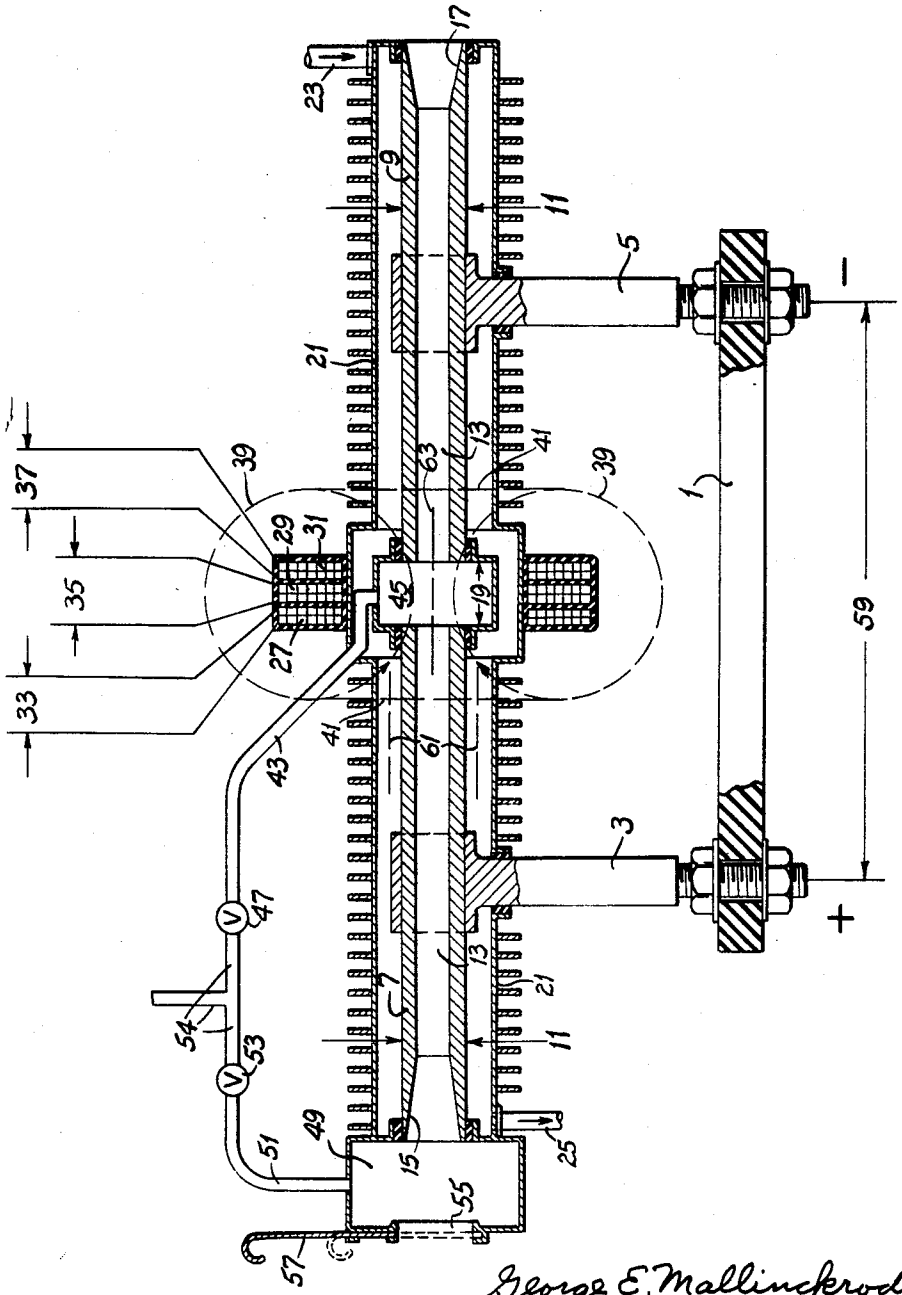
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ELECTRIC JET-FORMING APPARATUS
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ELECTRIC JET-FORMING APPARATUS

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13 Claims. (Cl. 313—63)

This invention relates to electric apparatus for the production of an atomic jet adapted for gas evacuation, spraying, reactive propulsion and any other processes which may be actuated by such a jet, such as low-energy nuclear reactions.

Among the several objects of the invention may be noted the provision of electric jet-forming apparatus adapted to maintain a rapid flow in jet form of atomic particles; and the provision of a simple form of such apparatus wherein the jet-forming material is accelerated as a stream of positively charged atoms and becomes a high-speed jet of atoms adapted for reactive propulsion, pumping of gases, nuclear reactions spraying of particles such as metal, and the like. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of which will be indicated in the following claims.

In the accompanying drawing, the single figure is a diagrammatic axial section of apparatus embodying my invention.

Referring now to the drawing, numeral 1 indicates an electrically insulating base on which are located spaced conductive terminals 3 and 5. These support conductive electrodes 7 and 9, respectively. The electrodes 7 and 9 are composed of the material or materials which are to become a desirable component of the jet to be produced, as for example a metal if the jet is to be used for metal spraying, an example of which would be copper. The term metal as used herein includes alloys. For reactive propulsion purposes, the heavier metals may be preferable. Or the electrodes 7 and 9 may be composed of nonmetallic materials such as carbon in propulsive applications of those wherein gas evacuation is the object in view.

Each electrode may be in the form of a hollow cylinder, which for example may be 2 feet long, 3 inches in diameter (shown at 11), and having a 1½-inch hole 13 therethrough. Electrode 7 has a tapered inlet opening 15, and electrode 9 has a tapered outlet opening 17. The electrodes 7 and 9 are spaced apart a distance 19 which may be approximately equal to the diameters indicated at 11. A finned cooling jacket 21 surrounds the electrodes and the space between them, and carries a liquid coolant, such as water or sodium. The coolant may flow in at an entrance 23 and leave at an exit 25 for circulation through a suitable heat exchanger.

The space between the electrodes 7 and 9 is surrounded by one or more annular field coils. For example, three of such coils 27, 29 and 31 are shown, having suitable exciting circuits 33, 35 and 37 for applying appropriate D.C. voltages to the coils. Each coil is so wound and each voltage is so applied that together the coils form aiding toroidal magnetic fields. The sectional form of the sum is suggested by the dotted circles 39. The circles suggest one axial section through a toroidal magnetic field 41. It will be understood that the form 41 is idealized and that it is subject to distortions, without, however, changing its essentially toroidal form. Thus the dotted lines 39 and 41 are skeleton representations of the actually more extensive toroidal field.

At 43 is shown a connection with the space 45 between the electrodes 7 and 9. This connection is provided with a valve 47. At 49 is shown an inlet chamber and at 51 a connection therewith in which is a valve 53. A common passage 54 to both valves 47 and 53 is for making a suitable connection with any compartment to be evacuated. The chamber 49 has a large atmospheric inlet opening 55 opposite the inlet opening 15 of the electrode 7. This opening 55 may be closed when desired by means of a control gate 57. Numeral 59 designates a D.C. supply circuit connected across the terminals 3 and 5. This circuit for all applications supplies a relatively large amperage at a substantial voltage, for example, 2,000 to 5,000 amperes at 100 to 250 volts. It is connected to charge 7 positively and 9 negatively. Upon supplying such a voltage and large current, any gas in space 45 is copiously ionized when an arc is struck between electrodes 7 and 9. The arc makes the electrodes incandescent and vaporizes material from electrode 7. This material becomes atomized and ionized. Since 9 is negative, it supplies negative charges which attract and neutralize at least a majority of the ionized atoms or groups of atoms (as the case may be) of materials in the arc reaching 9.

Assuming that the coils 27, 29, 31 are excited to produce the toroidal field 39, 41 as indicated, the flow of ions along the arc is subject to a magnetically constrictive spiraling action within the toroidal magnetic flux field 41. The action is as follows, assuming that the electrodes 7 and 9 are composed of copper, that the gate 57 is open, and that the valves 47 and 53 are shut:

Atoms of gaseous materials (air, for example) and atoms of material from electrode 7 which enter the arc all carry positive charges and, as above stated, are therefor attracted to the negatively charged electrode 9. It is the charged condition of the atoms or groups of them that is referred to herein as ionization. A tubular magnetic field is generated around the flow of current represented by the moving positive charges, as suggested by the dotted lines 61. Its circular lines of force combine vectorially with the lines of force of the toroidal field 41 spirally to guide the flow of ions in the space 45 between electrodes 7 and 9 toward and along the center line 63. The spiraling action is toward and along the axis 63 of the toroidal magnetic field 39, said axis passing through the arc and the tubes 7 and 9. Thus the charged atoms tend to escape from 7 to 9 through a small central core of the space 45. In doing so, they accelerate and enter the passage 13 in electrode 9. The highest velocities of these atoms are those segregated nearest the axis or center line 63. In passing through electrode 9, a majority of their positive charges are neutralized by the negative charges escaping from the hot electrode 9. Consequently at least some atoms become neutral and move with a considerable kinetic energy, which causes them to become ejected as a jet from the outlet 17 of electrode 9. The initial accelerating force on the particles is produced by the potential difference between the electrodes 7 and 9. However, the velocity of the stream of particles ejected from electrode 9 is higher than if this accelerating force were applied to the particles without the additional acceleration caused by the spiraling action toward and along axis 63, accomplished by the interaction of the magnetic fields 39 and 61. This spiraling action also has the effect of ordering the particle movements along the axis, so that those moving closer to the axis are not subject to the

large amount of resistance caused by random particle movements as would be had if the spiraling function were not present. In other words, by means of the invention the amount of accelerating force available, due to the voltage drop selected between the tubes 7 and 9, is more efficiently converted into kinetic energy associated with the higher particle velocities ejected. Since the electrode 7 is composed of copper, the copper atoms issuing from the electrode 9 may be used for metal spraying onto any suitable interposed surface. In spraying applications of the invention, the jet of atoms of gas ejected from the outlet 17 are not of practical significance. Obviously, if it is intended to form a metal spray of another metal or alloy, the electrode 7 is made of the appropriate material for the purpose. It will be apparent that in time a sufficient amount of material will be lost from the electrode 7 to require its replacement.

The kinetic energy of ejection is considerable, particularly that part of the flow along and close to the center lines of the holes in the electrodes 7 and 9. Velocities are progressively less as the walls in the holes of the electrodes are approached, which minimizes energy loss due to lateral eddy currents.

If it is desired to employ the apparatus as a reaction motor, the base 1 may be attached to the element to be moved, reaction due to acceleration of the particles being applied to the moving system through the electrodes 7, 9 and the supports 3, 5. It will be understood that in such applications, efficiency is increased with increasing speed of the device being moved. This application is therefore primarily for high-speed apparatus, which does not require a high starting force or torque.

Another application of the apparatus is as a gas pump to effect evacuation of gaseous materials. For this purpose the gate 57 is closed. Then valve 53 may be opened, connection being made through 51 and 54 with any compartment to be evacuated. The gas may be any one such as air, hydrogen, nitrogen, et cetera. Since discharge of the material from the outlet 17 includes the gas atoms, the chamber attached to the connection 51 becomes evacuated. An alternative evacuation method is to close gate 57 and valve 53 while opening valve 47, connection being then made with the chamber to be evacuated. Or gate 57 may be closed and both valves 47 and 53 opened. As a gas pump, the device is useful down to a pressure range on the order of 10^{-5} mm. mercury. Below such a pressure the arc cannot be sustained.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Electric jet-forming apparatus comprising a pair of spaced electrodes, a circuit connected to the electrodes adapted to maintain them positive and negative respectively and maintaining an ionized arc between them, whereby ions flow from the positive toward the negative electrode, the negative electrode supplying electrons neutralizing at least some of the ions which approach it, the ion flow establishing a first magnetic field surrounding itself, and means adapted to establish a toroidal second magnetic field having an axis and coacting with said first magnetic field to spiral said ions toward and along said axis in a direction from the positive to the negative electrode, whereby a jet of atoms is produced which accelerates from the positive electrode spirally inward toward the negative electrode.

2. Electric jet-forming apparatus comprising a pair of spaced electrodes, a circuit connected to the electrodes adapted to maintain them positive and negative respectively and maintaining an ionized arc between them, whereby ions flow from the positive toward the negative electrode, the negative electrode having wall portions forming a space surrounded thereby in which electrons are supplied for neutralizing at least some of the ions which move into the space, the ion flow establishing a first magnetic field surrounding itself, and means adapted to establish a toroidal second magnetic field having an axis extending through said space and coacting with said first magnetic field adapted to spiral said ions toward and along said axis and into said space, whereby the ions are accelerated and neutralized to form a jet of neutral atoms moving into said space.

3. Electric jet-forming apparatus made according to claim 2, including an enclosure surrounding said arc, and means establishing a connection between said enclosure and a supply of material for entrainment with the ions moving toward said space.

4. Electric jet-forming apparatus comprising a pair of spaced electrodes, a circuit connected to the electrodes adapted to maintain them positive and negative respectively and maintaining an ionized arc between them, whereby ions flow from the positive toward the negative electrode, the negative electrode having a hole therethrough in which electrons are supplied for neutralizing the ions, the ion flow establishing a first magnetic field surrounding itself, and means adapted to establish a toroidal second magnetic field having an axis extending through said hole and coacting with said first magnetic field adapted to spiral said ions toward and along said axis and through said hole, whereby an accelerated jet of neutral atoms is produced moving out of said hole.

5. Electric jet-forming apparatus comprising substantially axially spaced hollow tubular electrodes with adjacent ends of their hollow portions opposite one another, an electric circuit connected across said electrodes adapted to establish a potential and an ionized arc between them wherein ions flow from the electrode of positive potential to the electrode of negative potential, and means for establishing a toroidal magnetic flux field surrounding said arc in the region of the spacing between the electrodes, whereby the other end of the tubular electrode of positive potential constitutes a particle inlet and the other end of the tubular electrode of negative potential constitutes a particle outlet.

6. Electric jet-forming apparatus made according to claim 5, including means adapted to supply said inlet with material for entrainment with said ion flow.

7. An electric jet-forming apparatus made according to claim 6, including an enclosure surrounding said arc, and means establishing a connection between said enclosure and material for entrainment with said ion flow.

8. Electric jet-forming apparatus comprising tubular electrodes which are axially spaced, an electric circuit connected across said electrodes adapted to establish an ionized arc between them and traversing said space, and means for establishing a toroidal flux field surrounding said space and having an axis passing through the electrodes and through the arc.

9. Electric jet-forming apparatus comprising spaced first and second electrodes, an electric circuit connected across said electrodes adapted to make the first one positive relative to the second one and to establish between them an arc of ionized particles moving from the first to the second electrode, said second electrode being tubular and adapted to receive said ionized particles therein to become neutralized and ejected therefrom means adapted to establish a toroidal flux field around said arc, said field having an axis extending through the arc and directed into said tubular second electrode, and a connection with said space adapted to supply gas thereto.

10. Electric jet-forming apparatus made according to claim 9, wherein said connection is made through said first electrode.

11. Electric jet-forming apparatus comprising spaced

first and second electrodes, an electric circuit connected across said electrodes adapted to make the first one positive relative to the second and to establish between them an arc of ionized particles moving from the first to the second electrode, means for establishing a toroidal magnetic flux field around and in the arc and having an axis extending therethrough, said second electrode being hollow and adapted to receive ionized particles moving along said axis to become neutralized and to eject said particles, and a connection with said space adapted to supply gas thereto.

12. Electric jet-forming apparatus comprising spaced first and second electrodes, a source of D.C. power connected across said electrodes adapted to make the first one positive relative to the second and to establish between them a high-current-density and low-resistance arc of ionized particles accelerating from the first to the second electrode, said second electrode having a hole therethrough adapted to receive said ionized particles and to become heated by the action of said arc thereby to produce electrons, whereby said ionized particles become neutralized for ejection from the hole as neutral atoms to form a plasma jet.

13. Electric jet-forming apparatus as set forth in claim 12 which further includes means for introducing a gas into said arc.

References Cited in the file of this patent

UNITED STATES PATENTS

948,372	Du Pont	Feb. 8, 1910
2,215,155	Kallmann	Sept. 17, 1940
2,743,366	Hershberger	Apr. 24, 1956
2,765,975	Lindenblad	Oct. 9, 1956
2,808,510	Norton	Oct. 1, 1957

OTHER REFERENCES

Lapp et al.: Nuclear Radiation Physics, Prentice-Hall, Inc. (1948), pages 127–128, 261–262, 267–270, 274–275.

Oldenberg: Introduction to Atomic Physics, McGraw-Hill Book Company, Inc. (1949), page 63.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,960,614 November 15, 1960

George E. Mallinckrodt

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

Column 4, line 67, after "therefrom" insert a comma.

Signed and sealed this 25th day of April 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

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