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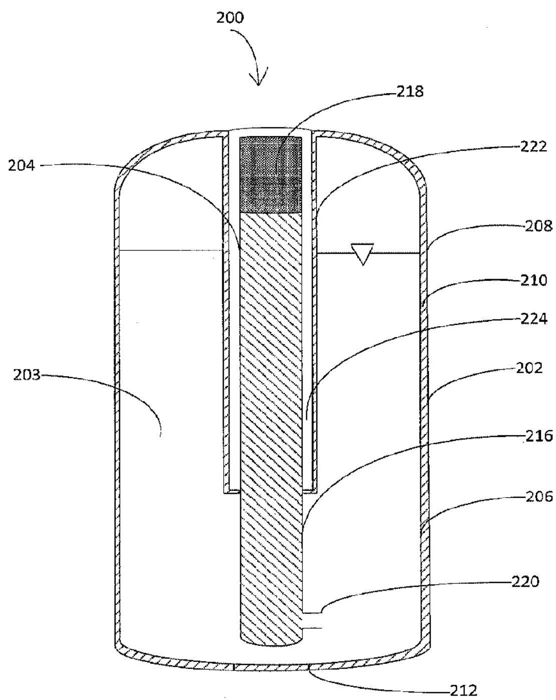
(54) Title: CRYOGENIC TANK ASSEMBLY WITH A PUMP DRIVE UNIT DISPOSED WITHIN FLUID STORAGE VESSEL



(57) Abrégé/Abstract:
A tank assembly including a vessel defining a cryogen space capable of storing fluid at a storage pressure and cryogenic temperature, the vessel having a sleeve extending into the cryogen space and a pump assembly therein. The pump assembly includes a pump, a pump drive unit, and a drive shaft operatively connecting the pump to the pump drive unit. The pump is configured to receive a quantity of the fluid from the cryogen space and deliver it therefrom at a delivery pressure higher than the storage pressure. The pump drive unit is at least partially disposed within the sleeve of the vessel.

Abstract

A tank assembly including a vessel defining a cryogen space capable of storing fluid at a storage pressure and cryogenic temperature, the vessel having a sleeve extending into the cryogen space and a pump assembly therein. The pump assembly includes a pump, a pump drive unit, and a drive shaft operatively connecting the pump to the pump drive unit. The pump is configured to receive a quantity of the fluid from the cryogen space and deliver it therefrom at a delivery pressure higher than the storage pressure. The pump drive unit is at least partially disposed within the sleeve of the vessel.

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CRYOGENIC TANK ASSEMBLY WITH A PUMP DRIVE UNIT DISPOSED WITHIN FLUID STORAGE VESSEL

Technical Field

[0001] The present application relates to a cryogenic tank assembly with a pump drive unit disposed within the storage vessel. More particularly, the cryogenic tank assembly has both a pump and pump drive unit disposed within the fluid storage vessel to make a more compact assembly that allows more storage volume and less empty space around the assembly when mounted, for example on a vehicle or machine.

Background

[0002] Developments in combustion engine technology have allowed for the use of gaseous fuels instead of diesel as a fuel, without sacrifices to vehicular performance or delivery. Such gaseous fuels include natural gas, methane, hydrogen and other combustible hydrocarbon derivatives. Because of its ready availability, low cost and potential for reducing particulate emissions, natural gas is increasingly used as the gaseous fuel of choice, to fuel a range of industrial and vehicle engines, including mine trucks, locomotives, ships and other heavy goods vehicles (HGVs). To increase the energy density of natural gas storage, especially on vehicles, liquefied natural gas (LNG) is an attractive solution compared to compressed natural gas (CNG) because of the higher energy density that can be achieved at much lower storage pressures.

[0003] For natural gas fuelled direct injection engines that can deliver similar performance profiles to diesel engines, this requires the fuel to be delivered to the engine at high pressures, to overcome the in-cylinder pressure for late-cycle injection. There are challenges that need to be overcome to enable the use of LNG as a vehicular fuel. A cryogenic tank assembly must be thermally insulated to maintain the stored LNG at cryogenic temperatures, defined herein to be temperatures at which natural gas will remain in liquefied form at the predetermined storage pressure. Thermal insulation prevents heat transfer from the surrounding environment to the cryogen storage space, because heat entering the cryogen space can cause some of the LNG to transform into vapor which increases the pressure of the stored fluid. If the fluid pressure exceeds a predetermined pressure limit, to prevent any damage to the cryogenic tank assembly, a pressure relief valve is normally triggered to vent vapor from the cryogen space. It is undesirable to vent vapor from the cryogen space so in addition to the thermal insulation, cryogenic tank assemblies normally avoid locating anything inside the storage vessel that can introduce heat into the cryogen space. The applicant has patented some inventive cryogenic tank assemblies that do place a pump inside the cryogen space, but with these arrangements the pump drive is always located outside of the storage vessel. In addition to the challenge of preventing heat from entering the cryogen space, there are other challenges associated with locating a pump drive unit inside the storage vessel, such as preventing the freezing of hydraulic fluid lines if the drive unit is a hydraulic drive unit.

[0004] However, for vehicular engine applications, locating the pump drive unit outside of the storage vessel can result in a shape for the overall cryogenic tank assembly that results in empty space that is not utilized. A more compact arrangement can be beneficial in allowing a greater fuel storage volume in the same space, which is advantageous on board vehicles where there can be limited space for storing fuel. Larger storage capacity in the fuel tanks helps to increase productivity by increasing operating time and distance travelled and/or work done between re-fuelling.

[0005] In this disclosure, for fluids that are normally in gaseous form at atmospheric pressure and temperature, cryogenic temperatures are defined as the temperature at which the pumped fluid can be maintained in a liquefied form, including fluids that are in a supercritical state.

[0006] Accordingly, there is a need for an improved cryogenic fuel storage suited for large-scale cryogenic storage vessels that increases the fuel storage volume within the designated fuel storage space on board the vehicle.

Summary

[0007] The claimed system is a tank assembly that includes a vessel with a cryogen space capable of storing fluid at a cryogenic temperature and a storage pressure, and a pump assembly to receive the cryogenic fluid and pressurize it to a pressure above the initial pressure, for use by a vehicular engine.

[0008] The pump assembly includes a pump configured to receive the fluid, pressurize it to a pressure above the storage pressure, and deliver it to an accumulator or other pressurized-fluid receiving device outside the tank assembly. The pump assembly also includes a pump drive unit, at least partially recessed within the cryogen space. The pump drive unit controls the pump such that the fluid received and delivered by the pump is in response to the engine needs.

[0009] The vessel includes an inner vessel surrounded by an outer shell, with an insulated space between the inner vessel and outer shell. The entire cryogen space is thus defined by the inner vessel and surrounded by the insulated space. The inner vessel and outer shell further include a sleeve, whereby the sleeve of the outer shell extends within the sleeve of the inner vessel, with the insulated space extending therebetween.

[0010] The pump assembly is disposed within the inner vessel such that the pump is immersed in the cryogen space, which allows the pump to be in a continuously cooled down state, and the pump drive unit is substantially recessed within the sleeve of the outer shell.

[0011] In an exemplary embodiment, the pump is a reciprocating piston pump, with at least one piston disposed within the pump cylinder. The reciprocating piston pump is preferably actuated by a hydraulic drive unit. The hydraulic drive unit comprises a piston disposed within a hydraulic cylinder, with the hydraulic piston operatively connected to the reciprocating pump piston, to actuate the pump piston. The piston shaft is disposed within the hydraulic drive end plate, and sealed by shaft seals disposed within the end plate.

[0012] The hydraulic drive also comprises a hydraulic fluid, hydraulic fluid lines supplying fluid to and from the pump drive unit, and hydraulic valves to control the delivery of the fluid to and from the drive unit, which causes reciprocating motion of the piston. In a hydraulic drive unit, any fluid that leaks past the hydraulic piston, shaft, and shaft seals, is directed out of the drive unit via a low pressure weep line.

[0013] Because the presently claimed system locates the drive unit within the inner vessel, the traditional configuration of the weep line is such that the weep line would be exposed to the cryogenic temperatures within the vessel. The fluid in the weep line is thus susceptible to freezing at these temperatures, which is undesirable. In exemplary embodiments, the hydraulic weep line is associated with an endplate of the pump drive unit proximate to the pump, and is nested within one of the hydraulic fluid lines, and thus insulated from the cryogenic temperatures within the vessel; by nesting the weep line within the fluid lines, the continuous flow of warm fluid within the fluid lines will reduce freezing of the weep line.

[0014] In alternate embodiments, various other drivers can be used to drive the reciprocating piston. By way of example, these may include electric motors, mechanical drive units, pneumatic drive units, or any other drive unit that doesn't depart from the spirit of the presently claimed system.

[0015] The pump drive unit is further surrounded by thermal insulation, to ensure that the cryogenic temperature does not affect the performance of the drive unit, and to ensure that there is no heat leak from the drive unit into the cryogen space, which may raise the temperature of the fluid and cause some of it to turn to vapor. The thermal insulation may include an aerogel jacket, or any other suitable insulation means.

Brief Description of the Drawings

FIG. 1 is a schematic view of a vehicle with the gaseous fuel storage assembly shown.

FIG. 2 is a cross sectional view of a cryogenic tank assembly that includes a storage vessel and a pump assembly configured to locate a pump drive unit within the pump assembly.

FIG. 3 is cross sectional view of a hydraulic drive unit, with the hydraulic weep line disposed within hydraulic fluid lines.

Detailed Description

[0016] Throughout the following description, specific details are disclosed to provide a more thorough understanding of the claimed system. However, some well-known elements have not been shown or described in detail to avoid obscuring the presently disclosed system. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than restrictive, sense. The drawings are not to scale.

[0017] With reference to FIG. 1, vehicle 100 is shown with cryogenic fuel storage assembly space 102 located on vehicle chassis 104, and between wheels 106. Vehicle 100 is, in an exemplary embodiment, a large heavy goods vehicle, however the vehicle can be understood to be any vehicle with an on-board tank assembly for storing cryogenic fuel. There is limited space available for the cryogenic fuel storage assembly, and the shape of conventional prior art cryogenic storage tank 108 with external pump drive unit 110 results in empty space 112 that is not utilized. Thus the presently claimed system aims to provide a more compact arrangement for increasing the volume of fuel that can be stored within the available cryogenic fuel storage assembly space 102, by locating drive unit 110 within cryogenic storage tank 108, such that empty space 112 is incorporated as part of the available fuel storage volume of cryogenic storage tank 108, as shown by outline 114.

[0018] Generally, the presently claimed system relates to a cryogenic tank assembly that includes a storage vessel with a cryogen space capable of storing fluid at a cryogenic temperature and at a storage pressure within a predetermined range, and a pump assembly. The pump assembly includes a pump to receive the cryogenic fluid and deliver it to a user at a higher pressure, and a pump drive unit. In exemplary embodiments, both the pump and the pump drive unit are disposed within the vessel, resulting in a more compact arrangement so that the cryogenic tank assembly can be mounted on a vehicle with less empty space surrounding it. For other applications, such as rail tender cars, the tank diameter can be made larger while maintaining the same overall height because the drive unit need not extend above the level of the cryogenic tank. While it is already known to locate a pump inside the storage vessel, locating the pump drive inside a storage vessel for fluids stored at cryogenic temperatures is more challenging. Even more than a pump, a pump drive unit may not work as well and may even freeze up and become inoperative if exposed to cryogenic temperatures, so it needs to be insulated from the cryogen space. Most drive units are also a source of heat, so such insulation is also needed to prevent heat generated in the drive unit from being transferred into the cryogen space. By placing a pump drive unit inside the storage vessel it can also be harder to cool (to prevent overheating) and harder to service.

[0019] With reference to FIG.2, cryogenic tank assembly 200 is shown, with storage vessel 202 and pump assembly 204. Storage vessel 202 comprises inner vessel 206 which defines the boundaries of cryogen space 203 and outer shell 208. Inner vessel 206 and outer shell 208 are separated by insulation space 210, which may be evacuated to provide thermal insulation for cryogen space 203 between inner vessel 206 and outer shell 208. Outer shell 208 is fixed to inner shell 206 by support structures 212, which are designed to reduce thermal conduction between the outer shell and the inner vessel. These support structures 212 are shown, in FIG.2 to be at the bottom of the vessel, however they may be any mechanical or structural component that supports outer shell 208 from inner vessel 206.

[0020] In this illustrated exemplary embodiment, pump assembly 204 includes pump 216 operatively connected to pump drive unit 218, both fully disposed within vessel 202. More specifically, pump assembly 204 is disposed within pump assembly sleeve 222 located within cryogen space 203. Pump assembly sleeve 222 can be a double walled assembly with the space between the walls connected to insulation space 210, thus providing thermal insulation between cryogen space 203 and pump assembly 204. Fully locating pump assembly 204 within vessel 202 means that the drive unit for the pump does not extend beyond outer shell 208, so that the tank assembly can be made larger and fill more of the available space on board a vehicle, increasing the total volume of fluid that can be stored. In other embodiments (not illustrated), a pump drive unit that is only partially disposed within the storage vessel can still provide a more compact arrangement compared to previously known arrangements that locate the entire drive unit outside of the outer shell. The prior art known to the applicant relating to storage vessels for holding fluid at cryogenic temperatures does not teach locating any part of a drive unit inside the storage vessel.

[0021] In an exemplary embodiment, pump 216 is a reciprocating piston pump that has pump inlet 220 located toward the bottom of vessel 202, within cryogen space 203. Pump 216 is shown immersed in cryogen space 203 so that the pump is maintained at the temperature of the stored fluid so that it does not require cooling to cryogenic temperatures before operation. In an exemplary embodiment, drive unit 218 is a hydraulic drive unit, however numerous other drive units may be substituted if suitably matched to the operating conditions. By way of example, these substitute drive units may include pneumatic drivers, mechanical drivers and electric motors.

[0022] A detailed view of hydraulic drive unit 218 is shown in FIG. 3. Hydraulic cylinder 301 is shown, within which reciprocating piston 302 is disposed. Hydraulic fluid flows to hydraulic cylinder inlet 303 via hydraulic fluid line 305, which causes reciprocating motion of piston 302. The hydraulic fluid then exits hydraulic cylinder 301 via hydraulic fluid line 312 located at hydraulic cylinder outlet 304, and is directed through pump housing 307 to hydraulic fluid outlet 314.

[0023] Any hydraulic fluid that leaks between drive shaft 309 and end plate 306 is collected via weep line 310, and directed outside storage vessel 202 via weep line outlet 316. Because hydraulic drive units are designed to minimize fluid leakage from hydraulic cylinder 301, the amount of hydraulic fluid flowing through weep line 310 is normally very small, making this fluid more prone to freezing if exposed to cryogenic temperatures. When the pump drive unit is located outside of the storage vessel this is not a problem because the weep line is not exposed to cryogenic temperatures. Freezing the hydraulic fluid in the weep line can be a problem when the pump drive unit is located inside a storage vessel where it can be exposed to cryogenic temperatures. A solution to this problem is illustrated by locating weep line 310 within pump housing 307, and specifically nested within hydraulic fluid line 312 to insulate the intermittent and/or low-flow leaked hydraulic fluid from the surrounding cryogenic temperatures. The continuous flow of high temperature hydraulic fluid within hydraulic fluid line 312 reduces heat transfer away from weep line 310, thus preventing the leaked hydraulic fluid from freezing.

[0024] In an exemplary embodiment, hydraulic weep line 310 is located within endplate 306 with an opening to the bore provided for drive shaft 309 of reciprocating piston 303, to collect hydraulic fluid that leaks past shaft seals 318, 320 and prevent the hydraulic fluid collecting in the sleeve that extends to the pump.

[0025] While particular elements, embodiments and applications of the presently claimed system have been shown and described, it will be understood that exemplary embodiments are disclosed herein as examples of the claimed concepts and described features, and the claimed system is not limited thereto since variations for practicing the same concepts can be made without departing from the scope of the present disclosure, particularly in light of the foregoing teachings.

Claims

1. A tank assembly comprising:
   a. a vessel defining a cryogen space capable of storing fluid at a storage pressure and cryogenic temperature, the vessel comprising a sleeve extending into the cryogen space; and
   b. a pump assembly further comprising:
      i. a pump disposed in a lower portion of the pump assembly and the lower end of the pump assembly extends from the sleeve of the vessel into the cryogen space, said pump configured to receive a quantity of the fluid from the cryogen space and deliver it therefrom at a delivery pressure higher than the storage pressure;
      ii. a drive shaft operatively connecting said pump to a pump drive unit, for driving the pump; and
      iii. said pump drive unit, at least partially disposed within the sleeve of the vessel, and wherein the pump drive unit is separated from the cryogen space by thermal insulation.

2. The tank assembly of claim 1 wherein the vessel is an inner vessel surrounded by an outer shell, with an insulated space between the inner vessel and the outer shell.

3. The tank assembly of claim 2 wherein the sleeve extends into the cryogen space from the inner vessel.

4. The tank assembly of claim 2 wherein the sleeve extends into the cryogen space from the outer shell.

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5. The tank assembly of claim 1 or 2 wherein the sleeve comprises an inner sleeve and an outer sleeve, with an insulated space therebetween.

6. The tank assembly of claim 2 wherein the insulated space between the inner vessel and the outer shell is a vacuum insulated space and the cryogen space is substantially surrounded by the vacuum insulated space.

7. The tank assembly of any one of claims 1 to 6 wherein the pump is immersed in the cryogen space thereby allowing the pump to be maintained at the temperature of the stored fluid when said fluid is stored within said cryogen space.

8. The tank assembly of any one of claims 1 to 7 wherein the pump drive unit is substantially disposed within the sleeve.

9. The tank assembly of any one of claims 1 to 8 wherein the pump drive unit is an electric motor.

10. The tank assembly of any one of claims 1 to 8 wherein the pump drive unit is a mechanical drive.

11. The tank assembly of any one of claims 1 to 8 wherein the pump drive unit is a pneumatic drive.

12. The tank assembly of any one of claims 1 to 8 wherein the pump drive unit is a hydraulic drive.

13. The tank assembly of any one of claims 1 to 12 wherein the pump is a reciprocating piston pump comprising at least one piston disposed within a pump cylinder.

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14. The tank assembly of any one of claims 1 to 8 wherein the pump drive unit is a hydraulic drive unit comprising:
    a. a hydraulic cylinder;
    b. a piston disposed within the hydraulic cylinder;
    c. hydraulic valves for controlling the delivery of fluid to and from the drive unit, causing reciprocating motion of the piston;
    d. hydraulic fluid lines supplying fluid to and from the pump drive unit;
    e. a hydraulic weep line located within the pump drive unit, for collecting hydraulic fluid leaking from the hydraulic cylinder.

15. The tank assembly of claim 14 wherein the hydraulic weep line is associated with an end plate of the pump drive unit proximate to the pump and the hydraulic weep line is nested within one of the hydraulic fluid lines.

16. The tank assembly of any one of claims 1 to 15 wherein the thermal insulation separating the pump drive unit from the cryogen space comprises an aerogel jacket.

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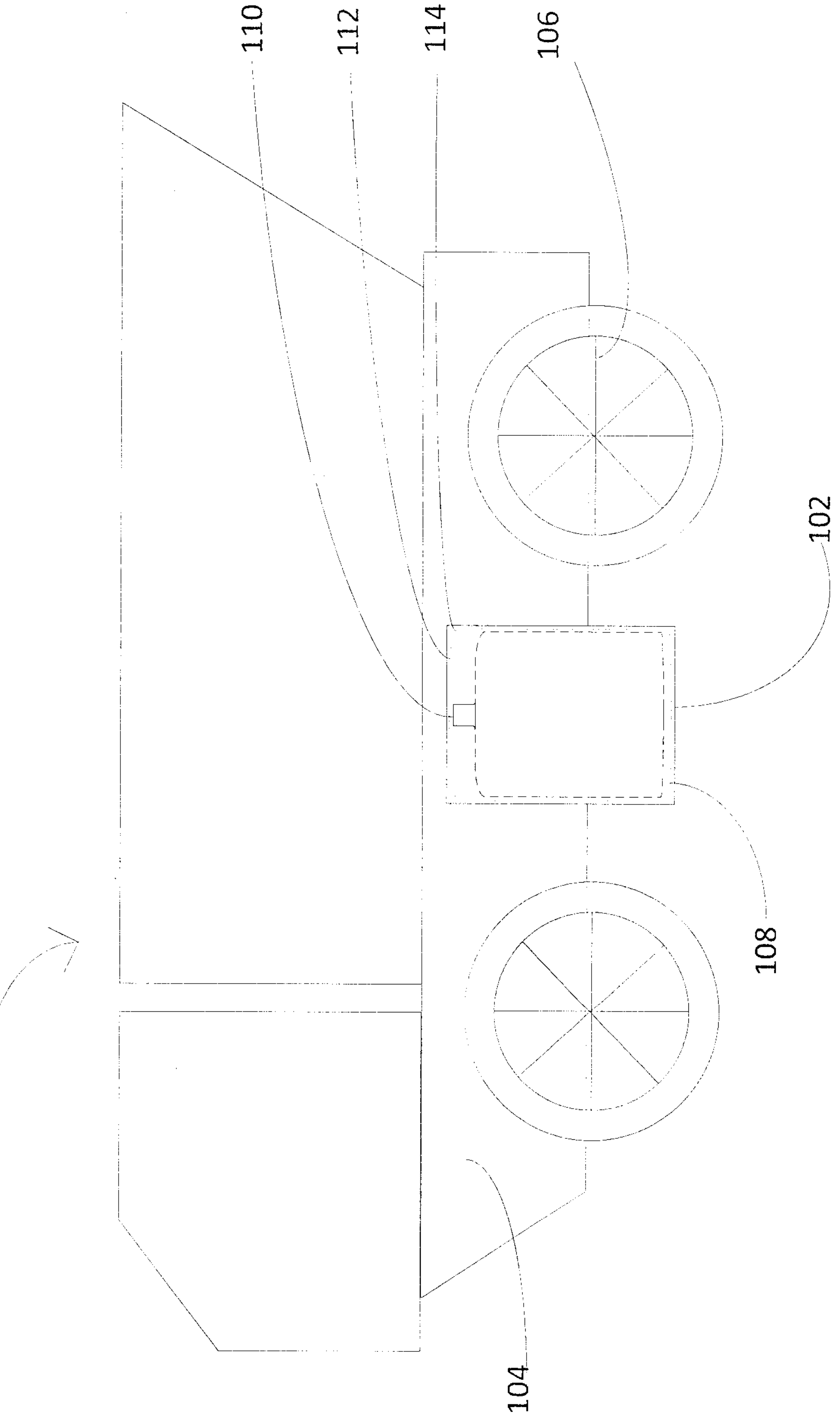


FIG 1

FIG 2

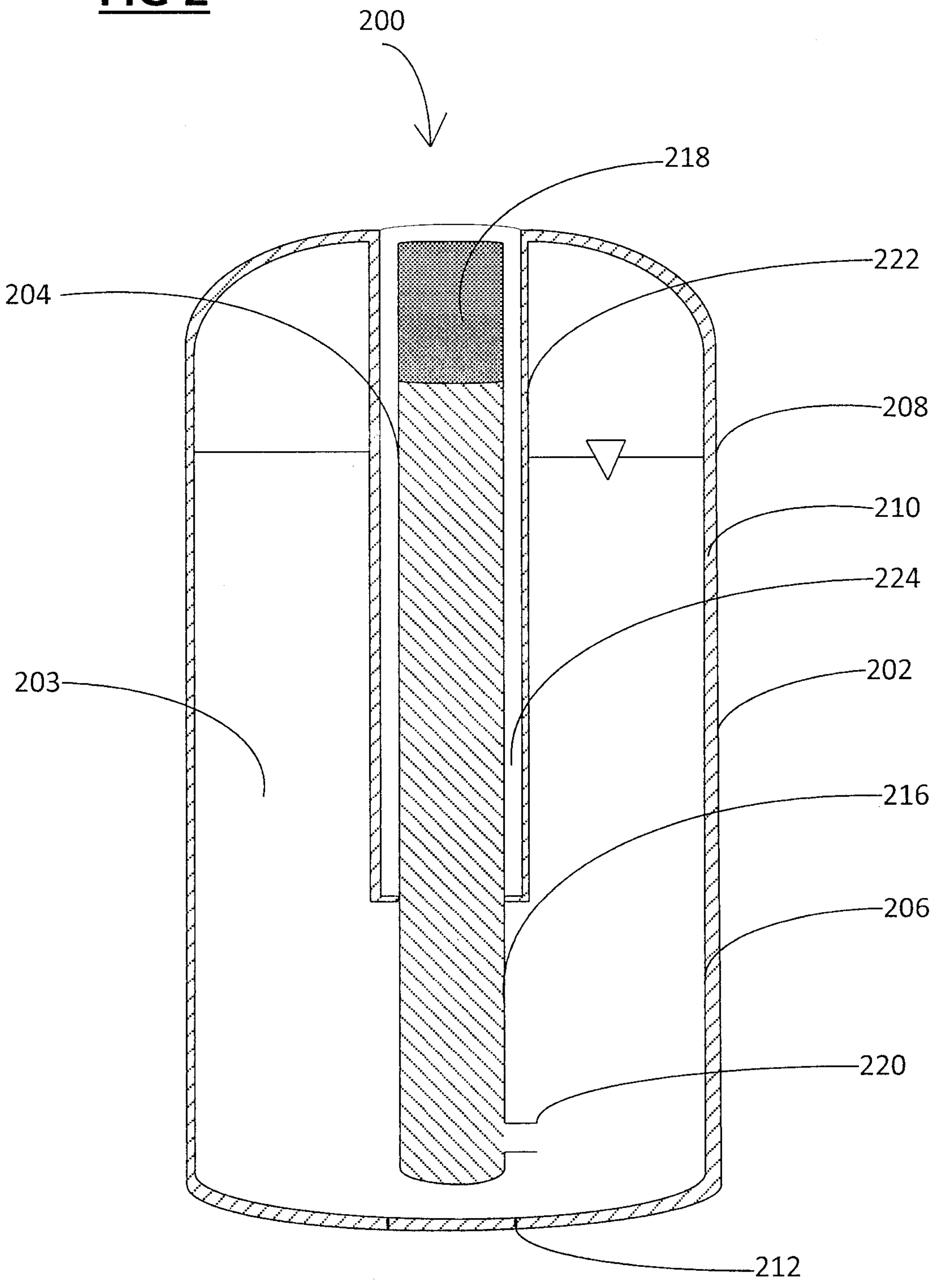
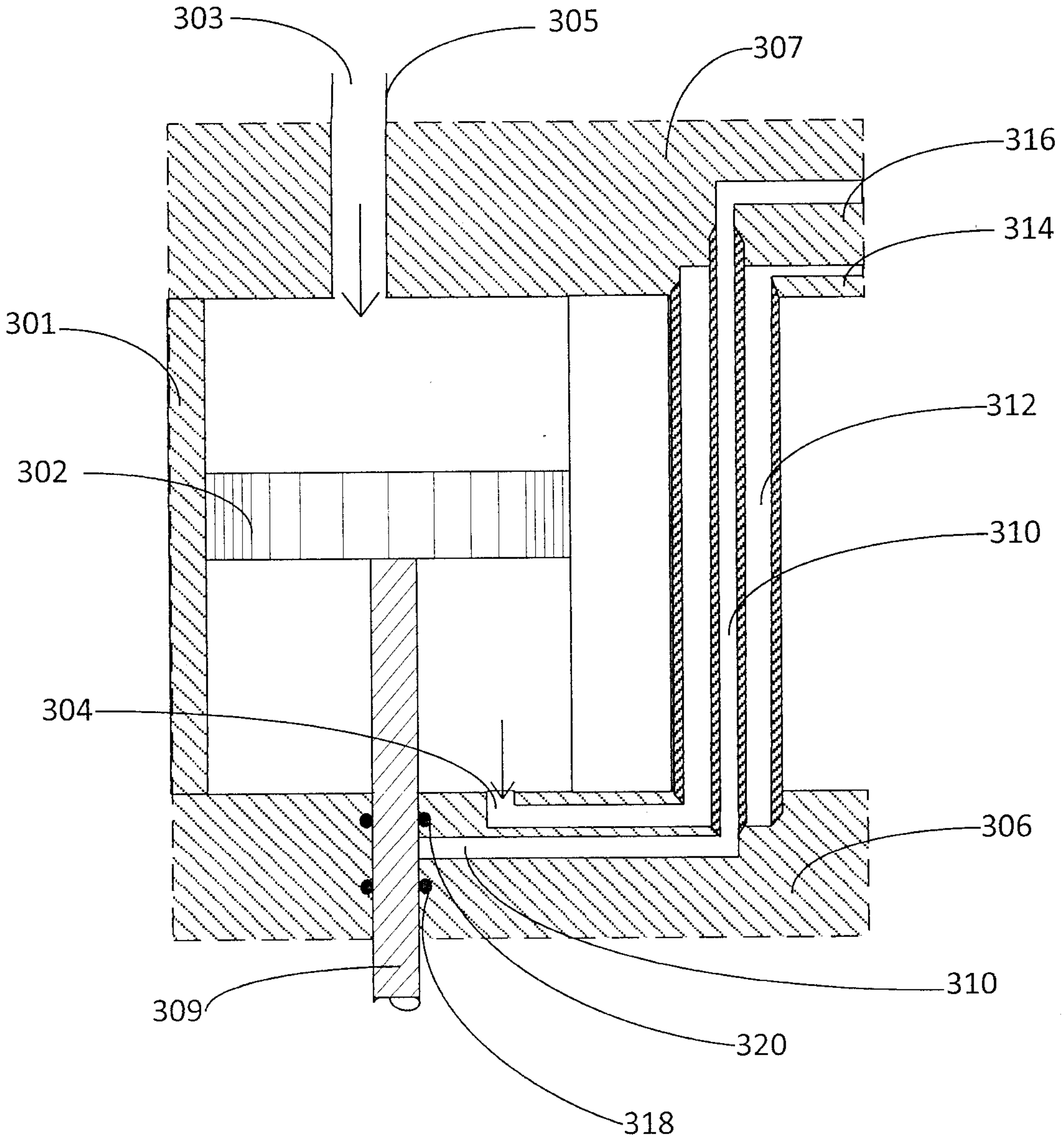
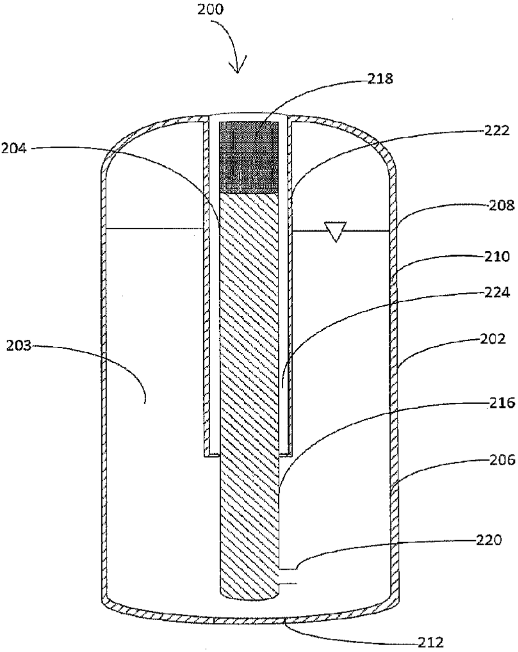


FIG 3





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