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(71) Applicant: **Shimadzu, Tadahiro**
6-1, Konohana-cho
Gifu-shi, Gifu-ken(JP)

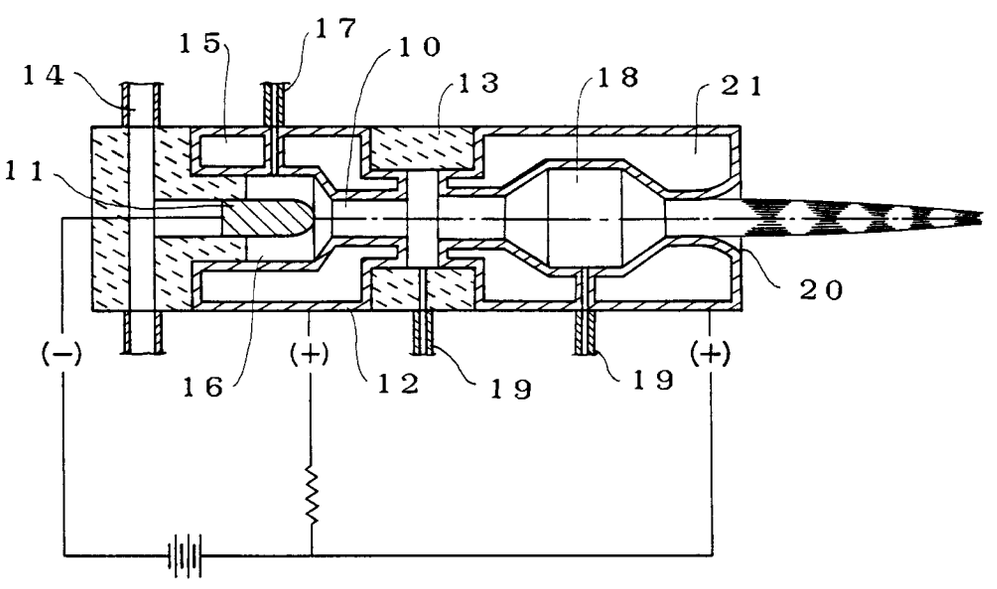
(72) Inventor: **Shimadzu, Tadahiro**
6-1, Konohana-cho
Gifu-shi, Gifu-ken(JP)

(74) Representative: **Schickedanz, Willi, Dipl.-Ing.**
Langener Strasse 68
W-6050 Offenbach/Main(DE)

(54) Method and apparatus for generating plasma flame jet.

(57) The invention relates to a method and an apparatus for generating a plasma flame jet. An ultra-high velocity and temperature plasma jet is generated by directly converting fuel gas into a plasma-forming gas. Also various temperatures and velocities of a plasma are provided by combining electrical and thermal energies. The methodes and apparatus of the present invention can be utilized in thermo-treatment, coating, cutting, welding and dehydrating, pulverizing or reducing metals, ceramics or the like, and as a plasma furnace or the like.

Fig. 2



EP 0 474 899 A1

Technical Field to which the Invention relates

The present invention relates to an improved method and apparatus for generating an ultra-high temperature and velocity plasma flame jet.

The method as well as the apparatus of the present invention effectively heat-treats, coats, cuts or welds metals, ceramics or the like, or dehydrates, pulverizes or resolves various types of waste matters.

Since a plasma flame formed electrically is capable of generating an ultra-high temperature of 2.500 - 9.000 ° C, it can provide a temperature high enough to fuse metal or ceramic particles which possess a high fusing point. The velocity of a conventional gaseous stream, however, is not very high, being merely 400 - 600 m/sec.

Therefore, particles fed in the gaseous stream do not possess a velocity sufficient enough to secure coating on a substrate surface.

Prior Art

U. S. Patent No. 4,370,538 discloses a method and apparatus for ultra-high velocity dual stream metal flame spraying.

The method and apparatus of said invention primarily comprises the combination of a primary jet stream generated by a plasma arc of an inert gas such as argon, helium or nitrogen and a secondary stream generated by combustion of the mixture of air and fuel within an internal burner under a high pressure. The high velocity gaseous accelerating secondary jet stream is directed as a converging annular flow about and into the primary jet stream of high temperature bearing melted particles to accelerate the particles for improved impingement coating of a substrate with the internal burner operated under parameters such that the secondary jet stream is at sufficient high temperature to prevent solidification of the particles during transport by the higher molten secondary stream prior to impact on the substrate surface.

As set forth above, the process that a plasma flame is first formed, particles are melted in the flame and then the particles are accelerated by another flame is already known.

Technical problem

The problem to be solved by the present invention is to improve a method and an apparatus for generating an ultra-high temperature and velocity plasma flame jet.

Solution of the Technical Problem

The above problem is solved by the features as defined by claim 1.

Advantages of the Invention

The method as well as the apparatus of the present invention effectively heat-treats, coats, cuts or welds metals, ceramics or the like, or dehydrates, pulverizes or resolves various types of waste matters.

By means of the present invention an effective as well as efficient method and apparatus for an ultra-high velocity and temperature plasma flame jet are provided, wherein, different from the above-identified prior art invention, fuel gas, instead of said inert gas, is utilized as a plasma-forming gas to form a plasma flame first and then a burning flame. Thus, a burning condition in the process of generating a plasma flame jet is obtained. In this way, a plasma flame jet with both thermal and inflational energies can be generated. The burning performed under a high-temperature, high-pressure condition brings about gaseous inflation which is by far greater than the critical inflation.

This inflational energy provides an ultra-high velocity plasma flame jet. Such a method and apparatus is capable of forming a plasma flame and a burning flame in a process and of generating an ultra-high velocity and temperature plasma flame jet.

Brief Description of the Drawings

Figs. 1 - 4 show longitudinal sectional views of apparatus of embodiments of the present invention;

Fig. 5 shows a longitudinal sectional view of an apparatus using a method of the present invention;

Figs. 6 - 7 are front views showing the supply nozzles and piece of the apparatus of Fig. 5;

Fig. 8 shows a longitudinal sectional view of the apparatus in Fig. 1 which shows the forming of a plasma flame;

Fig. 9 is a flow chart showing the steps for forming a plasma flame.

Wherein, 10 is passage, 11 cathode, 12 anode, 16 first chamber, 17 liquid or gaseous fuel supply tube, 18 second chamber, 19 oxygen or compressed air supply tube, and 20 is discharging opening.

Figs. 1 - 4 show simplified drawings of the apparatus embodiments of the present invention.

Fig. 1 shows a cylindrical torch body and a passage 10 within the body. At an end of the passage 10 is a cathode electrode 11 which is made of conductive material such as tungsten. Around the cathode 11 like constituting part of the passage 10 is a cylindrical-shape anode 12 which

is also made of conductive material. There exists an insulating piece 13 between the anode 12 and the cathode 11. Coolant conduits 14 and 15 are employed to cool the anode 12 and the cathode 11.

The end part of the passage and the anode 12 is made narrow. A gas supply tube 17 is connected to the space (first chamber) 16 created between said end part and the cathode 11 to introduce liquid or gaseous fuel. A gas supply system (not shown) with a gas meter and a control valve is connected to said gas supply tube 17.

Ahead of said end part of the passage and the anode 12 is another space (second chamber) 18 facilitated as a combustion chamber to burn fuel gas plasma formed by electrically converting liquid or gaseous fuel.

The second chamber 18 is so made that oxygen or compressed air is supplied there for combusting fuel gas plasma, and one of the oxygen or compressed air supply tubes 19 is connected with the passage part 10 between the first cahmber 16 and the second chamber 18 and the other is connected with the second chamber 18. A supply system (not shown) with a flow meter and a control valve for supplying oxygen or compressed air is connected to said supply tubes 19. The combusting condition of fuel gas plasma in the second chamber 18 is controlled by the supply of oxygen or compressed air from said supply tubes 19. Either both or one of these supply tubes can be utilized at a time.

A water conduit 21 for circulating coolant is facilitated around the second chamber 18. The end part of the second chamber 18 is a discharging opening 20 which is shaped like a throat.

In the apparatus shown in Fig. 1 liquid or gaseous fuel is introduced into the first chamber 16 from the supply tube 17. In the case of liquid fuel, the fuel is pressurized with nitrogen gas or the like or by a compressor and sprayed into the first chamber 16. Said gaseous or sprayed liquid fuel is then electrically converted into plasma by a plasma arc created by the voltage between the cathode 11 and the anode 12, becoming a fuel gas plasma. The fuel gas plasma is then mixed with the oxygen or compressed air fed through the supply tubes (19). The mixing proportion depends on the kind of fuel to be used. It is possible to form a plasma flame in an oxidized atmosphere or a deoxidized atmosphere by controlling the supply of oxygen or compressed air.

When oxygen or compressed air is mixed into the fuel gas plasma, combustion takes place in the second chamber 18 ignited by the extremely-high temperature fuel gas plasma. An ultra-high velocity and temperature plasma flame jet is thus generated and discharged from the discharging opening 20. The method and apparatus of the present invention is capable of generating a plasma flame jet of, in theory, 2.500 - 5.000 °C, 400 - 4.000 m/sec.

In case coating is to be performed using said plasma flame jet, a nozzle (not shown) is to be installed at the discharging opening 20 and a coating material is fed through the nozzle into the plasma flame jet.

The steps of forming a plasma flame in the apparatus of Fig. 1 is shown in Figs. 8 and 9. That is:

a plasma flame is formed in the steps of

A) introduction of fuel gas;

B) forming fuel gas plasma; and

C) combustion.

The apparatus shown in Fig. 2 is primarily the same as the one in Fig. 1, however, the second chamber 18 is constituted as an anode 12 which is made of conductive material. In this case, both electrical conversion and combustion are performed in the second chamber 18 generating an even higher temperature plasma flame jet.

The apparatus shown in Fig. 3 is the one applied to a transfer arc. As this type of apparatus is mainly used for cutting or welding metals, it is possible to utilize only the fuel gas plasma.

In the apparatus shown in Figs. 1, 2 and 3, one of the supply tubes 19 for supplying oxygen or compressed air is connected with the passage part 10 between the first chamber 16 and the second chamber 18 and the other is connected with the second chamber 18. In the case of the apparatus in Fig. 3 an apparatus with only one of the supply tubes may be utilized.

The apparatus shown in Fig. 4 possesses the function to form fuel plasma and combust it at the same time. The apparatus has a fuel supply tube 17 and oxygen or compressed air supply tubes 19 aligned which are connected with the same chamber 22.

The apparatus shown in Fig. 5 directly discharges a fuel gas plasma formed by electrical convertion of liquid or gaseous fuel and supply nozzles 23 to supply oxygen or compressed air into the fuel gas plasma are installed at the discharging opening 20. The supply nozzles 23 may be plurality of supply nozzles installed around the discharging opening 20 as shown in Fig. 6 or a circular supply piece around the discharing opening 20 as shown in Fig. 7. The apparatus shown in Fig. 5 is the one to burn a fuel gas plasma in the air and therefore does not posses a combustion chamber like the apparatus of Figs. 1 - 4.

Accordingly the velocity of the plasma flame jet generated in the apparatus in Fig. 5 is not as great as that of the apparatus in Figs. 1 - 4, however, it can still provide a faster plasma flame jet than a conventional one.

The apparatus shown in the above-mentioned figures have a liquid or gaseous supply tube 17 into the first chamber, however, it is also possible to install another tube into the second chamber in order to assist combustion. The apparatus of the present invention include not only the apparatus described above but also any combination of compositions of such apparatus.

As set forth above, the methods and apparatus of the present invention effectively provide an ultra-high velocity and temperature plasma jet by directly converting fuel gas into a plasma-forming gas.

The method of the present invention includes both the repeating and the concurrent processes of the following of electrical conversion into plasma and combustion: electrically converting liquid or gaseous fuel into plasma, forming a fuel gas plasma; mixing oxygen or compressed air into the fuel gas plasma; combusting the mixture; and electrically converting the combusted mixture.

Electrically converting gaseous fuel into plasma is performed by reducing said gaseous fuel into molecules and ionizating them. In the case of liquid fuel, the liquid fuel is first converted into gaseous fuel and then electrically converted into plasma by reducing said gaseous fuel into molecules and ionizating them. In this case, the conversion of said liquid fuel into gaseous fuel is assisted by the heat generated in the process of the electrical conversion.

Gaseous fuel to be used for the present invention may be acetylen, propane, propylene, butane, natural gas, coal gas, or the like. Liquid fuel to be used may be gasoline, kerosene, gas oil, alcohol, oils and fats, or the like. Among them, acetylene is capable of forming a plasma flame in a deoxidating atmosphere as it completely burns at a high temperature, and propylene is easier to handle than other hydrocarbonic types of gaseous fuel as it produces a higher steam pressure. It is also economical to utilize propane or natal gas as they are inexpensive.

An apparatus of the present invention comprises:
a torch body with electrodes and a passage for creating a plasma arc;
means to introduce liquid or gaseous fuel into said passage;
means to mix oxygen or compressed air into said passage; and
a combustion chamber in which the mixture of fuel gas plasma of either liquid or gaseous fuel and oxygen or compressed air is combused.

The methods and apparatus of the present invention also provides various temperatures and velocities plasma by combining electrical and thermal energies.

Therefore, the methods and apparatus of the present invention can be utilized in thermo-treatment, coating, cutting, welding and dehydrating, pulverizing and reducing metals, ceramics or the like, and as a plasma furnace or the like.

Claims

1. A method for generating a plasma flame jet comprising the steps:
introducing liquid or gaseous fuel into a passage (10) for creating a plasma arc;
electrically converting said liquid or gaseous fuel into plasma, forming fuel gas plasma;
mixing oxygen or compressed air into said fuel gas plasma; and
igniting said mixture of fuel gas plasma and oxygen or compressed air.

2. An apparatus for generating a plasma flame jet comprising:
a torch body with electrodes (11,12) and a passage (10) for creating a plasma arc;
means (17) to introduce liquid or gaseous fuel into said passage (10);
means to electrically convert said fuel into plasma, forming fuel gas plasma;
means (19) to introduce oxygen or compressed air into said passage and mix with said fuel gas plasma; and
a combustion chamber (18) for igniting said mixture of fuel gas plasma and oxygen or compressed air.

3. The apparatus for generating a plasma flame jet of claim 2 wherein a plasma arc for electrically converting said liquid or gaseous fuel into plasma is created in said combustion chamber (18).

4. An apparatus for generating a plasma flame jet, comprising:
a) a first chamber (16) being connected to a supply tube (17) for supplying liquid or gaseous fuel into said first chamber (16):
b) a second chamber (18) being connected to a supply tube (19) for supplying oxygen or compressed air into said second chamber (18);
c) a passage (10) between said first chamber (16) and said second chamber (18);
d) a cathode (10) and an anode (12) defining at least a portion of the inner and outer wall of at least one of said chambers (16,18).

5. An apparatus according to claim 4, **characterized in that** the cathode (11) defines a portion

of the inner wall of said first chamber (16), whereas the anode (12) defines the outer wall of said first chamber (16).

6. An apparatus according to claim 4, **characterized in that** the anode (12) defines the outer wall of said first chamber (16) as well as the outer wall of said second chamber (18) and said passage (10), said anode (12) being separated by an insulating piece (13) into two different portions, both portions being connected to the same electrical potential.

7. An apparatus according to claim 4, **characterized in that** a conduit (21) for circulating coolant is facilitated around the second chamber (18).

8. An apparatus according to claim 4, **characterized in that** the second chamber (18) includes an outlet (20) for the plasma flame jet.

9. An apparatus according to claim 4, **characterized in that** tow supply tubes for supplying oxygen or air are provided, one of said supply tubes being connected to the passage (10) between said first chamber (16) and said second chamber (18), whereas the other of said supply tubes is connected to said second chamber (18).

10. An apparatus for generating a plasma flame jet, comprising:

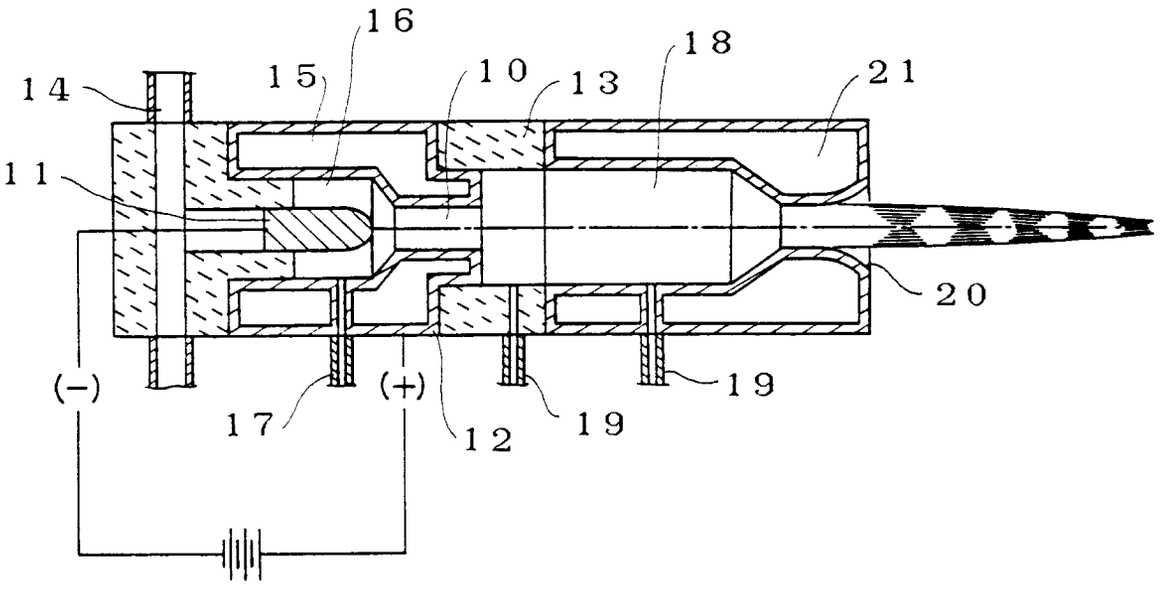
a) a chamber (22) being connected to a fuel supply tube (17) and to an oxygen or compressed air supply tube (19);

b) a cathode (11) being arranged within said chamber (22);

c) an anode defining the outer wall of said chamber (22);

d) an outlet (20) for the plasma flame jet being provided at one end of said chamber (22), said outlet (20) being arranged opposite to said cathode (11).

Fig. 1


16
18
14
15
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13
21
11
20
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19
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12
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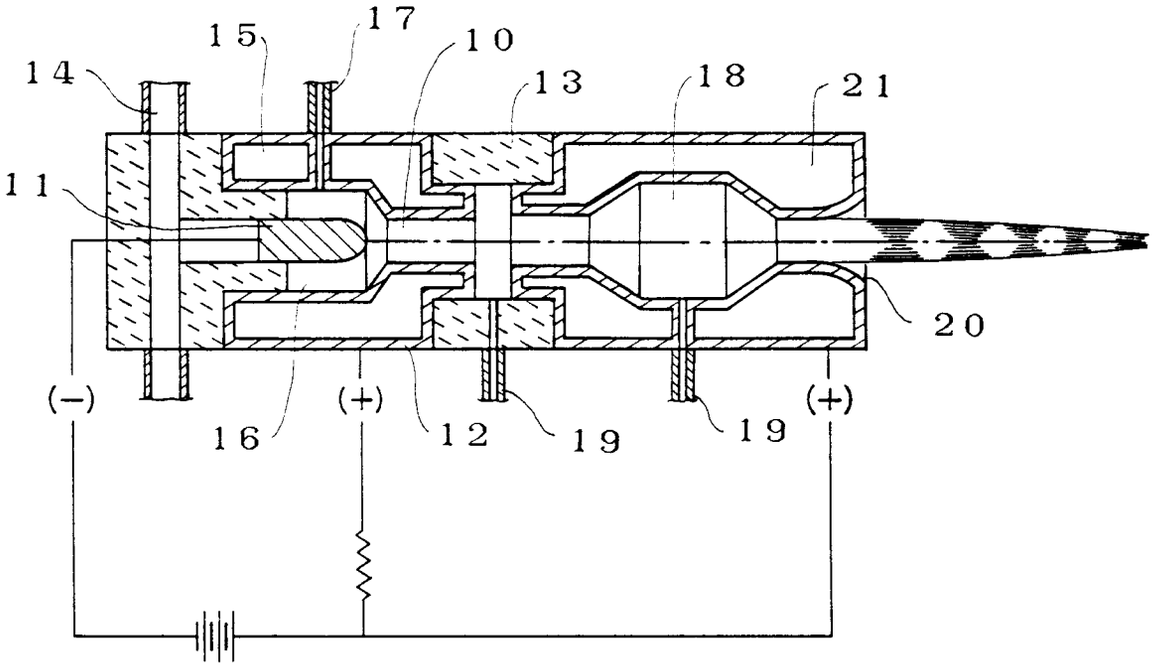
19

Fig. 2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19
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Fig. 3

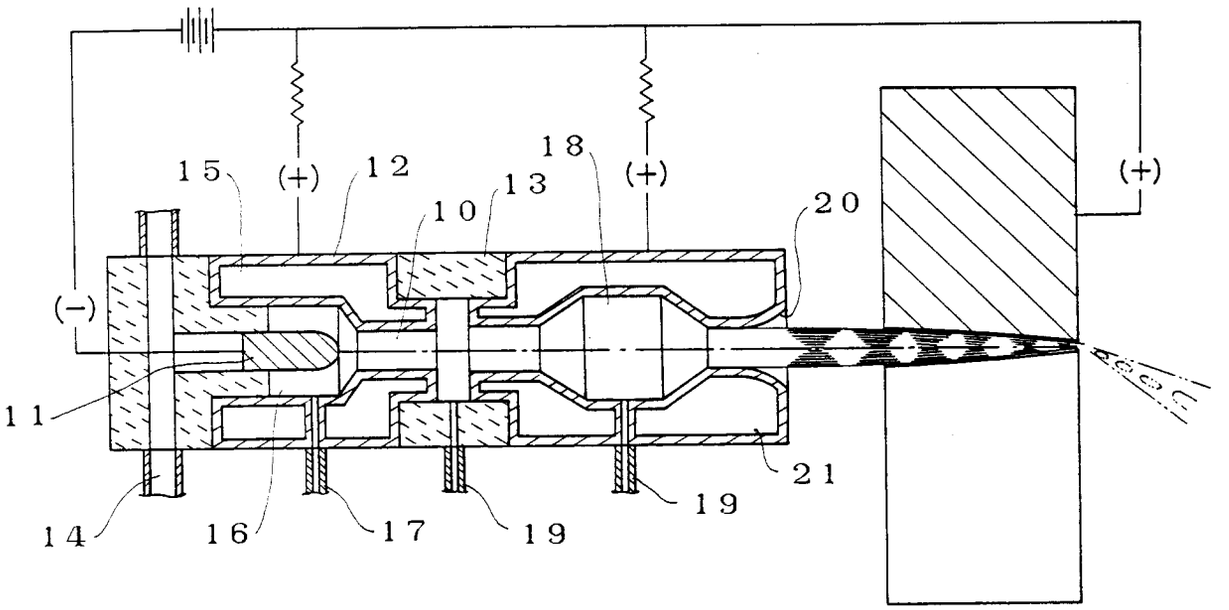


Fig. 4

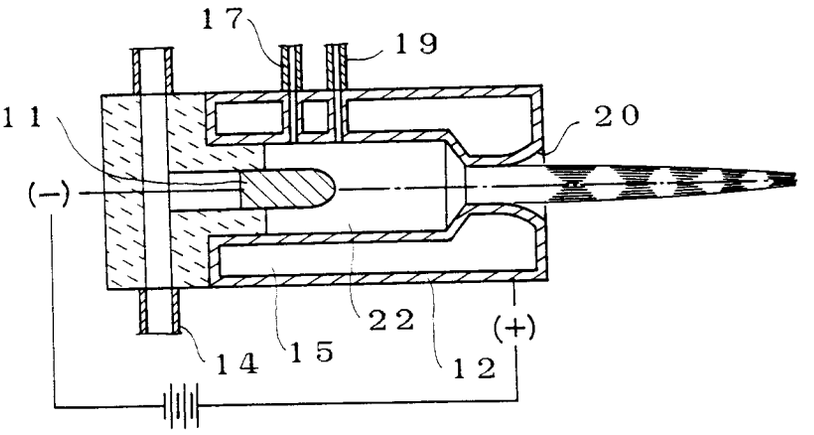


Fig. 5

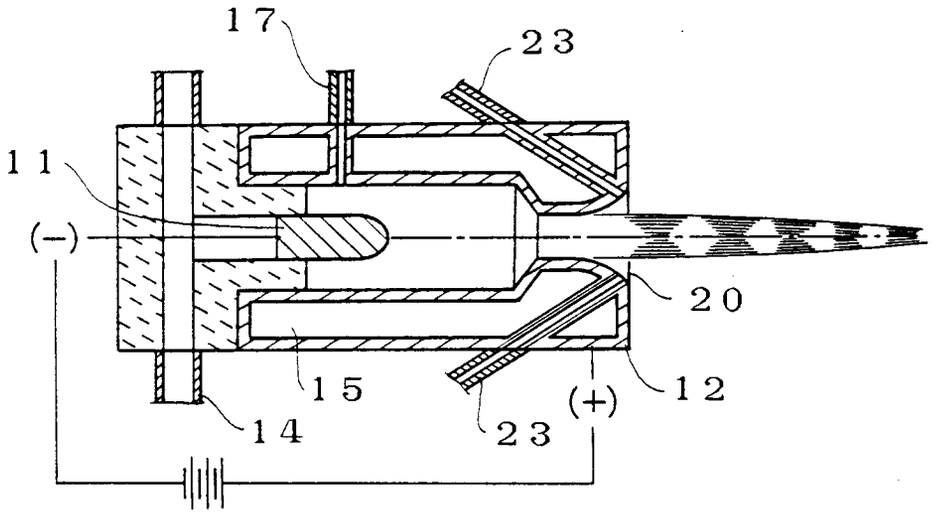


Fig. 6

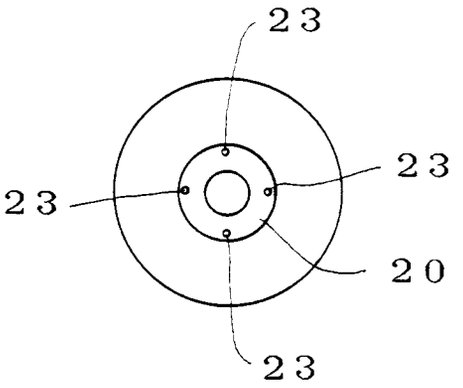


Fig. 7

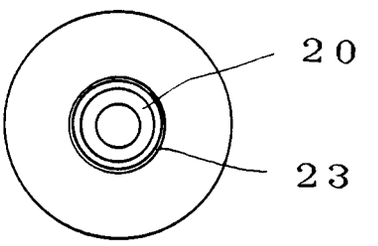


Fig. 8

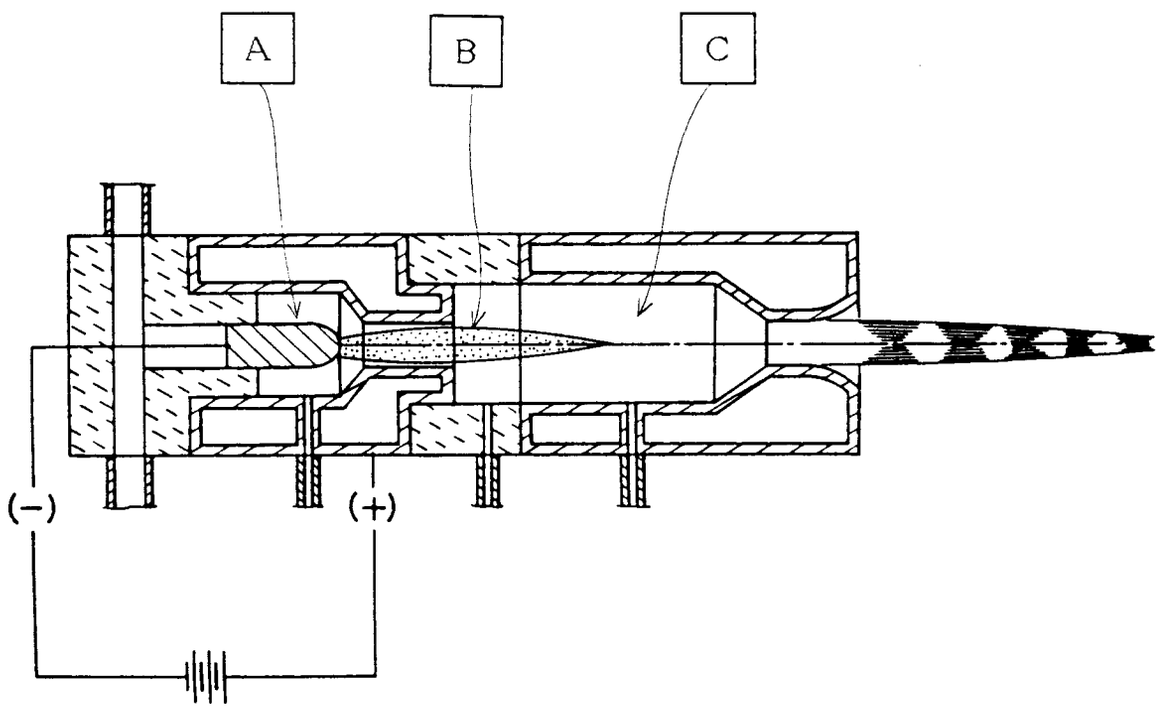
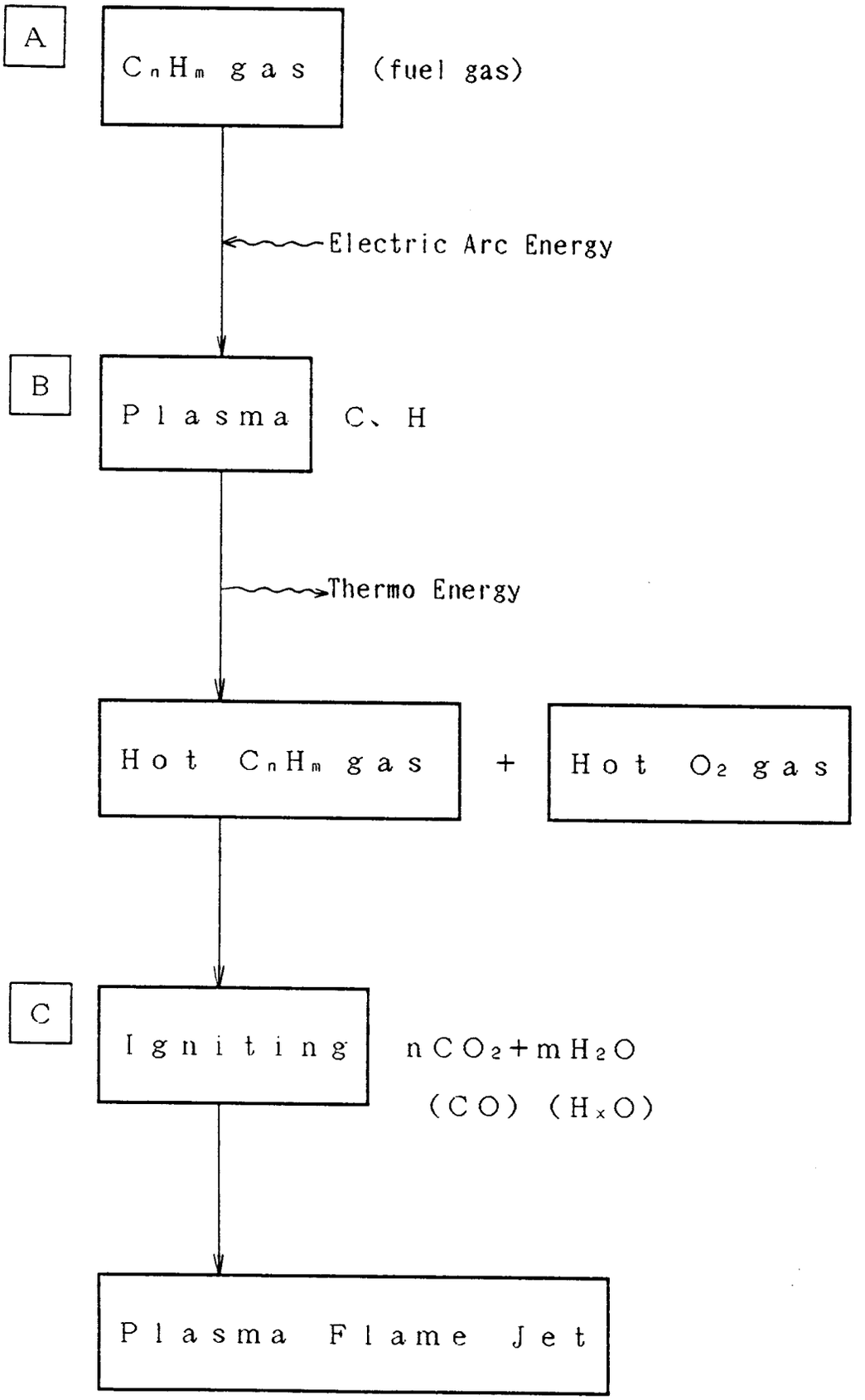


Fig. 9


A
CnHm gas
(fuel gas)
Electric Arc Energy
B
Plasma
C、H
Thermo Energy
Hot CnHm gas
+
Hot O2 gas
C
Igniting
nCO2+mH2O
(CO) (HxO)
Plasma Flame Jet

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 11 7441

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X,A	EP-A-0 203 556 (CABOT) * page 9, line 23 - page 11, line 7; claims 1, 5; figures *	1,2,3	H 05 H 1/32 H 05 H 1/34 B 05 B 7/22
A	US-A-4 078 097 (MILLER) * column 3, line 54 - column 4, line 34; figures 1, 3 *	1-4,10	
A	US-A-4 694 990 (KARLSSON ET AL) * column 4, line 44 - column 5, line 15; figure 1 *	1,2,4,9,10	
A	US-A-4 762 977 (BROWNING) * abstract; claims 1, 12; figures 1a, 2 *	1,2,4,9,10	
A	US-A-3 684 911 (PERUGINI ET AL)		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
H 05 H B 05 B

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	10 May 91	ERRANI C.

CATEGORY OF CITED DOCUMENTS

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