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STORAGE TANK FOR LOW TEMPERATURE LIQUIDS

Filed Sept. 20, 1954

2 Sheets-Sheet 1

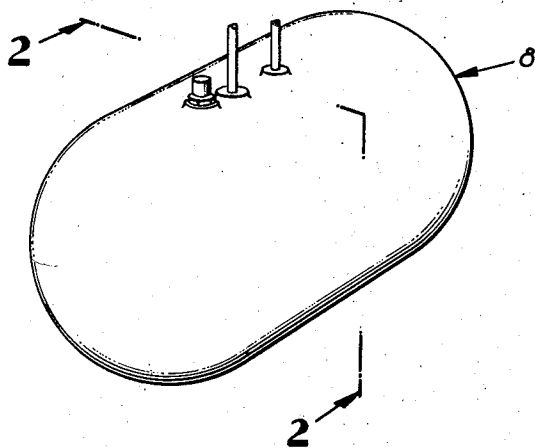


FIG. 1.

FIG. 2.

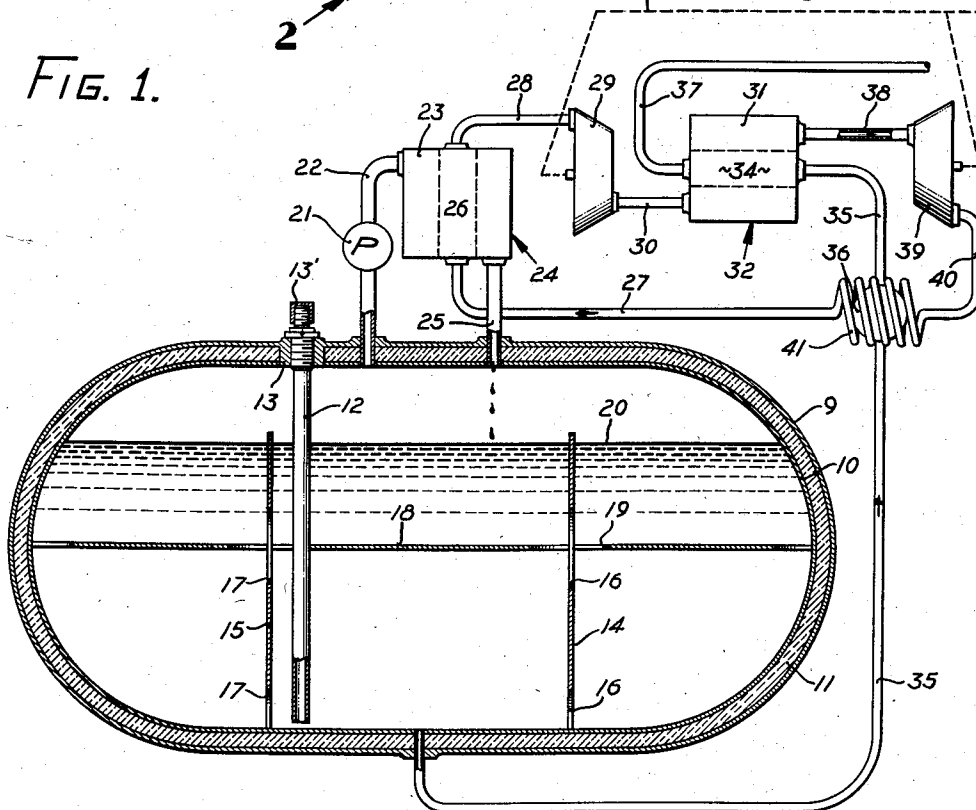
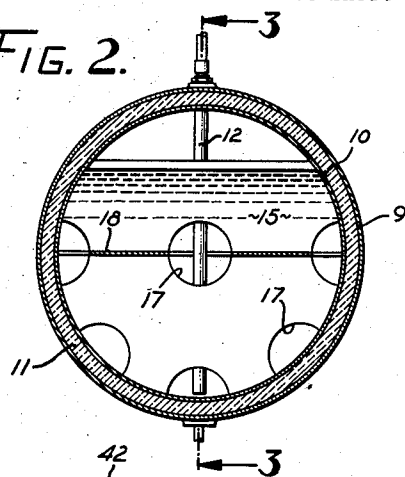


FIG. 3.

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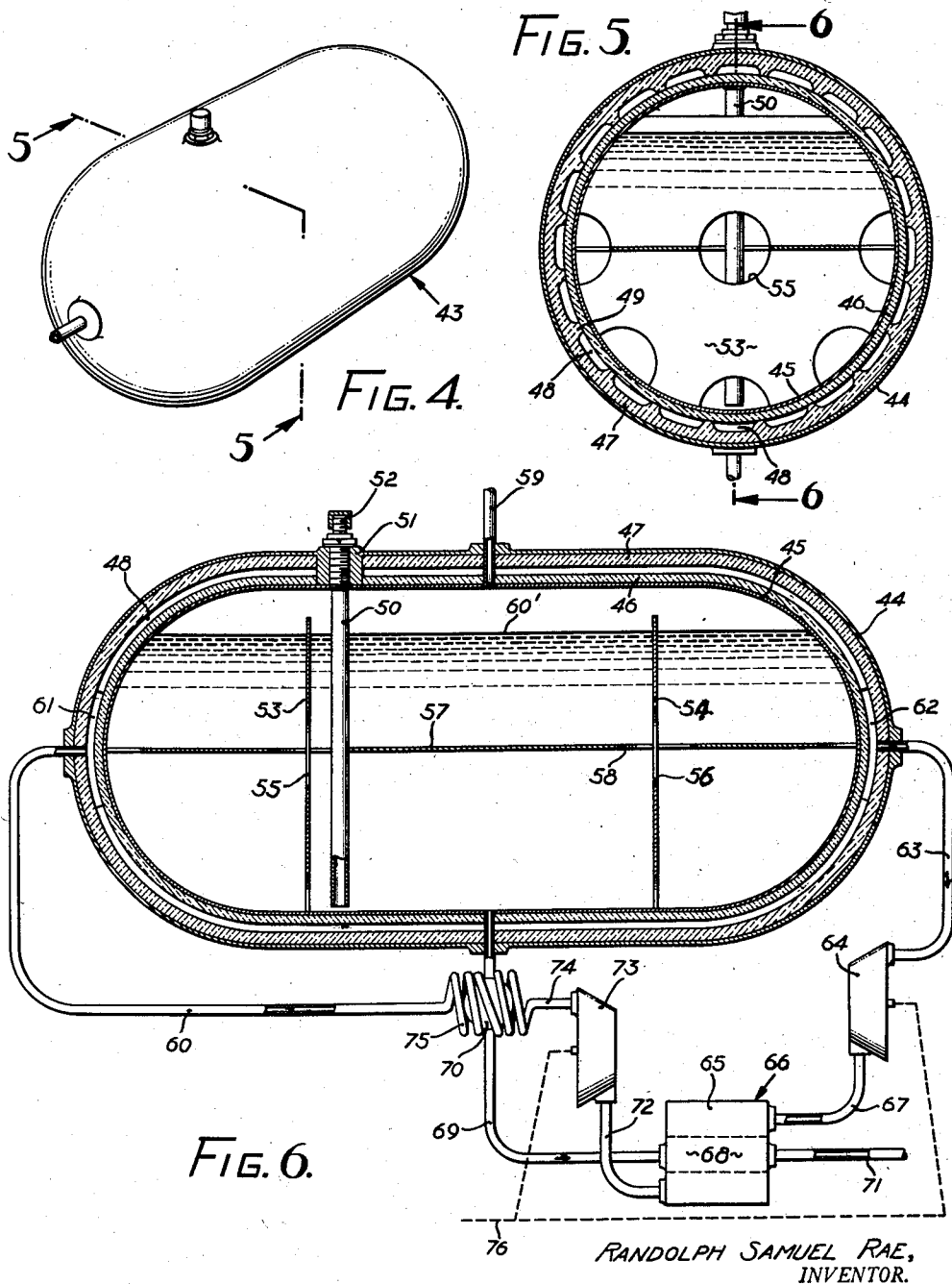
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STORAGE TANK FOR LOW TEMPERATURE LIQUIDS

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2 Sheets-Sheet 2



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STORAGE TANK FOR LOW TEMPERATURE LIQUIDS

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4 Claims. (Cl. 62—54)

This invention relates to a storage tank for low temperature liquids and more particularly to tanks for storing low temperature liquid gases, such as liquid hydrogen, and preventing loss of the liquid by evaporation.

Low temperature liquids, such as liquid hydrogen, can be utilized as fuel for non-air breathing engines such as disclosed in pending U.S. application Serial No. 417,867, filed March 22, 1954, by Randolph Samuel Rae and in order to conserve the liquid fuel it is necessary to prevent substantial evaporation. One method of continually cooling the low temperature liquid is disclosed in pending U.S. application Serial No. 417,658, filed March 22, 1954, by Randolph Samuel Rae, now Patent No. 2,811,234, October 29, 1957, and utilizes the liquid fuel passing to the engine for cooling the evaporated gases and these cooled gases are circulated around the liquid in the tank. By the present invention, it is proposed to use a separate refrigeration cycle in connection with the liquid storage tank so that a refrigerant of lower temperature than the liquid fuel within the tank can be utilized to prevent excessive evaporation.

In one form of the invention, the separate refrigeration cycle utilizes a heat exchanger for reliquifying the evaporated gases and returning the liquid to the tank. The low temperature liquid passing from the tank is utilized in a second heat exchanger to cool the refrigerant after it has been compressed to a high pressure. The refrigeration cycle can be of the usual type wherein the refrigerant is compressed, cooled and then expanded to a low temperature and pressure. In a second form of the invention, the refrigerant cycle also utilizes a heat exchanger which receives the low temperature liquid passing from the tank in order to cool the refrigerant after compression. However, after the refrigerant is expanded, it is passed around the tank in order to continually cool the liquid within the tank and thereby prevent any substantial evaporation. The small amount of liquid which will evaporate in the tank will be passed directly to atmosphere. Thus, both forms of the invention provide a liquid storage tank in which a low temperature liquid, such as liquid hydrogen, can be stored in ambient surroundings without excessive evaporation of the liquid by utilizing a separate refrigeration cycle with a refrigerant of lower temperature than the liquification temperature of the liquid. When liquid hydrogen is being stored, the refrigerant can consist of any suitable substance, such as helium or hydrogen at lower pressure than the pressure within the tank.

It is therefore an object of the present invention to provide a storage tank for low temperature liquids which utilizes a separate refrigeration system to prevent excessive evaporation of the liquid while in the tank.

Another object of the present invention is to provide a refrigeration system for cooling a low temperature liquid within a storage tank, which refrigeration system utilizes the liquid being removed from the tank to cool the refrigerant after compression.

Another object of the invention is to provide a storage

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tank for low temperature liquids wherein a separate refrigeration cycle is utilized to re-liquify gases evaporating from the tank.

A still further object of the invention is to provide a storage tank for low temperature liquids wherein a refrigeration cycle is utilized to continually cool the low temperature liquid within the tank so that only a small amount of evaporation takes place.

These and other objects of the invention not specifically set forth above will become readily apparent from the following description and drawings, in which:

Figure 1 is a perspective view of the first form of the invention showing the shape of the tank.

Figure 2 is a transverse vertical section along line 2—2 of Figure 1 illustrating the inlet passage and the baffles for the tank.

Figure 3 is a vertical section along line 3—3 of Figure 2 showing the separate refrigeration system associated with the tank.

Figure 4 is a perspective view of a second form of the invention illustrating the external connections to the tank.

Figure 5 is a transverse vertical section along line 5—5 of Figure 4 showing the baffles for the tank and the passages extending around the tank.

Figure 6 is a vertical section along line 6—6 of Figure 5 showing the refrigeration system associated with the tank.

Referring to the first form of the invention illustrated in Figures 1 through 3, the low temperature liquid is stored in a tank 8 which is in the form of a cylindrical body having dome shaped ends. The tank has an outer skin 9 which is separated from an inner container 10 by means of insulation 11. A supply tube 12, having a removable cap 13, is secured to a fitting 13 attached to the outer skin and inner container and the passage terminates adjacent the bottom surface of the tank. The inner container 10 supports two vertical baffles 14 and 15 having openings 16 and 17, respectively, and also supports a horizontal baffle 18 which has openings 19. The openings in both the vertical and horizontal baffles permit some movement of the liquid within the tank. The level 20 of the liquid within the tank can vary as the liquid is withdrawn from or supplied to the tank.

As the liquid within the tank evaporates, a pump 21 in passage 22 draws the gases into the outer chamber 23 of heat exchanger 24 where the evaporated gases are again liquified and returned to the tank through passage 25. The inner passage 26 of heat exchanger 24 receives the refrigerant, such as cold helium gas, from passage 27. When liquid hydrogen is stored in the tank, the helium gas temperature in passage 27 will be below the liquification temperature of the hydrogen in the tank in order to liquify the gases entering chamber 23. The refrigerant will leave the heat exchanger 24 through passage 28 at about the same temperature as the evaporated gases in passage 22 and will enter compressor 29 which serves to increase the pressure and temperature of the refrigerant. Compressor 29 discharges the refrigerant through passage 30 to the outer chamber 31 of heat exchanger 32 where the high pressure refrigerant gas is reduced in temperature. The inner chamber 34 of heat exchanger 32 connects with the low temperature liquid supply in the inner container 10 through a passage 35 which contains a pump 36 for removing the liquid. Because of the work done on the liquid by the pump 36, some evaporation of the lower temperature liquid will take place prior to reaching heat exchanger 32. The low temperature liquid will be completely evaporated in chamber 34 and will exhaust through passage 37 to its point of use, such as to a non-air breathing engine. The passage of the low temperature liquid through the inner chamber 34 serves to

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lower the temperature of the compressed refrigerant in passage 38 leaving the heat exchanger 32.

The high pressure, low temperature gas in passage 38 is expanded through turbine 39 in order to substantially lower the temperature and pressure of the refrigerant which leaves the turbine by passage 40. The passage 40 contains a cooling coil 41 which surrounds pump 36 and serves to decrease the cavitation losses which result from gas formation at the low pressure within the pump. The refrigerant leaving the coil 41 is again passed to the inner chamber 26 of heat exchanger 24 through passage 27. As is diagrammatically indicated, the turbine 39 and the compressor 29 can be connected together by any suitable connection so that the turbine will drive the compressor.

Referring now to the operation of the first form of the invention, a refrigerant, such as helium gas of very low temperature, is passed through heat exchanger 24 in order to continually liquify the gases which evaporate from the surface 20 of the low temperature liquid. The higher temperature refrigerant leaving heat exchanger 24 is then compressed by compressor 29 and these compressed, high temperature gases are cooled in heat exchanger 32 and then expanded through turbine 39 in order to obtain low pressure, low temperature refrigerant for the recirculation through heat exchanger 24. Low temperature, low pressure refrigerant serves to continually cool pump 36 to prevent cavitation losses and the pump 36 supplies the heat exchanger 32 with the low temperature liquid being withdrawn from the inner container 10. Thus, there is no loss of the low temperature liquid through evaporation to the atmosphere since all of the evaporated liquid is continually re-liquified in heat exchanger 24 and returned to the tank. It is understood that the heat exchangers 24 and 32 can take any desirable form and that the compressor 29 can be of the piston or turbine type. Also, the expansion turbine 39 can be replaced by a piston type expansion engine or by a throttle valve. Of course, the insulation 11 can be of any desired type and serves to prevent heat transfer from the tank surroundings to the low temperature liquid.

Referring to the second form of the invention illustrated in Figures 4 through 6, the liquid storage tank 43 also has a cylindrical body with dome shaped ends. The tank is formed of an outer skin 44 and an inner container 45 which contains the low temperature liquid substance. A uniform layer of insulation 46 covers the inner container 45 and an insulation member 47 is positioned between the outer skin and layer 46. The member 47 contains a plurality of passages 48 which pass around the tank from one end to the other and are separated by projections 49 of the member. A supply passage 50 is secured to a fitting 51 supported by both the outer skin and inner container and the passage has a cap 52 which can be removed to supply additional low temperature liquid to the tank. A pair of vertical baffles 53 and 54 are secured to the inner container 45 and contain openings 55 and 56, respectively, in order to permit some movement of the liquid. The inner container also supports a horizontal baffle 57 having openings 58 for permitting some movement of the liquid. A passage 59 connects with the upper surface of the inner container at a position normally above the level 60' of the low temperature liquid, and this passage permits the escape of evaporated liquid to the atmosphere.

In order to maintain the low temperature liquid at its liquification temperature and prevent any substantial evaporation of the liquid, a passage 60 supplies low temperature, low pressure refrigerant to a header space 61 which connects with all of the passages 48 extending around the surface of the inner container. This low temperature refrigerant gas passes from header 61 around the tank through passages 48 and collects at header space 62 at the opposite end of the tank, where the gases are at a higher temperature because of the heat transferred to the gases from the liquid and the surroundings. The

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header 62 connects through passage 63 to a compressor 64 which increases the pressure and temperature of the gases received from header 62 and the compressed gases from the compressor are connected with the outer chamber 65 of heat exchanger 66 through a passage 67. The inner chamber 68 of heat exchanger 66 is connected with the liquid in the tank through passage 69 which contains a pump 70 for withdrawing the liquid. The low temperature liquid in passage 69 serves to cool the refrigerant gas entering the heat exchanger from passage 67 and leaves the heat exchanger as a gas through passage 71 to its point of use, such as a non-air breathing engine. Refrigerant gas leaving heat exchanger 66 through passage 72 is expanded in an expansion turbine 73 in order to substantially reduce the temperature and pressure of the refrigerant in passage 74. A cooling coil 75 is connected between passage 74 and passage 60 and surrounds the pump 70 in order to prevent cavitation losses within the pump resulting from gas formation. As in the previous embodiment, the compressor 64 and turbine 73 are connected together by a suitable shaft connection 76 so that the turbine will drive the compressor.

In operation, the refrigerant system takes the low temperature gas, such as helium, and compresses it to high temperature and pressure in compressor 64. This gas is then cooled to a low temperature by heat exchanger 66 and is then expanded to a low pressure and lower temperature through expansion turbine 73. The expanded gas is then passed around the pump 70 and through the individual passages 48 which surround the inner container 35 to keep the liquid in the inner container from increasing above its liquification temperature. By passing a suitable amount of refrigerant gas through the passages 48, it is possible to hold the amount of liquid which evaporates from the liquid surface 60 to a minimum and thus substantially all of the low temperature liquid is available for its intended use. As in the previous embodiment, the compressor 64 can be either of the piston or turbine type and the expansion turbine 73 can be replaced by either a piston expansion engine or a throttle valve.

By the present invention, a storage tank for low temperature liquids has been provided which prevents the loss of any substantial portion of the liquid through evaporation. It is understood that any refrigerant can be used in the refrigeration cycle and that the refrigerant must be of a lower temperature than the stored low temperature liquid. When liquid hydrogen is stored, helium gas can be used as the refrigerant since it has a liquification temperature lower than that of hydrogen and other low temperature refrigerants could be used, including hydrogen at a lower pressure than the pressure of the liquid hydrogen within the tank. It is understood that the insulation members 11, 46 and 47 aid in preventing evaporation of the liquid by preventing heat transfer from the surrounding atmosphere. It is also contemplated that various types of passage means could extend around the inner container of the second form and that various types of insulation material could be used in both forms of the invention. The outer skin and inner container for both tanks can be formed of any suitable material, such as steel or plastic, which will withstand the low temperatures. Various other modifications are contemplated by those skilled in the art without departing from the spirit and scope of the invention as hereinafter defined by the appended claims.

What is claimed is:

1. An apparatus for storing gas material in the form of low temperature liquid comprising a storage tank for said liquid, passage means surrounding the liquid within the tank for cooling the liquid, and means for supplying refrigerant to said passage means at a lower temperature than said liquid, said supplying means comprising means for compressing said refrigerant to high pressure and means for expanding the compressed refrigerant

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to low pressure and temperature, heat exchanger means positioned between said compressor means and said expansion means to reduce the temperature of said refrigerant after compression, conduit means for connecting said low temperature liquid in the tank with said heat exchanger means, pump means positioned in said conduit means for circulating liquid from said tank through said heat exchange means, and coil means surrounding said pump means and connected with said expansion means to continually cool said pump means and prevent cavitation losses.

2. An apparatus for storing gas material in the form of low temperature liquid comprising a storage tank for said liquid, passage means located adjacent said tank and in heat exchange relationship with the gas evaporating from the liquid, and means for supplying said passage means with a refrigerant of lower temperature than said liquid in order to continually cool said evaporated gas, said supplying means comprising compressor means and expansion means for said refrigerant, heat exchanger means connected with said compressor means and said expansion means for cooling the compressed refrigerant prior to entering said expansion means, conduit means for connecting said heat exchanger means with the low temperature liquid in said tank, pump means in said conduit means for circulating low temperature liquid from said tank through said heat exchange means, and cooling means surrounding said pump means and connected to said expansion means in order to continually cool said pump and prevent cavitation losses.

3. An apparatus for storing gas material in the form of a low temperature liquid, comprising a tank having an inner container for housing said liquid and an outer shell, insulation means positioned between said inner container and said shell, passage means for a refriger-

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ant formed in said insulation means and completely surrounding the surface of said inner container to cool all the liquid, header means at each end of said tank connecting with said passage means, compressor means connected with one of said header means for compressing said refrigerant to high temperature and pressure, expansion means connected with said compressor means for expanding said compressed refrigerant to a low temperature, means connecting said expansion means to the other of said header means for circulating said refrigerant through said passage means to prevent any substantial evaporation from said liquid, heat exchanger means positioned between said compressor means and said expansion means, means for supplying low temperature liquid from said tank to said heat exchanger means in order to reduce the temperature of said compressed refrigerant, pump means for said supply means, and a coil in said connecting means and surrounding said pump means in order to prevent cavitation losses resulting from the evaporation of said liquid within said pump means.

4. An apparatus as defined in claim 3 having a passage connecting the upper space of said tank to atmosphere to vent any gas evaporating from said liquid.

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