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Papst

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[54] **METHOD FOR OPERATING AIRSHIPS, PARTICULARLY BY MEANS OF HYDROCARBON GAS OR HYDROGEN**

[76] Inventor: **Hermann Ernst Robert Papst,** Karl-Maier-Strasse 1, D7742 St. Georgen, Black Forest, Germany

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[63] Continuation of Ser. No. 227,887, Feb. 22, 1972, abandoned, which is a continuation-in-part of Ser. No. 119,335, Feb. 26, 1971, abandoned.

[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[2] **B64B 1/58**

[58] **Field of Search** ..... 244/97, 96, 98, 99, 61, 244/30, 31; 136/83 R, 86 B, 86 C, 97

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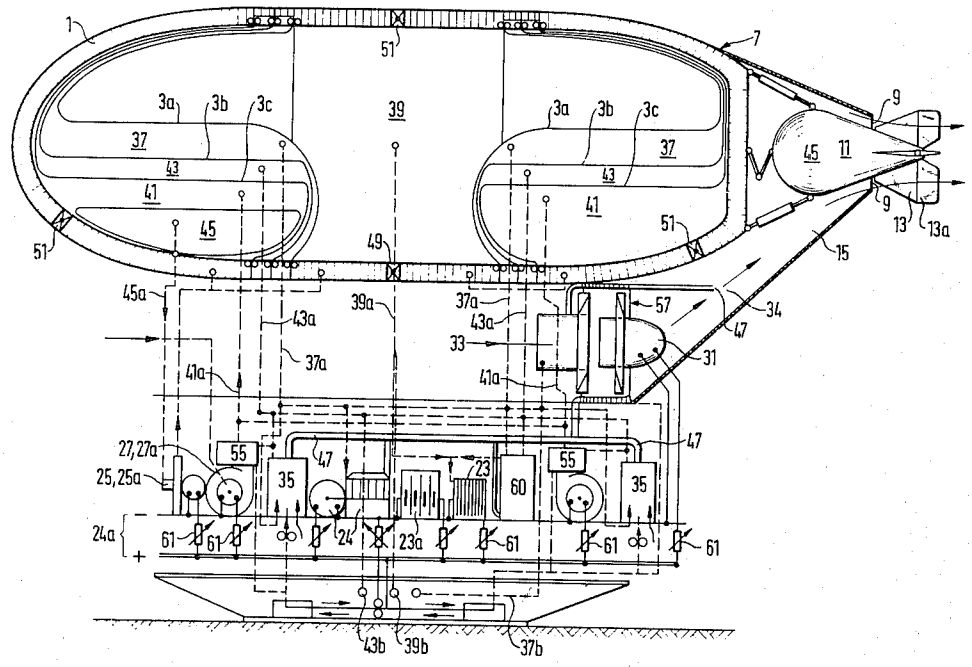
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Primary Examiner—Trygve M. Blix
Assistant Examiner—Barry L. Kelmachter
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A method of operating a lighter-than-air airship comprises utilizing natural gas and/or hydrogen as the buoyant lifting gas and as a source of power. The reduced buoyancy resulting from consumption of part of the gas is replaced with a gas species obtained by chemically converting part of the original gas. The gas species may be, for example, substantially saturated water vapor obtained by combustion of the original gas or hydrogen obtained by the catalytic partial oxidation of a hydrocarbon with water vapor.

11 Claims, 2 Drawing Figures



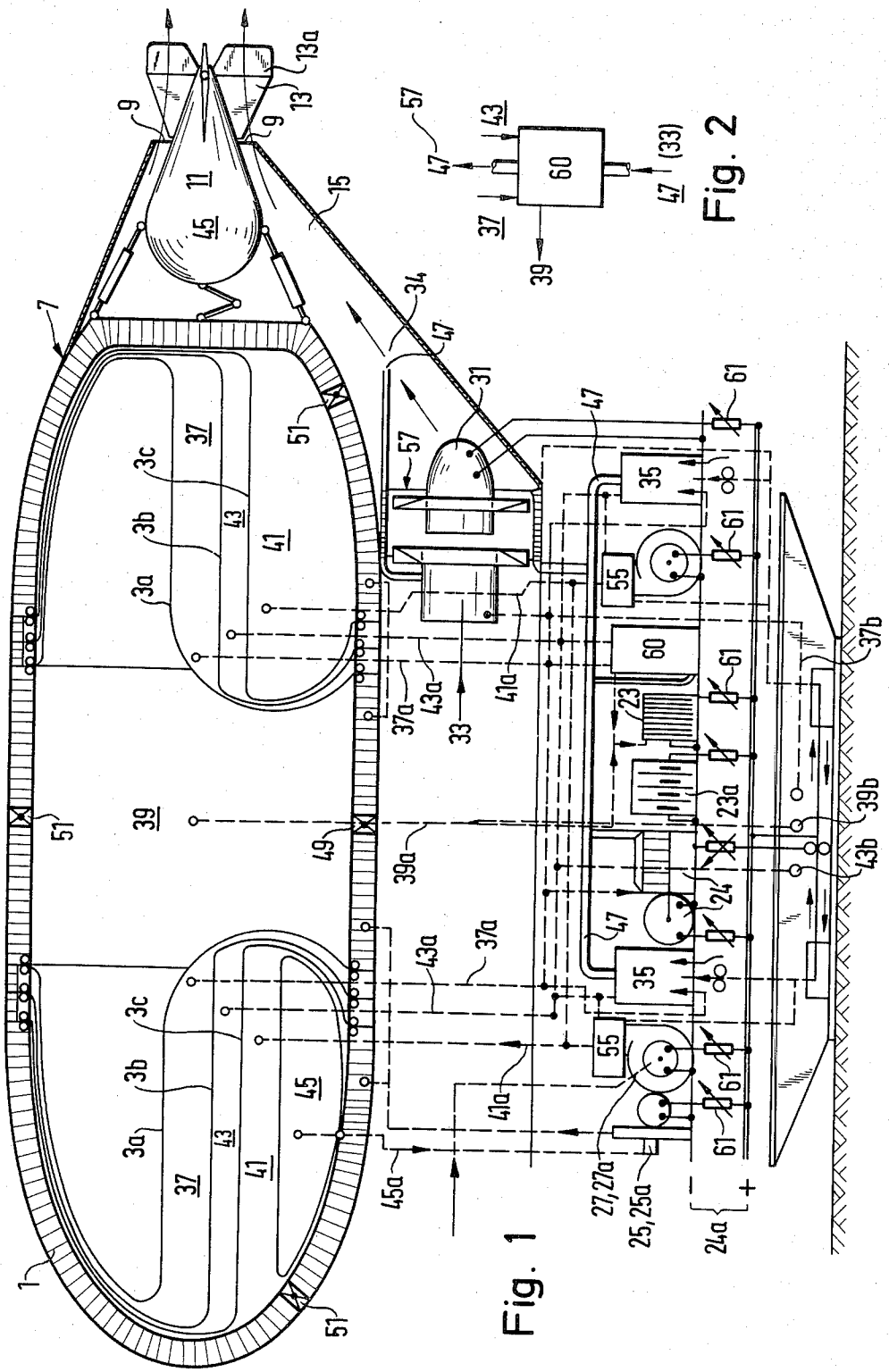

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Fig. 1

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Fig. 2

METHOD FOR OPERATING AIRSHIPS, PARTICULARLY BY MEANS OF HYDROCARBON GAS OR HYDROGEN

This is a continuation of application Ser. No. 227,887, now abandoned, filed Feb. 22, 1972 as a continuation-in-part of application Ser. No. 119,335, now abandoned, filed Feb. 26, 1971.

This invention relates to a method for operating lighter-than-air airships of the type which employs substantially natural gas and/or hydrogen both as the lifting or buoyancy means and also as the fuel for the power supply of the airship for the purpose to avoid the necessity of carrying additional solid or liquid fuels for generation of motion energy.

A proposal which has already been known for quite some time (Giffard **1855,** Paris) concerns a steam-driven airship the lifting body of which is filled with illuminating (coal) gas. The proposal contemplates providing the heat for the steam engine with coal and compensating for the loss in weight which occurs as a result of the use of the coal by burning appropriate amounts of the lifting illuminating gas.

It has been also proposed in U.S. Pat. No. 3,456,903, the disclosure of which is incorporated by reference, to consume natural gas in similar combination with Diesel oil for the power supply of the airship.

Another proposal contemplates using natural gas as buoyancy means and carrying water as additional ballast and vaporizing said water for compensation of the loss of buoyancy by burning the natural gas for power supply.

Due to this proposal, however, the additional water ballast reduces the lift of the airship from the beginning of a lift, thus also reducing the available lift for transport of goods.

In recently built dirigibles with helium as the lifting gas, to compensate for the loss in weight in liquid fuel resulting from the operation of the driving means the water was condensed from the waste gases of the internal-combustion engine, in order to produce ballast and to reduce the lift and thus reduce the otherwise necessary draining of expensive helium or hydrogen. The actual lift being available for transport purposes on a flight crossing the atlantic was about 15 metric tons, while the weight of the fuel including the weight of the container for the fuel was about 60 metric tons.

As far as it is also known (Zeppelin LZ 127) to use gaseous fuel for combustion engines such fuel is heavier than air and does not effect any positive effect on the buoyancy.

The purpose of the present invention is to eliminate the necessity of solid or liquid fuel and of any additional ballast, either. Thus, the airship of the invention is intended to avoid loss of free transport weight capacity or — from another view — can be built with reduced volume of buoyancy. Furthermore, it is another object of the invention to reduce the danger of fire by accidental burning of liquid fuel, which fuel normally would burn from the bottom of the airship while any used inflammable buoyant gas will burn over the head of any cabin in a direction less dangerous for passengers.

It is known from a photographic picture of the accident of the airship Hindenburg at Lakehurst in **1937** that most of the passengers could be rescued because of this fact while the rest of the passengers died because

of the burning Diesel fuel flowing out of the destroyed fuel tanks after heavily touching the ground.

Inflammable gases when used in an airship are not as much dangerous as generally believed, as long as such gases are under some pressure and are enclosed in a zone of noninflammable protection gas, because of the effect of flame out. The environed protection gas should be lowly heat conducting like carbon dioxide, nitrogen or argon and under a somewhat increased pressure in comparison with the buoyant gas. Also by way of this increased pressure the envelope of the airship can be built double walled; reference is made to U.S. Pat. No. 3,456,093.

Accordingly, the invention is characterized broadly in that the reduced lift resulting from use of the lifting gas is restored at least partially by gas which is obtained through the chemical transformation of the lifting gas or of components thereof. The obtained gas either specifically or with respect to its volume has at least the same total of buoyancy as the consumed original gas, i.e., in this way it is possible to maintain the total lift of the airship constant or even to increase it, which also makes it possible that with the gas which is obtained in the transformation the buoyancy effect, which differs according to the flying elevation of the airship, can be adjusted or altitude-stabilized through use of corresponding different portions of the transformed gas.

Such transformation can be accomplished by separating water from the exhaust gas of means for burning natural gas for instance driving combustion engines, heating apparatuses or even steam generating apparatuses and reheating and revaporizing said water preferably by use of the excess heat of said converting means. The generated steam, then, is transferred to the buoyancy chambers of the airship.

According to the invention the transformation of the natural gas can be accomplished by chemically breaking it down in the presence of water vapor in order to produce hydrogen gas to be employed partly for compensation of buoyancy and partly for the operation of fuel cells and other electric means. The transformation can be performed prior to starting the airship as well as during the flight.

According to the invention the specific overall buoyancy volume per weight to be transported can be surprisingly reduced because any additional lifting force for the motion fuel is avoided. Also the weight for the construction of the fuel containers is not necessary any more. Thus, the overall volume of the airship of the present invention only depends on the weight of its specific construction and on the desired capacity for transport weight.

If, for example, we proceed from the combustion of methane heated to 100°C by way of saturated water vapor being contained in chambers contacting the cells containing the methane and if we replace step by step its lifting volume having a lifting force of 0.77 kg/m^3 in environed air of 0°C by water vapor of approximately the same temperature having a lifting force of 0.695 kg/m^3, then we require for constant lift for 1 volume of methane approximately one quarter more of water vapor. For substitution of the natural gas by water vapor with respect to constant lifting force only 62.5% of the water component gained by the cleavage process is needed. In replacing the volume of natural gas the water vapor by way of its one-quarter excess volume replaces also an adequate volume of heated air being

provided in the compensation cells. Thus, by loss of the replaced heated air, having for instance a temperature of 100°C and a lifting force of 0.35 kg/m³, which loss increases because of expansion of the air with increased altitude of the flight, the airship maintains a definite altitude. With increasing replacement of air by vapor the lifting force increases and vice versa. Thus, in order to stabilize the altitude of the flight, it is one principle of the invention that the lift of consumed original gas is substituted by water vapor replacing with its increased volume an adequate volume of warm air being contained in the compensation cells.

The delivery of warm air from the compensation cells, which delivery, depending on the more expansion of the gases with increased altitude, is about 10% per kilometer, has to be restored if the airship decreases. In order to perform a stabilized flight without dropping ballast weight this restoration of lifting force is accomplished by taking into the compensation cells an adequate amount of air and heating it up to for instance 100°C, for which heating preferably the excess heat of the combustion engines is used.

Furthermore, according to the invention it is contemplated to employ a portion of the hydrogen produced by the cleavage process of the buoyant natural gas after removing the carbon dioxide for oxidation in fuel cells to generate electric power by means of which electric motors of the main blowers for driving the airship and of auxiliary equipment is supplied. If the electrically driven blowers are equipped for normal flight speed in time of top power circumstances additional combustion engines having a relatively light specific weight can be used.

The necessary power for driving the airship can be remarkably additionally reduced if the principle of removing the boundary layer by suction is applied or the outer surface of the keel of the airship; see U.S. Pat. Nos. 3,319,593, 3,410,510, 3,348,622 and 3,435,654. The airship is also covered by a foil of aluminum having a hydrophobic surface layer of fluoro carbon resins (U.S. Pat. application Ser. No. 808,636) which layer keeps the air flow along the airship in laminar condition and the friction low. By use of these principles the consumption of natural gas for driving purposes is reduced and an adequate excess volume of the buoyancy can be filled with other buoyant gases, like for instance helium or hydrogen, which do not need to be changed or converted.

The method according to the invention can also be performed if the saturated steam has another temperature than the natural gas. For instance, the lifting force of natural gas at a temperature of 57°C is the same as of water vapor at 100°C. Under such conditions also the volume of the natural gas to be replaced by vapor is the same as of the vapor and it is not anymore necessary to remove an excess of warm air from the compensation cells in the course of the change of water vapor for natural gas, constant altitude provided. By way of this effect the interchangeability of the gases can be controlled over a wide range of temperature and the energy of the gases can be used more effectively.

By conversion of 1 mol of methane aside from the carbon dioxide the volume of the produced water-component is twice the methane volume (2 mol) due to the equation

$$CH_4 + 2O_2 = CO_2 + 2H_2O \quad (1)$$

In the preferred embodiment of the method according to the invention the natural gas or any other hydrocarbon gases gained from natural oil, especially methane, is cleavaged in the presence of water vapor by partial oxidation into gaseous hydrogen, whereby an increased volume of gas is achieved. This conversion is performed by two main steps of the following reactions which are in general already known from the production of synthetic fertilizers:

$$CH_4 + H_2O = CO + 3H_2 \quad (2a)$$

$$CO + H_2O = CO_2 + H_2 \quad (2b)$$

$$CH_4 + 2H_2O = CO_2 + 4H_2 \quad (3)$$

The carbon dioxide component can be freezed out although its diminishing effect on the lifting force is only about 10% of the hydrogen heated at 100°C being contained in the buoyancy chambers. Thus, separation of the carbon dioxide is not compulsory and any additional equipment can be omitted.

For performance of reaction (3) rain water collected from the outer surface of the airship can be used.

The necessary water can be obtained also from the exhaust gas of burned natural gas along (1) of the following reactions:

$$CH_4 + 2O_2 = CO_2 + 2H_2O \quad (1)$$

$$\underline{CH_4 + 2H_2O = CO_2 + 4H_2} \quad (3)$$

$$2CH_4 + 2O_2 = 2CO_2 + 4H_2 \quad (4)$$

Thus, the lifting force of 1.5 kg of the consumed 2 m² CH_4 having a temperature of 100°C the produced 4 m³ H_2 at 100°C have a lifting force of 4.9 kg after reduction by the additional weight of 0.4 kg of the produced 2 m³ CO_2 (at 100°C). The gained new lifting force after conversion of the gases is about: 4.5 kg − 1.5 kg = 3 kg. Due to the remarkable increase of lifting force two third of the produced hydrogen may be used for other than buoyant purposes. According to reaction (3) by the use of water vapor already existing as buoyant gas a new lifting force of 2.75 kg is also gained.

This transformation which is given in the example and which occurs primarily in natural gas (i.e., the transformation of methane) is similarly valid for other hydrocarbons according to the invention, for example:

$$C_8H_{18} + 8H_2O = 8CO + 17H_2 \quad (5)$$

$$8CO + 8H_2O = 8CO_2 + 8CO_2 \quad (6)$$

$$C_8H_{18} + 16H_2O = 8CO_2 + 25H_2 \quad (7)$$

The supply for reaction (7) can be performed by taking up a storage of gaseous hydrogen at a natural oil well. Similar to the conversion of methane the reactions (5) (6) and (7) can be performed in presence of catalysts like for instance chromium oxide and zinc oxide or nickel oxide or the like.

The saturated water vapor serves as a supply source for heating the buoyant gases constantly at or close to 100°C whereby the vapor is partly condensed. By heating the gaseous hydrogen the increase of lifting force is only 27 g/m³, however, the volume of the hydrogen increases to the 1.367-fold. Thus, one cubic meter having a weight of 0.089 kg at 0°C after being heated to 100°C is able to substitute 1.767 kg air (1.367 × 1.293 = 1.767) and the increase of lifting force resulting from that replacing the air is from 1.21 kg to 1.678 kg at height above sea level (760 mm air pressure).

Due to the consumption of water from ballast according to the abovementioned reaction (3) an additional amount of lifting force is obtained and the overall increase in lifting force by conversion of one cubic meter natural gas at 100°C is even (4 × 1.23) + (2 ×

0.598) − 0.77 = 5.34 kg, without consideration of the carbon dioxide.

The necessary heat consumption for the above-mentioned reaction (3) is preferably covered by the excess heat of the combustion engines.

It has to be mentioned that by use of the saturated water vapor the buoyant gases can be maintained even at a less high temperature if the saturated water vapor is mixed with other gases. In such mixtures of gases the partial pressure of the saturated water vapor can be varied. For instance at a partial pressure of 92.5 mm mercury column or 0.083 kg/m^3 the saturated condition of the water vapor exists at a temperature of 50°C.

The main advantage of the method according to the invention is that the buoyant gas can be used for driving the airship without need for any solid on liquid fuel or additional ballast to compensate the consumption of the fuel buoyant gas. Consequently the airship operated in accordance with the invention can have a remarkably reduced overall volume or an adequately increased capacity of lifting force available for transport purposes.

The invention will be further understood from the following more detailed description taken with the drawing in which:

FIG. **1** is a schematic vertical sectional view of an airship driven according to the invention and having several separate chambers or cells within its body and a frame structure, indicated with dashed lines, within which all of the necessary equipment for the operation of the airship is installed as illustrated by means of an enlarged schematic: and

FIG. **2** is a partial schematic representation of the catalyzer reactor of FIG. **1.**

The airship which is shown in FIG. **1** has a foldable pressure airship hull **1** with properties which are as highly heat insulating as possible, in particular against heat losses from the inside of the airship to the atmosphere and, for example, with a construction according to U.S. Pat. No. 3,456,903. Inside of the chamber **39** which is encompassed by the double-walled pressure airship hull **1** there are one or more separating intermediate walls **3***a*, **3***b* and **3***c* which can be turned inside out within the airship hull and which are composed preferably of flexible material. Individual walls thereof can also be constructed as being heat insulating. These separating intermediate walls are preferably arranged symmetrical to the airship center.

The separating intermediate walls **3***a*, **3***b* and **3***c* subdivide the chamber **39** into chambers **41** which are separated from one another and which are equipped for cold air or heated air, for example by means of inlet and outlet connections **41***a*, and are used as lift compensating cells according to U.S. Pat. No. 3,456,903 the disclosure of which is incorporated here by reference. Chambers **43** are filled with water vapor under saturation vapor conditions (100°C) at least in the proximity of the wall. These chambers have an inlet and outlet connection **43***a*. Based on the invertible gas-tight separating intermediate walls the volumes in the chambers **41** and **43** are extraordinarily greatly changeable either in reciprocal dependence or at the cost of the free volume of the chamber **39** and, in all practice, to such an extent that the separating intermediate walls touch each other mutually in the longitudinal center of the airship and the volumes of the chambers **41** and **43** completely fill out the volume of the chamber **39.** This is correspondingly valid when, additionally to the chambers **41** and **43** through the separating intermediate walls **3***a* there are also provided separated chambers for impellent gases, preferably gases which produce lift, such as for example natural gas, methane (CH_4) or similar. Optionally, hydrogen can also be contained in these chambers. These chambers have an inlet-outlet connection **37***a*.

The centrally located chamber **39** contains very general lifting gases, for example also hydrogen (H_2) or other lifting gases including gas mixtures (even water vapor/gas mixtures) and has inlet-outlet connections **39***a* and **39***b*. The handling of water vapor or water vapor/gas mixtures is accomplished within the heat-insulated tight airship hull according to U.S. Pat. No. 3,456,903.

The chambers **39, 37, 41** and **43** are preferably filled symmetrically to the longitudinal center of the airship, but an asymmetric filling can also be provided for the purpose of trimming the airship. In addition, there can also be provided a so-called "ballonet" or storage chamber **45** for protective gas which is used preferably for filling the intermediate space of the double walled pressure hull. This chamber **45** has an inlet-outlet connection **45***a*. As protective gas one can use carbon dioxide (CO_2) and/or nitrogen (N_2) and also air, which are preferably dried.

The filling of the chamber **39** with combustible lifting gas, for example natural gas or methane (CH_4), is done by means of inlet and outlet connection **39***a*, **39***b* through a control valve **49** which is provided in the pressure airship hull **1.** In order to prevent damage from excess pressure the airship hull has preloaded outlet relief pressure valves **51.** Water vapor can also be filled in directly from the outside through the inlet connection **43***b* into the chamber **43,** whereas the chambers **37** can be filled with hydrogen gas through the inlet connection **37***b*. The inflammable lifting gas (CH_4) from the chambers **39** and/or **37** is converted to hydrogen successively in the amount of the required power, for example in the catalysis apparatus **60,** and the water which thereby is created is fed through waste gas pipes **47** to water vapor producers **35** and heated there before it is fed into the chambers **43.** The apparatus **60** may employ chromium oxide/zinc oxide or nickel oxide as the catalyst. The hydrogen which occurs during the transformation is fed to a fuel cell device **23** and **23***a* which also has storage batteries for the purpose of creating electrical power and which is started centrally from a control station **24** and for example by means of regulators (speed-controlling devices **61**) which is connected into the central electrical lead pipe **24***a*. The electrical connections belonging to the control devices **61** for speed and capacity control of the electrical motors are shown in FIG. **1** as short-dashed lines.

The main propulsion for the motion of the airship is provided by a double-staged main blower **33** which preferably can be driven by combustion motors or gas turbines, for which purpose the inflammable lifting gas which is contained in the chamber **39** is used as fuel. The airship moves by means of the forcing out of air from an annular nozzle **9** of a main nozzle **11** provided on the rear of the airship, whereby the propelling air is fed through a connection **34** into a channel **15,** as disclosed in U.S. Pat. No. 3,456,903 the disclosure of which is incorporated by reference. The airship assem-

bly **13** with steerable rudders **13***a* is connected to the cone **45** of the ring-slot nozzle **13***a*. An auxiliary blower **31** is used for propelling the airship during slow travel or normal travel.

A small blower **25** with electrical motor **25***a* is also provided which is used for maintaining the protection gas pressure in the intermediary space of the double walled pressure hull **1**. Another blower **27** with electrical motor **27***a* fills the chamber **41**.

Finally there are also heat exchangers **55**, the connecting leads of which are however not represented in detail, as well as a device **57** for condensing water vapor preferaby of water components contained in the exhaust gas. In these devices **57** parts are also appropriately contained which can remove the carbon dioxide (CO_2) from the converted gas.

According to the schematic representation of FIG. **2** the reaction heat which is released from the catalytic conversion of natural gas or methane to hydrogen can be used for the production of water vapor. This can also be achieved preferably together with the heat transfer from exhaust gas heat.

The exhaust gases can be fed to the channel **15** so that they can also be used for the lifting power of the airship.

With the above-mentioned devices the utilization of the inflammable gases used at the starting, therefore above all natural gas or methane (CH_4) or even hydrogen gas, can be obtained in the most varied manners in which they are taken from the chamber **39** (or **37**) and converted to replace the loss of lifting power by means of those exhaust gas components which themselves provide a usable lift, i.e., hydrogen gas and above all water vapor. This is possible in the most diverse variations so that in the figures by far not all of the possibilities are shown. In this way the lifting force can be regulated on a practically continuous basis by controlling the different lifting forces.

What is claimed is:

1. A method of operating an airship which is maintained buoyant in air by an original lifting gas which is inflammable and which is lighter than air, said method comprising carrying said original lifting gas in said airship as the sole fuel for generating driving power for the airship, consuming at least a part of the original lifting gas as fuel for supplying driving power for use by the airship thereby effecting a reduced buoyancy of the airship and restoring the reduced buoyancy by chemically converting a portion of the original lifting gas to a different gas species which has at least the same buoyancy effect as the gas which was consumed for supplying power and storing said gas species whereby all said lifting gas may be used for power production while maintaining buoyancy.

2. A method as in claim **1** wherein the original lifting gas contains a hydrocarbon and wherein the gas species obtained by chemically converting a portion of the original lifting gas includes at least one of water vapor and hydrogen, said method further including feeding at least a portion of said gas species to a gas bag which is separate from the original lifting gas.

3. A method as in claim **1** wherein the step of chemically converting includes combustion of at least a portion of the original lifting gas to produce heat and a combustion gas which includes water vapor, said method further including condensing the water vapor from the combustion gas, reconverting the condensed water to water vapor with the heat obtained from said combustion, and feeding a portion of the reconverted water vapor to a gas bag maintained separate from the original lifting gas.

4. A method as in claim **3** including thermally insulating said gas bag from the atmosphere.

5. A method as in claim **1** wherein the original lifting gas contains a hydrocarbon and wherein the step of chemically converting includes catalytically converting the hydrocarbon in the presence of water vapor to hydrogen, carbon monoxide and carbon dioxide.

6. A method as in claim **1** wherein the step of chemically converting produces hydrogen, said method further including generating electrical energy with the hydrogen in fuel cells and propelling the airship with blowers operated by the electrical energy.

7. A method as in claim **1** wherein the original lifting gas is methane and wherein the step of chemically converting includes reacting the methane with water vapor to produce carbon dioxide and hydrogen.

8. A method as in claim **1** wherein the original lifting gas contains a hydrocarbon and wherein the step of chemically converting is carried out prior to take-off of the airship and produces at least one of water vapor and hydrogen.

9. A method of operating an airship substantially without need for liquid or solid fuel for motive energy, the airship employing as a lifting medium an original buoyant gas including a hydrocarbon as a portion of the lifting medium, said method comprising: carrying said original buoyant gas in said airship as the sole fuel for generating driving power for the airship, chemically reacting at least a portion of the hydrocarbon with a reactant to generate power for operating the airship and to produce a buoyant reaction product which includes a gas selected from at least one of water vapor and hydrogen, and compensating for reduced buoyancy resulting from the chemical reaction by taking the original buoyant gas from one chamber containing the same and storing said buoyant reaction products in gaseous condition in separate buoyant gas chambers.

10. A method as in claim **9** wherein the hydrocarbon is methane, wherein the reactant is oxygen and wherein the step of chemically reacting includes the step of reacting the methane with the oxygen to produce carbon dioxide and water.

11. A method as in claim **9** wherein the hydrocarbon is methane, wherein the reactant is water vapor and wherein the step of chemically reacting includes reacting the methane with the water vapor to produce carbon dioxide and hydrogen.

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