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(54) **MOBILE GASEOUS AND LIQUID HYDROGEN REFUELING APPARATUS**

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(57) **ABSTRACT**

Disclosed is a mobile gaseous and liquid hydrogen refueling apparatus including a main storage module configured to receive liquid hydrogen from a tank lorry and to generate first gaseous hydrogen from the liquid hydrogen, a liquid pumping and transportation module configured to receive the liquid hydrogen from the main storage module, to generate second gaseous hydrogen from the liquid hydrogen while pumping the liquid hydrogen, and to deliver the second gaseous hydrogen to the main storage module, and a gas compression and storage module configured to receive at least one of the first gaseous hydrogen or the second gaseous hydrogen from the main storage module, to compress the at least one gaseous hydrogen, and to store the compressed gaseous hydrogen.

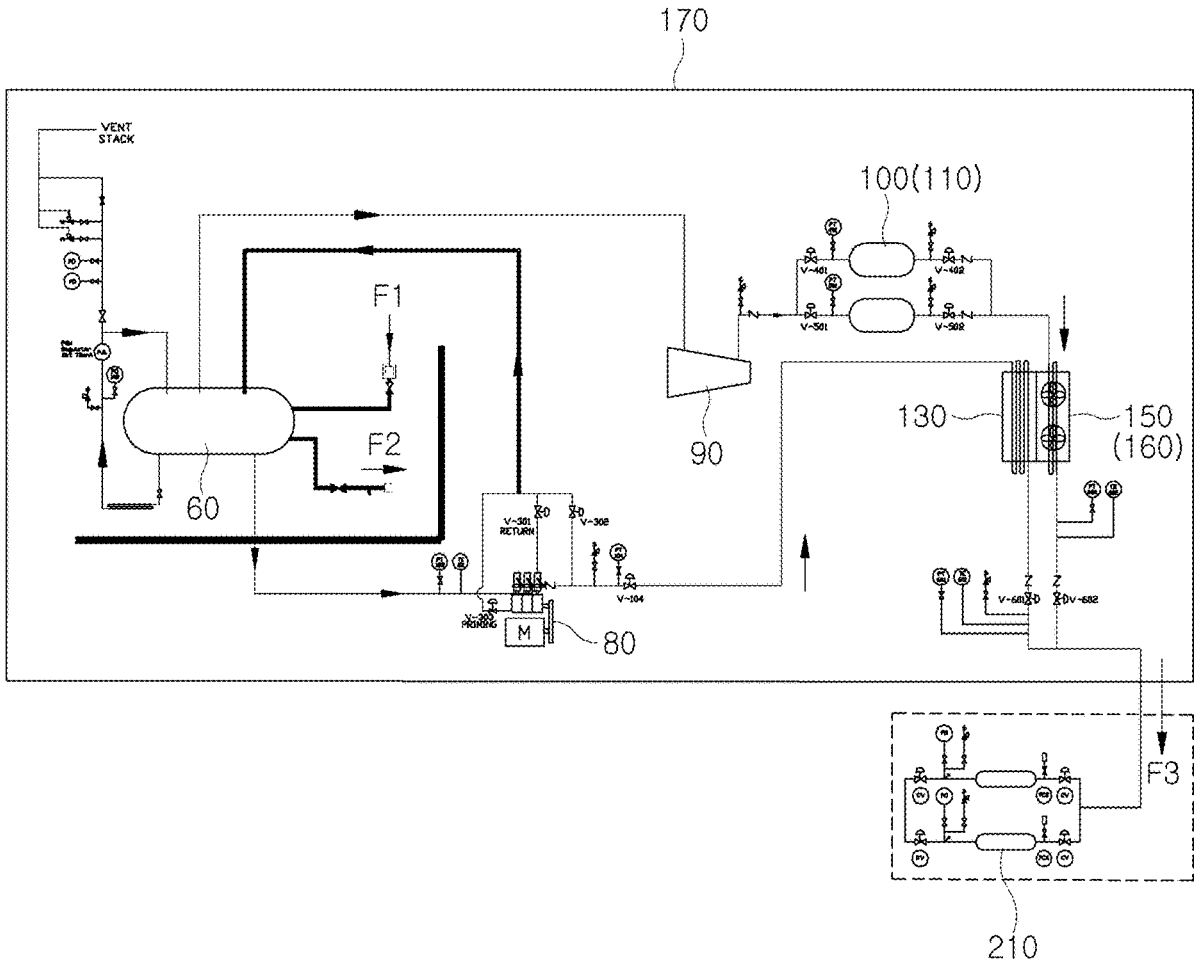


FIG. 1

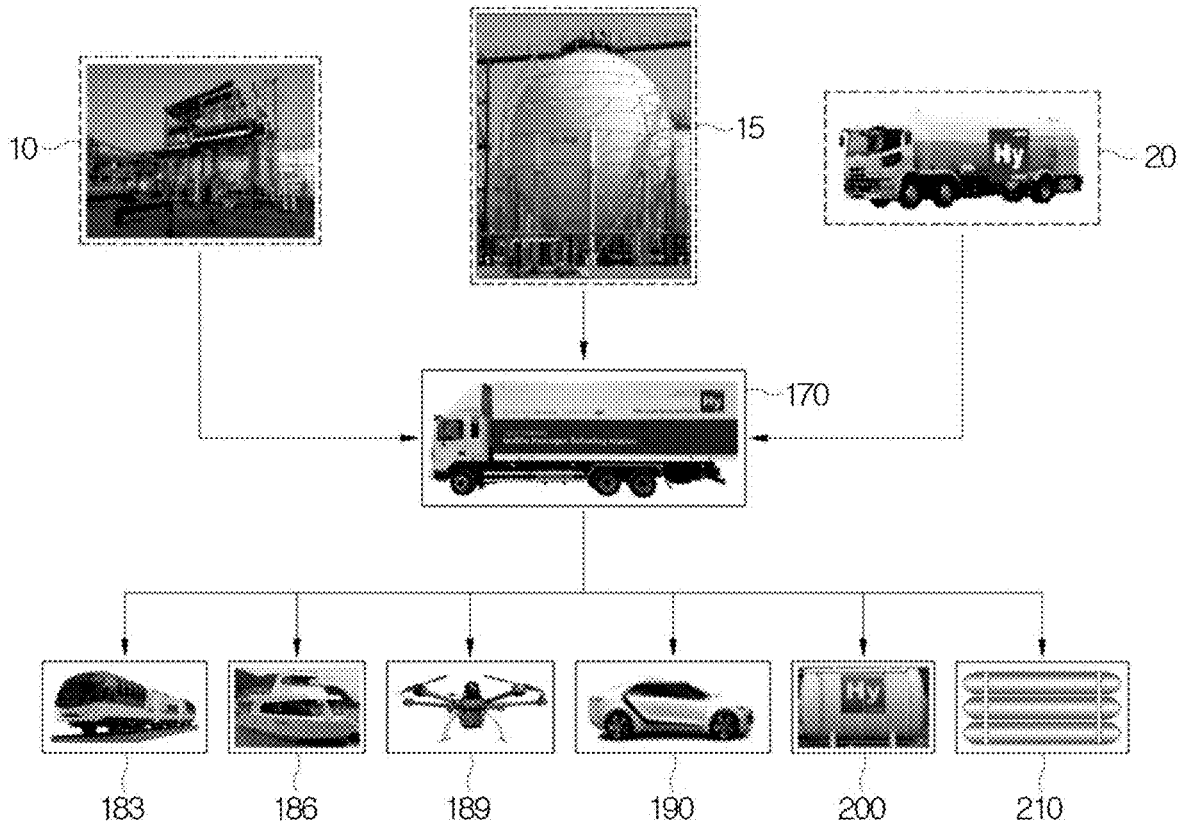


FIG. 2

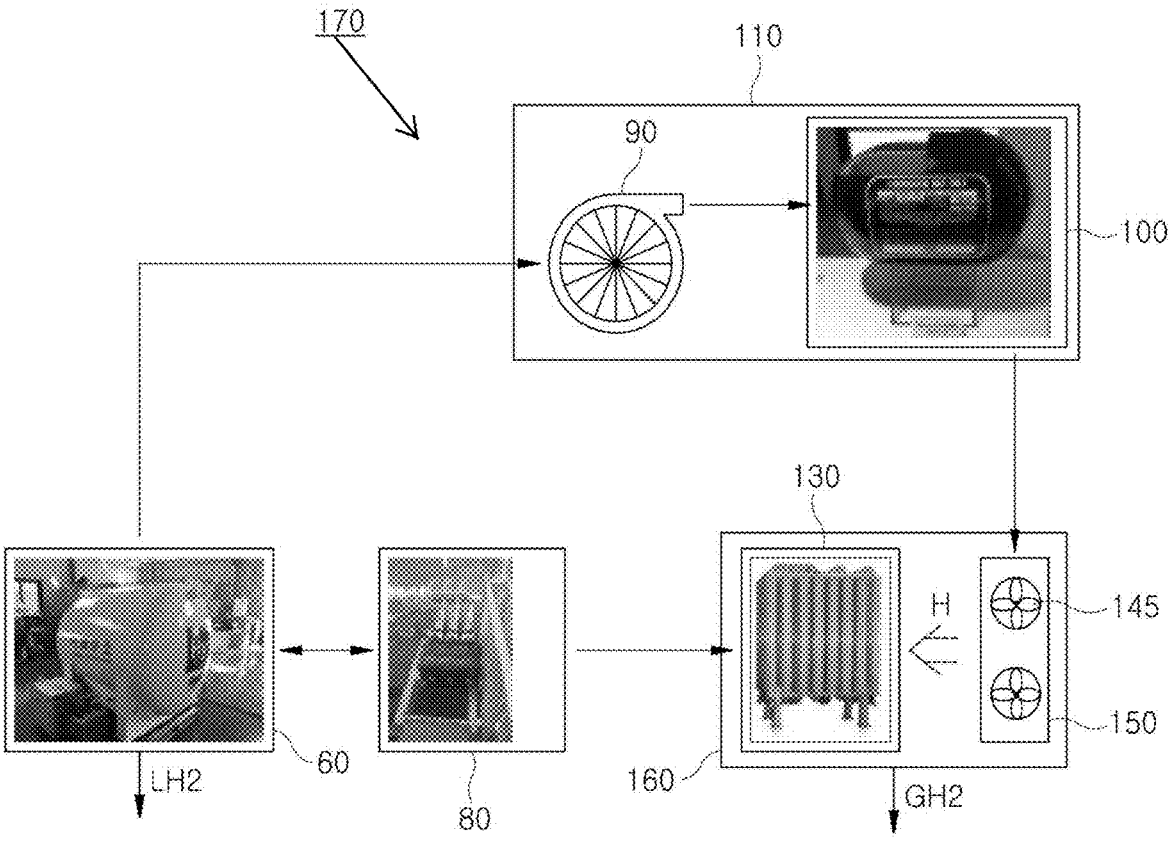


FIG. 3

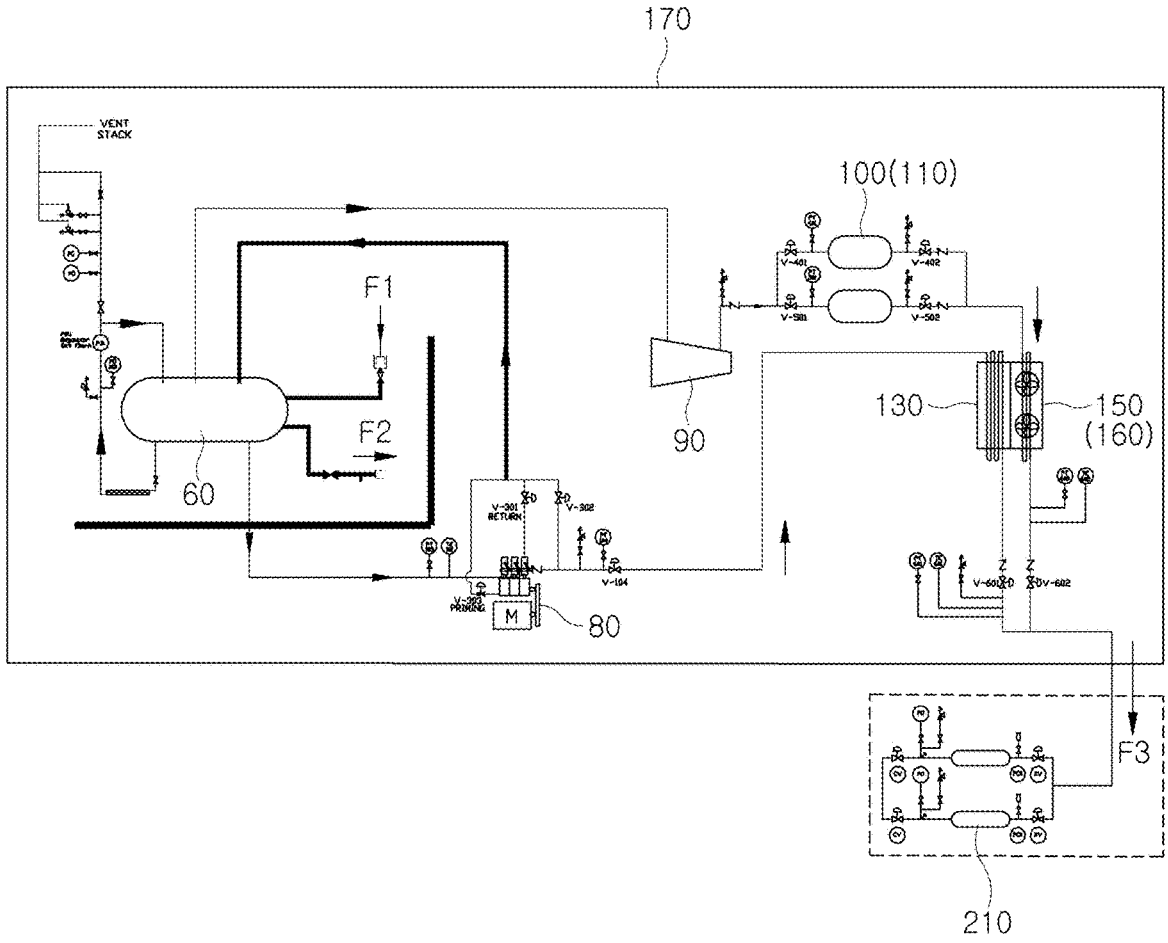


FIG. 4

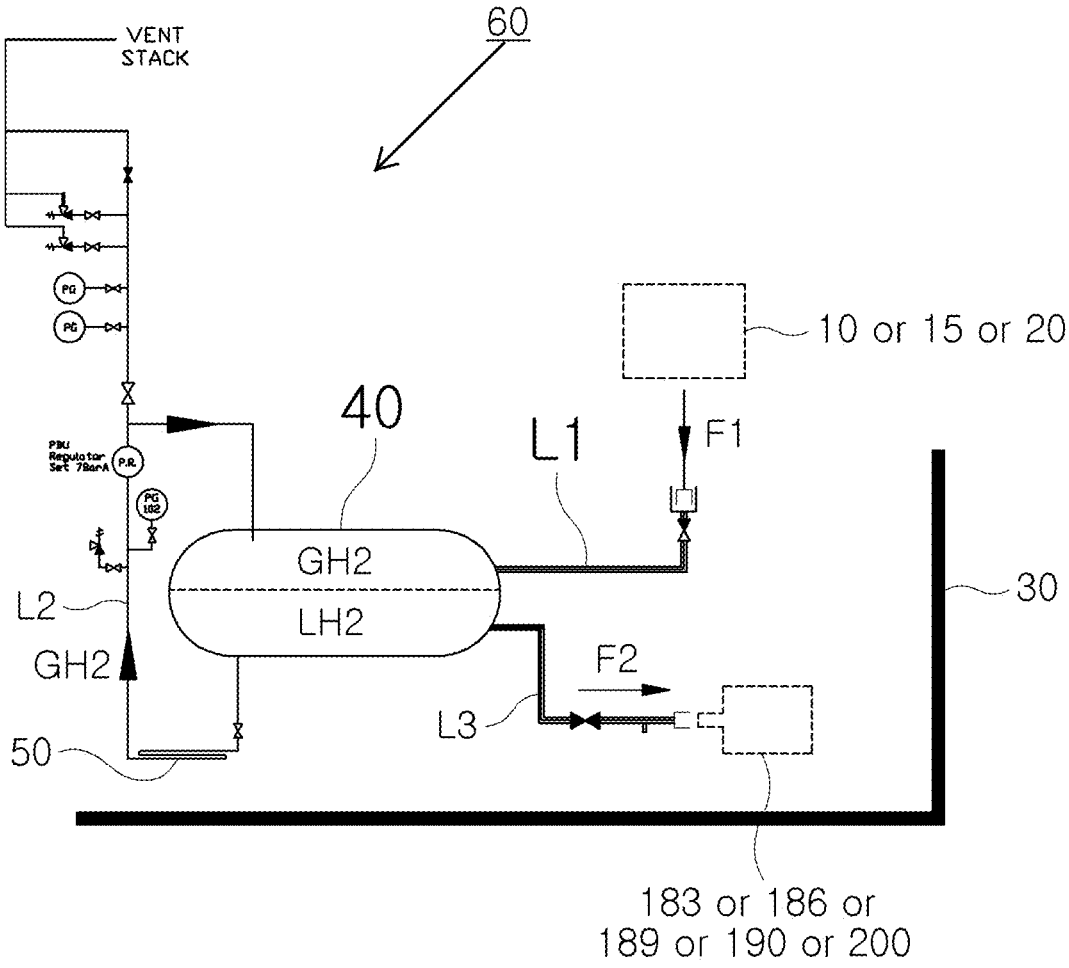

60
VENT
STACK
10 or 15 or 20
40
L1
F1
GH2
LH2
L2
GH2
30
F2
L3
50
183 or 186 or
189 or 190 or 200

FIG. 5

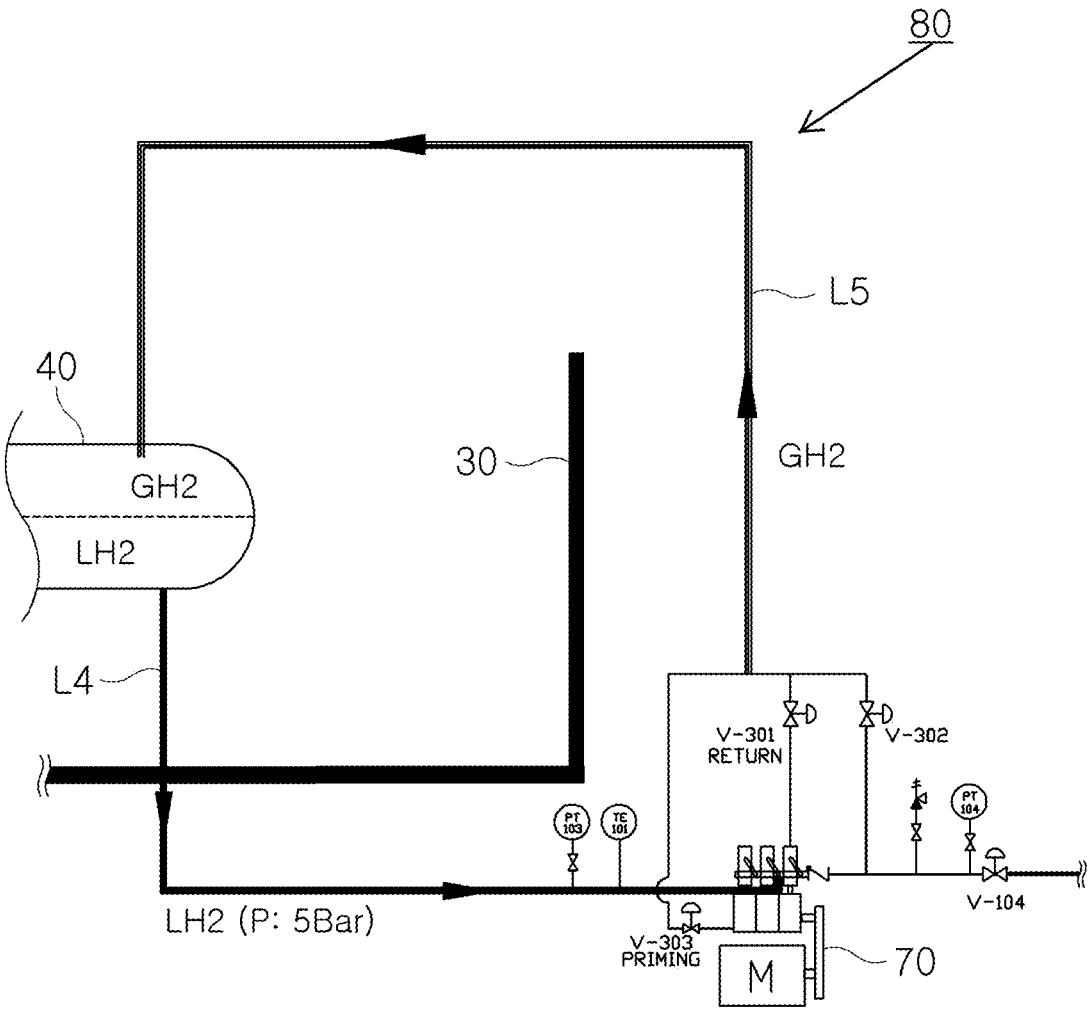

80
L5
40
30
GH2
GH2
LH2
L4
V-301
RETURN
V-302
PT
103
TE
101
PT
104
V-104
LH2 (P: 5Bar)
V-303
PRIMING
M
70

FIG. 6

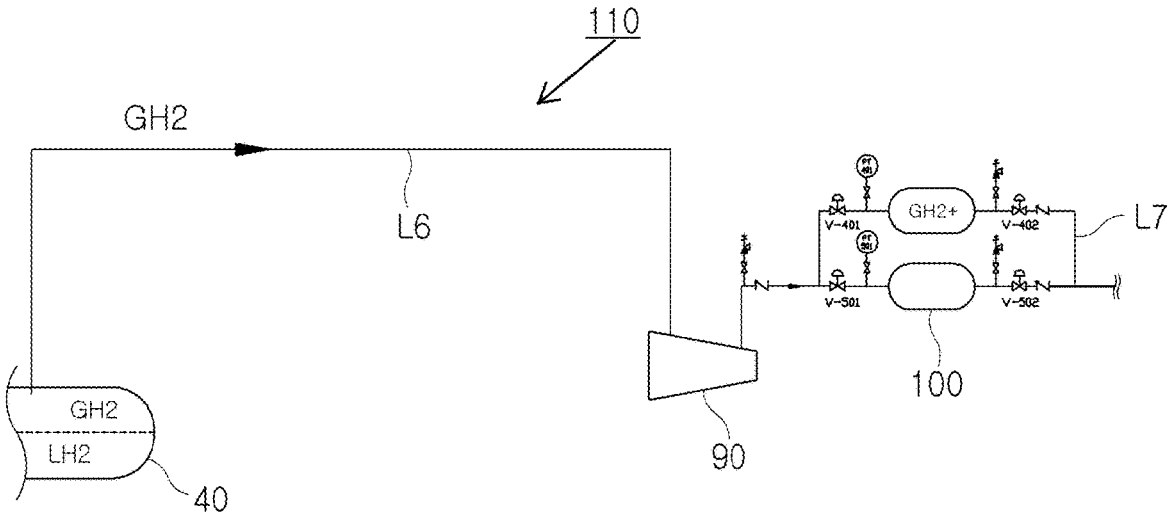

110
GH2
L6
GH2+
L7
V-401
V-402
V-501
V-502
100
GH2
LH2
40
90

FIG. 7

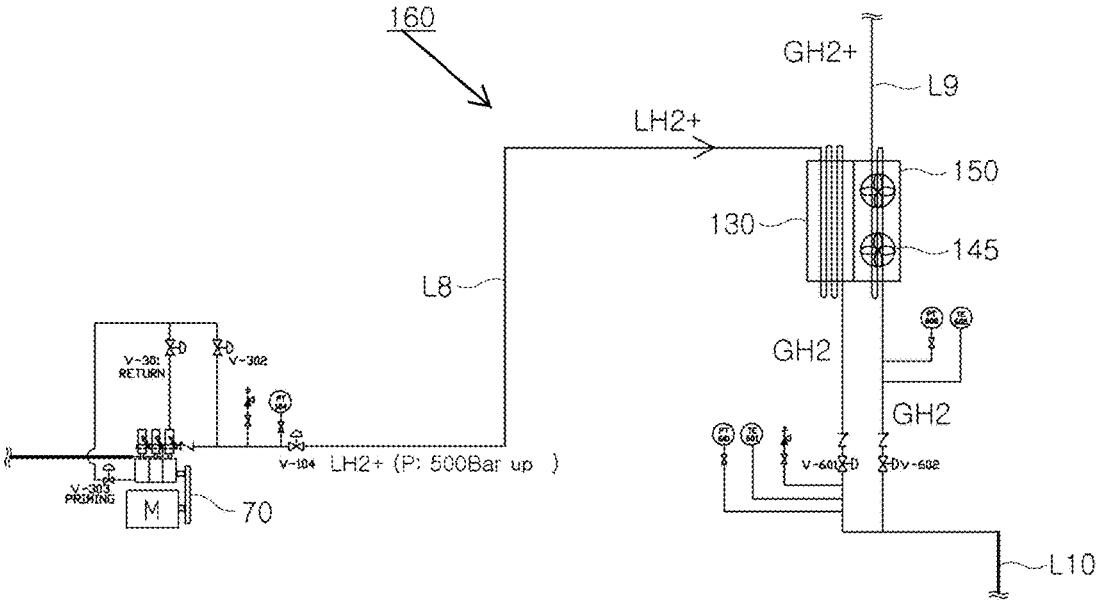

160
GH2+
L9
LH2+
150
130
145
L8
GH2
GH2
V-301
RETURN
V-302
V-104 LH2+ (P: 500Bar up)
V-303
PRIMING
M
70
V-601
V-602
L10

FIG. 8

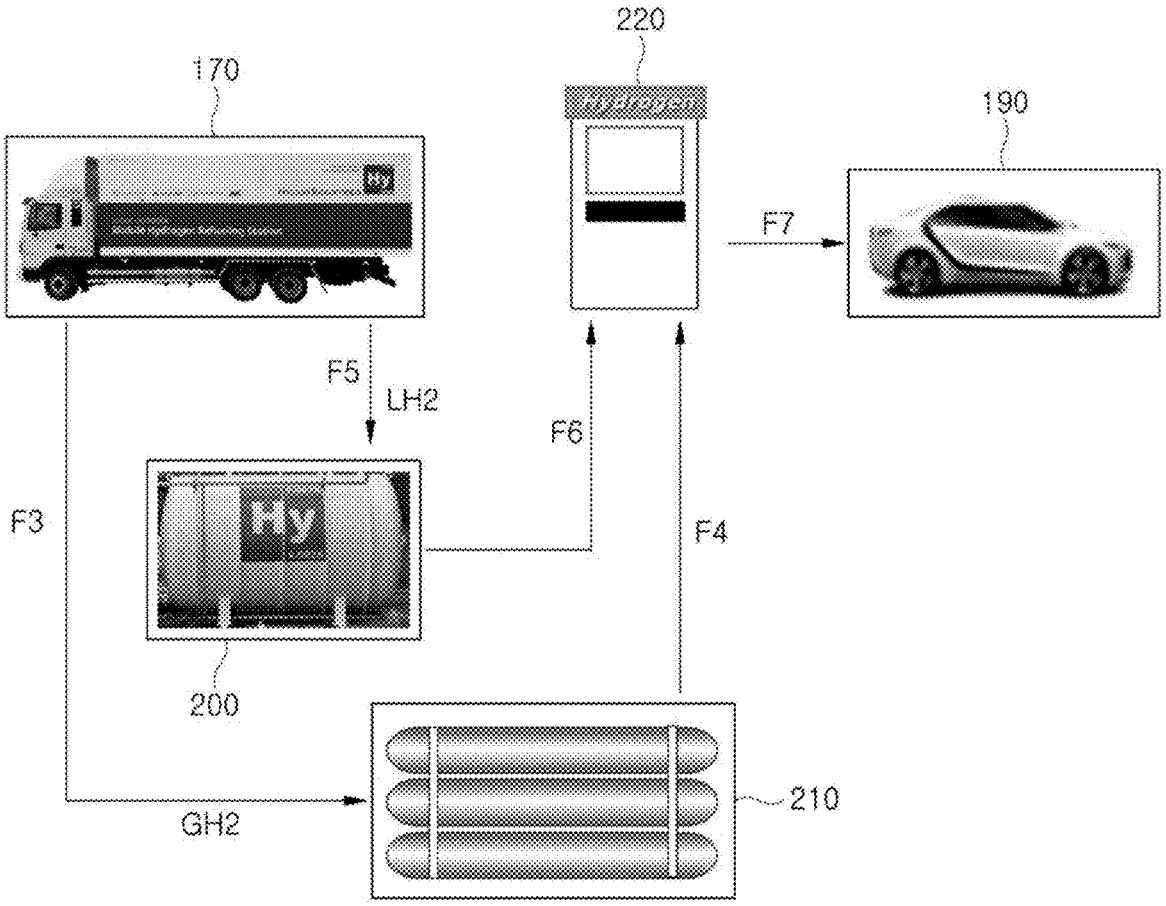
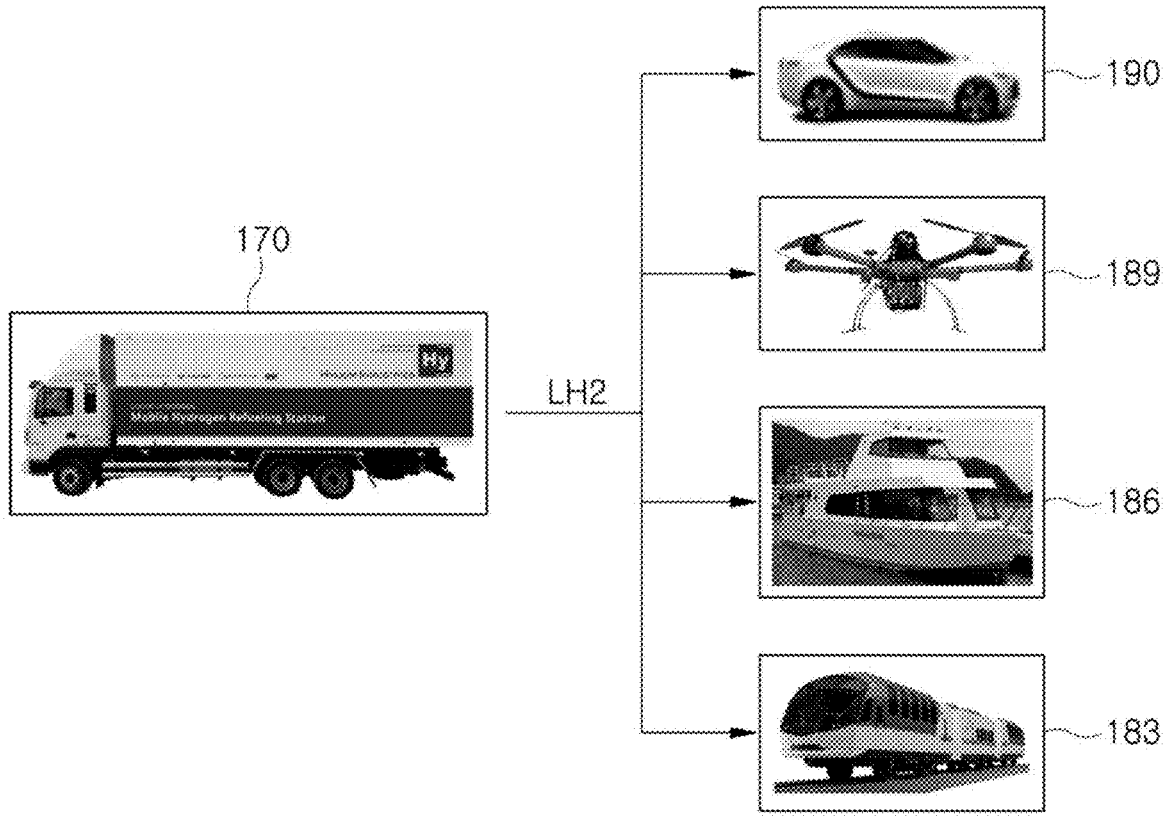


FIG. 9



MOBILE GASEOUS AND LIQUID HYDROGEN REFUELING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from Korean Patent Application No. 10-2019-0058695, filed on May 20, 2019, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the invention

[0002] The present invention relates to a mobile gaseous and liquid hydrogen refueling apparatus using a road in a hydrogen filling mode.

2. Description of the Related Art

[0003] As is generally known, hydrogen is an element that is the lightest and the most abundant among elements on earth. Specifically, hydrogen occupies 75% of the mass of the universe. Hydrogen is a resource that is capable of being obtained simply by electrolyzing water and is very environmentally friendly since hydrogen emits no pollutants.

[0004] In addition, hydrogen has advantages in that hydrogen has very high energy efficiency, and therefore energy efficiency per unit weight of hydrogen is the highest among all resources including competing resources, such as gasoline, diesel, propane, methane, and ethanol.

[0005] Hydrogen has high energy efficiency, as described above. Due to recent development of technology, therefore, hydrogen is produced at a production plant in the form of production raw materials (e.g. petroleum, coal, natural gas, liquefied petroleum gas (LPG), biofuel, and nuclear energy) and is transported to a point of use (e.g. a filling station, a building, a power plant, and a general house) in a gaseous state or in a liquid state.

[0006] Here, gaseous hydrogen has lower energy density per unit weight than liquid hydrogen (liquid hydrogen: 22 MJ/kg, gaseous hydrogen: 4.8 MJ/kg) and lower energy density per unit volume than liquid hydrogen (liquid hydrogen: 7.8 MJ/L (liter), gaseous hydrogen: 2.5 MJ/L (liter)). For these reasons, energy activation is limited in the case in which hydrogen is transported in a gaseous state.

[0007] Meanwhile, in a conventional hydrogen filling mode, hydrogen in a gaseous state (hereinafter referred to as "gaseous hydrogen") is compressed to high pressure by a compressor before being supplied to a point of use. As a result, temperature of the gaseous hydrogen increases due to normal temperature expansion thereof when the gaseous hydrogen is injected into a fuel tank. For this reason, a cooler capable of cooling the gaseous hydrogen to −40° C. is inevitably required.

[0008] The compressor and the cooler have high power consumption, and form a complicated structure together with structural components therearound. In addition, hydrogen in a liquid state (hereinafter referred to as "liquid hydrogen") needs a compressor capable of compressing the liquid hydrogen to high pressure together with an evaporator capable of converting the liquid hydrogen into a gaseous state before being supplied to a point of use.

[0009] In the aspect of use of the liquid hydrogen, however, the compressor is connected to the evaporator such that the liquid hydrogen is expanded and then compressed. As a result, components of the compressor and the evaporator easily corrode and suffer from a severe change in pressure, whereby the lifespan of the components is shortened. In addition, stability of the compressor and the evaporator is reduced due to high pressure, and therefore merits in use of the liquid hydrogen are deteriorated.

[0010] A mode of filling the gaseous hydrogen is similarly disclosed in Korean Patent Application Publication No. 10-2017-0066587 entitled HYDROGEN STATION as a conventional art. A mode of filling the liquid hydrogen is similarly disclosed in Korean Patent Application Publication No. 10-2019-0031386 entitled HYDROGEN FILLING APPARATUS as a conventional art.

SUMMARY OF THE INVENTION

[0011] The present invention has been made in view of the above problems, and it is an object of the present invention to provide a mobile gaseous and liquid hydrogen refueling apparatus that is capable of increasing pressure of liquid hydrogen in a main storage tank without using a compressor, whereby it is not necessary to use electric power due to an increase in pressure, that is capable of activating a connection relationship between the main storage tank and a hydrogen fuel consumption structure (e.g. a hydrogen fuel flight means, a hydrogen fuel land and sea movement means, or a hydrogen fuel industrial power generation house facility), and that is suitable for positively using a byproduct of liquid hydrogen in order to convert liquid hydrogen into gaseous hydrogen.

[0012] In accordance with the present invention, the above and other objects can be accomplished by the provision of a mobile gaseous and liquid hydrogen refueling apparatus including a main storage module configured to receive liquid hydrogen from a hydrogen liquefaction plant, a liquid hydrogen storage and distribution tank, or a tank lorry and to generate first gaseous hydrogen from the liquid hydrogen, a liquid pumping and transportation module configured to receive the liquid hydrogen from the main storage module, to generate second gaseous hydrogen from the liquid hydrogen while pumping the liquid hydrogen, and to deliver the second gaseous hydrogen to the main storage module, a gas compression and storage module configured to receive at least one of the first gaseous hydrogen or the second gaseous hydrogen from the main storage module, to compress the at least one gaseous hydrogen, and to store the compressed gaseous hydrogen, and a gas conversion and transportation module configured to receive the pumped liquid hydrogen and the compressed gaseous hydrogen from the liquid pumping and transportation module and the gas compression and storage module, respectively, to perform heat exchange between the pumped liquid hydrogen and the compressed gaseous hydrogen to generate gaseous hydrogen filling gas from the pumped liquid hydrogen and the compressed gaseous hydrogen, and to deliver the gaseous hydrogen filling gas to a gaseous hydrogen storage and filling tank of a hydrogen gas filling station, wherein the main storage module pressurizes the liquid hydrogen based on pressure of the at least one gaseous hydrogen, and directly supplies the pressurized liquid hydrogen to a fuel tank of a hydrogen fuel consumption structure or to a liquid hydrogen storage and filling tank of the hydrogen gas filling station, even before

or after being connected to the hydrogen gas filling station via the gas conversion and transportation module.

[0013] The main storage module may include a main storage tank surrounded by a protective wall, a first pipe line, a second pipe line, and a third pipe line, the main storage tank may individually communicate with the first pipe line, the second pipe line, and the third pipe line, each of the first pipe line and the third pipe line may be formed of a double insulative vacuum pipe in order to prevent heat exchange between the liquid hydrogen and the atmosphere, the second pipe line may be formed of a single pipe in order to allow heat exchange between the liquid hydrogen and the atmosphere, and the liquid hydrogen may have an absolute temperature of 20K (=−253° C.) and a pressure of 5 bar.

[0014] The first pipe line may be fixed to the main storage tank, may receive the liquid hydrogen from the hydrogen liquefaction plant, the liquid hydrogen storage and distribution tank, or the tank lorry, and may inject the liquid hydrogen into the main storage tank.

[0015] The second pipe line may be fixed to the upper part and the lower part of the main storage tank, may surround the main storage tank at one side of the main storage tank, and may have a zigzag pressure build-up unit under the main storage tank, and the second pipe line may phase-change the liquid hydrogen into the first gaseous hydrogen through heat exchange between the liquid hydrogen and the atmosphere performed by the pressure build-up unit during flow of the liquid hydrogen from the lower part of the main storage tank, and may deliver the first gaseous hydrogen to the upper part of the main storage tank.

[0016] The third pipe line may be fixed to the main storage tank, and may inject the liquid hydrogen into the fuel tank of the hydrogen fuel consumption structure or into the liquid hydrogen storage and filling tank of the hydrogen gas filling station during pressurization of the at least one gaseous hydrogen into the liquid hydrogen in the main storage tank, and the hydrogen fuel consumption structure may include a hydrogen fuel flight means, a hydrogen fuel land and sea movement means, or a hydrogen fuel industrial power generation house facility, configured to receive the liquid hydrogen in the fuel tank and to be driven using the liquid hydrogen.

[0017] The liquid pumping and transportation module may include a high-pressure liquid pump, a fourth pipe line, and a fifth pipe line, the high-pressure liquid pump may be individually connected to the fourth pipe line and the fifth pipe line, and may communicate with a main storage tank of the main storage module via the fourth pipe line and the fifth pipe line, the fourth pipe line may be formed of a double insulative vacuum pipe in order to prevent heat exchange between the liquid hydrogen and the atmosphere, the fifth pipe line may be formed of a double insulative vacuum pipe in order to prevent heat exchange between the second gaseous hydrogen and the atmosphere, and the liquid hydrogen may have an absolute temperature of 20K (=−253° C.) and a pressure of 5 bar.

[0018] The fourth pipe line may be fixed to one side of the main storage tank of the main storage module, may communicate with the main storage tank, may connect the main storage tank and the high-pressure liquid pump to each other, may receive the liquid hydrogen from one side of the main storage tank, and may inject the liquid hydrogen into the high-pressure liquid pump.

[0019] The high-pressure liquid pump may receive the liquid hydrogen from the main storage tank of the main storage module through the fourth pipe line, may pump the liquid hydrogen to generate the pumped liquid hydrogen and the second gaseous hydrogen, and may deliver the pumped liquid hydrogen and the second gaseous hydrogen to the gas conversion and transportation module and the fifth pipe line, respectively, and the pumped liquid hydrogen may have a pressure of 500 bar or higher.

[0020] The fifth pipe line may be fixed to the other side of the main storage tank of the main storage module, may communicate with the main storage tank, may connect the main storage tank and the high-pressure liquid pump to each other, may receive the second gaseous hydrogen from the high-pressure liquid pump, and may inject the second gaseous hydrogen into the main storage tank.

[0021] The gas compression and storage module may include a compressor, a buffer storage tank, a sixth pipe line, and a seventh pipe line, the compressor and the buffer storage tank may be connected to each other via the sixth pipe line and the seventh pipe line and may communicate with the main storage tank of the main storage module, and each of the sixth pipe line and the seventh pipe line may be formed of a single pipe.

[0022] The sixth pipe line may be fixed to the main storage tank, may communicate with the main storage tank, may be located between the main storage tank and the compressor, may receive the at least one gaseous hydrogen from the main storage tank, and may inject the at least one gaseous hydrogen into the compressor.

[0023] The compressor may receive the at least one gaseous hydrogen from the sixth pipe line, may compress the at least one gaseous hydrogen to generate the compressed gaseous hydrogen, and may supply the compressed gaseous hydrogen to the seventh pipe line, and the compressed gaseous hydrogen may have density, pressure, and heat higher than density, pressure, and heat of the at least one gaseous hydrogen, respectively.

[0024] The seventh pipe line may connect the compressor and the buffer storage tank to each other on the seventh pipe line, may have a plurality of buffer storage tanks located on the seventh pipe line so as to be connected to each other in parallel, may receive the compressed gaseous hydrogen from the compressor, and may inject the compressed gaseous hydrogen into the buffer storage tanks, and the compressed gaseous hydrogen may have a pressure of 500 bar or higher.

[0025] The gas conversion and transportation module may include a thermal absorber, a radiator, an eighth pipe line, a ninth pipe line, and a tenth pipe line, each of the eighth pipe line, the ninth pipe line, and the tenth pipe line may be formed of a single pipe, the eighth pipe line may be connected to the high-pressure liquid pump of the liquid pumping and transportation module and may extend toward the tenth pipe line via the thermal absorber, the ninth pipe line may be connected to the buffer storage tank of the gas compression and storage module and may extend toward the tenth pipe line via the radiator, and the tenth pipe line may be connected to the eighth pipe line and the ninth pipe line around the thermal absorber and the radiator.

[0026] The eighth pipe line may receive the pumped liquid hydrogen from the high-pressure liquid pump of the liquid pumping and transportation module and may inject the pumped liquid hydrogen into the thermal absorber, and the

eighth pipe line may receive heat from the thermal absorber to phase-change the pumped liquid hydrogen into the gaseous hydrogen filling gas and may deliver the gaseous hydrogen filling gas to the tenth pipe line.

[0027] The thermal absorber may surround the eighth pipe line, may communicate with the radiator, may receive heat from the radiator and the atmosphere, and may deliver the heat to the eighth pipe line.

[0028] The ninth pipe line may receive the compressed gaseous hydrogen from the buffer storage tank of the gas compression and storage module, may inject the compressed gaseous hydrogen into the radiator, may deliver heat of the compressed gaseous hydrogen to the radiator to convert the compressed gaseous hydrogen into gaseous hydrogen filling gas, and may deliver the gaseous hydrogen filling gas to the tenth pipe line.

[0029] The radiator may surround the ninth pipe line, may communicate with the thermal absorber, and may deliver heat of the compressed gaseous hydrogen from the ninth pipe line to the thermal absorber during rotation of a blowing fan of the radiator.

[0030] The tenth pipe line may receive the gaseous hydrogen filling gas from the eighth pipe line or the ninth pipe line and may inject the gaseous hydrogen filling gas into the gaseous hydrogen storage and filling tank of the hydrogen gas filling station, a plurality of gaseous hydrogen storage and filling tanks or a plurality of liquid hydrogen storage and filling tanks may be located under the ground or on the ground at the hydrogen gas filling station, and the gaseous hydrogen filling gas may haves a pressure of 500 bar or higher.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0032] FIG. **1** is an image schematically showing a hydrogen industry supply chain according to the present invention;

[0033] FIG. **2** is an image schematically showing components of a mobile gaseous and liquid hydrogen refueling apparatus of FIG. **1**;

[0034] FIG. **3** is a system diagram showing in detail a connection relationship between the components of the mobile gaseous and liquid hydrogen refueling apparatus of FIG. **1**;

[0035] FIG. **4** is a view showing a main storage module extracted from the system diagram of FIG. **3**;

[0036] FIG. **5** is a view showing a liquid pumping and transportation module extracted from the system diagram of FIG. **3**;

[0037] FIG. **6** is a view showing a gas compression and storage module extracted from the system diagram of FIG. **3**;

[0038] FIG. **7** is a view showing a gas conversion and transportation module extracted from the system diagram of FIG. **3**; and

[0039] FIGS. **8** and **9** are images schematically illustrating a method of using the mobile gaseous and liquid hydrogen refueling apparatus of FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0040] Hereinafter, the most preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings such that the present invention can be easily embodied by a person having ordinary skill in the art to which the present invention pertains.

[0041] FIG. **1** is an image schematically showing a hydrogen industry supply chain according to the present invention.

[0042] Referring to FIG. **1**, the hydrogen industry supply chain according to the present invention includes a hydrogen liquefaction plant **10**, a liquid hydrogen storage and distribution tank **15**, a tank lorry **20**, a mobile gaseous and liquid hydrogen refueling apparatus **170**, a hydrogen fuel consumption structure (not shown), and a hydrogen gas filling station (not shown). The hydrogen liquefaction plant **10** generates and liquefies hydrogen gas using production raw materials (e.g. petroleum, coal, natural gas, liquefied petroleum gas (LPG), biofuel, and nuclear energy) to produce liquid hydrogen.

[0043] The liquid hydrogen storage and distribution tank **15** receives and stores the liquid hydrogen from the hydrogen liquefaction plant **10**, and distributes the liquid hydrogen to hydrogen use markets as needed. The tank lorry **20** receives the liquid hydrogen from the liquid hydrogen storage and distribution tank **15**, stores the liquid hydrogen in a tank, and delivers the liquid hydrogen to the hydrogen use markets. However, the hydrogen liquefaction plant **10**, the liquid hydrogen storage and distribution tank **15**, and the tank lorry **20** may individually supply liquid hydrogen to the mobile gaseous and liquid hydrogen refueling apparatus **170** in addition to the supply connection relationship therebetween described above.

[0044] The mobile gaseous and liquid hydrogen refueling apparatus **170** supplies liquid hydrogen or gaseous hydrogen to the hydrogen fuel consumption structure or the hydrogen gas filling station on a road. That is, the mobile gaseous and liquid hydrogen refueling apparatus **170** may inject liquid hydrogen into a fuel tank of a hydrogen fuel flight means, a hydrogen fuel land and sea movement means, or a hydrogen fuel industrial power generation house facility, which is the hydrogen fuel consumption structure (see the arrow accompanied by LH**2** in FIG. **2** or **9**).

[0045] Here, the hydrogen fuel flight means includes a drone **189**, the hydrogen fuel land and sea movement means includes a train **193**, a ship **186**, or a hydrogen fuel cell vehicle **190**, and the hydrogen fuel industrial power generation house facility includes a general electronic device for home use. In addition, at the hydrogen gas filling station, the mobile gaseous and liquid hydrogen refueling apparatus **170** may inject liquid hydrogen into a liquid hydrogen storage and filling tank **200** (see the arrow accompanied by LH**2** in FIG. **2** or **8**) or may inject gaseous hydrogen into a gaseous hydrogen storage and filling tank **210** (see the arrow accompanied by GH**2** (also referred to as "gaseous hydrogen filling gas") in FIG. **2** or **8**).

[0046] A plurality of liquid hydrogen storage and filling tanks **200** and a plurality of gaseous hydrogen storage and filling tanks **210** may be located under the ground or on the ground at the hydrogen gas filling station.

[0047] FIG. **2** is an image schematically showing components of the mobile gaseous and liquid hydrogen refueling apparatus of FIG. **1**, and FIG. **3** is a system diagram showing

in detail a connection relationship between the components of the mobile gaseous and liquid hydrogen refueling apparatus of FIG. **1**.

[0048] FIG. **4** is a view showing a main storage module extracted from the system diagram of FIG. **3**, FIG. **5** is a view showing a liquid pumping and transportation module extracted from the system diagram of FIG. **3**, and FIG. **6** is a view showing a gas compression and storage module extracted from the system diagram of FIG. **3**.

[0049] In addition, FIG. **7** is a view showing a gas conversion and transportation module extracted from the system diagram of FIG. **3**.

[0050] Referring to FIGS. **2** to **7**, the mobile gaseous and liquid hydrogen refueling apparatus **170** includes a main storage module **60**, a liquid pumping and transportation module **80**, a gas compression and storage module **110**, and a gas conversion and transportation module **160**, as shown in FIGS. **2** and **3**. Here, as shown in FIG. **1** or **4**, the main storage module **60** receives liquid hydrogen LH**2** (see FIG. **4**) from the hydrogen liquefaction plant **10**, the liquid hydrogen storage and distribution tank **15**, or the tank lorry **20**, and generates first gaseous hydrogen GH**2** (see FIG. **4**) from the liquid hydrogen LH**2**.

[0051] The liquid pumping and transportation module **80** receives the liquid hydrogen LH**2** from the main storage module **60**, generates second gaseous hydrogen GH**2** (see FIG. **5**) from the liquid hydrogen LH**2** while pumping the liquid hydrogen LH**2**, and delivers the second gaseous hydrogen GH**2** to the main storage module **60**.

[0052] The gas compression and storage module **110** receives at least one of the first gaseous hydrogen GH**2** or the second gaseous hydrogen GH**2** from the main storage module **60**, compresses the at least one gaseous hydrogen GH**2**, and stores the compressed gaseous hydrogen, as shown in FIG. **6**.

[0053] The gas conversion and transportation module **160** receives the pumped liquid hydrogen LH**2**+ (see FIG. **7**) and the compressed gaseous hydrogen GH**2**+ (see FIG. **6** or **7**) from the liquid pumping and transportation module **80** and the gas compression and storage module **110**, respectively, performs heat exchange between the pumped liquid hydrogen LH**2**+ and the compressed gaseous hydrogen GH**2**+ to generate gaseous hydrogen filling gas GH**2** (see FIG. **7**) from the pumped liquid hydrogen LH**2**+ and the compressed gaseous hydrogen GH**2**+, as shown in FIG. **2** or **7**, and fills the gaseous hydrogen storage and filling tank **210** of the hydrogen gas filling station (not shown) with the gaseous hydrogen filling gas GH**2** under a pressure of 500 bar or higher.

[0054] Here, the main storage module **60** may pressurize the liquid hydrogen based on the pressure of the at least one gaseous hydrogen, and may directly supply the pressurized liquid hydrogen to a fuel pack of the fuel tank of the hydrogen fuel consumption structure (e.g. the hydrogen fuel flight means, the hydrogen fuel land and sea movement means, or the hydrogen fuel industrial power generation house facility), or may directly supply the pressurized liquid hydrogen to the liquid hydrogen storage and filling tank **200** of the hydrogen gas filling station, even before or after being connected to the hydrogen gas filling station via the gas conversion and transportation module **160**.

[0055] More specifically, referring first to FIGS. **3** and **4**, the main storage module **60** includes a main storage tank **40** surrounded by a protective wall **30**, a first pipe line L**1**, a second pipe line L**2**, and a third pipe line L**3**. The main storage tank **40** individually communicates with the first pipe line L**1**, the second pipe line L**2**, and the third pipe line L**3**.

[0056] Each of the first pipe line L**1** and the third pipe line L**3** is formed of a double insulative vacuum pipe in order to prevent heat exchange between the liquid hydrogen LH**2** and the atmosphere. The second pipe line L**2** is formed of a single pipe in order to allow heat exchange between the liquid hydrogen LH**2** and the atmosphere. Here, the liquid hydrogen LH**2** has an absolute temperature of 20K (=−253° C.) and a pressure of 5 bar.

[0057] The first pipe line L**1** is fixed to the main storage tank **40**, receives the liquid hydrogen LH**2** from the hydrogen liquefaction plant **10**, the liquid hydrogen storage and distribution tank **15**, or the tank lorry **20** along a flow line F**1**, and injects the liquid hydrogen LH**2** into the main storage tank **40**. The second pipe line L**2** is fixed to the upper part and the lower part of the main storage tank **40**, surrounds the main storage tank **40** at one side of the main storage tank **40**, and has a zigzag pressure build-up unit **50** under the main storage tank **40**.

[0058] In addition, the second pipe line L**2** phase-changes the liquid hydrogen LH**2** into first gaseous hydrogen GH**2** through heat exchange between the liquid hydrogen LH**2** and the atmosphere performed by the pressure build-up unit **50** during flow of the liquid hydrogen LH**2** from the lower part of the main storage tank **40**, and delivers the first gaseous hydrogen GH**2** to the upper part of the main storage tank **40**. Here, the second pipe line L**2** has a vent stack configured to discharge the first gaseous hydrogen GH**2** to the outside through a plurality of safety valves at a predetermined pressure or higher.

[0059] The third pipe line L**3** is fixed to the main storage tank **40**, and injects liquid hydrogen LH**2** into the fuel tank of the hydrogen fuel consumption structure **183**, **186**, **189**, or **190** (see FIG. **1** or **4**) or into the liquid hydrogen storage and filling tank **200** of the hydrogen gas filling station along a flow line F**2** during pressurization of at least one gaseous hydrogen GH**2** into the liquid hydrogen LH**2** in the main storage tank **40**. The hydrogen fuel consumption structure includes a hydrogen fuel flight means, a hydrogen fuel land and sea movement means, or a hydrogen fuel industrial power generation house facility, which is configured to receive liquid hydrogen LH**2** in a fuel tank thereof and to be driven using the liquid hydrogen LH**2**.

[0060] More specifically, referring to the system diagrams of FIGS. **3** and **5**, the liquid pumping and transportation module **80** includes a high-pressure liquid pump **70**, a fourth pipe line L**4**, and a fifth pipe line L**5**. The high-pressure liquid pump **70** is individually connected to the fourth pipe line L**4** and the fifth pipe line L**5**, and communicates with the main storage tank **40** of the main storage module **60** via the fourth pipe line L**4** and the fifth pipe line L**5**. The fourth pipe line L**4** is formed of a double insulative vacuum pipe in order to prevent heat exchange between the liquid hydrogen LH**2** and the atmosphere.

[0061] The fifth pipe line L**5** is formed of a double insulative vacuum pipe in order to prevent heat exchange between the second gaseous hydrogen GH**2** and the atmosphere. Here, the liquid hydrogen LH**2** has an absolute temperature of 20K (=−253° C.) and a pressure of 5 bar. The fourth pipe line L**4** is fixed to one side of the main storage tank **40** of the main storage module **60**, communicates with

the main storage tank **40**, connects the main storage tank **40** and the high-pressure liquid pump **70** to each other, receives the liquid hydrogen LH**2** from one side of the main storage tank **40**, and injects the liquid hydrogen LH**2** into the high-pressure liquid pump **70**.

[0062] The high-pressure liquid pump **70** receives the liquid hydrogen LH**2** from the main storage tank **40** of the main storage module **60** through the fourth pipe line L**4**, pumps the liquid hydrogen LH**2** to generate pumped liquid hydrogen LH**2+** (see FIG. **7**) and second gaseous hydrogen GH**2**, and delivers the pumped liquid hydrogen LH**2+** and the second gaseous hydrogen GH**2** to the gas conversion and transportation module **160** and the fifth pipe line L**5**, respectively. Here, the pumped liquid hydrogen LH**2+** has a pressure of 500 bar or higher.

[0063] The fifth pipe line L**5** is fixed to the other side of the main storage tank **40** of the main storage module **60**, communicates with the main storage tank **40**, connects the main storage tank **40** and the high-pressure liquid pump **70** to each other, receives the second gaseous hydrogen GH**2** from the high-pressure liquid pump **70**, and injects the second gaseous hydrogen GH**2** into the main storage tank **40**.

[0064] In addition, more specifically, referring to the system diagrams of FIGS. **3** and **6**, the gas compression and storage module **110** includes a compressor **90**, a buffer storage tank **100**, a sixth pipe line L**6**, and a seventh pipe line L**7**. The compressor **90** and the buffer storage tank **100** are connected to each other via the sixth pipe line L**6** and the seventh pipe line L**7**, and communicate with the main storage tank **40** of the main storage module **60**. Each of the sixth pipe line L**6** and the seventh pipe line L**7** is formed of a single pipe.

[0065] The sixth pipe line L**6** is fixed to the main storage tank **40**, communicates with the main storage tank **40**, is located between the main storage tank **40** and the compressor **90**, receives at least one gaseous hydrogen GH**2** from the main storage tank **40**, and injects the at least one gaseous hydrogen GH**2** into the compressor **90**. The reason for this is that the first gaseous hydrogen GH**2** and the second gaseous hydrogen GH**2** may be simultaneously or individually generated by the mobile gaseous and liquid hydrogen refueling apparatus **170** as needed.

[0066] The compressor **90** receives the at least one gaseous hydrogen GH**2** from the sixth pipe line L**6**, compresses the at least one gaseous hydrogen GH**2** to generate compressed gaseous hydrogen GH**2+**, and supplies the compressed gaseous hydrogen GH**2+** to the seventh pipe line L**7**. The compressed gaseous hydrogen GH**2+** has density, pressure, and heat higher than those of the at least one gaseous hydrogen GH**2**.

[0067] The seventh pipe line L**7** connects the compressor **90** and the buffer storage tank **100** to each other on the seventh pipe line L**7**, has a plurality of buffer storage tanks **100** located on the seventh pipe line L**7** so as to be connected to each other in parallel, receives the compressed gaseous hydrogen GH**2+** from the compressor **90**, and injects the compressed gaseous hydrogen GH**2+** into the buffer storage tanks **100**. Here, the compressed gaseous hydrogen GH**2+** has a pressure of 500 bar or higher.

[0068] In addition, more specifically, referring to the system diagrams of FIGS. **3** and **7**, the gas conversion and transportation module **160** includes a thermal absorber **130**, a radiator **150**, an eighth pipe line L**8**, a ninth pipe line L**9**, and a tenth pipe line L**10**. Each of the eighth pipe line L**8**, the ninth pipe line L**9**, and the tenth pipe line L**10** is formed of a single pipe.

[0069] As shown in FIG. **3**, the eighth pipe line L**8** is connected to the high-pressure liquid pump **70** of the liquid pumping and transportation module **80**, and extends toward the tenth pipe line L**10** via the thermal absorber **130**. As shown in FIG. **3**, the ninth pipe line L**9** is connected to the buffer storage tank **100** of the gas compression and storage module **110**, and extends toward the tenth pipe line L**10** via the radiator **150**. The tenth pipe line L**10** is connected to the eighth pipe line L**8** and the ninth pipe line L**9** around the thermal absorber **130** and the radiator **150**.

[0070] Here, the eighth pipe line L**8** receives the pumped liquid hydrogen LH**2+** from the high-pressure liquid pump **70** of the liquid pumping and transportation module **80**, and injects the pumped liquid hydrogen LH**2+** into the thermal absorber **130**. In addition, the eighth pipe line L**8** receives heat from the thermal absorber **130** to phase-change the pumped liquid hydrogen LH**2+** into gaseous hydrogen filling gas GH**2**, and delivers the gaseous hydrogen filling gas GH**2** to the tenth pipe line L**10**.

[0071] The thermal absorber **130** surrounds the eighth pipe line L**8**, communicates with the radiator **150**, receives heat from the radiator **150** and the atmosphere, and delivers the heat to the eighth pipe line L**8**. The ninth pipe line L**9** receives the compressed gaseous hydrogen GH**2+** from the buffer storage tank **100** of the gas compression and storage module **110**, injects the compressed gaseous hydrogen GH**2+** into the radiator **150**, delivers heat of the compressed gaseous hydrogen GH**2+** to the radiator **150** to convert the compressed gaseous hydrogen GH**2+** into gaseous hydrogen filling gas GH**2**, and delivers the gaseous hydrogen filling gas GH**2** to the tenth pipe line L**10**.

[0072] The radiator **150** surrounds the ninth pipe line L**9**, communicates with the thermal absorber **130**, and delivers the heat H (see FIG. **2**) of the compressed gaseous hydrogen GH**2+** from the ninth pipe line L**9** to the thermal absorber **130** during rotation of a blowing fan **145** of the radiator **150**.

[0073] The tenth pipe line L**10** receives the gaseous hydrogen filling gas GH**2** from the eighth pipe line L**8** or the ninth pipe line L**9**, and injects the gaseous hydrogen filling gas GH**2** into the gaseous hydrogen storage and filling tank **210** of the hydrogen gas filling station along a flow line F**3** (see FIG. **3**). A plurality of liquid hydrogen storage and filling tanks **200** or a plurality of gaseous hydrogen storage and filling tanks **210** is located under the ground or on the ground at the hydrogen gas filling station. The gaseous hydrogen filling gas GH**2** has a pressure of 500 bar or higher.

[0074] FIGS. **8** and **9** are images schematically illustrating a method of using the mobile gaseous and liquid hydrogen refueling apparatus of FIG. **1**.

[0075] Referring first to FIG. **8**, in a hydrogen filling mode according to a first embodiment of the present invention, the mobile gaseous and liquid hydrogen refueling apparatus **170** may be connected to the gaseous hydrogen storage and filling tank **210** via the tenth line L**10** of the gas conversion and transportation module **160**, as described with reference to FIGS. **3** and **7**.

[0076] The gaseous hydrogen storage and filling tank **210** may receive gaseous hydrogen filling gas GH**2** from the buffer storage tank **100** (see FIG. **6**) of the mobile gaseous and liquid hydrogen refueling apparatus **170** through the tenth line L**10** along the flow line F**3**, may store the gaseous

hydrogen filling gas GH2, and may deliver the gaseous hydrogen filling gas GH2 to a filling terminal **220** along a flow line F4 in response to the request of a driver of the hydrogen fuel cell vehicle **190**. In this case, the filling terminal **220** may inject the gaseous hydrogen filling gas GH2 into the fuel tank of the hydrogen fuel cell vehicle **190** along a flow line F7.

[0077] In addition, the mobile gaseous and liquid hydrogen refueling apparatus **170** may be connected to the liquid hydrogen storage and filling tank **200** via the third line L3 of the main storage module **60**, as described with reference to FIGS. **3** and **4**. The liquid hydrogen storage and filling tank **200** may receive liquid hydrogen LH2 from the main storage tank **40** (see FIG. **4**) of the mobile gaseous and liquid hydrogen refueling apparatus **170** through the third line L3 along a flow line F5, may store the liquid hydrogen LH2, and may deliver the liquid hydrogen LH2 to the filling terminal **220** along a flow line F6 in response to the request of the driver of the hydrogen fuel cell vehicle **190**.

[0078] In this case, the filling terminal **220** may inject the liquid hydrogen LH2 into a fuel pack of the hydrogen fuel cell vehicle **190** along the flow line F7.

[0079] Next, referring to FIG. **9**, in a hydrogen filling mode according to a second embodiment of the present invention, the mobile gaseous and liquid hydrogen refueling apparatus **170** may directly inject liquid hydrogen LH2 into the fuel tank or the fuel pack of the hydrogen fuel flight means, including the drone **189**, on a road, or may directly inject liquid hydrogen LH2 into the fuel tank or the fuel pack of the hydrogen fuel land and sea movement means, including the train **183**, the ship **186**, or the hydrogen fuel cell vehicle **190**, as described with reference to FIGS. **3** and **4**.

[0080] In this case, the liquid hydrogen LH2 may be injected from the mobile gaseous and liquid hydrogen refueling apparatus **170** into the fuel tank or the fuel pack of the train **183**, the ship **186**, the drone **189**, or the hydrogen fuel cell vehicle **190** through the third line L3 of the main storage tank **40**. In addition, the mobile gaseous and liquid hydrogen refueling apparatus **170** may directly inject the liquid hydrogen LH2 into the fuel tank or the fuel pack of the hydrogen fuel industrial power generation house facility, including the general electronic device for home use.

[0081] As is apparent from the above description, the mobile gaseous and liquid hydrogen refueling apparatus according to the present invention includes a main storage tank, a high-pressure liquid pump, and a thermal absorber, wherein the pressure of liquid hydrogen in the main storage tank is increased using the high-pressure liquid pump, and the pumped liquid hydrogen is delivered to the thermal absorber, and therefore, in the present invention, it is possible to reduce power consumption to 1/10 through the use of the high-pressure liquid pump, whereby it is possible to improve hydrogen filling performance, compared to the use of a compressor in the conventional art, as is known to those skilled in the art.

[0082] The mobile gaseous and liquid hydrogen refueling apparatus according to the present invention further includes a pipe line surrounding a portion of the main storage tank in addition to the main storage tank, wherein the pipe line absorbs heat from the atmosphere to phase-change liquid hydrogen into gaseous hydrogen during flow of the liquid hydrogen from the main storage tank to the pipe line, and the gaseous hydrogen is delivered to the main storage tank such that the liquid hydrogen is pressurized in the main storage tank based on pressure of the gaseous hydrogen, whereby it is possible to directly fill a fuel tank or a fuel pack of a hydrogen fuel consumption structure (e.g. a hydrogen fuel flight means, a hydrogen fuel land and sea movement means, or a hydrogen fuel industrial power generation house facility) with the liquid hydrogen.

[0083] The mobile gaseous and liquid hydrogen refueling apparatus according to the present invention further includes a compressor, a buffer storage tank, and a radiator in addition to the main storage tank, the high-pressure liquid pump, and the thermal absorber, wherein at least one of first gaseous hydrogen generated by partially phase-changing liquid hydrogen in the main storage tank or second gaseous hydrogen generated as a byproduct during pumping of the liquid hydrogen by the high-pressure liquid pump is compressed by the compressor and is stored in the buffer storage tank, whereby it is possible to perform heat exchange between the compressed gaseous hydrogen and the pumped liquid hydrogen through the thermal absorber and the radiator, and therefore it is possible to convert both the compressed gaseous hydrogen and the pumped liquid hydrogen into gases hydrogen filling gas.

[0084] Although the present invention has been described in detail based on the concrete embodiment, those skilled in the art will appreciate that the present invention is not limited thereto and that various modifications, additions, and substitutions are possible without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

What is claimed is:

1. A mobile gaseous and liquid hydrogen refueling apparatus comprising:

a main storage module configured to receive liquid hydrogen from a hydrogen liquefaction plant, a liquid hydrogen storage and distribution tank, or a tank lorry and to generate first gaseous hydrogen from the liquid hydrogen;

a liquid pumping and transportation module configured to receive the liquid hydrogen from the main storage module, to generate second gaseous hydrogen from the liquid hydrogen while pumping the liquid hydrogen, and to deliver the second gaseous hydrogen to the main storage module;

a gas compression and storage module configured to receive at least one of the first gaseous hydrogen or the second gaseous hydrogen from the main storage module, to compress the at least one gaseous hydrogen, and to store the compressed gaseous hydrogen; and

a gas conversion and transportation module configured to receive the pumped liquid hydrogen and the compressed gaseous hydrogen from the liquid pumping and transportation module and the gas compression and storage module, respectively, to perform heat exchange between the pumped liquid hydrogen and the compressed gaseous hydrogen to generate gaseous hydrogen filling gas from the pumped liquid hydrogen and the compressed gaseous hydrogen, and to deliver the gaseous hydrogen filling gas to a gaseous hydrogen storage and filling tank of a hydrogen gas filling station, wherein

the main storage module pressurizes the liquid hydrogen based on pressure of the at least one gaseous hydrogen, and directly supplies the pressurized liquid hydrogen to a fuel tank of a hydrogen fuel consumption structure or

to a liquid hydrogen storage and filling tank of the hydrogen gas filling station, even before or after being connected to the hydrogen gas filling station via the gas conversion and transportation module.

2. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **1**, wherein

the main storage module comprises a main storage tank surrounded by a protective wall, a first pipe line, a second pipe line, and a third pipe line,

the main storage tank individually communicates with the first pipe line, the second pipe line, and the third pipe line,

each of the first pipe line and the third pipe line is formed of a double insulative vacuum pipe in order to prevent heat exchange between the liquid hydrogen and an atmosphere,

the second pipe line is formed of a single pipe in order to allow heat exchange between the liquid hydrogen and the atmosphere, and

the liquid hydrogen has an absolute temperature of 20K (=−253° C.) and a pressure of 5 bar.

3. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **2**, wherein the first pipe line is fixed to the main storage tank, receives the liquid hydrogen from the hydrogen liquefaction plant, the liquid hydrogen storage and distribution tank, or the tank lorry, and injects the liquid hydrogen into the main storage tank.

4. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **2**, wherein

the second pipe line is fixed to an upper part and a lower part of the main storage tank, surrounds the main storage tank at one side of the main storage tank, and has a zigzag pressure build-up unit under the main storage tank, and

the second pipe line phase-changes the liquid hydrogen into the first gaseous hydrogen through heat exchange between the liquid hydrogen and the atmosphere performed by the pressure build-up unit during flow of the liquid hydrogen from the lower part of the main storage tank, and delivers the first gaseous hydrogen to the upper part of the main storage tank.

5. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **2**, wherein

the third pipe line is fixed to the main storage tank, and injects the liquid hydrogen into the fuel tank of the hydrogen fuel consumption structure or into the liquid hydrogen storage and filling tank of the hydrogen gas filling station during pressurization of the at least one gaseous hydrogen into the liquid hydrogen in the main storage tank, and

the hydrogen fuel consumption structure comprises a hydrogen fuel flight means, a hydrogen fuel land and sea movement means, or a hydrogen fuel industrial power generation house facility, configured to receive the liquid hydrogen in the fuel tank and to be driven using the liquid hydrogen.

6. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **1**, wherein

the liquid pumping and transportation module comprises a high-pressure liquid pump, a fourth pipe line, and a fifth pipe line,

the high-pressure liquid pump is individually connected to the fourth pipe line and the fifth pipe line, and communicates with a main storage tank of the main storage module via the fourth pipe line and the fifth pipe line,

the fourth pipe line is formed of a double insulative vacuum pipe in order to prevent heat exchange between the liquid hydrogen and an atmosphere,

the fifth pipe line is formed of a double insulative vacuum pipe in order to prevent heat exchange between the second gaseous hydrogen and the atmosphere, and

the liquid hydrogen has an absolute temperature of 20K (=−253° C.) and a pressure of 5 bar.

7. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **6**, wherein the fourth pipe line is fixed to one side of the main storage tank of the main storage module, communicates with the main storage tank, connects the main storage tank and the high-pressure liquid pump to each other, receives the liquid hydrogen from one side of the main storage tank, and injects the liquid hydrogen into the high-pressure liquid pump.

8. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **6**, wherein

the high-pressure liquid pump receives the liquid hydrogen from the main storage tank of the main storage module through the fourth pipe line, pumps the liquid hydrogen to generate the pumped liquid hydrogen and the second gaseous hydrogen, and delivers the pumped liquid hydrogen and the second gaseous hydrogen to the gas conversion and transportation module and the fifth pipe line, respectively, and

the pumped liquid hydrogen has a pressure of 500 bar or higher.

9. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **6**, wherein the fifth pipe line is fixed to the other side of the main storage tank of the main storage module, communicates with the main storage tank, connects the main storage tank and the high-pressure liquid pump to each other, receives the second gaseous hydrogen from the high-pressure liquid pump, and injects the second gaseous hydrogen into the main storage tank.

10. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **1**, wherein

the gas compression and storage module comprises a compressor, a buffer storage tank, a sixth pipe line, and a seventh pipe line,

the compressor and the buffer storage tank are connected to each other via the sixth pipe line and the seventh pipe line, and communicate with the main storage tank of the main storage module, and

each of the sixth pipe line and the seventh pipe line is formed of a single pipe.

11. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **10**, wherein the sixth pipe line is fixed to the main storage tank, communicates with the main storage tank, is located between the main storage tank and the compressor, receives the at least one gaseous hydrogen from the main storage tank, and injects the at least one gaseous hydrogen into the compressor.

12. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **10**, wherein

the compressor receives the at least one gaseous hydrogen from the sixth pipe line, compresses the at least one gaseous hydrogen to generate the compressed gaseous hydrogen, and supplies the compressed gaseous hydrogen to the seventh pipe line, and

the compressed gaseous hydrogen has density, pressure, and heat higher than density, pressure, and heat of the at least one gaseous hydrogen, respectively.

13. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **10**, wherein

the seventh pipe line connects the compressor and the buffer storage tank to each other on the seventh pipe line, has a plurality of buffer storage tanks located on the seventh pipe line so as to be connected to each other in parallel, receives the compressed gaseous hydrogen from the compressor, and injects the compressed gaseous hydrogen into the buffer storage tanks, and

the compressed gaseous hydrogen has a pressure of 500 bar or higher.

14. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **1**, wherein

the gas conversion and transportation module comprises a thermal absorber, a radiator, an eighth pipe line, a ninth pipe line, and a tenth pipe line,

each of the eighth pipe line, the ninth pipe line, and the tenth pipe line is formed of a single pipe,

the eighth pipe line is connected to a high-pressure liquid pump of the liquid pumping and transportation module, and extends toward the tenth pipe line via the thermal absorber,

the ninth pipe line is connected to a buffer storage tank of the gas compression and storage module, and extends toward the tenth pipe line via the radiator, and

the tenth pipe line is connected to the eighth pipe line and the ninth pipe line around the thermal absorber and the radiator.

15. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **14**, wherein

the eighth pipe line receives the pumped liquid hydrogen from the high-pressure liquid pump of the liquid pumping and transportation module, and injects the pumped liquid hydrogen into the thermal absorber, and

the eighth pipe line receives heat from the thermal absorber to phase-change the pumped liquid hydrogen into the gaseous hydrogen filling gas, and delivers the gaseous hydrogen filling gas to the tenth pipe line.

16. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **14**, wherein the thermal absorber surrounds the eighth pipe line, communicates with the radiator, receives heat from the radiator and an atmosphere, and delivers the heat to the eighth pipe line.

17. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **14**, wherein the ninth pipe line receives the compressed gaseous hydrogen from the buffer storage tank of the gas compression and storage module, injects the compressed gaseous hydrogen into the radiator, delivers heat of the compressed gaseous hydrogen to the radiator to convert the compressed gaseous hydrogen into gaseous hydrogen filling gas, and delivers the gaseous hydrogen filling gas to the tenth pipe line.

18. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **14**, wherein the radiator surrounds the ninth pipe line, communicates with the thermal absorber, and delivers heat of the compressed gaseous hydrogen from the ninth pipe line to the thermal absorber during rotation of a blowing fan of the radiator.

19. The mobile gaseous and liquid hydrogen refueling apparatus according to claim **14**, wherein

the tenth pipe line receives the gaseous hydrogen filling gas from the eighth pipe line or the ninth pipe line, and injects the gaseous hydrogen filling gas into the gaseous hydrogen storage and filling tank of the hydrogen gas filling station,

a plurality of gaseous hydrogen storage and filling tanks or a plurality of liquid hydrogen storage and filling tanks is located under a ground or on the ground at the hydrogen gas filling station, and

the gaseous hydrogen filling gas has a pressure of 500 bar or higher.

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