Feb. 4, 1969 J. A. BROWNING 3,425,223

ELECTROTHERMAL THRUSTER

Original Filed Sept. 8, 1964

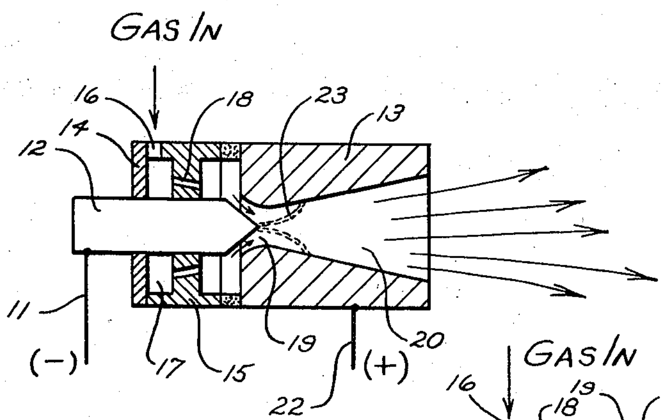

Fig. 1

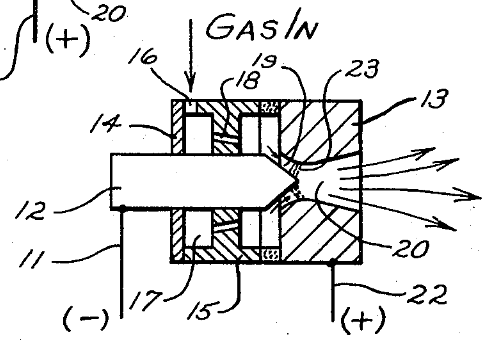

Fig. 2

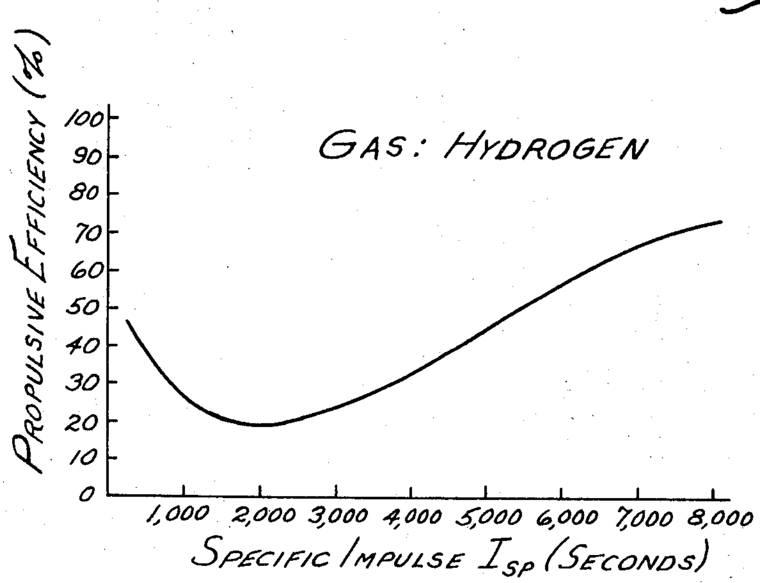

Fig. 3

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ELECTROTHERMAL THRUSTER

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Continuation of application Ser. No. 394,980, Sept. 8, 1964. This application Mar. 7, 1967, Ser. No. 645,555

U.S. Cl. 60—203 4 Claims

Int. Cl. F02k *7/08;* B64g *1/00;* F23r *1/04*

This application is a continuation of application Ser. No. 394,980, filed Sept. 8, 1964.

My invention relates to propulsion techniques and devices for space vehicles and relates more particularly to a plasma forming thrustor capable of producing high specific impulse values.

Electrothermal means for producing thrust have not previously held promise of achieving the required efficiencies. This has been largely due to the fact that plasma forming devices were limited to specific impulse values of about 2,000 seconds. At that level, with hydrogen, a minima in the efficiency versus specific impulse curve is reached.

Realized thrust is a function of enthalpy. An energy investment must be made in the dissociation of diatomic hydrogen and its ionization. This energy, in thrustor devices, is termed "frozen." That is, it is not recaptured in the form of useful thrust. Once this investment is made, however, further increases in heat content are expressed as velocity, and thrust is a function of this velocity. It should be pointed out that the "frozen" energy is recovered by recombination in outer space, at a time when no contribution to thrust can be made.

Therefore, once the initial dissociation-ionization energy penalty is paid, further increases in enthalpy lead to a rising efficiency curve. At these higher levels, then, the electrothermal expansion process becomes competitive with ion propulsion devices. My invention is based on a plasma generator operating in the laminar mode, the fundamentals of which are described in U.S. Patent No. 3,027,447 to James A. Browning et al. and dated Mar. 27, 1962.

Prior art studies have limited projected results to those achievable in the turbulent gas flow mode. I have found that the laminar principle leads to enthalpies of over one million B.t.u. per pound of gas (hydrogen) as against 200,000 b.t.u. per pound in the turbulent mode.

A better understanding of my invention may be had from the following description and drawing, in which:

FIGURE 1 is an electrothermal thruster device in cross section;

FIGURE 2 is a modification of the device of FIGURE 1; and

FIGURE 3 is a graph plotting the operating efficiency of my device.

Turning now to FIGURE 1, it will be seen that electrical power is delivered from a suitable source through lead **11** to an electrode **12**. A second electrode **13** forms a nozzle with an expanding bore at **20**. These electrodes are coaxially arranged and spaced by body elements **14** and **15**. A plasma forming gas is introduced under controlled pressure into the annular distribution chamber **17** through aperture **16**. Multiple passages **18** arranged around the electrode **12** distribute the gas evenly and introduce a smooth laminar flow of gas into the nozzle bore at **19**. An arc **23** is maintained, as shown, and is stabilized by the gas flow. The gas, passing through the arc region, is heated to extremely high temperatures prior to expansion to the vacuum of outer space. Since the thrustor must operate in the non-transferred mode, an electrical return to a closed power loop is provided by the lead **22**.

The ability of the laminar mode to heat gases to increased enthalpy levels is not well understood. It is certain, however, and confirmed by experimental data, that higher current levels may safely be used. In the turbulent mode a tunnelling effect is observed, with the arc striking and maintaining a position at some preferred spot in the nozzle electrode. With laminar flow, on the other hand, a diffuse glow is observed, indicating that the electron return is spread over a wide area. Thus current densities are drastically reduced permitting, for any given electrode geometry, much higher total current levels. The heating effect of the arc is thus enhanced.

These results have led to the use of even shorter nozzles, as depicted in FIGURE 2. The arc **23** in FIGURE 2 presents itself as a diffuse cone of fire, with sufficiently low current density to permit a high total current level. The gas atoms in a laminar stream passing through this diffuse arc are thus dissociated, ionized, and further heated to useful thrust levels. It is important to maintain the laminar mode of flow and avoid radial flow components and eddies. Various techniques of assuring laminar operation, as well as a more thorough description are given in U.S. Patent 3,027,447 referred to above. The passages **18** may be inclined to the axis of electrode **12** to provide a gentle tangential velocity component to the gas if desired.

From the curve of FIGURE 3 it is seen that once the minima at 2000 seconds is passed, efficiency rises substantially linearly and reaches acceptable levels at 5000 seconds and above. The falling portion of the curve, up to 2000 seconds, is due to the frozen losses described earlier. Once the gas molecules have been dissociated, no further energy is consumed by this process. Further increases are realized as thrust, although a small portion of the energy is inevitably lost as radiation to the nozzle inner walls.

I claim:

1. A method of producing thrust by electrothermal means comprising, establishing an electric arc between two electrodes, passing a gas therethrough under laminar flow conditions, heating said gas substantially beyond the point required to completely dissociate said gas, and allowing the resultant heated particles of said dissociated gas to expand and escape in a coherent frozen flow stream.

2. A method according to claim **1** in which said gas is hydrogen.

3. A method according to claim **1** in which said arc is stabilized by the laminarly flowing gas to form a diffused heating zone in the interelectrode region.

4. A method according to claim **3** in which said gas is hydrogen.

References Cited

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U.S. Cl. X.R.

60—204; 219—121