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PULSED ABLATING THRUSTER APPARATUS

Filed Oct. 25, 1966 Sheet 1 of 2

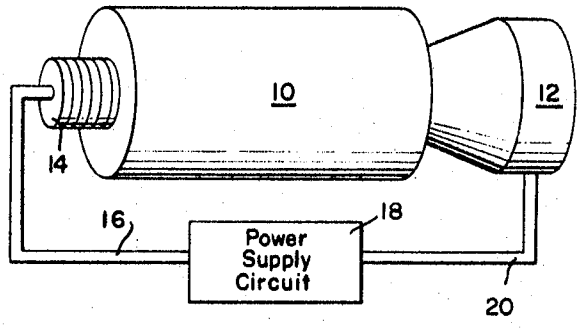


Fig. 1.

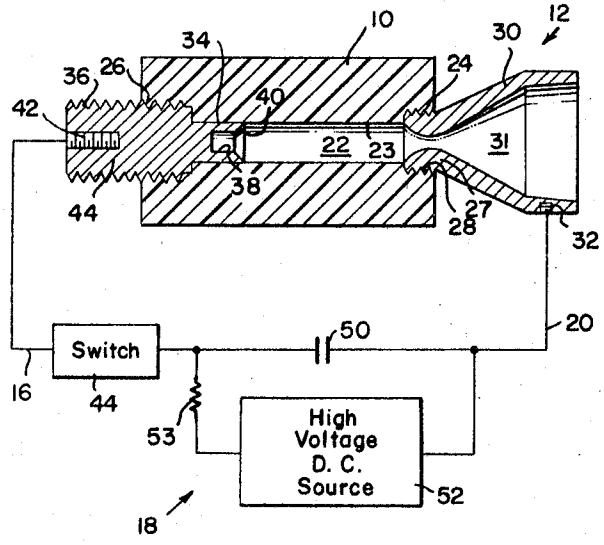


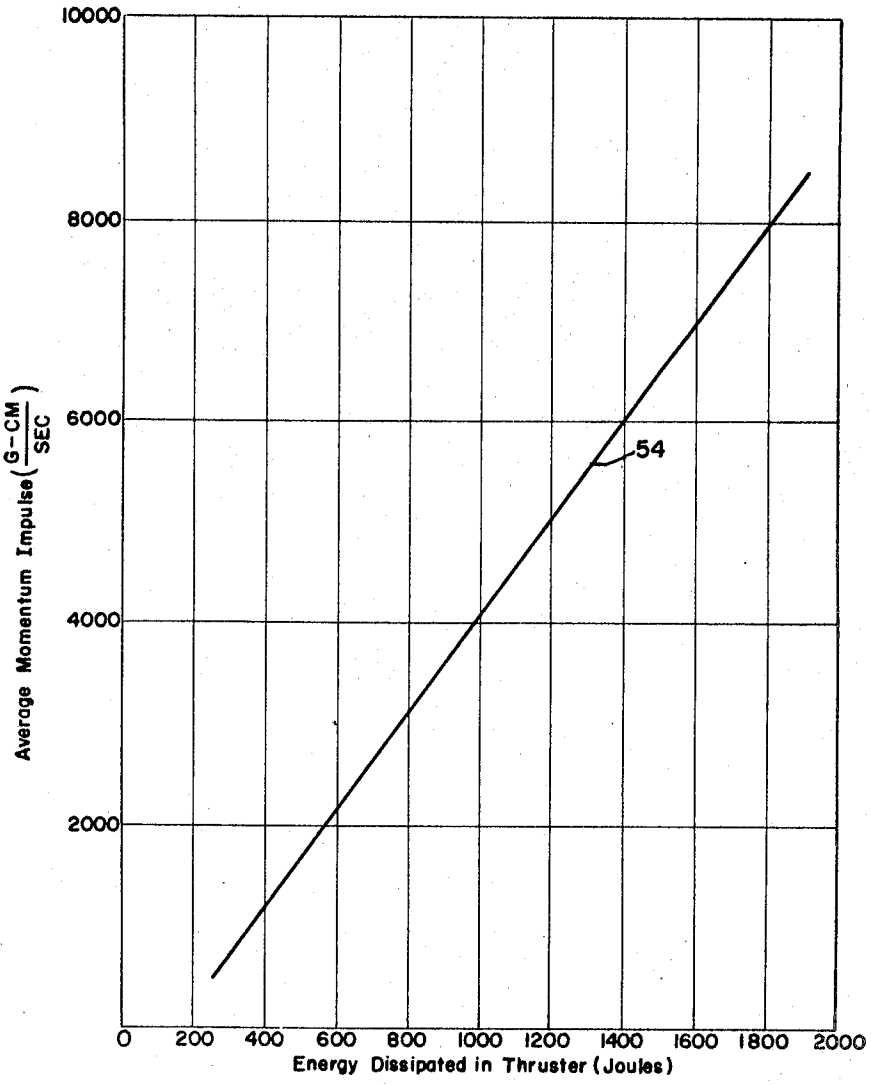
Fig. 2.

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Fig. 3.



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PULSED ABLATING THRUSTER APPARATUS

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U.S. Cl. 60—203 5 Claims

ABSTRACT OF THE DISCLOSURE

Propulsion apparatus having a body with a passage therethrough, the body being of dielectric material capable of releasing gas when subjected to heat. One electrode member is positioned to seal one end of the passage and another electrode member with an aperture therein is positioned in the other end of the passage. Electrical apparatus is connected to the electrode to generate electrical discharge arcs along the passage to effect heating of the material to release gas therefrom into the passage and through the passage and out the other electrode member to develop thrust in the body.

This invention relates generally to rocket propulsion apparatus, and more particularly relates to pulsed mode thruster apparatus producing thrust in a member by means of plasma ablated from the member.

Briefly, in accordance with the invention there is provided novel propulsion apparatus capable of use in high vacuum conditions such as encountered in space environments wherein stored electrical energy is discharged in an arc confined to a chamber in the interior of a dielectric insulating material body. The arc is initiated by a sliding spark and is sustained by the dielectric material ablated from the walls of the chamber to form plasma at high pressure. The plasma escapes at one end of the chamber through one electrode which has a passage therethrough and is shaped in the form of a rocket nozzle. The other electrode blocks the other end of the chamber to compel the plasma to exit only through the nozzle to provide thrust to the body.

In the drawings:

FIG. 1 is a perspective pictorial showing of the novel propulsion apparatus of the invention;

FIG. 2 is a side elevation view in section of the thruster and a schematic diagram of the electrical circuit of the propulsion apparatus of FIG. 1; and

FIG. 3 is a graph depicting the average momentum impulse versus the energy dissipated in the thruster of FIGS. 1 and 2 constructed in accordance with this invention.

Referring now to FIG. 1 the novel propulsion apparatus of the present invention is shown as consisting of an ablating thruster body **10**, an expansion nozzle **12** connected to one end of the thruster body, an electrode **14** connected to the other end of the thruster body, an electrical line **16** connecting an electrical power supply circuit **18** to the electrode **14**, and an electrical line **20** connecting the nozzle **12** to the circuit **18**.

Referring now to FIG. 2, the thruster body **10** is shown as an elongated cylindrical shaped member fashioned from dielectric plastic material. It has been found that materials such as Plexiglas, nylon, and Teflon are suitable materials for the member **10**. It should be understood that there is a wide variety of materials which are suitable for use to fashion the member and that the present invention is not limited to those specific preferred materials mentioned above.

A cylindrical bore **22** having a wall **23** is provided within the thruster body **10** to serve as a spark discharge channel. At one end the bore is slightly enlarged and provided with threads **24**. The other end of the bore **22** is also enlarged and threaded at **26**.

Expansion nozzle **12** is preferably fashioned from electrical conducting metal such as stainless steel or the like with a throat portion **27**, suitably threaded at **28** to engage the threads **24**, and an expansion portion **30**. A threaded bore **32** in the expansion portion **30** is adapted to receive a suitable threaded connection (not shown) which is adapted to be connected to the electrical line **20**.

The metallic electrode **14** is shown as having a portion **34** adapted to closely fit the bore **22** and external threads **36** engageable with the internal threads **26**. The portion **34** is bored at **38** and counterbored at **40**. A threaded bore **42** in the electrode **14** is adapted to receive a suitable connector (not shown) which is adapted for connection to the line **16**.

The electrical power supply circuit **18** consists of a switch **44** connected to the line **16** and a parallel arrangement of a capacitor **50** and a high voltage D.C. source **52** with a series charging resistor **53**. The line **20** is connected to the capacitor **50** and voltage source **52**. The switch **44** can be a conventional ignitron switch or the like capable of providing variable switch rates. The direct current source **52** should be capable of supplying D.C. potentials of up to about 5 kv.

In operation the capacitor **50** is initially charged to a voltage V_0 with resultant stored energy in the capacitor according to the equation $\frac{1}{2}CV_0^2$, where C is the capacitance of the capacitor **50**. When the switch is closed, the voltage V_0 of the capacitor **50** is suddenly applied to the electrodes **12** and **14** across the bore **22**. If a sufficiently high voltage V_0 is applied a sliding high vacuum spark first develops on the bore wall **23** and vaporizes a small amount of the dielectric material of body **10** to form gaseous products which discharge into the bore **22**. The gaseous products thus discharged into the bore **22** serve as the carrier gas or plasma for the electrical discharge arc which now develops. Upon initiation of the electrical discharge arc heat transfer to the wall **23** of the bore **22** evolves yet more gaseous products to build up pressure in the bore on the order of one to a hundred atmospheres and at a temperature of about 20,000° K. The gas products escape from the bore **22** through the nozzle **12** thereby imparting thrust to the thruster apparatus including the member **10**. The escaping gaseous products also radiate energy in the ultraviolet, visible, and infrared region of the spectrum. If now the switch **44** is opened to allow the capacitor to charge to the voltage V_0 and again closed to discharge the capacitor, a repetition of the cycle of events hereinbefore set forth results, thus providing pulsed mode thrust generation. Average thrust output can be controlled simply by varying the electrical energy $\frac{1}{2}CV_0^2$ applied to the capacitor **50**. This can be accomplished by varying the applied voltage V_0 generated by the voltage source **52**. Thrust output can also be controlled by varying the discharge rate of capacitor **50**. This can be accomplished by regulating the rate at which the switch **44** is opened and closed.

Referring to FIG. 3, wherein test data obtained on thruster apparatus constructed in accordance with this invention is exemplified by the curve **54**, it can be seen from inspection of curve **54** that impulse versus the electrical energy dissipated in the thruster body is approximately a linear function.

The advantages of the thruster apparatus of the present invention are numerous and is especially adapted for operation in the high vacuum conditions encountered in space. Neither gas, liquids, nor chemically reactive substances have to be supplied to the thruster body. Fuel injection systems are not needed. The thruster body is

compact and has no moving parts and is very resistant to damage by impact and vibration.

While I have described and illustrated a specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be made without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. In combination, comprising:
   - a body member having a passage therethrough, said body member being of dielectric material capable of releasing gas when subjected to heat;
   - a pair of electrodes, one of said electrodes sealing one end of said passage and the other of said electrodes having an aperture opening the other end of said passage; and
   - means for applying electrical potential between said electrodes to generate electrical discharge arcs along said passage to effect heating of said material to a predetermined temperature to release gas therefrom into said passage at a predetermined pressure and through said passage and aperture to develop thrust in said body member.

2. The combination as set forth in claim 1, wherein the other of said electrodes is a gas expansion nozzle.

3. The combination as set forth in claim 1 said electrical potential applying means comprising:
   - an electrical circuit arrangement consisting of electric charge storage means as a D.C. potential source; and
   - switch means for periodically connecting said circuit arrangement across said pair of electrodes to discharge said charge storage means.

4. The combination as set forth in claim 1, wherein said temperature is on the order of 20,000° K. and the pressure is greater than one atmosphere but less than two hundred atmospheres.

5. In combination, comprising:
   - a body member having a passage therethrough, said body member being of dielectric material capable of releasing gas radiating radiant energy into said passage when subjected to the heating of electrical discharge arcs developed within said passage;
   - a first electrode sealing one end of said passage;
   - a second electrode in the form of a gas expansion nozzle positioned in said passage to open the other end of said passage;
   - a parallel electric circuit arrangement consisting of capacitor means and a D.C. potential source; and
   - switch means for periodically connecting said circuit arrangement across said electrodes to discharge said capacitor means to generate said electrical discharge arcs along said passage to effect heating of said material to a temperature of about 20,000° K. to release said gas therefrom into said passage at a pressure on the order of more than one atmosphere but less than two hundred atmospheres and through said passage and gas expansion nozzle to develop thrust in said body member.

References Cited

UNITED STATES PATENTS

2,765,975	10/1956	Lindenblad	60—203 XR
2,816,419	12/1957	Mueller	60—39.48
3,140,421	7/1964	Spongberg	219—121 XR
3,156,092	11/1964	Holzman	60—251
3,358,452	12/1967	Ehrenfeld et al.	60—200

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U.S. Cl. X.R.

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