naturally, it is not common to produce temperatures as elevated as 15,000° F. or more on a large scale. The power requirements for raising a large quantity of such material to a temperature that high, considering also the losses of heat that must be sustained, are enormous. It has been discovered, however, that with the use of a direct current arc of, for example, 650 amperes and 144 volts, using a tungsten electrode shielded with nonreactive gas, it is possible to strike an arc and feed thereto relatively modest flows of gas that will thereby be transformed into the plasma state of matter.

Thus, it is known from U.S. Pat. Nos. 2,806,124 and 2,858,411, to construct a cutting torch, for use in the cutting of metal, that relies upon the transformation of gas into the plasma state of matter in the manner indicated above.

It is also known, from U.S. Pat. No. 2,862,099 to practice an arc torch process in which there is fed a gas that is reactive with the inner torch electrode. To be more specific, the teaching of the patentee is that there should be used reactive gases containing oxygen, and as examples, the patentee mentions oxygen, air, carbon dioxide, or water vapor. The patentee further teaches: "The water may be introduced into the arc area by means of a porous metal insert in the nozzle through which a portion of the nozzle cooling water may pass. Other reactive liquids may be introduced through a porous insert in a similar manner." In essence, the teaching of this patent is that, merely because a gas happens to be reactive with the torch electrode, this does not mean that one cannot obtain the benefits that are to be had by having such reactive gas present in the vicinity of, for example, the middle or the tip of the plasma jet. If, for example, oxygen is reactive with the tungsten electrode that is to be used, but it is nevertheless desired that oxygen be present in the effluent plasma used for the cutting of aluminum or mild steel, the patent teaches that the oxygen may be introduced downstream of the tip of the electrode. The patent falls short of teaching the introduction of a substantial flow of liquid water near the base of the plasma jet and the advantages thereof as regards arc stability and cutting performance of the resultant plasma jet, that characterize the present invention. Although the patent mentions the use of water vapor as a reactive gas that might be used, this is by no means the same as using liquid water; the number of molecules of material introduced and the magnitude of the effect to be expected therefrom is remarkably different. With reference to the mention in the U.S. Pat. No. 2,862,099 of the introduction of liquid water by permitting the cooling water to seep through a porous member, it is possible that in this way at least some water is drawn into the plasma

jet, where it dissociates and recombines, but the quantity of water involved is substantially lower than that used with the present invention. In this connection, it is worth noting that 1 cubic centimeter of water forms, when vaporized, about 1,700 cubic centimeters of water vapor or steam at normal temperature and pressure. The U.S. Pat. No. 2,862,099 gives no indication that the process of the present invention could be practiced safely, and it gives no indication of the benefits as respects arc stability and cutting performance that are obtained when the present invention is used.

It is also known, from U.S. Pat. No. 3,131,288, to adopt a practice in which there is fed to a plasma arc cutting torch a mixture of gas and liquid water, with the water issuing from the mouth of the torch with the effluent plasma jet. The patent teaches, however, that the water is not even vaporized, but is rather projected through a swirl ring to cause it to be propelled tangentially against the inner wall of the arc passageway of the torch to form an insulating layer thereagainst, thereby permitting the torch tip to be made of material of low thermal conductivity. The patent further teaches that the water emerges from the arc passageway as a diverging cone of spray, serving to cool the workpiece in areas that are not to be heated. The patent states that in the cutting of thin metal plates, warpage can thereby be avoided.

It is known, moreover, from U.S. Pat. Nos. 2,906,858 and 3,097,292, to conduct plasma arc torch processing with the plasma jet being surrounded by and constricted by a vortex of water. The processes of these patents are distinguishable from the present invention. The present invention places no reliance upon the maintenance of a layer of liquid water in contact with the exterior of the plasma jet.

BRIEF SUMMARY OF THE INVENTION

A plasma arc is stabilized and, in the cutting of hard-to-cut materials such as stainless steel or high-speed tool steel in plate form, better cutting performance is obtained (higher traverse rate, cleaner and straighter kerf) by introducing into the plasma arc a substantial quantity of liquid water, so that the water is vaporized and dissociated thereby and then recombines exothermically on contact with a cooling surface and/or in the vicinity of the tip of a plasma jet.

BRIEF DESCRIPTION OF THE DRAWINGS

A complete understanding of the invention may be had from the foregoing and following description thereof, taken together with the appended drawings, in which:

FIG. 1 is a schematic showing of an embodiment of apparatus in accordance with the invention, for use in practicing the method of the invention; and

FIG. 2 is an illustration showing the shape of the kerf formed in the practice of the present invention, in comparison with the shape of a kerf formed in a plasma-arc cutting process in accordance with the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a cutting torch 2 that is operated, using a direct current power supply 4 to cut a piece of work 6, leaving a cut edge or kerf 8. The direct current power supply 4 is connected by lines 10 and 12 to an electrode 14 and the work 6, respectively. The electrode 14 is of suitable material, such as tungsten, and is contained in a holder 16 having a central bore or cavity 18 for the receipt of plasma gas through a line 20. The plasma gas, i.e., a gas that is to be turned into plasma by the action of an arc struck between the electrode 14 and the work 6, as hereinafter described, may be any gas suitably unreactive with the electrode 14, such as argon, nitrogen, hydrogen, or mixtures thereof. The holder 16 comprises one or more other openings or passages 20 for the passage of additional gas, which may be called "blanket gas" or "shield gas" and is conveyed to the passage or passages 20 through a line 22. The blanket gas may be air, oxygen, nitrogen, hydrogen, argon, water vapor, acetylene, or other suitable gas, or mixtures thereof.

Liquid water is provided to the plasma jet. There is provided a reservoir 24 having an outlet line 26 that contains a valve 28 and communicates with a line 30 running through the passage 20. Conveniently, line 26 may be of plastic tubing and line 30 may be of stainless steel capillary tubing 0.060 inch in diameter. Although the valve 28 may be of the manually operated type, it is convenient to use a valve of the solenoid-actuated type. The water system should be capable of delivering a substantial flow of water, such as about 2 cubic centimeters per second, to the vicinity of the plasma jet.

If desired, water is delivered by the capillary tube or tubes 30 to an annular space 32 between the member 16 and head member 34, which may conveniently be joined by screw threads or other suitable means to the member 16. The head member 34 has a central portion 36 that cooperates with a portion 38 of the member 16 to prevent gases coming through the line 20 from entering the space 18 through which the plasma gases are traveling. The portion 36 has a central bore 40, through which the plasma jet 44 passes, traveling from the electrode 14 to the work 6.

The head member 34 also contains a number of passages 42 that converge inwardly upon the plasma jet 44.

Surrounding the head member 34, and suitably secured thereto, there is a tip member 46.

The members 16, 34 and 46 are all preferably provided with passages (not shown) to permit the circulation therethrough of cooling water.

As will be seen from the drawings, water passes through the passage 42 and is introduced into the plasma jet 44 at a point relatively near to the base thereof. As a result of the high temperatures present in the plasma jet 44, i.e., temperatures of about 15,000—50,000° F., water so introduced into the plasma jet 44 is instantaneously dissociated into its elements, hydrogen and oxygen. The dissociation reaction is quite endothermic, so that there is a considerable cooling effect upon the part of the jet 44 in the vicinity where the water is introduced.

On the other hand, in the vicinity of the kerf 8 of the workpiece 6, where the materials of the plasma jet are at lower temperatures such as 2,500—5,000° F., the reverse chemical reaction, combination of hydrogen and oxygen to form water, is taking place. This is an exothermic reaction. This reaction produces heat where it is most useful, namely, in the vicinity of the cut.

The addition of water to the plasma jet 44 increases the material flow therein, so that the plasma jet 44 is lengthened, strengthened, and stabilized. In connection with a cutting application, additional mass is thus provided that moves at high velocity and serves to drive molten metal from the cut. The acceleration of this added mass serves, upon contact between the jet and the metal to be cut, to transfer the available energy more effectively into the work. Thus, while the addition of water may be important for other purposes, it is especially helpful in the use of a plasma jet to cut a thick section, such as about 1 inch or more, of a difficult-to-cut material, such as stainless steel or high-speed tool steel or a heat-resistant superalloy of the nickel-base or cobalt-nickel-base type.

Referring now to FIG. 2, there is shown a cross-sectional view of a workpiece 6 that has been cut in accordance with the invention, leaving a relatively straight-sided kerf 8. Indicated by the dotted line 48 is the shape of the kerf produced by plasma arc cutting without use of liquid water injection; the showing is somewhat exaggerated for the sake of clarity.

It will be understood that the torch 2, in most instances, is mounted on suitable means for movement along a predetermined path in spaced relationship to the workpiece to be cut. The cutting torch travels with respect to the work at a suitable rate, such as about 10—40 inches per minute.

Materials differ remarkably in the readiness with which they may be cut. Mild steel or aluminum in the form of an inch-thick plate may be cut rather readily (for example, at a rate of about 12—15 inches per minute) with the use of an oxyacetylene torch. In cutting inch-thick AISI Type 304 stainless steel plate, however, an oxyacetylene torch works at a low

traverse rate, such as about 1 or 2 inches per minute, and this can be increased only slightly with the use of metal powder or other modified oxyacetylene torch cutting techniques. Plasma jet torches of the kind known before the present invention operating at a power level of about 125 kilowatts have exhibited the ability to cut inch-thick Type 304 stainless steel at a traverse rate of about 12—18 inches per minute. With the present invention, the same material is cut at a traverse rate still higher, such as about 20—30 inches per minute with only a relatively small change in power level.

From the foregoing, it is seen that the invention is especially suited for the cutting of hard-to-cut material. Hard-to-cut material includes the stainless steels and high-speed tool steels, as well as the nickel-base and nickel-cobalt-base, heat-resistant superalloys, and excludes such materials as aluminum and its alloys and mild steel. For the most part, the hard-to-cut materials melt at about 2,500° F. or higher. There must be considered as falling within the purview of the invention the cutting of alloys or metals that have such melting points, such as the metals tungsten, molybdenum, columbium, tantalum, zirconium, vanadium, palladium, ruthenium, rhodium, platinum, iridium, and osmium and their alloys that melt at about 2,500° F. or higher.

It is observed, moreover, in the cutting of stainless steel or high-speed tool steel, that the present invention yields a kerf that is not only straighter sided but also different in its appearance from that obtained with previous plasma cutting processes. The processes of the prior art often yielded surfaces that looked oxidized or burnt, whereas the present invention yields surfaces that are generally shiny and lustrous.

The invention described above is illustrated by the following specific examples:

EXAMPLE I

A commercial plasma cutting torch (Thermal Dynamics Model M-200-DF), modified as taught above to permit the introduction of liquid water into the plasma jet, was used to cut Type M-2 high-speed tool steel in the form of a plate 2¼ inches thick. Surrounding the electrode, there was a flow of plasma gas comprising 1.25 cubic feet per minute of nitrogen and 0.3 cubic feet per minute of hydrogen. The flow of blanket gas, as through the passage or passages 20 described above, consisted of 10 cubic feet per minute of nitrogen. An arc was established, using a direct current source of 144 volts and 650 amperes, or 93.6 kilowatts. Thereafter, there was introduced into the blanket gas, using a capillary tube as taught above, liquid water at the rate of 120 milliliters per minute. Type M-2 high-speed tool steel as mentioned above was cut, at a traverse rate of about 20 inches per minute, and the above-mentioned advantages concerning the shape and appearance of the kerf were observed. As an experiment, the injection of water was periodically started and stopped, and there were noticeable differences between the areas cut with the use of water injection and the areas cut without it.

EXAMPLE II

Example I was repeated, except that the work was a 1-inch thick plate of AISI Type 304 stainless steel. Similar improvements in cutting performance were obtained.

Although it is with respect to plasma arc cutting that the present invention is, from the foregoing teachings, most clearly applicable, it is also considered within the scope of the invention to improve the performance of other cutting processes that will respond favorably whenever liquid water is forced into a jet of material having a temperature that is high enough to cause, to a substantial and effective extent, dissociation of the water into its elements. Thus, the invention may be considered, in its broader aspects, as finding use with processes of cutting with an oxyacetylene torch or other means generative of temperatures sufficient to cause the above-mentioned substantial dissociation. Such temperatures are about 3,500° F. or higher. Thus, it is not essential, in ac-

cordance with the invention in its broadest aspects, that a plasma-arc temperature such as 15,000—60,000° F. be reached. For many of the uses of the invention, however, such as the cutting of pieces having substantial thickness and composed of exceptionally hard-to-cut material, such high arc temperature will prove desirable, or even essential.

The possibility of employing in place of water another medium capable of dissociating and reforming is not to be ruled out, but water is considered desirable because of its low cost, ready availability, and high heat of formation.

While I have shown and described herein certain embodiments of my invention, I intend to cover as well any change or modification therein which may be made without departing from its spirit and scope.

I claim:

1. A method of increasing the effectiveness of a metal-cutting process wherein a plasma jet of material is brought into contact with a piece of metal to be cut, said method comprising introducing to penetrate into said jet in the vicinity of its base flow of liquid water in an amount that said water becomes dissociated into hydrogen and oxygen.

2. A method as defined in claim 1, characterized in that said jet is an arc plasma jet having a temperature of about 15,000—60,000° F.

3. A method as defined in claim 2, further characterized in that said piece of metal melts at about 2,500° F. or higher.

4. A method as defined in claim 3, characterized in that said metal is selected from the group consisting of stainless steel

and high-speed tool steel, and in that cutting is effected by causing relative movement between said jet and said piece of metal at a traverse rate of about 20—30 inches per minute.

5. A method as defined in claim 2, characterized in that said jet is established between a gas-shielded electrode and a piece of metal to be cut, said flow of water being about 120 milliliters per minute.

6. In apparatus for cutting a plate of metal, the combination with:

an electrode;

means for establishing between said electrode and said plate a direct current arc;

means for directing, into said arc, gases to be heated thereby to form a plasma jet;

means for causing relative motion between said jet and said plate over a predetermined path while maintaining said jet in spaced relation to said plate improvement comprising:

means for introducing to penetrate into said plasma jet in the vicinity of its base a flow of liquid water in an amount that said water becomes dissociated into hydrogen and oxygen at a temperature of about 15,000—60,000° F.

7. The combination as defined in claim 6, characterized in that said means for introducing into said plasma jet a flow of liquid water comprising a capillary line contained within a passage for blanketing said jet, said capillary having an outlet in the vicinity of the base of said electrode.

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