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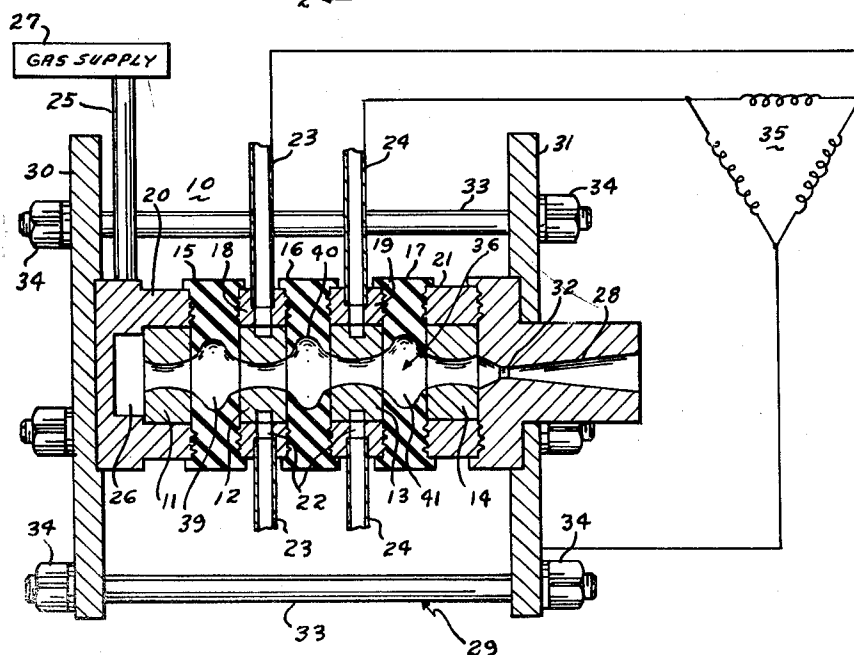
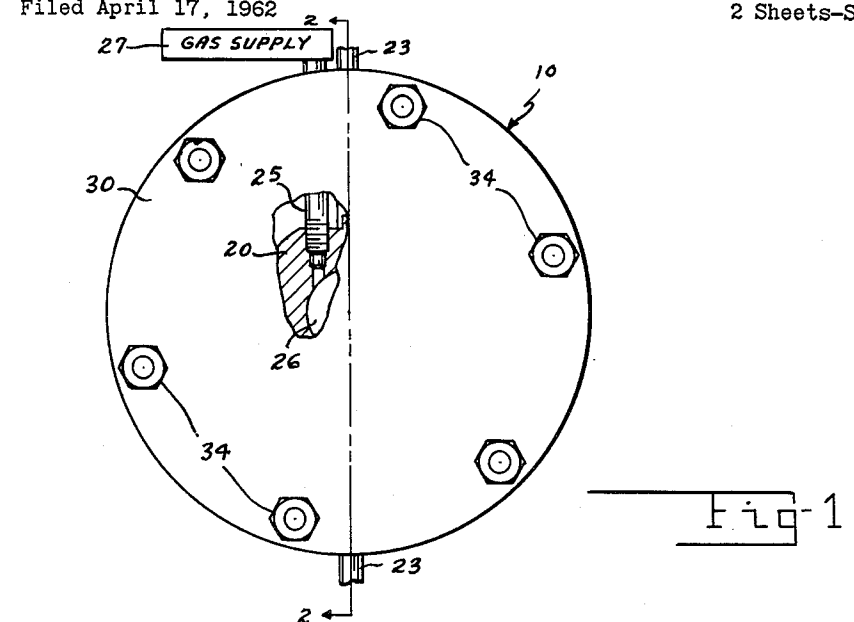
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3,140,421

MULTIPHASE THERMAL ARC JET

Filed April 17, 1962

2 Sheets-Sheet 1



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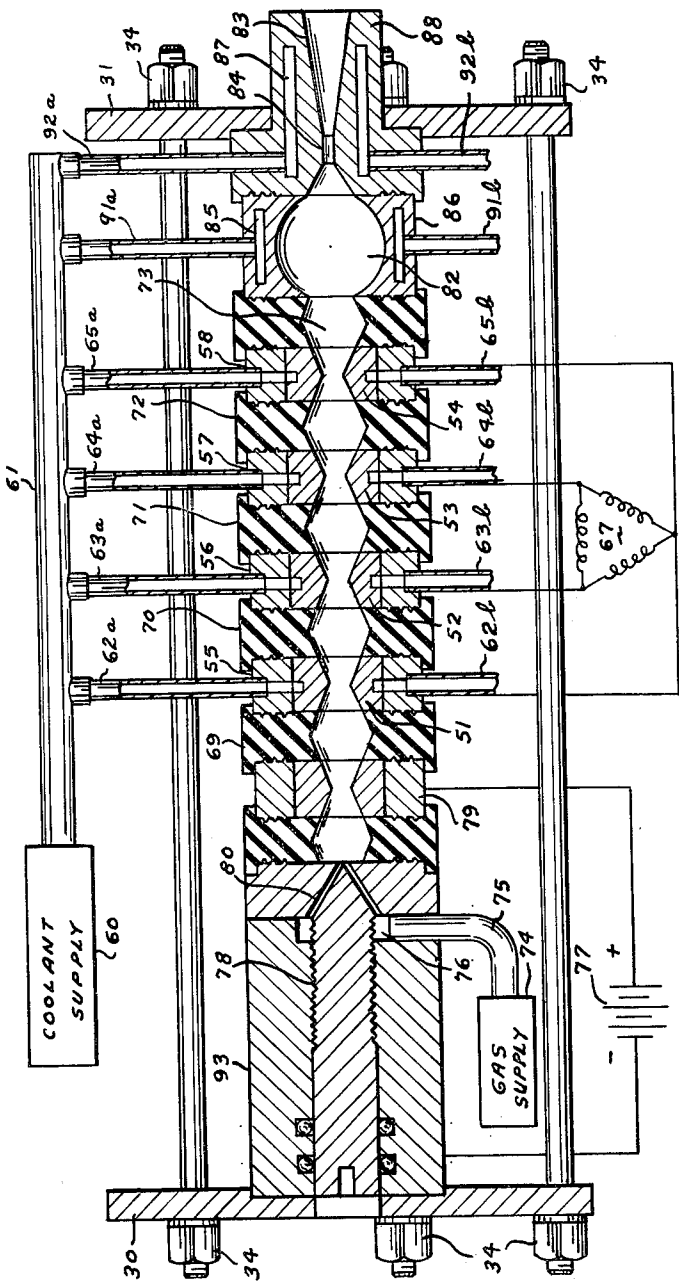


Fig-3

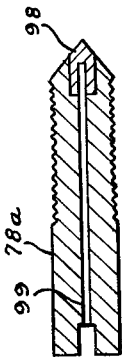


Fig-4

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MULTIPHASE THERMAL ARC JET
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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to a thermal arc jet device for creating a high enthalpy gas by the transfer of power to the gas from a multiphase electrical power source.

One object of the invention is to provide a thermal arc jet device which avoids local heating and the subsequent deterioration of the electrodes.

Another object is to provide a thermal arc jet device which permits high current densities and in which there is a minimum of heat transfer to the electrodes.

A further object is to provide a thermal arc jet device wherein the arc travels in line with the gas thus providing a large heat transfer to the gas.

A still further object is to provide a multiphase thermal arc jet with an electrode arrangement wherein the arc occurs only between adjacent electrodes without bridging an intermediate electrode.

These and other objects will be more fully understood from the following detailed description taken with the drawing wherein:

FIG. 1 shows a partially cutaway end view of a thermal arc jet according to the invention;

FIG. 2 shows a sectional view of the device of FIG. 1 along the line 2-2;

FIG. 3 shows a modification of the device of FIGS. 1 and 2 using diffusion of the gas past a pin electrode in a multiphase system; and,

FIG. 4 shows a modification of the pin electrode of FIG. 3.

A thermal arc jet is a device which transfers electrical energy to a gas. Positive and negative ions are accelerated between the electrodes and collide with neutral gas molecules thus imparting momentum and energy to these neutral particles and also provide additional ionization of the gas. According to this invention, a plurality of annular electrodes separated by insulating spacers are connected to a high frequency multiphase power source with the first and last electrodes connected in-phase so that a new arc will strike between the first two electrodes following the striking of an arc between the last two electrodes. The use of a high frequency multiphase system is superior to D.C. systems of this type because the arcs are periodic instead of continuous and thus increase electrode life. Also, the heat transfer to the gas is more efficient.

In one embodiment of the invention, a D.C. arc is used to provide preionization of the gas.

Referring more particularly to the drawing, FIGS. 1 and 2 show a multiphase thermal arc jet 10 having a plurality of annular shaped electrodes 11, 12, 13 and 14 separated by insulator spacers 15, 16 and 17. In one device built, the spacers were made of "Teflon" but other insulating materials may also be used.

The electrodes 11, 12, 13 and 14 are made of a heat resistant conductive material such as tungsten. However, in some systems, it is possible to use copper electrodes or electrodes of other conducting materials. Cooling jackets 18 and 19 surround electrodes 12 and 13. These may be made of copper or other conducting material for supplying power to electrodes 12 and 13. Coolant mate-

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rial is supplied to channels 22 in members 12, 13, 18 and 19 through the coolant supply tubes 23 and 24 which may also be used as electrical leads. Heat and electrical conducting members 20 and 21 surround electrodes 11 and 14. Cooling means may also be provided for electrodes 11 and 14, if desired, though this, in some cases, is not needed.

A gas supply tube 25 supplies gas along the tangent of chamber 26 in member 20 from gas supply 27, as shown in FIG. 1. An expansion nozzle 28 is connected to the electrode assembly at the opposite end from member 20. The electrode assembly and nozzle are held in sealed relation by means of a frame 29 made up of end plates 30 and 31 which are secured by tie rods 33 and nuts 34. The frame 29, member 20, nozzle 28 and member 21, act as the power lead for electrodes 11 and 14. Multiphase current is supplied to the electrodes 11, 12, 13 and 14 by means of tubes 23 and 24, end plates 30, 31, and tie rods 33 from a multiphase supply 35 shown schematically as a three-phase supply in FIG. 2. The electrodes 11 and 14 are connected in-phase so that a new arc discharge between electrodes 11 and 12 follows the discharge between electrodes 13 and 14. Insulators 15, 16 and 17 have annular recessed portions 39, 40 and 41 to reduce heating of the insulators and to prevent breakdown across the surface of the insulators.

In the operation of the device, a three-phase power supply is connected to the electrodes 11, 12, 13 and 14 as described above. A gas such as air, hydrogen, helium, nitrogen or argon is introduced from supply source 27 through supply tube 25 tangentially into chamber 26 in member 20 and then travels down the discharge cavity 36 with a vortex motion past electrodes 11, 12, 13 and 14 through the constriction 32 into the expansion nozzle 28. As the gas flows down the tube, arc discharges are set up first between electrodes 11 and 12, then 12 and 13 and, in turn, electrodes 13 and 14, and then back again to electrodes 11 and 12. The arc discharge column is parallel to the gas flow so that the arc travels in line with the gas which allows for greater heat transfer to occur. The swirl added to the gas causes the arc to be constricted to a small column in the center of the electrodes to allow high current densities and high enthalpy levels to be achieved in the device and, also to maintain a cooler gas sheath close to the electrodes which reduces heat transfer to the electrodes. The gas enters the constriction 32 in nozzle 28 at sonic or greater velocity and is expanded to higher velocities in the nozzle 28.

In the device of FIG. 3 the annular electrodes 51, 52, 53 and 54 are substantially the same as the annular electrodes in FIGS. 1 and 2. Cooling jackets 55, 56, 57 and 58 are provided for each of these electrodes. A non-conducting cooling material such as air is supplied to the cooling jackets 55, 56, 57 and 58 from supply 60 through an insulating tube 61 made of a material such as rubber and through tubes 62a, 63a, 64a and 65a. The coolant discharge tubes 62b, 63b, 64b and 65b are made of conducting material and act as leads for electrodes 51, 52, 53 and 54 from the multiphase power supply 67, which is shown as a three-phase supply, though more phase and additional annular electrodes may be used, if desired. The electrodes 51, 52, 53 and 54 are separated by insulator spacers 69, 70, 71 and 72 as in FIGS. 1 and 2. The electrodes and spacers provide a central cavity 73 for the passage of gas to be heated as in FIGS. 1 and 2. The gas to be heated is supplied to the tube from gas supply 74 through tube 75 to a chamber 76 as in FIGS. 1 and 2. A direct current supply 77 is connected between pin electrode 78 and an additional annular electrode 79 and causes ionization of the gas which is diffused past the pin electrode 78 in space 80. The gas diffusing past the pin electrode acts to cool the pin electrode. The ionized gas

entering the discharge space between electrodes 51 and 52 permits breakdown between these electrodes at lower voltages and thus provides greater heating of the gas.

A plenum or mixing chamber 82 is provided between the electrode system and a nozzle 83 so that the heat of the gas entering the constriction 84 is substantially uniform. The coolant from supply 60 is supplied to the cooling space 85 in member 86 surrounding the mixing chamber and to space 87 in nozzle member 88 through tubes 91a and 92a. The cooling spaces 85 and 87 are provided with discharge tubes 91b and 92b. Cooling may be provided for the members 93 and 79 in a similar manner, if desired.

The operation of the device of FIG. 3 is similar to the device of FIGS. 1 and 2. Gas from supply 74 enters the chamber 76 with a vortex motion. The gas diffuses past the pin electrode 78 and annular electrode 79 wherein it is ionized. It then passes through the tube cavity 73 to the mixing chamber 82. Because of the three-phase power supply connected to these electrodes, a discharge is first started between electrodes 51 and 52, then between electrodes 52 and 53, and then between electrodes 53 and 54. This adds heat energy to the gas so that a high energy gas enters the mixing chamber 82. This high energy gas is then expanded to a high velocity in the expansion nozzle 83. After the discharge between electrodes 53 and 54 the next discharge will be between electrodes 51 and 52 since electrodes 51 and 54 are connected in-phase.

In FIG. 4, a modification of the pin electrode 78 of FIG. 3 is shown. The pin electrode 78a has a tungsten tip 98 to provide a longer life for the pin electrode. A channel 99 is provided as a path for escape of the gas that builds up behind the tungsten tip 98 during the manufacture of the device. The tip may be made porous so that additional gas from supply 74 may be supplied through channel 99 to aid in cooling the tip. The electrodes 51, 52, 53 and 54 may also be made porous so that additional gas may be supplied to the cavity 73 through the electrodes which will aid in cooling the electrodes.

While a separate coolant supply has been shown, in some cases the gas from the supply source can be used as the cooling material such as when the porous electrodes are used. Also, a heat exchanger may be provided surrounding the electrode system for adding heat to the supply gas.

Also, various means may be used to provide the vortex motion for the gas such as a spiral plate adjacent the chambers 26 and 76. The electrodes are made to project toward the central cavity in the center to increase the effective length of the conductor and to aid in removing the insulators from the discharge path. The systems have been shown with a single A.C. supply but as the D.C. supply is not electrically connected outside the tube to the A.C. supply, so also more than one multiphase A.C. system connected to separate electrodes in the same gas flow path could be used. For example, four additional electrodes could be located between electrode 54 and the mixing chamber 82 and these could be connected to a separate three-phase A.C. supply to add more energy to the gas.

There is thus provided a multiphase thermal arc jet for creating high enthalpy gas. It is obvious that there may be other uses for the device than that disclosed.

While certain specific embodiments have been described in detail, it is obvious that numerous changes may be made without departing from the general principle and scope of the invention.

I claim:

1. A multiphase thermal arc jet device, comprising: an electrode system including four annular electrodes of heat resistant material, an annular electrical insulator spacer between each pair of electrodes to thereby provide a plurality of discharge spaces within said electrode

system, a cooling jacket surrounding the two intermediate electrodes, means for supplying a coolant to said cooling jackets, a conductive cup-shaped member surrounding one of the other of said four electrodes, a cavity in said cup-shaped member adjacent said one of the other electrodes, means for supplying a gas along the tangent of said cavity to thereby give the gas a vortex motion within said electrode system, a conductive expansion nozzle at the end of said electrode system remote from said cavity in electrical engagement with the remaining one of said four electrodes, a first conductive plate member at one end of said electrode system in electrical engagement with said cup-shaped member, a second conductive plate member at the other end of said electrode system in electrical engagement with said nozzle, conductive means connected between said first and second plate members, a three-phase power supply, means including said means connected between said plate members for connecting one phase of said power supply to said first and said second plate members and means for connecting the other two phases of said power supply to said two intermediate electrodes.

2. A multiphase thermal arc jet device, comprising: an electrode system including a plurality of annular electrodes, means for cooling said annular electrodes, an annular electrical insulator spacer between each pair of electrodes to thereby provide a plurality of discharge spaces, a multiphase power supply, means for connecting two non-adjacent annular electrodes to one phase of said power supply, means for connecting the annular electrodes intermediate said two annular electrodes to the other phases of said power supply, means for supplying gas with a vortex motion at one end of said electrode system into said discharge spaces, an expansion nozzle at the end of said electrode system remote from said gas supply means and a mixing chamber between said electrode system and said expansion nozzle.

3. A multiphase thermal arc jet device, comprising: an electrode system including a plurality of annular electrodes of heat resistant material, means for cooling said annular electrodes, an annular electrical insulator spacer between each pair of electrodes to thereby provide a plurality of discharge spaces, a multiphase power supply, means for connecting two nonadjacent annular electrodes to one phase of said power supply, means for connecting the annular electrodes intermediate said two annular electrodes to the other phases of said power supply, a pin electrode at one end of said electrode system, a direct current supply, means for connecting said direct current supply between said pin electrode and one of said annular electrodes adjacent said pin electrode, a chamber adjacent and surrounding a portion of said pin electrode, means for supplying gas with a vortex motion tangential to said chamber past said pin electrode into said discharge spaces, an expansion nozzle at the end of said electrode system remote from said pin electrode and a mixing chamber between said electrode system and said expansion nozzle.

4. A multiphase thermal arc jet device, comprising: an electrode system including a plurality of annular electrodes of heat resistant material having inwardly directly projecting surfaces; an annular electrical insulator spacer between each pair of electrodes to thereby provide a plurality of discharge spaces; said insulator spacers having inwardly directly concave surfaces; a multiphase power supply; means for connecting two nonadjacent annular electrodes to one phase of said power supply; means for connecting the annular electrodes intermediate said two annular electrodes to the other phases of said power supply; a pin electrode, having a conical tip, at one end of said electrode system; a pin support member surrounding said pin electrode; an annular member, having a conical opening therein, adjacent said pin electrode; said pin electrode having its conical tip projecting into said conical opening; a direct current supply; means for connecting said direct current supply between said pin electrode and one

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of said annular electrodes adjacent said pin electrode; means for supplying gas with a vortex motion past said pin electrode into said discharge spaces; an expansion nozzle at the end of said electrode system remote from said pin electrode; a mixing chamber between said electrode sys-
tem and said expansion nozzle and means for cooling said annular electrodes, said nozzle and said mixing chamber.

5. A multiphase thermal arc jet device, comprising: an electrode system including a plurality of annular electrodes of heat resistant material having inwardly directly projecting surfaces; an annular electrical insulator spacer between each pair of electrodes to thereby provide a plurality of discharge spaces; said insulator spacers having inwardly directly concave surfaces; a multiphase power supply; means for connecting two nonadjacent annular electrodes to one phase of said power supply; means for connecting the annular electrodes intermediate said two annular electrodes to the other phases of said power supply; a cooling jacket surrounding each of the annular electrodes connected to said multiphase power supply; said annular electrodes and said surrounding cooling jackets having annular cooling chambers; means for supplying a coolant to said annular cooling chambers; a pin electrode,

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having a conical tip, at one end of said electrode system; a pin support member surrounding said pin electrode; and annular member, having a conical opening therein, adjacent said pin electrode; said pin electrode having its conical tip projecting into said conical opening; a direct current supply; means for connecting said direct current supply between said pin electrode and one of said annular electrodes adjacent said pin electrode; means for supplying gas with a vortex motion past said pin electrode into said discharge spaces; an expansion nozzle member at the end of said electrode system remote from said pin electrode; a mixing chamber member between said electrode system and said expansion nozzle, said nozzle member and said mixing chamber member having annular cooling channels therein; and means for supplying a coolant to said channels in said nozzle member and said chamber member.

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