Disclosed is an improved plasma jet generator comprising at least two plasma jet torches and a guide attachment integrally connected to the torches with a view to fixing the anode foot of a non-transferred type plasma jet. This special structure permits the proper selection of the point of the anode foot of the plasma jet with respect to the cathode spot of the plasma jet, thus realizing a high voltage plasma jet. Also, the new structure prevents the local erosion to the parts of the electrodes on which the anode foot and the cathode spot stand by means of an inactive gas, thus allowing the main arc column to directly heat a high concentrated active gas.

3 Claims, 11 Drawing Figures
PLASMA JET GENERATOR

This invention relates to a plasma jet generator including a plurality of plasma jet torches which are capable of independently functioning as the plasma jet torch of straight polarity.

Thus, the wall of the torch will be free from the damage which would be caused by using the torch wall as the negative electrode if the torch is used in the mode of reverse polarity. The plasma jets ejected from those plasma jet torches will meet one another in the inner space of a guide attachment which are integrally connected with the torches. A main arc can be established in the electrically conductive space by applying a voltage from a main power supply with one electrode of each plasma jet torch used as the positive or negative electrode, and the gas supplied will be heated by the main arc and then properly directed by the guide attachment.

A plasma jet generator (hereinafter abbreviated to P.J.G.) has been widely used in cutting, welding, coating and other operations. The basic structure of P.J.G. (see U.S. Pat. No. 2,806,124) was originally developed by Union Carbide Corporation, and numerous improvements have been proposed. In these P.J.G.'s, the factors to determine the electric characteristics thereof are as, for instance, follows: gas flow rate, gas compositions, size of caliber, distance between the electrodes, and electric current values. It should be noted that the arc voltage also depends on these factors.

The efficiency of heating gas is usually given by the following equation:

$$\eta = \text{Arc Voltage(V)} \times \text{Electric Consumption(I)}$$

provided that:

$$\text{Torch Consumption(Ld)} = K \times \text{Electric Current(I)} + \text{Thermal Conduction to Casing Wall(Lw)}$$

where $K$ is a constant.

By substituting Equation (2) for the corresponding term of Equation (1) the following equation can be obtained:

$$\eta = 1 - K/V - Ld/VI$$

The last term is negligible for its smallness, and therefore it is apparent the efficiency will increase with the arc voltage.

A conventional method of increasing the arc voltage is to increase the eddy component of the gas stream in passing through the torch.

Another means to increase the arc voltage is to provide recessed portions electrically isolated both from the anode and the cathode in the flow path of gas. However, relying on these means, the arc voltage for given values of gas flow rate and electric current cannot be raised beyond a certain critical value without accompanying adverse effects such as double arcing, damage of the throat aperture, and deviation or instability of the arc column. P.J.G.'s heretofore proposed still have defects such as complicatedness in structure, difficulty in operation and narrow range for varying electric current, gas flow rate and other factors.

An object of this invention is to provide an improved P.J.G. which is characteristic of the high arc voltage and hence the highly improved efficiency of heating gas and little or no electrode consumption.

Another object of this invention is to provide a new high-voltage P.J.G. in which an active gas of high density can be heated directly by the arc column. This direct heating of concentrated active gas by means of the arc column was deemed impossible in the prior art.

This invention will be better understood from the following description which is to be made with reference to the accompanying drawings:

FIG. 1 shows an embodiment of the P.J.G. according to this invention in section and an associated electric circuit;

FIG. 2 is a similar view to FIG. 1, but shows a different embodiment suitable for a concentrated active gas and an associated electric circuit;

FIGS. 3 – 8 show partly in section, different guide attachments suitable for use in the P.J.G. given in FIG. 1;

FIG. 9 is a similar view to FIG. 2, except for the structure of the guide attachment;

FIG. 10 shows in section an embodiment of this invention having two positive plasma jet torches and one negative plasma jet torch, and an associated circuit; and

FIG. 11 shows in cross-section, different shapes of the white-bright portion of the plasma flame at the outlet.

Referring to FIG. 1 there is shown a primary P.J.G. according to this invention which consists of a positive plasma jet torch A, a negative plasma jet torch B and a guide attachment C. The positive plasma jet torch A has a cathode rod 1 and at least two bushings 2, 3 mounted concentric with the cathode rod. The second bushing 3 has an arc throttle aperture 4. A gas such as Argon, Helium and other inactive gases is supplied in the form of stream 7 and 8 from the inlets 5 and 6 to the annular space formed between the cathode and the first bushing 2 and the one between the first bushing 2 and the second bushing 3 respectively. The negative plasma jet torch B has a cathode rod 9 and a bushing 11 positioned concentric with the cathode. The bushing 11 has an arc throttle aperture 10. An inactive gas 13 is supplied from the inlet 12 to the annular space formed between the cathode 9 and the bushing 11.

The guide attachment C has two inlets 15 and 16 and one outlet 17. These inlets are so positioned that when the guide attachment is fixed to the positive and negative jet torches, these inlets function to direct the gas streams from the torches to the intersection of the center axis of these torches, whereas the outlet is so positioned that it functions to allow the resultant gas stream to flow from the intersection to the exterior.

It should be noted that the guide attachment is fixed to at least one bushing (the bushing 3 of the positive plasma jet torch in FIG. 1) via an insulator 18 of a dielectric material, and that a gas 20 is supplied from the inlet 19 to the annular space formed by the insulator 18 at the joint part. The cathode holders 50, 51 and the bushings 2, 3, 11 and the guide attachment C are water-cooled by a proper means (not shown), and are integrated via insulators 52 of, for instance, Bakelite in a complete air-tight manner.

An auxiliary power supply 21 includes a high-frequency oscillator for arc-establishment. The neg-
tive terminal of the power supply 21 is connected to the cathode 1 of the positive jet torch A via an electric switch 22 whereas the positive terminal is connected to the bushing 2 of the torch A.

Likewise, the negative terminal of the main power supply 23 containing a high-frequency oscillator for arc-establishment is connected to the cathode 9 of the negative plasma jet torch B, and the positive terminal of the main power supply is connected to the bushing 2 of the torch A. The positive terminals of the power supplies 21, 23 are connected to the bushing 11 via a switch 24. The P.J.G. thus connected to the associated circuit will be operated as follows:

1. Gas 7, 8 is supplied to the positive plasma jet torch A, and then the high-frequency oscillator of the auxiliary power supply 21 is put into operation by closing the switch 22. As a result an auxiliary arc 25 is established and finally a plasma jet flame is formed and extends from the arc-throttle aperture 4 into the guide attachment C.

2. Gas 13 is supplied, and then the high-frequency oscillator of the main power supply 23 is brought into operation by closing the switch 24. As a result an arc 26 is established, and then a plasma jet flame is formed and extends from the arc-throttle aperture 10 into the guide attachment C.

3. After the plasma jet flames of straight polarity are thus established and meets one another at the intersection 14, the switch 24 is opened. Then a hairpin shaped main arc is formed, and the plasma jet flame 28 extends from the outlet 17 of the guide attachment C to the exterior.

The supply of the gas stream 20 from the inlet 19 of the guide attachment C may be begun before or after operation 3 above. The hairpin-shaped arc happens to open wide, and as a result the curved leg of the arc approaches one side of the inlet 15 of the attachment to excessively heat the wall of the inlet 15. Partly because of this and partly because of the injection of ions into the inlet wall it is most likely that a cathode spot is formed on the inlet wall. This is the cause for the formation of a double arc. The supply of the gas stream 20 is useful to first, prevent the “hairpin” arc from opening wide and second, prevent ions from invading the inlet wall, thus finally eliminating the possibility of establishing a double arc.

The high-voltage P.J.G. thus operated is capable of establishing a stable arc whose arc-voltage is at least two times as high as the arc-voltage of the conventional P.J.G. for given electric current and gas flow rate.

**EXAMPLE 1**

The particulars of the apparatus according to the embodiment shown in FIG. 1 are:

- Diameter of the throttle aperture 4 of the bushing 3 — 2 mm
- Diameter of the inlet 15 of the guide attachment — 3 mm
- Diameter of the inlet 16 of the guide attachment — 2.2 mm
- Diameter of the passage 30 of the guide attachment — 5 mm
- Distance from the intersection 14 to the end of the bushing 2 — 18 mm
- Distance from the intersection 14 to the tip of the cathode 9 — 27 mm
- Flow rate of gas 7 (Argon) — 0.2 l/min.

**EXAMPLE 2**

The particulars of the apparatus shown in FIG. 2 are:

- Diameter of the inlet 15 or 16 of the guide attachment C — 3 mm
- Flow rate of gas 8 (Argon) — 0.4 l/min.
- Flow rate of gas 13 (Argon) — 3.0 l/min.
- Flow rate of gas 20 (Argon) — 0.2 l/min.
- Arc current — 20 A

A possible longest plasma jet flame was formed and the arc voltage was as high as 76 volts. (The arc voltage in the conventional plasma jet torch is 30 volts or less for the same current and flow rate.)

Referring to FIG. 2, there is shown a P.J.G. according to this invention which is capable of heating a concentrated (90 percent or more) gas chemically active to the material of the electrode such as oxygen or air directly by means of an arc column.

In spite of ever increasing demand for this capability of direct heating an active gas in the fields of chemical reactions, coating, cutting and other appliances since the appearance of the P.J.G., it could not be attained before the completion of this invention.

In the apparatus of FIG. 2 the positive plasma jet torch A is similar to that of the apparatus of FIG. 1. The negative plasma jet torch B has an extra bushing 34 with a throttle aperture 34' and extra inlets 35, 36 for gas 37, 38, compared with the negative plasma jet torch B in FIG. 1. The guide attachment C is fixed to the bushing 34 via an electric insulator 18. Complying with this modification the positive terminal of the main power supply 23 is connected to the bushings 11 and 34 and the guide attachment C.

This apparatus can be operated as:

1. Argon is supplied in the form of gas streams 7, and then the switch 22 is closed to start the operation of the high-frequency oscillator of the auxiliary power supply 21 with a result of establishing an auxiliary arc 25. Then, the plasma jet flame is ejected from the throttle aperture 4, and it extends into the main passage 30. Additionally, argon is supplied in the form of the gas streams 8 and 20.

2. Argon is supplied in the form of the gas streams 13, 37 and 38, and then the switches 24, 24' and 24" are closed for the main power supply 23 to apply a d.c. voltage and a high-frequency voltage to the torch B and the guide attachment C with a result of establishing the first non-transferred arc 26. Then, the switch 24 is opened, transforming the arc column into the second non-transferred arc 26'. Next, the switch 24' is opened, thus again transforming the arc column into the third non-transferred arc 26". Then, the supply of gas 13 to the cathode is made to cease, and the switch 24" is opened with a result of establishing the main arc column 27.

3. The switch 22 is opened to extinguish the arc 25, and at the same time the supply of gas 7 to the cathode is made to cease. Finally, the gas streams 20 and 38 are switched from argon to air or oxygen. Thus, a highly concentrated active gas plasma jet can be obtained.

This operation can be reduced to a full automatic "on-off" operation by using a piping system which includes pre-adjusted needle valves and electromagnetic valves.
Diameter of the gas channel of the guide attachment 5 mm
Diameter of throttle aperture 34' of the bushing 34 2 mm
Distance from the intersection 14 to the end surface of the bushing 2 18 mm
Distance from the intersection 14 of the tip of the cathode 9 34 mm
Flow rate of the gas stream 8 (Argon) 0.3 l/min.
Flow rate of the gas stream 20 (Oxygen) 0.2 l/min.
Flow rate of the gas stream 37 (Argon) 0.3 l/min.
Flow rate of the gas stream 38 (Oxygen) 5 l/min.
Arc current 20 A
A plasma flame of 90 percent oxygen concentration was obtained, and the arc voltage was as high as 115 volts. The substitution of air for oxygen caused the arc voltage to rise up to 135 volts.
A mixture of a higher active gas content can be used by enhancing the cooling capability to the bushings and by increasing the arc current.
With a view to improving the directional stability of the plasma jet flame and at the same time with a view to increasing the efficiency of heating gas the inventors carried out experiments on a variety of guide attachments as follows:
The guide attachment shown in FIG. 3 is the same as the corresponding part of the apparatus shown in FIG. 1 except for a notched portion a at the downstream side thus making the terminal end of the outlet 17 fairly close to the "hairpin" arc column. In this modification the plasma jet flame 28 deviated apart from the center axis 29 of the outlet 17, and the directionality varied with the gas flow rate and the value of electric current.
FIG. 4 shows further modification of the guide attachment of FIG. 3 in that the gas channel is enlarged around the intersection 14 at the upstream side while still maintaining the cross-section of the outlet equal to that of the outlet of the guide attachment shown in FIG. 1 or 3. In this case the plasma jet flame 28 was positioned on the center axis 29 of the outlet 17.
FIG. 5 shows a guide attachment shown in FIG. 1 modified in the same manner as in FIG. 4. In this modification, likewise, the plasma jet flame 28 was positioned on the center axis 29 of the outlet 17, and what was better, the length of the white bright portion of the laminated flow of the plasma jet flame was increased approximately 50 percent. This indicates that the ejection of the plasma jet flame was remarkably enhanced. A similar result was obtained with regard to the guide attachment the gas channel of which was modified as indicated by broken line 31.
FIG. 6 shows further modification of the guide attachment of FIG. 5 in that the part b indicated by broken line was removed. In this case the laminar stream of the plasma jet flame 28 deviated with respect to the center axis 29 of the outlet 17.
The guide attachments shown in FIGS. 3, 4, 5 and 6 were tested for the same values of gas flow rate and electric current.
The results of these experiments indicate that:
1. The removal of the part a from the end of the attachment in FIG. 1 is useful to direct the plasma jet flame along the center axis 29 of the guide channel.
2. The cross-sectional enlargement of the guide channel shown in FIG. 4 endows the guide attachment with the directionality of the plasma jet flame.
3. The enlargement of the guide channel in the guide attachment free of the notched portion a as shown in FIG. 5 is useful to reduce the loss of the plasma jet flame which otherwise would be caused at the part corresponding to the notched portion a in FIG. 3.
4. If the cross-sectional enlargement extends far to the inlet of the guide attachment as shown in FIG. 6, the effect of directing the plasma jet flame on the center line will disappear. From the results of the experiments above mentioned, the inventors reached the conclusion as follows:
The structures of the guide attachments given in FIGS. 4 and 5 are useful to throttle the disturbing fluid flow which results from the two gas streams supplied from the two inlets of the guide attachment so as to allow the resultant flow to align in the center line of the guide attachment.
As seen from FIG. 6, the position of the outlet relative to the arc column is critical, and it is necessary to allow a part of the "hairpin" arc or at least the sharp bent portion of the "hairpin" to appear in the throttle aperture for the following reasons:
First, the entrance of a part of the arc column into the throttle aperture will cause the rise of the temperature of the gas in the throttle aperture, and hence the increase of the cubic expansion of the gas, finally resulting in the increase of the flow resistance of the throttle, which is useful to improve the directing capability of the throttle. Second, the directing effect realized by the wall of the aperture at the sacrifice of the heat loss as is the case with the device in FIG. 1, can be reduced, and the ejection of the plasma jet flame will be improved because the "hairpin" of the arc whose thermal energy is about half the total energy of the arc column, is aligned in the central axis of the throttle aperture for heating the gas.
FIGS. 7 and 8 show other modifications of the guide attachment. The guide attachment of FIG. 7 is specifically designed for the cutting operation. In this example the space 32 which the "hairpin" enters is made larger than the outlet 17 of the guide attachment which is for instance as small as 1.0 mm diameter across, because otherwise the "hairpin" would not enter the throttle aperture.
FIG. 8 shows a modification of the guide attachment of FIG. 4. In this modification a blind hole 33 is made on the wall of the guide channel opposite to the inlet 15 of the guide attachment. Thus, the directness of a laminar flow of plasma jet which is ejected from an aperture 17 of relatively small diameter was substantially improved.
As is apparent from the results of the experiments on the modifications given in FIGS. 3 - 6, the directness of a plasma jet flame can be improved, and at the same time the efficiency of heating gas can be raised by enlarging the cross-section of the guide channel over the length of the channel beyond the intersection of the two center axes of the positive and negative plasma jet torch towards the outlet.
FIG. 9 shows a P.I.G. which is equivalent to the embodiment of FIG. 2 modified by substituting the guide attachment of FIG. 4 or 5 for the corresponding member of the apparatus of FIG. 2. This modification was compared with the apparatus of FIG. 2 as follows:
EXAMPLE 3
Operating condition:
Gas stream 8 — Argon 0.3 l/min.
Gas stream 37 — Argon 0.3 l/min.
Gas stream 7 — none
Gas stream 13 — none
Gas stream 38 — Oxygen 4 l/min.
Gas stream 20 — Oxygen 1 l/min.
Arc voltage — 95 V
Arc current — 50 A

P.J.G. of FIG. 2
Diameters $d_i$, $d_o$ of the inlets 15, 16 — $d_i$, $d_o$ = 3.0 mm
Diameter $d_i$ of the outlet
Distance $l$ from the intersection 14 to the outlet

The plasma jet flame extended 25 to 30 cm, and it deviated about 2° apart from the center axis.

P.J.G. of FIG. 9
Diameters $d_i$, $d_o$ of the inlets 15, 16 — $d_i$, $d_o$ = 3.0 mm
Diameter $d_i$ of the outlet — $d_i$ = 7.0 mm
Distance $l$, from the intersection to the outlet

The plasma jet flame extended 35 to 50 cm on the central axis.

The throttle part was modified into the two step form as shown in FIG. 7.

The following arc voltages were realized for different diameters $d_i$ and $d_o$ of the inlet and the outlet, and the ejection of the plasma jet flame suitable for the cutting operation was substantially improved.

<table>
<thead>
<tr>
<th>$d_i$ (mm)</th>
<th>$d_o$ (mm)</th>
<th>Arc Voltage</th>
<th>Pressure in the Guide Attachment (Gauge Pressure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>3.0</td>
<td>95 V</td>
<td>0.1 kg/cm²</td>
</tr>
<tr>
<td>2.0</td>
<td>1.5</td>
<td>110 V</td>
<td>1.0 kg/cm²</td>
</tr>
<tr>
<td>2.0</td>
<td>1.0</td>
<td>120 V</td>
<td></td>
</tr>
</tbody>
</table>

EXAMPLE 4
Operating Condition:
Gas stream 38 — Oxygen 12 l/min.
Gas stream 20 — Oxygen 3 l/min.
(The flow rates of the other gas streams were equal to those in Example 3.)
Arc voltage — 130 V
Arc current — 50 A

P.J.G. of FIG. 2
The dimensions of the apparatus were identical with those of Example 3. The incandescent part of the flame was composed of a disturbed flow about 2 cm. long, and the plasma jet flame deviated about 3° or more apart from the central axis.

P.J.G. of FIG. 9
The particular dimensions of the apparatus were identical with those of Example 3. The incandescent part of the flame was composed of a disturbed stream about 3.5 cm. long, and the plasma jet flame was directed straight.

The deviation and the length of the plasma jet flame is a direct measure for the efficiency of heating gas for a given condition. In view of this it is apparent that the effect of the special structure of the guide attachment given in FIG. 4 or 5 is remarkable for improving the efficiency of heating gas. Additionally, the capability for varying the flow rate of the gas stream 20 over a wide range facilitates the operation of the apparatus.

As seen from the above, the P.J.G. according to this invention has a single throttle aperture and at least one anode electrode, essentially different from a conventional P.J.G. using the inside wall of the throttle aperture as the anode electrode.

The advantages attributable to the use of a plurality of positive plasma jet torches are:

First, as a matter of course, the anode input power can be equally divided into as many parts as the positive plasma jet torches, thus avoiding the damage of the throttle aperture due to the local concentration of heat as is the case with the conventional P.J.G. Second, the adverse effect by the gas injection from the inlet 15 on the main arc column can be substantially reduced.

FIG. 10 shows a P.J.G. having a negative plasma jet torch and two positive plasma jet torches positioned symmetrical to the negative torch. This apparatus is identical with the apparatus of FIG. 1 except for the guide attachment. A single switch 24 is provided for generating a plasma jet flame in each of the negative torches. Although two auxiliary power supplies 21 are shown in the drawing, a single power supply in place of these devices can be used by properly modifying the relevant electrical connection because the device is not used with regard to the positive plasma jet torches at the same time.

In operation, a main arc is established by the positive plasma jet torch to which the switch 24 is connected (right torch in the drawing), in the same manner as in the apparatus of FIG. 1. With the main arc thus established, an auxiliary arc is established by the other positive plasma jet torch (left torch in the drawing), and then a main arc is established therein. After the establishment of the main arc at the left side the switch 22 is opened, and then the supply of the gas stream 7 is made to cease. The flow rates of the gas 7 and 8, such as argon are set to a proper value, for instance 0.2 l/min. Thus, the main arc 27 is finally established.

In a particular example of the apparatus, the total electric current was 40 A and the arc voltage was 73 V.

FIG. 11 shows the shapes of the cross-sections of the incandescent cores of different plasma jet flames which are ejected from the main channel 38 when the gas is supplied from either of the right and left positive plasma jet torches at an equal pressure balancing at the center of the main channel. In this drawing the outer circle 39 is the wall of the main channel of the guide attachment, and the direction of the gas supplied by the positive plasma jet torch is indicated by the arrow. The shaded part 40 is the cross-section of the incandescent part or core of the plasma jet flame in the outlet 17.

FIG. 11-I pertaining the use of a single positive plasma jet torch shows the "on-center" position of the incandescent core, the cross-section of which is of an ellipse. This phenomenon is observed in the plasma jet flame in a conventional torch.

FIG. 11-II pertaining to the use of two positive plasma jet torches shows the "on-center" position of the incandescent core 40, the cross-section of which is almost circular.
FIG. 11-IV pertaining to the angular arrangement of four positive plasma jet torches 90° apart shows the "on-center" position of the incandescent core, the cross-section of which approaches a circle.

The positioning of the incandescent core on the exact center of the throttle aperture as shown in FIGS. 11-II, III and IV means the aligning of the plasma jet flame in the central axis of the main channel, thus decreasing the thermal loss which would be caused if the plasma jet flame approaches the channel wall apart from the center. The centering of the plasma jet flame by means of a plurality of positive plasma jet torches is useful to improve the efficiency of the apparatus.

For the sake of simplicity this invention has been hereto above described with reference to the non-transferred type straight polarity P.J.G., but it should be noted that the reverse polarity P.J.G. according to this invention is equally useful. It is commonly admitted that the use of oxygen or air in the transferred type P.J.G. will increase the cutting speed for steel or aluminum sheets. However, in order to avoid the damage to the electrode of a conventional P.J.G. (more specifically in order to assure the life of the apparatus as long as the apparatus using argon), it is necessary to use an inactive gas in the mode of non-transferred operation and then introduce oxygen or air as a substitute for the inactive gas after the transition of the arc to the workpiece. This operation is too inconvenient, and it makes the apparatus actually useless. This defect is overcome by, according to this invention, generating first non-transferred plasma jet with the aid of an auxiliary power supply and second, a transferred plasma jet between the cathode rod and the workpiece with the aid of the main power supply.

This invention has been hereto above described as using plasma jet of straight polarity, but it is apparent to the skilled in the art that a P.J.G. according to this invention can equally use plasma jet of reverse polarity. In other words, a P.J.G. according to this invention will not be deteriorated, which type of plasma jet may be used. The embodiments herein disclosed have the axis of the positive plasma jet torch and the axis of the negative plasma jet torch transverse therewith. However, in cutting a workpiece of a dielectric material, such as concrete in the mode of non-transferred operation or in cutting a workpiece of a conductive material, such as aluminum, iron and other metals in the mode of transferred operation, two plasma jet torches were angularly arranged 60°, thus first allowing the "hairpin" arc to approach the outlet with a result of increasing the thermal energy to the workpiece and second, making the outlet accessible to the workpiece because the plasma jet units causes little or no hindrance against the workpiece. As a matter of course, the angle at which the two plasma jet units arc arranged can be arbitrarily determined to meet the requirements.

The P.J.G. has been widely used in numerous industrial fields since it appeared in the world, and this invention enlarges the domain of appliance to the possible extremity from the points of economical and technical views.

What is claimed is:

1. A plasma jet generator comprising a plurality of plasma jet torches, a hollow guide attached to said torches, said hollow guide having an outlet and a plurality of inlets, said inlets being disposed to receive and direct the gas streams from respective torches to intersect at a given location within the guide to form a combined plasma jet exiting the guide through said outlet, said inlets and outlets being the only openings in said hollow guide, one of said torches including a cathode rod and at least two bushings which define a gas flow space, and said hollow guide being electrically insulated from at least one of said torches by a body of dielectric material.

2. A plasma jet generator according to claim 1 including two plasma jet torches disposed to produce gas streams that are oriented generally perpendicular to each other.

3. A plasma jet generator according to claim 1 including three plasma jet torches disposed to produce gas streams, two of which gas streams are oriented generally symmetrical with respect to the third gas stream.

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