Nov. 7, 1967 D. P. L. J. COLOMBANI ET AL 3,350,884

PROPELLENT SUPPLY TO ELECTRO-THERMIC EJECTORS

Filed Aug. 5, 1964 4 Sheets-Sheet 1

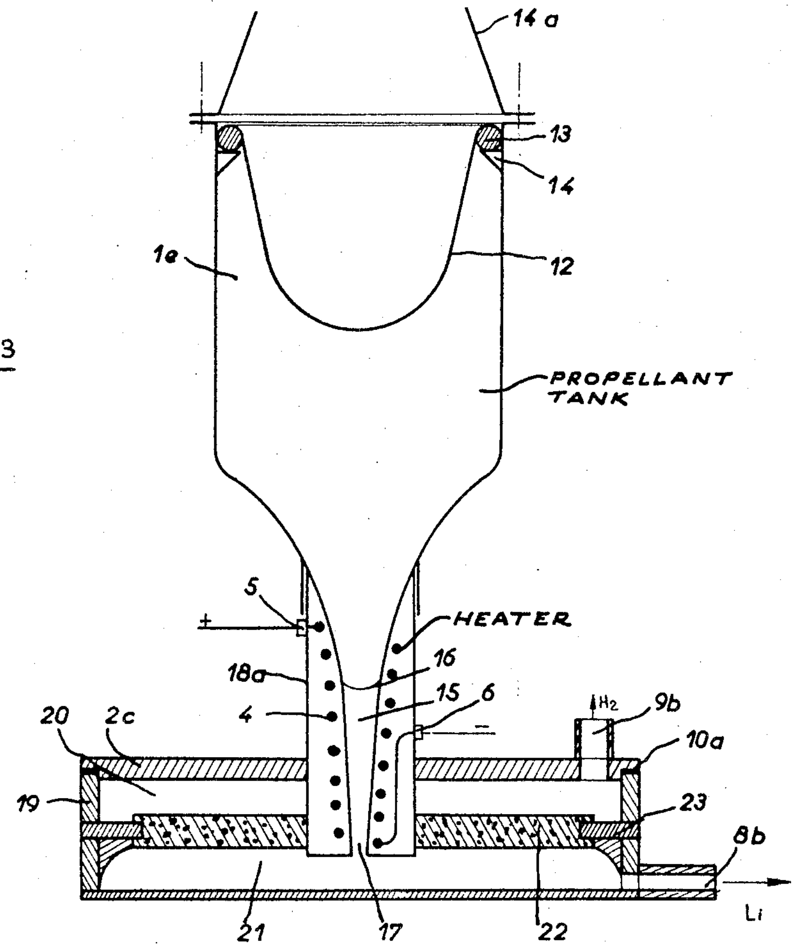

Fig.3

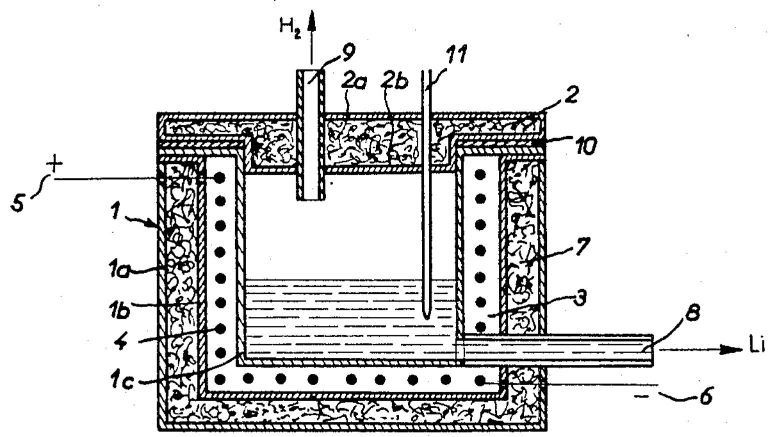

Fig.1

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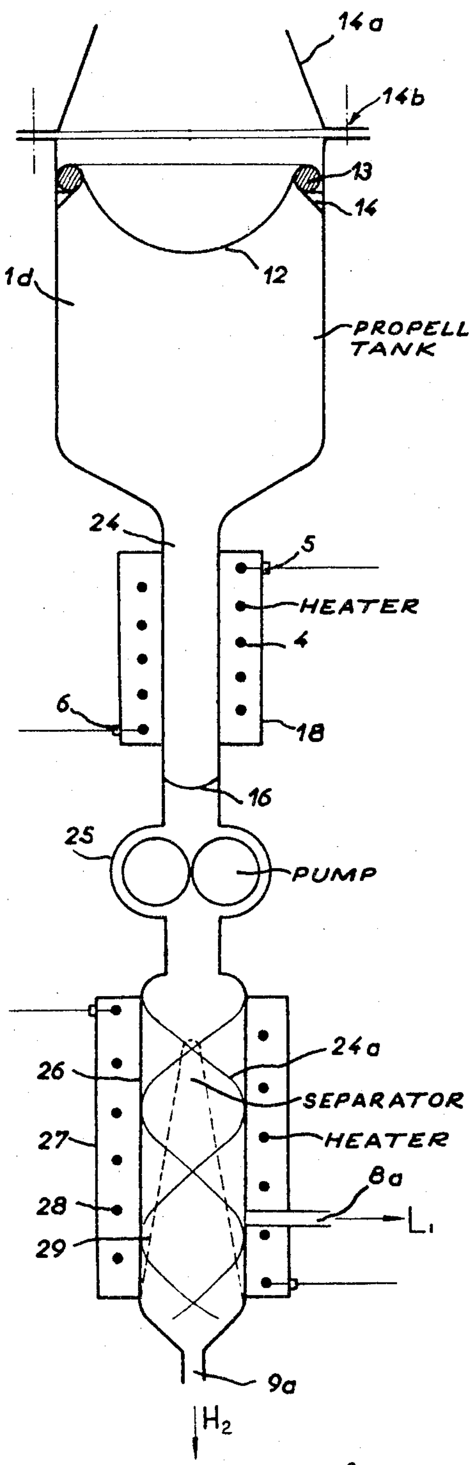

Fig. 2

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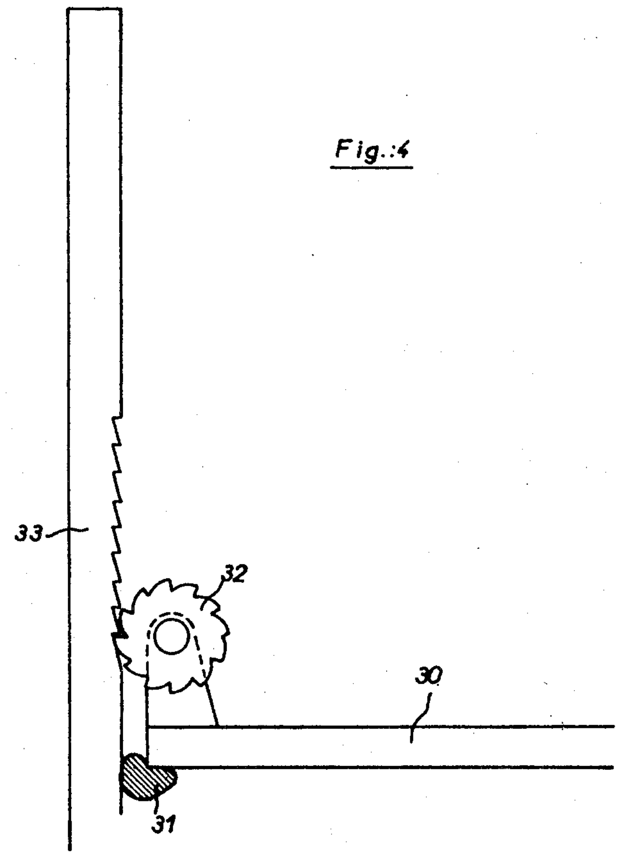
Fig.:4



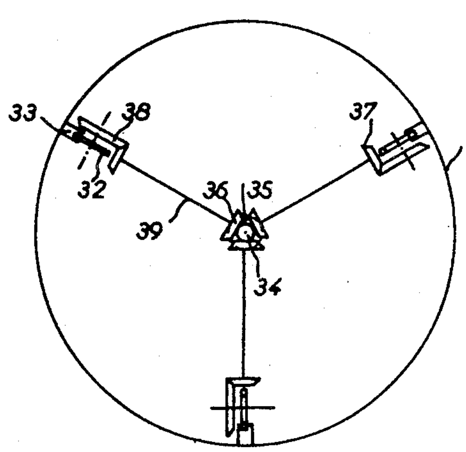


Fig.:5

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Fig.:6

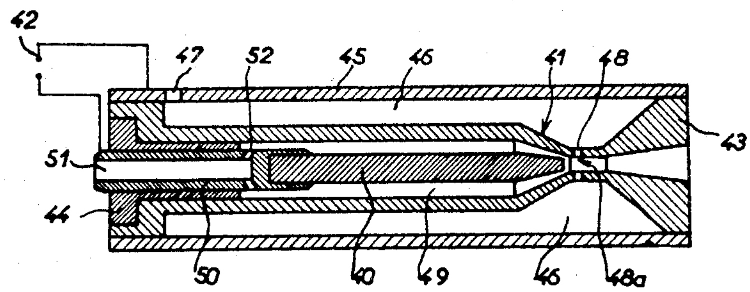
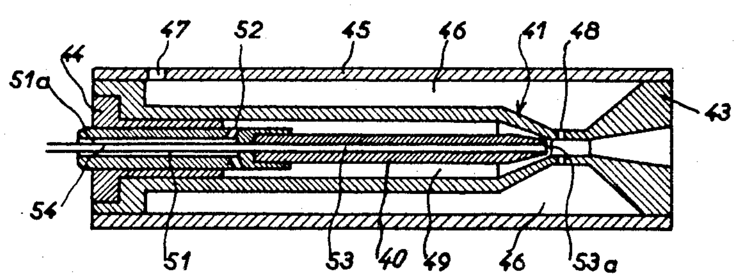


Fig.: 7



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United States Patent Office

3,350,884
Patented Nov. 7, 1967

3,350,884

PROPELLENT SUPPLY TO ELECTRO-THERMIC EJECTORS

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Filed Aug. 5, 1964, Ser. No. 387,702
Claims priority, application France, Aug. 19, 1963, 945,032
11 Claims. (Cl. 60—203)

The present invention relates to the field of space and in particular to the use of electro-thermic ejectors for the propulsion of space devices. It has more particularly for its object the supply of propellent to these ejectors together with means especially permitting the preparation of the propellents.

In space propulsion, propellents with low molecular weights are the most advantageous by reason of the high speeds of ejection required. In this latter category, those which are also gaseous provide the lightest ejection fluids, but have the disadvantage of necessitating tanks of large capacity because of their low specific mass, even if they are employed in the liquid state. For example, the specific mass of liquid hydrogen is of the order of 0.07 kg./cu. dm. and in consequence it requires tanks of large size which must furthermore be cryogenic and therefore heavy and complicated.

The invention overcomes these drawbacks by permitting the storage in non-cryogenic tanks of propellents of low molecular weight, in the form of solid or liquid substances having a relatively high specific mass.

In accordance with the present invention, a solid or liquid substance of relatively high specific mass is decomposed into at least one constituent in the liquid state and one constituent in the gaseous state, having a low molecular weight, and these constituents are introduced separately as propellents into the electro-thermic ejector.

This substance may be for example, lithium hydride obtained in the solid state (powder or granules). Its relatively high specific mass (0.8 kg./cu. dm.) makes it possible, for an equal ejectable mass, to adopt tanks which are much smaller and much lighter than if liquid hydrogen were employed and also avoids the complication of cryogenic tanks.

In addition, ionized hydrogen has the disadvantage that it is very difficult to return to the state of equilibrium in the discharge nozzles of the ejectors utilized for spatial propulsion. The "congealing" of the gas is thus a considerable cause of loss of energy. On the other hand, the simultaneous use as a propellent of hydrogen and lithium, derived from the decomposition of HLi has the advantage of facilitating the return to equilibrium, which permits an increase in the efficiency of the device.

The invention also comprises means for decomposing a solid or liquid substance, and for separating the constituents in the gaseous phase and in the liquid phase, in the weightless state.

The process of decomposition of a solid or liquid substance into at least one liquid constituent and at least one gaseous constituent within the field of gravity is known per se, and depends on the substance chosen. With certain substances, it is only necessary to apply heat. This is the case, for example, in the decomposition of lithium hydride in powder or in finely-divided form, into hydrogen and liquid lithium. The separation of the hydrogen and the lithium is easy on the earth where the benefit of the effect of gravity is obtained. This en-

ables the liquid lithium, which is much heavier, to occupy the bottom of the heated receptacle, from which it is extracted by a conduit system. As regards the hydrogen, which is lighter, this can be evacuated through an orifice pierced in the upper portion of the receptacle. The circulation of the fluids is then effected by the pressure resulting from the increase in temperature, or by appropriate pumps. In the case of lithium, for example, a magnetic pump will preferably be employed.

On the other hand, in the utilization in space, the lack of gravity complicates the problem presented by the separation of the liquid and gaseous constituents.

In particular, in the case of lithium hydride, the contact between the solid HLi and the hot wall of the receptacle in which the heating is carried out is much more difficult to effect since the particles of HLi move about in the whole of the free space of this receptacle. It is therefore necessary to take physical action in order to apply these particles against the walls.

In addition, the lithium particles, although heavier, have no reason to become separated from the hydrogen molecules and they continue to move about together if there is not applied a physical factor capable of grouping together the lithium on one side and the hydrogen on the other.

According to the invention, the absence of gravity is overcome by compressing the solid or liquid substance during the process of decomposition and the liquid constituents are separated from the gaseous constituents, either by creating a gravity field, for example by centrifuging, or by filtering the gaseous constituents, for example through a porous wall.

The description which follows below with reference to the accompanying drawings (which are given by way of example only and not in any limitative sense) will make it quite clear how the invention can be carried into effect, the particular features which are brought out either in the text or in the drawings being understood to form part of the said invention.

FIG. 1 shows in vertical section a device which can be used to effect the decomposition and the separation of the constituents in the field of gravity.

FIG. 2 shows an axial section of a device which enables this decomposition and separation to be effected in the absence of gravity.

FIG. 3 represents a view in longitudinal section of another device which operates in the absence of gravity.

FIG. 4 shows a detail of an alternative form of the devices of FIGS. 2 and 3, seen in partial longitudinal section.

FIG. 5 is a plan view showing diagrammatically how the device of FIG. 4 can be operated.

FIGS. 6 and 7 show diagrammatically two forms of construction of an electro-thermic ejector supplied separately with liquid propellent and gaseous propellent, seen in longitudinal section.

The device shown in FIG. 1 is intended for the decomposition of lithium hydride into hydrogen and lithium, and for the separation of these constituents. It is utilizable on the ground, and more generally in a place where a field of gravity exists.

The device comprises essentially a fluid-tight chamber, preferably cylindrical, constituted by a tank **1** and its cover 2.

The tank **1** is formed by a partition with a triple wall *1a*, *1b*, *1c*. The space **3** between the inner wall *1c* and the central wall *1b* contains a heating resistance **4** which can be supplied from the terminals **5** and **6** of a source of electric current. The space **7** between the central casing *1b* and the outer casing *1a* is filled with a heat-insulating material.

The tank 1 comprises an evacuation conduit 8 at its lower portion.

The cover 2 with a double wall *2a, 2b,* also contains an insulating material. It is also provided with an evacuation conduit 9. This cover is fixed on the receptacle by appropriate means (not shown). Air-tightness is ensured by a copper joint 10. The rise in temperature can be supervised by a pyrometer probe 11. The HLi in powder form is introduced into the tank 1, the latter is then closed and the electric current is applied to the resistance 4. As a result of the temperature rise which results from the passage of the current, the HLi first melts and then decomposes before vaporization. By levigation, the two products of the decomposition become separated: the gaseous hydrogen escapes from the upper portion through the pipe 9 formed in the cover 2, while the liquid lithium collects in the lower part of the tank and is evacuated through the pipe 8.

The device shown in FIG. 2 is utilizable in a space apparatus, in a weightless condition, gravity being created by a field of centrifugal forces due to the rotation of the apparatus in which the decomposition and the separation of the hydrogen and the lithium take place.

With this device, a receptacle **1*d*** provided with a flexible bottom **12** is in communication at its other extremity with a conduit **24**. Along the course of this conduit there are successively seen:

A sleeve **18** surrounding the pipe **24** and containing an electric resistance **4** connected to the terminals **5** and **6**, and a source of electric current or any other heating device;

A gear pump **25** of known type, utilizable for liquid metals;

A single or double helicoid **24*a***, surrounded by a heating sleeve **27**, similar to the sleeve **18**, and containing an electric resistance **28** or any other heating means. A pipe **8*a*** intended for the outlet of the lithium separated by the helicoid, starts from the periphery of the latter, in the vicinity of its extremity. A pipe **9*a***, intended for evacuating the hydrogen, starts from the extremity of the helicoid, in the extension of its axis.

The flexible bottom **12** may be for example a diaphragm of natural or synthetic rubber, for example of synthetic rubber manufactured from butadiene and which is sold under the name of "Buna." It is fixed on the tank **1*d*** by means of a removable ring **13** held in place by an edge **14** of this tank. A gas under pressure is applied against the upper face of the flexible bottom **12** through a conduit **14*a*** removably fixed at **14*b*** on the upper extremity of the tank **1*d***.

The solid HLi (in powder or granular form) is introduced into the tank **1*d*** after having removed the flexible bottom **12** and the conduit **14*a***, which are then replaced in position. The solid HLi contained in the tank **1*d*** is pushed by the gas under pressure acting on the diaphragm **12** and is evacuated through the conduit **24**. This latter is heated by the electric resistance **4**. It may also be heated by other means, for example in the case of propulsion of a satellite, by means of hot gases extracted from other apparatus of this satellite and passing through an appropriate heat exchanger.

The HLi, thus brought up to a temperature intermediate between its melting temperature and its temperature of decomposition, passes in the liquid state into the pump **25** which sends it under pressure into the helicoid **26**, in which it is heated by the electric resistance **28** of the sleeve **27** to a temperature of about 1,000° C., at which it decomposes into gaseous hydrogen and liquid lithium.

The mixture of liquid lithium hydride, gaseous hydrogen and liquid lithium, pushed by the delivery pressure of the pump **25**, begins a movement of rotation induced by the reaction forces of the surface of the helicoid or helicoids. After decomposition, the centrifugal force separates the lithium from the hydrogen approximately following the surface **29**. The liquid lithium which is more dense, is projected to the periphery from which it is evacuated through a conduit **8*a***, while the less dense gaseous hydrogen remains in the centre from which it can be extracted through the pipe **9*a***.

The separated hydrogen and lithium are thus made available for supplying an electro-thermic ejector.

The device shown in FIG. 3 also operates under conditions of absence of gravity. It comprises a tank **1*e***, the filling extremity of which is arranged like that of the tank of FIG. 2, and similarly comprises a flexible bottom **12** fixed by a keeper-ring **13** and being subjected on its upper face to the pressure brought in through the conduit **14*a***. At the opposite end, this tank **1*e*** terminates in a convergent neck **15** with a filter **16** at its inlet and a neck **17** at its outlet. A sleeve **18*a*** surrounds the neck **15** and encloses an electric resistance **4** which can be supplied from the terminals **5** and **6** of a source of electric current. The sleeve may also be heated by other means, such as hot fluids. The neck **15** opens into a receptacle **19** of large diameter, provided with a cover **2*c*** which closes it hermetically by means of a joint **10*a***. This receptacle is divided into two chambers **20** and **21** separated by a partition formed by two portions **22** and **23**, the central portion **22** being porous.

The cover **2*c*** and the partition **22** are passed through by the sleeve **18*a*** containing the electric resistance **4**, so that the outlet opening **17** of the neck **15** of the tank **1*e*** opens into the second chamber **21**. Pipes **8*b*** and **9*b*** provide outlet openings on the chambers **21** and **20** respectively.

After removing the flexible bottom **12**, as in the case of FIG. 2, the HLi is introduced in granular or powder form into the tank **1*e***. The flexible bottom is replaced hermetically, the conduits **8*b*** and **9*b*** are closed and the resistance **4** is put under tension.

The pressure of a gas brought in through the conduit **14*a*** is then applied on the flexible diaphragm. The portion of the HLi powder in the vicinity of the filter **16** melts at about 700° C. As soon as the fluidity is sufficient, the substance under pressure passes through the filter **16**. The temperature rises very rapidly since the heat is applied over a smaller and smaller section of the neck **15** so that the HLi is decomposed at the outlet **17** of the neck **15**. The temperature should however remain sufficiently low so as not to cause vaporization of the lithium. The conduits **8*b*** and **9*b*** are then opened. The mixture of liquid lithium and gaseous hydrogen thus passes, under the action of the pressure, into the chamber **21** and moves from the center towards the periphery. The porous wall **22** permits the hydrogen to pass only into the chamber **20**, from which it is evacuated through the pipe **9*b***, when so required under partial vacuum, if the pressure on the flexible bottom **12** is not sufficient.

The thickness of the layer of mixture is small and the portion of the mixture in contact with the wall **22** constantly changes due to its forward movements. The diameter of the receptacle **19** is calculated so that only the liquid lithium reaches the periphery, from which it is evacuated by the pipes **8*b***. The time of contact of the substances with the porous wall can obviously be increased by giving them a longer travel, by sub-dividing the chamber **21** with partitions of suitable shape, of spiral shape for example, or by increasing the contact surface by non-planar faces.

Under the action of the pressure applied to the bottom **12**, the lithium and hydrogen, thus separated, can be introduced into a thermo-electric ejector.

In order to apply the pressure on the lithium hydride in powder or granular form, any device equivalent to the diaphragm **12** of FIGS. 2 and 3 can be employed, for example the arrangement shown in FIGS. 3 and 5. In these figures, a piston **30** is mounted inside the tank **1*d***. A joint **31** provides a fluid-tight seal. Three toothed wheels **32** fixed on the piston and arranged at 120° along its periphery engage with three toothed racks **33** mounted along the generator lines of the cylinder which forms the wall of the tank. The three toothed wheels can be actuated separately or may be operated by a single shaft **34**, arranged in the center (FIG. 5), and coupled mechanically to the toothed wheels, for example by bevel pinions **35**, **36**, **37** and **38**, the first being keyed on the shaft **34**, the following two on the intermediate shafts **39** and the last on the axis of the toothed wheels **32**.

FIGS. 6 and 7 show diagrammatically two methods of supplying an electro-thermic ejector with a liquid propellent and a gaseous propellent, for example with lithium and hydrogen separated by the means above described.

The ejector is essentially constituted by a cathode **40** and an anode **41**, between which is struck an arc or a spark. When the apparatus is supplied with direct or alternating current from a source **42**, an arc is obtained, whereas when the source **42** is made-up of condensers which discharge into the ejector, the operation is carried out discontinuously by sparks at a certain recurrent frequency. The propellent, which is introduced in a manner which will be described below, arrives in turbulence around the cathode and is then ionized by the passage of the current. These ionized gases then pass out at high speed through the discharge nozzle **43**. An insulating sleeve **44** is interposed between the electrodes **40** and **41**.

In FIG. 6, the anode **41** is of refractory metal which is a relatively poor conductor, such as stainless steel, and is enclosed in a casing **45** which forms around it a space **46** adapted to receive liquid lithium under pressure through an orifice **47**. The anode **41** is pierced slightly downstream of the extremity of the cathode **40** with an orifice **48** for the introduction of the lithium, and this orifice may be constituted by a circular slot or by holes arranged in a ring.

The liquid lithium coming in under pressure to the annular cavity **46** passes through the orifice or orifices **48** and forms at the outlet into the ionization chamber **49** a surface having the form of a convex meniscus **48*a*** which, by reason of the excellent conductivity of liquid lithium, serves as an anode proper and receives the impact of the arc or the sparks which are formed between this surface and the cathode **40**. The injection pressure of the liquid lithium is higher than that existing in the chamber **49**. It is regulated in such manner that the whole of the lithium which flows out is vaporized by the jet at high temperature, taking account of the dimensions of the orifices **48**. The separating surface **48*a*** thus remains stationary, the flow-rate of the supply being equal to that of the consumption. The ionization of the lithium after its vaporization causes it to assist the production of the jet with the hydrogen. Although liquid lithium is much more conductive than the wall **41**, the position of the orifices **48** is chosen in such manner that the liquid meniscuses **48*a*** forming the wall of the anode are closer to the cathode than any other part of the discharge nozzle **43**, so that the electrically-charged particles can effectively impinge against them.

The cathode **40** is fixed to a cathode carrier **50** which is separated from the anode by the insulator **44** and comprises an axial conduit **51** which opens into the ionization chamber **49** through the orifices **52**, the hydrogen under pressure comes in through the conduit **51**, passes out through the orifices **52** round the cathode and proceeds towards the point of the said cathode.

The form of construction of FIG. 7 only differs from that of FIG. 6 in that the cathode **40** is pierced with a conduit **53** which is extended into the cathode carrier by a pipe **54**, around which the conduit **51** forms an annular passage **51*a*** communicating with the orifices **52**. In this form of embodiment, the liquid lithium is sent simultaneously into the cavity **46** of the anode and into the conduit **54** communicating with the conduit **53** of the cathode, while the hydrogen is sent into the annular passage **51*a*** and passes into the chamber **49** through the orifices **52**, as in the arrangement shown in FIG. 6.

With this arrangement, the cathode **40** is also made of a metal which is relatively a poor conductor. The liquid lithium coming in through the conduit **53** forms at the outlet **53*a*** of this conduit into the ionization chamber a meniscus which serves as the cathode proper, receiving the impact of the arc or the sparks and vaporizing the lithium by a process similar to that which has been described with reference to the anode.

It will of course be evident that the orifices **48** and **52** (FIG. 6) or the orifices **48**, **53*a*** and **52** must be arranged and dimensioned so that the lithium and hydrogen produced by the decomposition of the lithium hydride are consumed as propellents in the electro-thermic ejector in suitably determined proportions.

What we claim is:

1. A method of supplying propellent to an electro-thermic ejector, said method comprising the steps of: storing a nongaseous fluid substance of relatively high specific mass and capable of decomposing into at least one constituent of low molecular weight in the liquid state and one constituent of low molecular weight in the gaseous state; effecting the decomposition of said substance into said constituents; separating the constituent in the liquid state from the constituent in the gaseous state; and introducing separately as propellent into said electro-thermic ejector, the constituent in the liquid state on the one hand and the constituent in the gaseous state on the other.

2. A method as claimed in claim 1, in which said substance is lithium hydride.

3. A device for supplying propellent to an electro-thermic ejector located in a field of gravity, said device comprising a heat-insulated tank adapted to receive lithium hydride in a finely-divided state, means for heating said tank to the temperature of decomposition of said lithium hydride so as to decompose said hydride to liquid lithium and gaseous hydrogen, means for collecting said liquid lithium at the lower portion of said tank and for conveying it under pressure into said electro-thermic ejector, and means for collecting the gaseous hydrogen at the upper part of said tank and conveying it into said ejector.

4. A device as claimed in claim 3, in which said electro-thermic ejector comprises an anode device, a cathode device, electrical energizing means for producing sparks across the gap between the anode device and the cathode device, and orifices for the introduction of the lithium arranged so as to receive the impact of said sparks, said means for sending the lithium under pressure into the ejector being disposed in such manner that the lithium forms at the outlet of said orifices a free surface which is renewed as and when the lithium is consumed in said ejector.

5. A device for supplying propellent to an electro-thermic ejector in the absence of gravity, said device comprising a tank adapted to receive a non-gaseous fluid substance capable of being decomposed into at least one constituent in the liquid state and one constituent in the gaseous state, means in said tank for decomposing said substance into said constituents, means for applying pressure on said substance during the process of decomposition, means for separating the liquid constituent from the gaseous constituent, means for collecting said liquid constituent and for conveying it under pressure into said ejector, and means for collecting said gaseous constituent and for conveying it into said ejector.

6. A device as claimed in claim 5, in which said tank comprises an elastic diaphragm dividing the tank into a first chamber adapted to receive the non-gaseous fluid substance and a second chamber, and means for feeding a fluid under pressure into said second chamber to pressurize the same.

7. A device as claimed in claim 5, in which said tank is cylindrical and comprises a piston slidably mounted in said cylindrical tank and defining in said tank a chamber adapted to receive said non-gaseous fluid substance, and mechanical means for displacing said piston so as to compress said substance.

8. A device as claimed in claim 5, further comprising a separating device provided with helicoidal walls, means for sending said liquid and gaseous constituents mixed together and under pressure into said separating device, means for collecting the liquid constituent at the periphery of said separating device, and means for collecting the gaseous constituent in the axis of said separator device.

9. A device as claimed in claim 5, further comprising a separator device provided with a filtering wall dividing said separator into a first chamber and a second chamber, means for conveying the solid and liquid constituents mixed and under pressure into said first chamber in such manner that they flow along said filtering wall, means for collecting the liquid constituent in said first chamber and means for collecting said gaseous constituent in said second chamber.

10. A device as claimed in claim 9, and further comprising means for evacuating said second chamber.

11. A device as claimed in claim 5, in which said electro-thermic ejector comprises an anode device, a cathode device, electrical energizing means for producing sparks across the gap between the anode device and the cathode device, and orifices for the introduction of said lithium arranged so as to receive the impact of the sparks, said means for sending the lithium under pressure into said ejector being arranged in such manner that the lithium forms at the outlet of said orifices a free surface which is renewed as and when said lithium is consumed in said ejector.

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