(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 132 065**
A2

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **84304344.9**

(22) Date of filing: **27.06.84**

(51) Int. Cl.⁴: **F 03 H 1/00**

(30) Priority: **13.07.83 GB 8318919**

(43) Date of publication of application: **23.01.85 Bulletin 85/4**

(84) Designated Contracting States: **BE DE FR IT NL SE**

(71) Applicant: **THE MARCONI COMPANY LIMITED**
The Grove Warren Lane
Stanmore Middlesex HA7 4LY(GB)

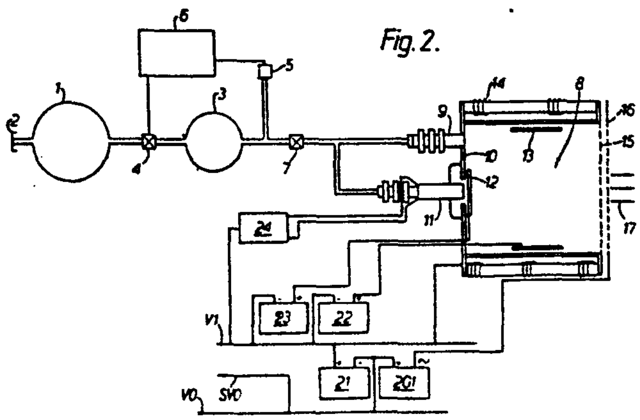
(72) Inventor: **Smith, Peter**
4 Hazel Road
Clanfield Hampshire(GB)

(74) Representative: **Dolwin, John Davison**
Central Patent Department Wembley Office The General Electric Company, p.l.c. Hirst Research Centre East Lane Wembley Middlesex HA9 7PP(GB)

(54) **Electric thruster for space propulsion.**

(57) An electric thruster for spacecraft propulsion has an ionisation chamber (8), and inlet (9) for supplying gaseous propellant into the chamber (8) via a valve (7) when thrust is required, a hollow cathode electron emitter (11) and keeper (12) and an anode (13) for ionising the propellant by electron collision, an accelerating grid (16) at one end of the chamber (8), and an alternating voltage supply (201) connected to the grid (16) such that positive propellant ions and electrons are alternately accelerated out of the chamber (8) to provide an exhaust beam (17) which gives the required thrust and has a predetermined net electrical charge (typically zero).

Fig. 2.



EP 0 132 065 A2

Croydon Printing Company Ltd

SS/2245

Electric thruster for spacecraft propulsion.

This invention relates to an electric thruster for spacecraft propulsion, the thruster including an ionisation chamber, means for providing propellant in the chamber when thrust is required, means for ionising the propellant in the chamber, a grid at one end of the chamber and means for providing an electrostatic field to accelerate positive propellant ions out of the chamber through the grid as an exhaust beam which gives the required thrust.

Figure 1 shows a schematic diagram of a known electric thruster according to the above description.

Referring now to Figure 1, propellant gas, for example xenon, is provided to a propellant tank 1 through a fill and drain valve 2. The tank 1 feeds a plenum tank 3 with propellant gas at reduced pressure through a solenoid operated valve 4. The plenum tank 3 is monitored with a pressure sensor 5 and feedback control electronics 6 used to operate the valve 4. When thrust is required a solenoid operated thruster inlet valve 7 is opened. Approximately 90% of the propellant gas flowing from the valve 7 is supplied into an ionisation chamber 8 through a main flow assembly inlet 9 connected to a back plate 10 of the chamber 8. Approximately 5% of the propellant gas flowing from the valve 7 is supplied via a first tee junction through a hollow cathode 11 into the chamber 8 and picks up electrons which are emitted by the hollow cathode 11. These electrons are accelerated from the region of a keeper 12 towards an anode 13 by an electrostatic field provided between the

0132065

keeper and the anode and they ionise the propellant gas supplied from the inlet 9 by a collision process. A series of solenoids 14 (or possibly permanent magnets) provide a magnetic field which causes the electrons to spiral between the keeper 12 and anode 13 so increasing their path length and hence the number of collisions and the ionisation efficiency. Positive propellant ions produced in the chamber 8 at a very low pressure, for example 10^{-3} to 10^{-4} Torr, tend to drift towards a screen grid 15 at the front end of the chamber 8 and an accelerator grid 16 at that end of the chamber 8 in front of the screen grid 15. A high negative voltage applied to the accelerator grid 16 provides an electrostatic field which accelerates positive propellant ions out of the chamber 8 through the two grids 15 and 16 as an exhaust beam 17 which gives the required thrust. In a typical thruster as described so far approximately 1000V is applied to the accelerator grid 16, the positive xenon ions have an exhaust velocity of approximately 30Km/s and the thrust produced is approximately 10mN. Accelerator grid and beam supply d.c. power supplies 20, 21 have terminals connected to the spacecraft potential V0 provided by the connection SV0 to the spacecraft, to the accelerator grid 16 and to the thruster potential V1 as shown. Anode and discharge chamber keeper d.c. power supplies 22, 23 have terminals connected to the anode 13, to the keeper 12, and to the thruster potential V1 as shown. A heater 24 for the hollow cathode 11 is also connected to the potential V1. The supplies 20,21,22,23 and the heater 24 are controlled together with the thruster inlet valve 7 from a central processor (not shown) and switched on simultaneously when thrust is required

In the arrangement as described so far, the emission of the positive ion exhaust beam would result in the thruster and spacecraft becoming electrically negatively charged which would impair the performance of the thruster and be generally undesirable. To overcome this problem, a separate electron emitter, known as a neutraliser, is used to dissipate electrons and in effect produce a net neutral exhaust. The neutraliser includes a second tee junction which supplies approximately 5% of the propellant gas flowing from the thruster inlet valve 7 through a second hollow cathode 30 which emits electrons to a second keeper 31. The electrons picked up by propellant gas from the region of the keeper 31 tend to be caught up in the ion beam emitted from the chamber 8 and so effectively neutralise the ion beam to prevent the thruster and spacecraft becoming charged. A neutraliser bias d.c. power supply 32 has one terminal connected to the spacecraft potential V0 and the other terminal provides a neutraliser potential V2. The hollow cathode 30 and keeper 31 are connected to the terminals of a neutraliser keeper d.c. power supply 33 connected to the neutraliser potential V2 and a heater 34 for the hollow cathode 30 is also connected to the neutraliser potential V2. The neutraliser power supplies are also switched on under control of the central processor when thrust is required.

One disadvantage of the separate neutraliser just described is the extra cost in providing the second tee junction propellant supply, the second hollow cathode device, and its associated heater and power supplies. Another disadvantage is that hollow cathode electron emitters presently available are inherently rather unreliable devices due to, for example, the use of a heater which could fail and contamination problems. The use of the first hollow cathode device 11, 12 is at present required as part of the preferred means for producing ionisation in the chamber 8,but the increased risk in using the second hollow cathode device is undesirable for spacecraft where reliability is a prime factor.

An object of the invention is substantially to overcome the disadvantages just described.

According to the invention there is provided an electric thruster for spacecraft propulsion, the thruster including an ionisation chamber, means for providing propellant in the chamber when thrust is required, means for ionising the propellant in the chamber, a grid at one end of the chamber and means for providing an electrostatic field to accelerate positive propellant ions out of the chamber through the grid as an exhaust beam which gives the required thrust, characterised in that said means for providing an electrostatic field comprises an alternating voltage supply connected to the grid such that positive propellant ions and negatively charged particles are alternately accelerated out of the chamber through the grid to provide an exhaust beam having a predetermined net electrical charge.

The invention will now be described in more detail will reference to the accompanying drawings, in which:

Figure 1 shows a schematic diagram of a known electric thruster as has been described above,

Figure 2 shows a schematic diagram of the thruster of Figure 1 modified in accordance with the invention, and

Figure 3 shows a diagram of the voltage waveform applied to the accelerator grid of the thruster of Figure 2.

Referring now to Figures 1 to 3, where the same reference numerals are used in Figure 2 as in Figure 1 this indicates that the same component parts are present and operate in the same manner. The separate neutraliser of the thruster of Figure 1, that is to say the second tee junction for propellant gas, the second hollow cathode electron emitter 30 and keeper 31 and the associated power supplies 32, 33 and heater 34 are entirely eliminated in the thruster of Figure 2. The d.c. accelerator grid power supply 20 of the thruster of Figure 1 is replaced by an alternating voltage power supply 201 in the thruster of Figure 2 such that positive propellant ions and electrons are alternately accelerated out of the chamber 8 through the grids 15, 16 to provide an exhaust beam from the chamber having a predetermined net electrical charge. It may also be desirable to isolate the screen grid 15 and provide it with a separate alternating voltage power supply, but this will depend upon the individual thruster parameters including the type of propellant used.

To produce a neutral exhaust beam, that is to say one in which the predetermined net electrical charge of the exhaust beam is zero, the amount of charge contained in the alternating negative and positive sections of the exhaust beam must be equal. Because the electrons are much lighter and more abundant in the ionisation chamber 8 than the positive propellant ions, much shorter electron accelerating periods and much smaller electron accelerating voltages are required than the equivalent positive propellant ion accelerating parameters. As a result a waveform of the type shown in Figure 3 is required to be supplied to the accelerating grid 16 by the alternating voltage power supply 201. The normal convention is to consider zero potential as that which exists an infinite distance downstream of the exhaust beam, but it is adequate to consider the abscissa axis of Figure 3 representing time to intersect the ordinate axis at the spacecraft potential V0. The values of the positive propellant ion and electron accelerating grid voltages V3 and V4 are dependent on the type of propellant, and thruster design, and are therefore well defined for any particular thruster. The periods t1 and t2 for which positive propellant ions and electrons respectively are accelerated are less well defined but again depend upon the thruster design. In a typical example with a xenon gas propellant, V3 and V4 are -1000V and +5V respectively, and t1 is equal to 98% of the waveform period T.

Spacecraft tend to become electrically charged for a variety of environmental reasons other than that related to the thruster as described above and this is undesirable. Since a system is normally fitted for measuring spacecraft potential it is envisaged that this system can be linked with means for varying the ratio of t1 to t2 so that the exhaust beam of the thruster may have a net positive or negative electrical charge which balances these other spacecraft charging effects and maintains a spacecraft zero potential.

It has been suggested that molecular compounds may be used as the propellant in the type of electric thruster to which this invention relates, that is to say as described in the first paragraph of this specification. In this case negatively charged particles will be produced in the form of negative ions in the ionisation chamber. It is envisaged that this invention is applicable to such use of molecular compound propellants so that positive propellant ions and negatively charged particles are alternately accelerated out of the ionisation chamber to provide an exhaust beam having a predetermined net electrical charge.

CLAIMS

1. An electric thruster for spacecraft propulsion, the thruster including an ionisation chamber (8), means (7, 9) for providing propellant in the chamber (8) when thrust is required, means (11, 12, 13) for ionising the propellant in the chamber (8), a grid (16) at one end of the chamber (8) and means for providing an electrostatic field to accelerate positive propellant ions out of the chamber (8) through the grid (16) as an exhaust beam which gives the required thrust, characterised in that said means for providing an electrostatic field comprises an alternating voltage supply (201) connected to the grid (16) such that positive propellant ions and negatively charged particles are alternately accelerated out of the chamber (8) through the grid (16) to provide an exhaust beam having a predetermined net electrical charge.

2. An electric thruster as claimed in Claim 1, in which the predetermined net electrical charge of the exhaust beam is zero.

3. An electric thruster as claimed in Claim 1 or Claim 2, in which the means (7,9) for providing propellant in the chamber includes an inlet (9) for supplying a gaseous element propellant into the chamber (8) and in which the negatively charged particles exhausted from the chamber are electrons.

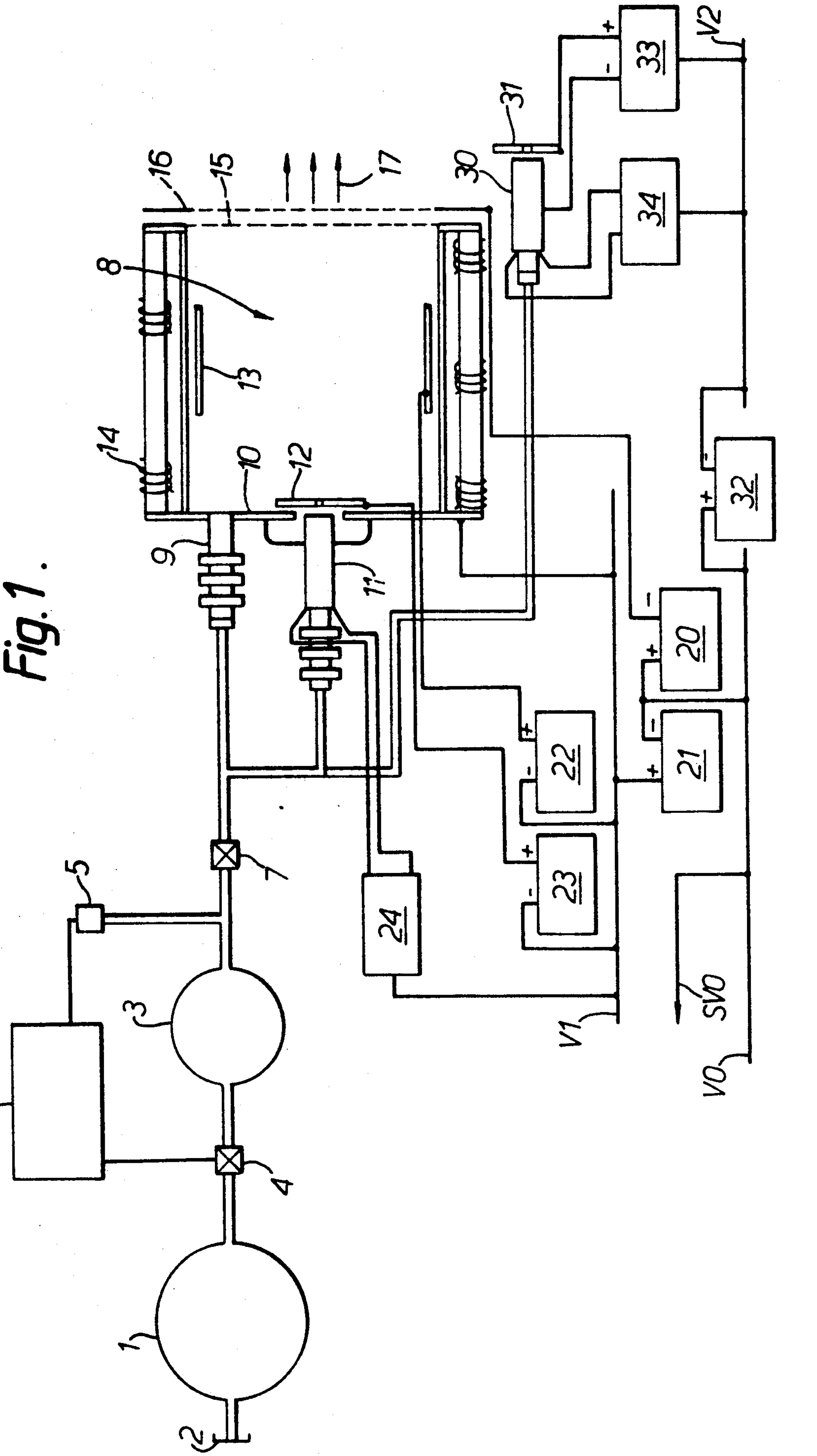
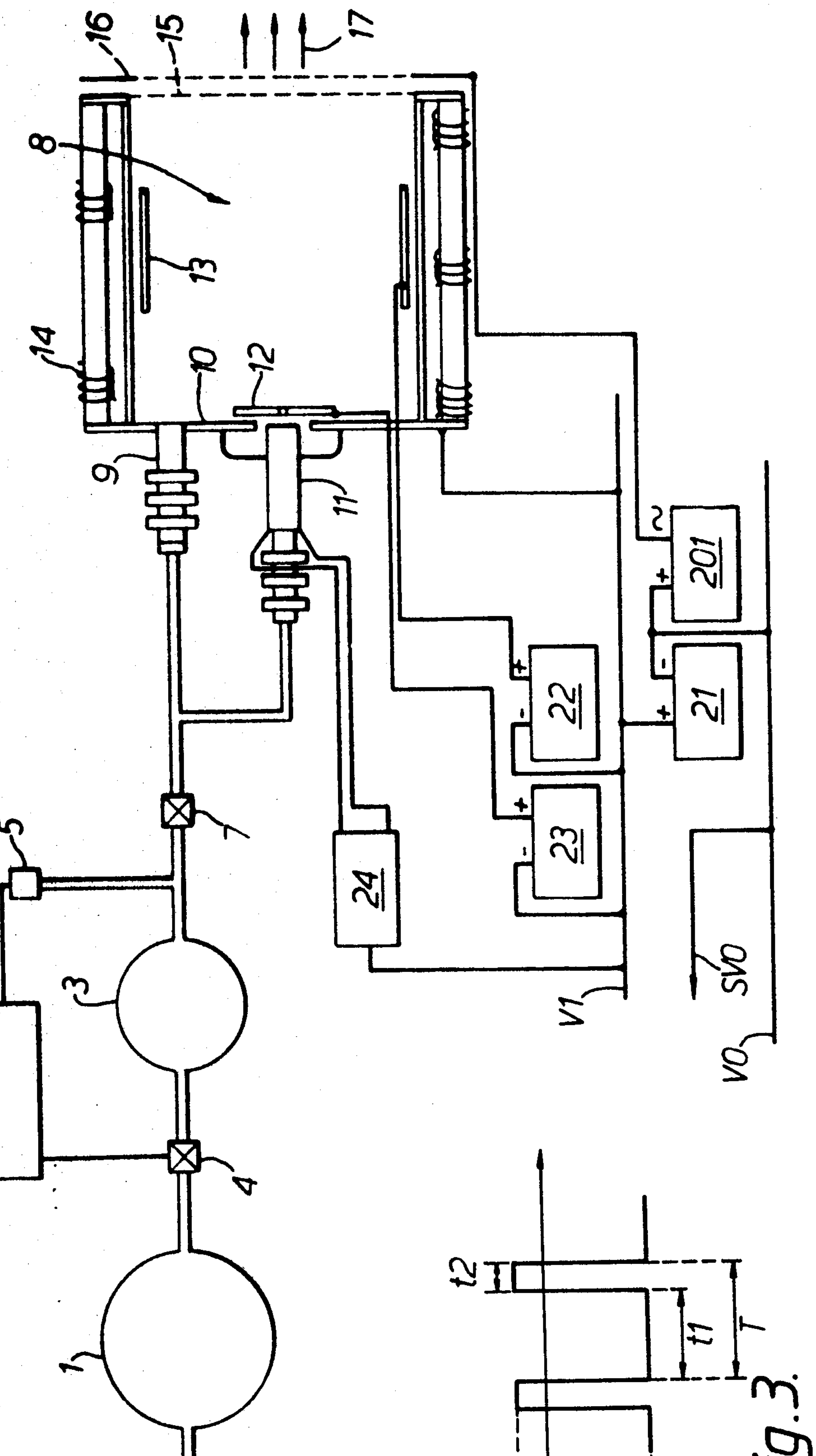

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
20
21
22
23
24
30
31
32
33
34
V1
V2
V0
SV0

Fig. 1.

Fig. 2.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
21
22
23
24
201
V1
V0
SV0

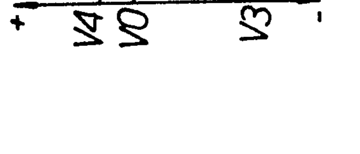

V4
V0
V3
t1
t2
T

Fig. 3.