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(54) **STATION SIDE COOLING FOR REFUELING VEHICLE STORAGE TANKS WITH HIGH PRESSURE FUEL**

KÜHLUNG AN DER TANKSTATION FÜR TANKFAHRZEUGSPEICHERTANKS MIT HOCHDRUCKBRENNSTOFF

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Description

TECHNICAL FIELD

[0001] The present invention relates to a station side gas cooling apparatus and a system for enhancing the refueling efficiency of high pressure on board vehicle storage tanks for compressed natural gas or hydrogen.

BACKGROUND OF THE INVENTION

[0002] In the use of hydrogen (for fuel celts or internal combustion engines) or compressed natural gas, CNG, (for internal combustion engines) to power motor vehicles, present practice is that hydrogen is stored in refillable on board fuel tanks having a maximum design pressure in the range of about 34.5MPa (5000 psi) and CNG is stored in tanks having a maximum design pressure in the range of about 24.8MPa (3600 psi). Pressures exceeding 24.8MPa (3600 psi) for CNG and 34.5MPa to 69MPa (5000 psi to 10,000 psi) or more for hydrogen are likely to be utilized as high pressure fuel gas technology becomes more widespread and motor vehicle applications require an extended vehicle travel range before refill. High pressure gas powered vehicles typically utilize light weight reinforced polymer / composite storage tanks to store gaseous fuel on board at high pressure. Herein, reference to hydrogen powered vehicles correlates with the use of the invention with compressed natural gas powered vehicles (CNGVs). When hydrogen is referred to in the specification, that term is intended to be interchangeable, evident in context, with compressed natural gas, high pressure fuel gas, or gaseous fuels in general.

[0003] Several of my applications for patent originally filed in the United States, and thereafter in various Nations and Regions, relate to technologies for high pressure refueling systems that include *in situ* and on board cooling apparatus and system controls. In a high pressure refueling process, the interior of an on board tank, and the gas therein, becomes heated as a result of the compression of the gas as the tank pressure increases while the gas Is loaded into a fixed volume. Conventionally, it is not usually possible to obtain a full refill tank to match a high pressure tank design maximum, for example, (69MPa) (10,000 psi). without a pressure or temperature compensation system during the course of refueling. Namely, the charge of gas fuel input into and stored in the tank must be initially in excess of the optimal tank design pressure because of the gas compression and heating effect caused by the high pressure compression of gas in the tank as a result of refueling. Without some form of compensation or treatment, vehicle mileage in terms of vehicle range is reduced as a result of the compression and heating effect that lowers the effective amount of gas that a tank can receive during a refill. As higher tank design pressures are utilized, a full tank refill to optimum capacity becomes more difficult and an under fill results.

[0004] Solutions have been proposed to resolve under fill problems encountered with high pressure tanks. A slower flow rate during refill results in a lower initial tank temperature. A slow fill, however, is undesirable and may be impractical when significant numbers of refuel customers are involved at a same location. An undesirable consequence of a slow flow rate during refueling to avoid heat build up is a longer refueling time. An alternative process cools the gas before refueling. Pre-cooling to a very low temperature to ameliorate compression heating effects, however, requires substantial energy, thereby reducing overall energy efficiency of a high pressure gas infrastructure. In pre cooling, a low temperature pre cool occurs in real time simultaneously with the introduction of high pressure gas into the vehicle tank; or a quantity of high pressure gas at the tank farm intended for refueling dispensation is pre cooled in bulk at the station, and then conveyed to the vehicle tank through the refuel meter. A pressure overfill is another option that requires an additional energy expense in gas compression. Higher pressure, however, exacerbates the heat generated in the tank as a result of higher pressure compression.

[0005] German patent application No. DE 33 44 770 A1 discloses an apparatus for the automatic refilling of a liquid hydrogen tank in a motor vehicle in which the tank is connected to a liquid hydrogen supply line as well as a hydrogen gas return line. Prior to commencement of refilling the liquid hydrogen tank, the liquid hydrogen supply line in the vehicle is connected to the hydrogen gas return line and liquid hydrogen is passed through the lines in order to pre-cool them.

[0006] Secondary pre-treatment of refill gas is generally unnecessary when fill pressures are approximately 34.5MPa (5000 psi) or lower. When tank pressures exceed 24.8MPa (3600 psi) for CNG and 34.5MPa (5000 psi) for hydrogen, gas volume or quantity compensation becomes an important factor in the refueling process so that a full tank capacity fill may be achieved.

OBJECTS OF THE INVENTION

[0007] It is an object of the present invention to minimize energy consumption and reduce the expense and complexity of cooling systems used to enhance efficiency in high pressure fuel gas refilling systems. Typically, each time a vehicle is refueled with high pressure gas, compression energy results in heating the tank and the gas inside the tank; hence, it is an object of the invention to minimize high pressure gas and tank heating and to increase the efficiency and refueling capacity of an on board fuel storage tank in high pressure gas powered motor vehicles. It is an object of the invention to provide a station side cooling system that can remove the compression heat resulting from the refueling of an on board tank during a high pressure refuel. A faster refueling time, increased refueling efficiency and an extended vehicle range will result when improved tank capacity per unit volume is achieved, particularly where nominal or optimum design capacity refill pressure approaches 69MPa (10,000 psi) or greater.

DISCLOSURE OF INVENTION

[0008] In accordance with the present invention, reduction of fuel tank heating during the refueling process, is effected by a coolant exchange between the station and the vehicle. The station coolant cools the refill gas through an on board heat exchanger as the tank is charged with a high pressure refill from the station. As a result of station provided cooling in accordance with the invention, the vehicle does not need to have particularly complicated on-board cooling devices, nor does the station need to be encumbered with complex and expensive cooling devices. Vehicle cost and weight are reduced. In the invention, the refueling station requires a modest coolant system, generally capable of reducing gas temperature to an ambient level associate with "normal" tank temperature, typically 20° to 25° C, dependent on weather and climate conditions. Because the cooling temperature in the invention is ambient temperature, the cost of the cooling system of the invention is less than the cost of a conventional pre-cooling, or gas cooling, unit that reduces the refuel gas to a low temperature range of about -20° C or less in the process of refilling.

[0009] In the invention, an interior tank heat exchanger (HEX 1) absorbs the heat of refueling and is interconnected with an on board heat exchanger (HEX 2). HEX 2 is in turn interconnected at the station with a station provided ambient temperature cooling unit. The tank interior HEX 1 absorbs tank heat resulting from high pressure gas compression; the compression heated gas is circulated through a cooling loop system through the on board HEX 2 until the gas is cooled sufficiently to ambient temperature for storage in the on board tank.

[0010] The invention is described more fully in the following description of the preferred embodiment considered in view of the drawings in which:

BRIEF DESCRIPTION OF DRAWINGS

[0011]

Figure 1 is a diagram of a conventional station side gas pre cooling, or gas cooling, system characterized by an operating cooling temperature of - 20° C or less.

Figure 2A illustrates a station side system of the invention wherein an ambient temperature cooler is interconnectable with an on board vehicle heat exchanger during the process of a refill from the gas refueling depot to the vehicle tank. Figure 2B shows a plug, and Figure 2C shows a receptacle, both in plan view, of an interconnection system for the cooling loop and the refill gas in an interconnection between the station meter and the vehicle. Figure 2D shows separate station gas meter and coolant systems interconnectable with a vehicle. Figure 2E and Figure 2F show examples of plug/receptacle devices used in the system of Figure 2D.

Figure 3 shows an example of a system of the invention wherein a vehicle is interconnected with the refuel station gas and cooling supply and gas flows from the station dispenser through internal vehicle HEX 1, *in situ* in the tank, where heat is absorbed, and then through on board HEX 2, on the vehicle and external to the tank, for cooling. HEX 2 is interconnected with the station side cooler.

Figure 4 shows an example of the invention wherein the coolant circuit is formed in a conduit flow path within a vehicle sub frame structure comprising HEX 2 to provide gas cooling; the refill gas circulation path from the *in situ* tank HEX 1 is also formed within the vehicle sub frame structure proximate to the HEX 2 conduit.

Figure 5A, Figure 5B, Figure 5C, and Figure 5D are cross sections, through section 5 → ← 5 of Figure 4, illustrating examples of conduit paths from the station side cooler and refuel gas flow conduit paths embedded in a vehicle sub frame structure.

BEST MODE FOR CARRYING OUT THE INVENTION

[0012] The invention increases the refueling energy efficiency of hydrogen powered vehicles by withdrawing the heat of refilling compression from the high pressure gas introduced into on board tanks whether or not a slow fill, a pressure overfill or pre cooling of the gas occurs at the refueling station. Because the invention reduces the overall energy required to recharge the on board vehicle tanks with high pressure gas to an optimal measure, overall infrastructure energy requirements are reduced. When a full refill is achieved, vehicle mileage range is increased, the need for short interval refills is reduced, and consumer satisfaction is enhanced. A cooling circuit is disposed within the on board tank circulating the refill gas through an *in situ* on board tank HEX 1. Heat absorbed in HEX 1 is conveyed by the circulating refueling gas to a second on board heat exchanger, HEX 2, exterior to the tank, where the absorbed heat is eliminated by an ambient temperature heat exchange with a station side cooler.

[0013] The invention provides a coolant system wherein a station cooler at the high pressure gas refueling station provides a cooling temperature to a coolant media circulating therein approximately equivalent to the ambient temperature in the tank environment. The cooler includes an inlet and an outlet for the flow of the coolant media there through, from and returning to the cooler. The vehicle gas tank includes an interior heat exchanger (HEX 1) having a gas flow circuit allowing the flow of gas there through from a gas inlet to a gas outlet HEX 1 allows heat generated by the high pressure refueling to be transferred to the gas flowing there through. A second heat exchanger exterior to the vehicle fuel tank (HEX 2) is also provided. HEX 2 has a gas flow circuit allowing the flow of gas there through from a gas inlet to a gas outlet and dissipates the heat absorbed by the gas flowing within HEX 1. HEX 2 also includes a coolant media flow circuit therein, separate from the gas flow circuit, allowing the flow of coolant media there through from a coolant inlet of HEX 2 to the coolant outlet of HEX 2. The elements are interconnected in a gas flow circuit interconnection from the refueling station to the inlet of HEX 1 and from the outlet of HEX 1 to the inlet of HEX 2 and from the outlet of HEX 2 into the vehicle tank. A separate flow circuit for coolant media leads in a closed flow loop from the outlet of the cooler at the station to the coolant inlet of HEX 2; the coolant circulates through HEX 2, exits from the coolant outlet of HEX 2, and returns to the cooler through the cooler inlet. Interconnections are provided between the vehicle and station for temporarily allowing a refueling gas flow interconnection between the inlet of HEX 1 and the refueling station gas dispenser and a coolant media flow interconnection connecting the flow of the coolant media to and from HEX 2 and from and to the station cooler during the process of refueling.

[0014] The system typically cools to an ambient temperature usually in the range of approximately 20° C to approximately 25° C. Receptacle and plug devices interconnect the coolant and gas flows between the vehicle and the station. In one example, HEX 2 is a stand alone unit installed upon the vehicle frame or HEX 2 may be a unit installed at the station exterior to the vehicle allowing gas flow there through in the same manner. Cooperative receptacle and plug interconnections for the refueling gas and the coolant media may be combined in the plug/receptacle device on each of the station side and the vehicle side of the system.

[0015] In another example, the gas flow circuit of HEX 2 and the coolant media flow circuit of HEX 2 are integrated in the vehicle frame, preferably integrated in separate flow conduits intrinsic to the vehicle frame and comprising separate conduit systems. The station cooler may include an assistive refrigerant system for maintaining the temperature thereof at an ambient level and/or a fan for air circulation. Gas and coolant flow conduits may be formed in a sub frame structure of the vehicle such as a sub frame within which one or more vehicle tanks are installed.

[0016] A conventional station side gas pre cooling system characterized by an operating cooling temperature of - 20° C or less is shown in Figure 1. In Figure 1, the high pressure gas powered vehicle, shown at **100,** includes a fuel tank 102 interconnectable to a refuel depot receptacle through filling tube 103; gas flow from the refueling station meter 210 to the vehicle tank 102 is indicated by arrow 11. A refueling station will typically include a grounding pad 200 interconnected with the consumer dispensing meter 210 to reduce static electric effects that may cause a spark. The station will also include a tank farm 205, comprised of multiple tanks, 205a, 205b, ... 205x, being a high pressure source of gas interconnected through gas flow conduit 211 with the dispensing meter 210. A fluid coolant (gas or liquid) circulates (driven by pump) in a loop from very low temperature cooling unit 220 that provides a low temperature in the range of about -20° C. The loop circulates through a station HEX where the refill gas is exposed to the very low -20° C temperature and heat in a pre cooling operation before the gas is introduced at high pressure into the vehicle tank. In such a pre cooling system, cooling the gas to a low temperature reduces the gas volume pre pressure unit and permits more gas to be filled into the lank. Without temperature reduction, a high pressure gas refill will increase gas temperature and gas volume, reducing the amount of gas available to be stored in a tank of given capacity. Using a hydrogen refill as an example, refueling gas is transferred to the vehicle tank at the rate of 1kg H_2 per minute. When gas is filled in the vehicle tank, entropy will result in a tank/gas temperature approximating the ambient temperature, 20° to 25° C, dependent on weather and climate conditions. The temperature difference between tank gas and the pre cooling is approximately 45° C, hence, with pre cooling, the cooler the gas is at refill, the more gas that can be loaded into the tank.

[0017] In the example of the invention shown in Figure 2A, an ambient temperature cooler 250 is provided at the station such that the coolant fluid of the cooler may be interconnected (either through the station pump 210 (Figure 2A) or separately (Figure 2D)) to provide a cooling loop between HEX 1 on board the vehicle and the station cooler 250. Unit 250 is a typical ambient refrigerator/cooler including a compressor, motor, fan, temperature control and the like such that temperature in the refilling gas will be maintained at an ambient level, for example, 20° to 25° C, despite the high pressure (and heat) resulting in the refill. Cooler capacity is determined as a result, *inter alia,* of the coefficient of heat transfer of the refill gas, gas circulation volume, heat exchanger efficiency for HEX 1 and HEX 2, temperature difference and other known parameters. Coolant flow conduits 250_{OUT} and 250_{RETURN} lead from the ambient cooling unit 250 to the consumer meter 210. The consumer meter 210 integrates gas flow from the station tank farm 205 and the cooling system 250. Leading from the meter to the vehicle is an integrated conduit cable 275 including separate conduits for fuel gas 210_{FUEL} and vehicle coolant in $250_{VEH\ IN}$ and vehicle coolant return $250_{VEH\ RET}$ for the ambient cooling system 250. The cable 275 is interconnectable with the vehicle through a plug and receptacle system 215 at the terminal ends of each conduit 210_{FUEL}, $250_{VEH\ IN}$ and $250_{VEH\ RET.}$ Examples of plug and receptacle devices are respectively shown in Figure 2B and Figure 2C as reverse images of each other, plug 216_{P} and receptacle $216_{H.}$ Key 216_{KEY} is provided to prevent misalignment of the plug and receptacle when interconnected. Figure 2D shows an example wherein the gas flow conduit 210 FUEL and the coolant in / coolant out conduits. $250_{VEH\ IN}$ and $250_{VEH\ RET,}$ are separately provided for interconnection to the vehicle at the station.

Figure 2E and Figure 2F show coolant 221 and gas 222 receptacle/plug devices useful with the system of Figure 2D.

[0018] Figure 3 shows an example of a tank 102 including internal HEX 1 installed in a vehicle sub frame 300 proximate to an on board cooler HEX 2 within a vehicle body 101. Gas from the inlet tube 103 flows through HEX 1 through HEX 2 and ultimately into the tank 102 through inlet opening 225. The gas flow conduit and the coolant in and coolant return conduits are interconnected with the refuel station apparatus, meter 210 and cooler 250 separately through the interconnections shown at $G_{R\text{-}P}$ and $C_{R\text{-}P}$.

[0019] In Figure 4, the internal heat exchanger HEX 1 in the tank 601 is interconnected with a gas flow conduit circuit 610 and coolant flow conduit circuit 620. both embedded in a vehicle sub frame structure 690. Refill gas flows through conduit 103 into tank HEX 1, then through gas flow sub frame conduit 610 and enters the tank through inlet 650. In the example of Figure 4, the sub frame 690 is HEX 2 wherein the heat from gas circulating in conduit 610 is cooled by coolant circuit 620 within the sub frame 690. The gas from meter 210 and coolant from cooler 250 interconnections between the vehicle and the station are effected by the cooperative receptacle plug device shown at $G\text{-}C_{R\text{-}P}$. Figure 5A. Figure 5B and Figure 5C depict examples of configurations of coolant conduit 620 and gas conduit 610 tube circuits embedded in the vehicle sub frame. In Figure 5C, fins within the sub frame assist in cooling. Figure 5D depicts a plurality of coolant tubes. 620a and 620b, embedded in the sub frame proximate to the gas flow conduit 610. The number of flow tubes for gas and coolant embedded within the vehicle frame and their respective configurations and relationships are matters of design choice dependent on factors such as rate of gas flow, heat transfer coefficient of the sub frame material, gas residence time, and other parameters. A fan passing ambient air through the interstices of the internal space within the sub frame may assist in cooling.

[0020] Having described the invention in detail, those skilled in the art will appreciate that, given the present description, modifications may be made to the invention without departing from the inventive concept herein described. Therefore, it is not intended that the scope of the invention be limited to the specific and preferred embodiments illustrated and described. Rather, it is intended that the scope of the invention be determined by the appended claims.

INDUSTRIAL APPLICABILITY

[0021] High pressure CNG or hydrogen gas fueled vehicles powered by engines or fuel cells require an extended driving range. As tank pressures exceed 24.8MPa (3600 psi) for CNG and 34.5MPa (5000 psi) for hydrogen to increase the quantity of gas stored, and consequently, to increase vehicle range, gas volume or quantity compensation becomes an important factor in the refueling process so that a full tank capacity fill may be achieved. The invention increases the refueling energy efficiency of hydrogen powered vehicles by withdrawing the heat of refilling compression from the high pressure gas introduced into on board tanks whether or not a slow fill, a pressure overfill or pre cooling of the gas occurs at the refueling station. Because the invention reduces the overall energy required to recharge the on board vehicle tanks with high pressure gas to a full optimal state, overall infrastructure energy requirements are reduced. When a full refill is achieved, vehicle mileage range is increased, the need for short interval refills is reduced, and consumer satisfaction is enhanced. Thus, the present invention minimizes energy consumption and reduces the expense and complexity of cooling systems used to enhance efficiency in high pressure fuel gas refilling systems. Faster refueling time, increased refueling efficiency and overall vehicle range increase because improved tank storage capacity per unit volume is achieved, particularly where nominal or optimum design capacity refill pressure approaches 69MPa (10,000 psi) or greater for hydrogen and 24.8MPa (3600 psi) for CNG. When used with many configurations of auxiliary and *in situ* heat exchange systems, the invention enhances convenience, refill speed, efficiency, vehicle range, durability, and customer satisfaction in a high pressure fuel gas system. Station side ambient temperature refuel gas cooling is provided. The vehicle does not need to have particularly complicated on-board cooling devices nor does the station need to be encumbered with complex and expensive pre cooling devices.

Claims

1. A cooling system for reducing the heat of compression of a high pressure gas in the refill of a vehicle fuel tank (102, 601) at a high pressure gas refueling station (205) **characterised by** comprising:

a station cooler (250) at the high pressure gas refueling station providing a temperature to a coolant media circulating therein approximately equivalent to the ambient temperature in the tank environment, the cooler having an inlet (250_{RETURN}) and an outlet (250_{OUT}) for the flow of the coolant media from and returning to the cooler;

an interior heat exchanger (HEX 1) in the vehicle fuel tank, the interior heat exchanger having a gas flow circuit (610) allowing the flow of gas therethrough from a gas inlet (103) to a gas outlet thereof, the interior heat exchanger allowing heat generated by the high pressure refueling to be transferred to the gas flowing therethrough;

a heat exchanger (HEX 2) exterior to the vehicle fuel tank , the exterior heat exchanger (HEX 2) having a gas flow circuit allowing the flow of gas therethrough from a gas inlet to a gas outlet thereof, the exterior heat exchanger dissipating the heat absorbed by the gas flowing within the interior heat exchanger (HEX 1), the exterior heat exchanger further having a coolant media flow circuit (620) therein, separate from the gas flow circuit, allowing the flow of coolant media therethrough from a coolant inlet of the exterior heat exchanger to the coolant outlet of the exterior heat exchanger.

a gas flow circuit interconnection for gas flow from the refueling station (205) to the inlet of the interior heat exchanger and from the outlet of the interior heat exchanger to the inlet of the exterior heat exchanger and from the outlet of the exterior heat exchanger into the vehicle tank (102, 601);

a flow circuit for the coolant media leading in a closed flow loop from the outlet of the cooler (250) at the station (205) to the coolant inlet of the exterior heat exchanger, circulating through the exterior heat exchanger, exiting from the coolant outlet of the exterior heat exchanger, and returning the coolant media to the cooler through the cooler inlet;

a refueling gas flow interconnection (G_{R-P}) between the inlet of the interior heat exchanger and the refueling station gas dispenser (210); and

a coolant media flow interconnection (C_{R-P}) connecting the flow of the coolant media to and from the exterior heat exchanger and from and to the station cooler (250).

2. The system of claim 1 wherein the ambient temperature is typically in the range of approximately 20°C to approximately 25°C.

3. The system of claim 1 wherein refueling gas flows through a conduit interconnection (G_{R-P}) between the interior heat exchanger (HEX 1) and the station dispenser (210) and coolant media flows through a conduit interconnection (C_{R-P}) between the exterior heat exchanger (HEX 2) and the cooler (250) and the flows of refueling gas and the coolant media through the conduits are connected between the vehicle and the station (205) by a receptacle (216_R) at one side of the vehicle or station and a plug (216_P) at the other side of the vehicle or station.

4. The system of claim 1 wherein the exterior heat exchanger (HEX 2) comprises a stand alone heat exchange unit installed upon the vehicle frame (300, 690).

5. The system of claim 1 wherein the exterior heat exchanger (HEX 2) comprises a stand alone heat exchange unit installed at the station (205), exterior to the vehicle.

6. The system of claim 3 wherein the receptacle (216_R) and plug (216_P) interconnections for the refueling gas and the coolant media are combined in the same single plug/receptacle device ($G\text{-}C_{R-P}$) cooperative with the station side and the vehicle side of the system.

7. The system of claim 1 wherein the gas flow circuit (610) of the exterior heat exchanger (HEX 2) and the coolant media flow circuit (620) of the exterior heat exchanger (HEX 2) comprise separate conduit systems integrated in separate flow conduits intrinsically disposed in a frame component (300, 690) of the vehicle.

8. The system of claim 1 or claim 2 wherein the station cooler (250) includes a refrigerant system for maintaining the temperature thereof at an ambient level.

9. The system of claim 1 or claim 2 or claim 3 or claim 5 wherein the station cooler (250) includes a fan (M) for air circulation.

10. The system of claim 8 wherein the refrigerant system includes a fan (M).

11. The system of claim 7 wherein the gas flow circuit (610) and the coolant media flow circuit (620) comprise separate conduit systems integrated into a sub frame structure (300, 690) of the vehicle.

12. The system of claim 1 wherein the gas flow circuit (610) of the exterior heat exchanger (HEX 2) and the coolant media flow circuit (620) of the exterior heat exchanger (HEX 2) comprise separate conduit systems integrated in separate flow conduits intrinsically disposed in a sub frame component (300, 690) of the vehicle within which one or more gas storage tanks (102, 601) for the vehicle are installed.

Patentansprüche

1. Kühlsystem zum Reduzieren der Kompressionswärme eines Hochdruckgases beim Betanken eines Fahrzeugkraftstofftanks (102, 601) an einer Hochdruck-Gasbetankungsstation (205), **gekennzeichnet durch**:

einen Stationskühler (250) an der Hochdruck-Gasbetankungsstation, der einem darin zirkulierenden Kühlmedium eine Temperatur gibt, die in etwa äquivalent zu der Umgebungstemperatur in der Tankumgebung ist, wobei der Kühler einen Einlass (250_{RETURN}) und einen Auslass

(250_{OUT}) für die Strömung des Kühlmediums von dem Kühler weg und zu diesem zurück aufweist,
einen inneren Wärmetauscher (HEX1) in dem Fahrzeugkraftstofftank, wobei der innere Wärmetauscher einen Gasströmungskreislauf (610) aufweist, der die Strömung von Gas **durch** denselben von seinem Gaseinlass (103) zu seinem Gasauslass erlaubt, wobei der innere Wärmetauscher erlaubt, **durch** die Hochdruckbetankung erzeugte Wärme auf das **durch** ihn strömende Gas zu übertragen,
einen Wärmetauscher (HEX2) außerhalb des Fahrzeugkraftstofftanks, wobei der äußere Wärmetauscher (HEX2) einen Gasströmungskreislauf aufweist, der die Strömung von Gas **durch** denselben von seinem Gaseinlass zu seinem Gasauslass erlaubt, wobei der äußere Wärmetauscher die Wärme abführt, die durch das im inneren Wärmetauscher (HEX1) strömende Gas absorbiert wurde, wobei der äußere Wärmetauscher ferner innen einen separat von dem Gaströmungskreislauf vorgesehenen Kühlmedium-Strömungskreislauf (620) aufweist, der die Strömung des Kühlmediums **durch** denselben von einem Kühlmitteleinlass des externen Wärmetauschers zu dem Kühlmittelauslass des externen Wärmetauschers erlaubt,
eine Gasströmungskreislaufverbindung für Gasströmung von der Betankungsstation (205) zu dem Einlass des inneren Wärmetauschers, von dem Auslass des inneren Wärmetauschers zu dem Einlass des äußeren Wärmetauschers und von dem Auslass des äußeren Wärmetauschers in den Fahrzeugtank (102, 601),
einen Strömungskreislauf für das Kühlmedium, der in einem geschlossenen Strömungskreis von dem Auslass des Kühlers (250) an der Station (205) zu dem Kühlmitteleinlass des externen Wärmetauschers führt, **durch** den externen Wärmetauscher zirkuliert, von dem Kühlmittelauslass des externen Wärmetauschers austritt und das Kühlmedium **durch** den Kühlereinlass zu dem Kühler zurückführt,
eine Betankungsgasströmungsverbindung (G_{R-P}) zwischen dem Einlass des inneren Wärmetauschers und der Betankungsstations-Gasausgabe (210) und
eine Kühlungsmedium-Strömungsverbindung (C_{R-P}), die die Strömung des Kühlmediums zu und von dem externen Wärmetauscher und von und zu dem Stationskühler (250) verbindet.

2. System nach Anspruch 1, wobei die Umgebungstemperatur typischerweise in dem Bereich von etwa 20°C bis etwa 25°C liegt.

3. System nach Anspruch 1, wobei das Betankungsgas von einer Leitungsverbindung (G_{R-P}) zwischen dem inneren Wärmetauscher (HEX1) und der Stationsausgabe (210) strömt, Kühlmedium durch eine Leitungsverbindung (C_{R-P}) zwischen dem äußeren Wärmetauscher (HEX2) und dem Kühler (250) strömt, und die Strömungen des Betankungsgases und des Kühlmediums durch die Leitungen zwischen dem Fahrzeug und der Station (205) durch eine Buchse (216_R) auf einer Seite des Fahrzeugs oder der Station und einen Stecker (216_P) an der anderen Seite des Fahrzeugs oder der Station verbunden sind.

4. System nach Anspruch 1, wobei der äußere Wärmetauscher (HEX2) eine freistehende Wärmetauscheinheit aufweist, die auf dem Fahrzeugfahrgestell (300, 690) eingerichtet ist.

5. System nach Anspruch 1, wobei der äußere Wärmetauscher (HEX2) eine freistehende Wärmetauscheinheit aufweist, die an der Station (205) außerhalb des Fahrzeugs eingerichtet ist.

6. System nach Anspruch 3, wobei die Buchsen- (216_R) und Stecker- (216_P) Verbindungen für das Betankungsgas und das Kühlmedium in der gleichen einzigen Stecker/Buchse-Vorrichtung ($G\text{-}C_{R-P}$) kombiniert sind, die mit der Stationsseite und der Fahrzeugsseite des System zusammenwirkt.

7. System nach Anspruch 1, wobei der Gasströmungskreislauf (610) des äußeren Wärmetauschers (HEX2) und der Kühlmedium-Strömungskreislauf (620) des äußeren Wärmetauschers (HEX2) separate Leitungssysteme aufweisen, die in separate Strömungsleitungen integriert sind, die intrinsisch in einer Fahrgestellkomponente (300, 690) des Fahrzeugs angeordnet sind.

8. System nach Anspruch 1 oder 2, wobei der Stationskühler (250) ein Kältemittelsystem zum Aufrechterhalten seiner Temperatur auf einem Umgebungsniveau aufweist.

9. System nach Anspruch 1, 2, 3 oder 5, wobei der Stationskühler (250) einen Lüfter (M) zur Luftzirkulation aufweist.

10. System nach Anspruch 8, wobei das Kühlmittelsystem einen Lüfter (M) aufweist.

11. System nach Anspruch 7, wobei der Gasströmungskreislauf (610) und der Kühlmedium-Strömungskreislauf (620) separate Leitungssysteme aufweisen, die in eine Unterfahrgestellstruktur (300, 690) des Fahrzeugs integriert sind.

12. System nach Anspruch 1, wobei der Gasströmungskreislauf (610) des externen Wärmetauschers (HEX2) und der Kühlmedium-Strömungskreislauf (620) des externen Wärmetauschers (HEX2) separate Leitungssysteme aufweisen, die in separate Strömungsleitungen integriert sind, die intrinsisch in einer Unterfahrgestellkomponente (300, 690) des Fahrzeugs angeordnet sind, in der ein oder mehrere Gasspeichertanks (102, 601) für das Fahrzeug eingerichtet sind.

Revendications

1. Système de refroidissement, pour réduire la chaleur de compression d'un gaz sous haute pression, dans le rechargement d'un réservoir à carburant de véhicule (102, 601) à une station de remplissage à la pompe en gaz sous haute pression (205), **caractérisé par** le fait de comprendre :

   un refroidisseur de station (250), à la station de remplissage à la pompe en gaz sous haute pression, fournissant une température à un fluide de refroidissement y circulant à peu près équivalente à la température ambiante dans l'environnement de réservoir, le refroidisseur ayant une entrée (250_{RETURN}) et une sortie (250_{SORTIE}) pour l'écoulement de fluide de refroidissement provenant de et allant au refroidisseur ;
   un échangeur de chaleur intérieur (HEX 1) dans le réservoir à carburant de véhicule, l'échangeur de chaleur intérieur présentant un circuit d'écoulement de gaz (610) permettant l'écoulement de gaz à travers lui, d'une entrée de gaz (103) à une sortie de gaz de celui-ci, l'échangeur de chaleur intérieur permettant à de la chaleur, générée par le remplissage à la pompe sous haute pression, d'être transférée au gaz passant à travers lui ;
   un échangeur de chaleur (HEX 2) extérieur au réservoir à carburant de véhicule, l'échangeur de chaleur (HEX 2) extérieur ayant un circuit d'écoulement de gaz permettant l'écoulement de gaz à travers lui, d'une entrée de gaz à une sortie de gaz de celui-ci, l'échangeur de chaleur extérieur dissipant la chaleur absorbée par le gaz s'écoulant dans l'échangeur de chaleur intérieur (HEX 1), l'échangeur de chaleur extérieur comprenant en outre en son sein un circuit d'écoulement de fluide de refroidissement (620), séparé du circuit d'écoulement de gaz, permettant l'écoulement de fluide réfrigérant à travers lui, d'une entrée de réfrigérant de l'échangeur de chaleur extérieur à a sortie de réfrigérant de l'échangeur de chaleur extérieur, une interconnexion de circuit d'écoulement de gaz, pour un écoulement de gaz, de la station de remplissage à la pompe (205) à l'entrée de l'échangeur de chaleur intérieur et de la sortie de l'échangeur de chaleur intérieur à l'entrée de l'échangeur de chaleur extérieur et de la sortie de l'échangeur de chaleur extérieur dans le réservoir de véhicule (102, 601) ;
   un circuit d'écoulement pour le fluide réfrigérant, menant, en une boucle d'écoulement fermée, de la sortie du refroidisseur (250) à la station (205) à l'entrée de réfrigérant de l'échangeur de chaleur extérieur, en circulant à travers l'échangeur de chaleur extérieur, sortant de la sortie de réfrigérant de l'échangeur de chaleur extérieur, et retournant le fluide réfrigérant au refroidisseur, par l'entrée de refroidisseur ;
   une interconnexion d'écoulement de gaz de remplissage à la pompe (G_{R-P}), entre l'entrée de l'échangeur de chaleur intérieur et le distributeur de gaz de station de remplissage à la pompe (210) ; et
   une interconnexion d'écoulement de fluide de refroidissement (C_{R-P}), connectant l'écoulement de fluide réfrigérant, vers et à partir de l'échangeur de chaleur extérieur et à partir de et vers le refroidisseur de station (250).

2. Système selon la revendication 1, dans lequel la température ambiante est typiquement dans la fourchette d'à peu près 20°C à à peu près 25°C.

3. Système selon la revendication 1, dans lequel le gaz de remplissage à la pompe s'écoule à travers une interconnexion de conduit (G_{R-P}), entre l'échangeur de chaleur intérieur (HEX 1) et le distributeur de station (210) et le fluide réfrigérant s'écoule à travers une interconnexion de conduit (C_{R-P}), entre l'échangeur de chaleur extérieur (HEX 2) et le refroidisseur (250) et les écoulements de gaz de remplissage à la pompe et de fluide réfrigérant passant par les conduits sont connectés entre le véhicule et la station (205), par un réceptacle (216_R) disposé sur un côté du véhicule ou de la station et un bouchon (216_P) disposé sur l'autre côté du véhicule ou de la station.

4. Système selon la revendication 1, dans lequel l'échangeur de chaleur extérieur (HEX 2) comprend une unité d'échange de chaleur autonome, installée sur le châssis de véhicule (300, 690).

5. Système selon la revendication 1, dans lequel l'échangeur de chaleur extérieur (HEX 2) comprend une unité d'échange de chaleur autonome installée à la station (205), extérieure au véhicule.

6. Système selon la revendication 3, dans lequel les interconnexions de réceptacle (216_R) et de bouchon (216_P) pour le gaz de remplissage à la pompe et le fluide réfrigérant sont combinés dans le même dis-

positif à bouchon/réceptacle (G-CR-P) unique, coopérant avec le côté station et le côté véhicule du système.

7. Système selon la revendication 1, dans lequel le circuit d'écoulement de gaz (610) de l'échangeur de chaleur extérieur (HEX 2) et le circuit d'écoulement de fluide réfrigérant (620) de l'échangeur de chaleur extérieur (HEX 2) comprennent des systèmes à conduits séparés, intégrés dans des conduits d'écoulement séparés, intrinsèquement disposés dans un composant de châssis (300, 690) du véhicule.

8. Système selon la revendication 1 ou la revendication 2, dans lequel le refroidisseur de station (250) comprend un système réfrigérant pour maintenir sa température à un niveau ambiant.

9. Système selon la revendication 1, ou la revendication 2 ou la revendication 3 ou la revendication 5, dans lequel le refroidisseur de station (250) comprend un ventilateur (M) pour la circulation d'air.

10. Système selon la revendication 8, dans lequel le système réfrigérant comprend un ventilateur (M).

11. Système selon la revendication 7, dans lequel le circuit d'écoulement de gaz (610) et le circuit d'écoulement de fluide de refroidissement (620) comprennent des systèmes à conduits séparés, intégrés dans une structure de sous-châssis (300, 690) du véhicule.

12. Système selon la revendication 1, dans lequel le circuit d'écoulement de gaz (610) de l'échangeur de chaleur extérieur (HEX 2) et le circuit d'écoulement de fluide de refroidissement (620) de l'échangeur de chaleur extérieur (HEX 2) comprennent des systèmes à conduits séparés, intégrés dans des conduits d'écoulement séparés, intrinsèquement disposés dans un composant de sous-châssis (300, 690) du véhicule, à l'intérieur duquel un ou plusieurs réservoirs de stockage de gaz (102, 601) pour le véhicule sont installés.

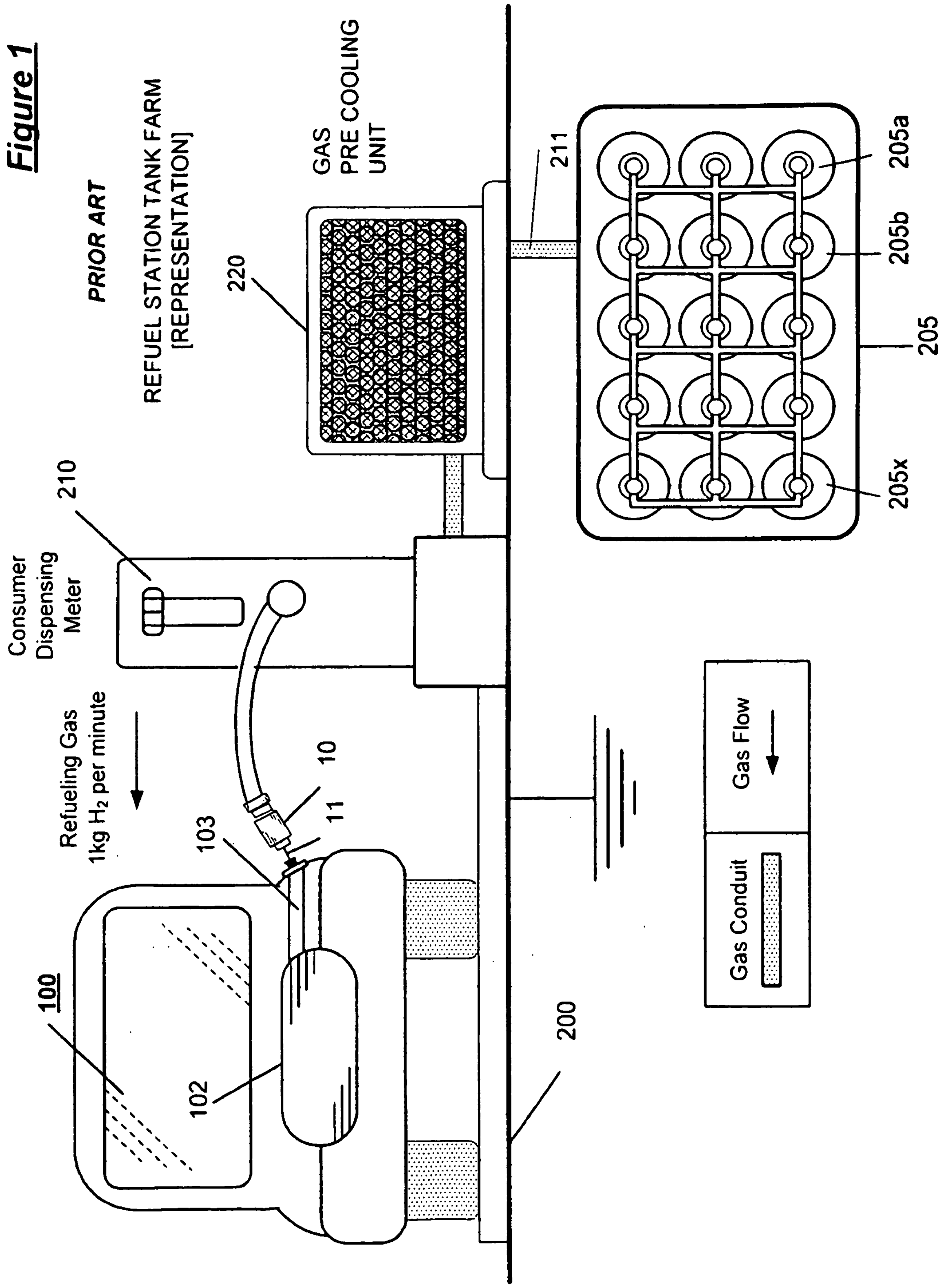


Figure 1
PRIOR ART
REFUEL STATION TANK FARM
[REPRESENTATION]
GAS
PRE COOLING
UNIT
220
Consumer
Dispensing
Meter
210
Refueling Gas
1kg H2 per minute
100
102
103
10
11
200
211
205a
205b
205
205x
Gas Conduit
Gas Flow

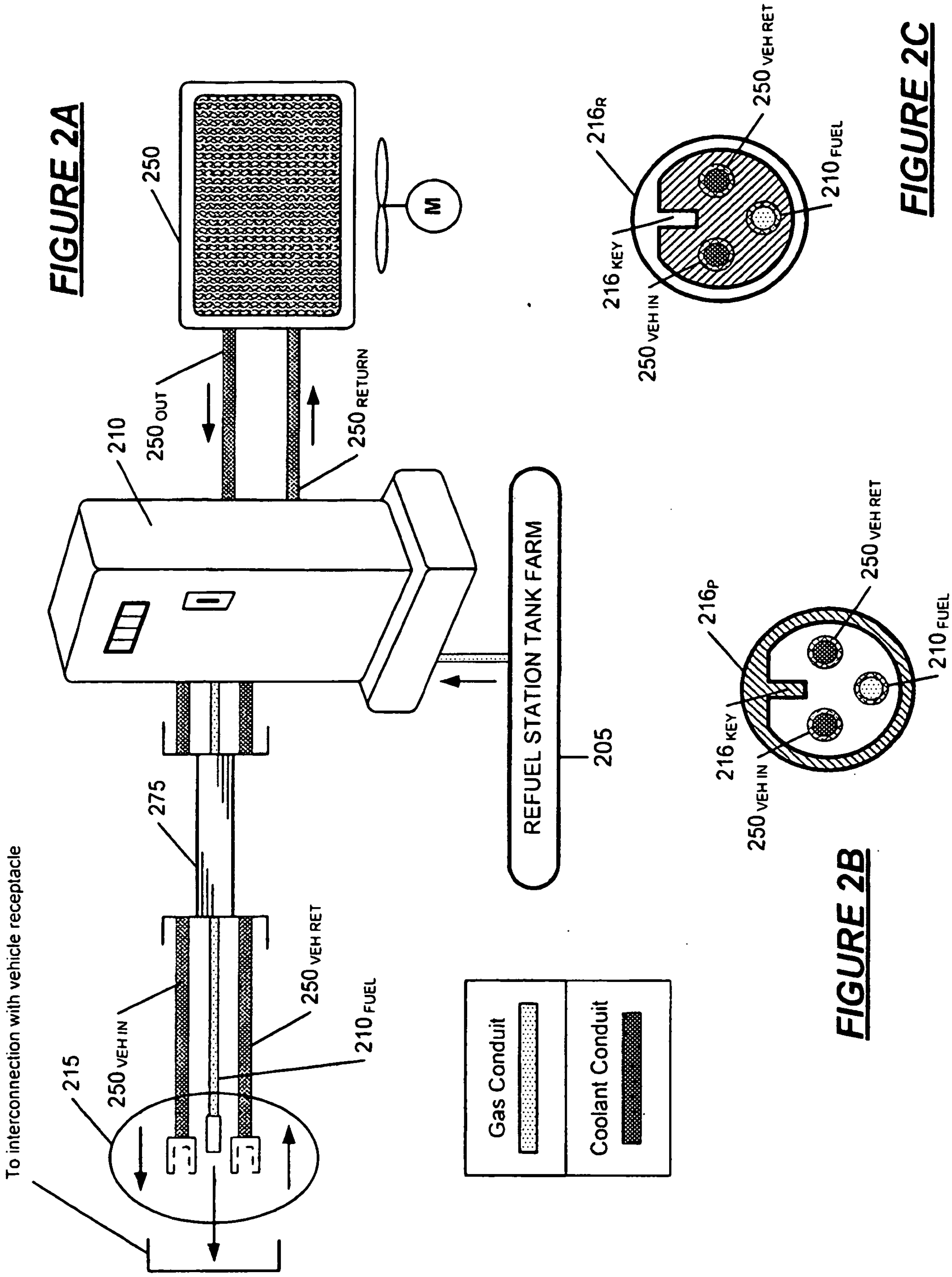


FIGURE 2A
FIGURE 2B
FIGURE 2C
To interconnection with vehicle receptacle
215
250 VEH IN
250 VEH RET
210 FUEL
275
210
250 OUT
250 RETURN
250
M
REFUEL STATION TANK FARM
205
Gas Conduit
Coolant Conduit
216P
216KEY
216R

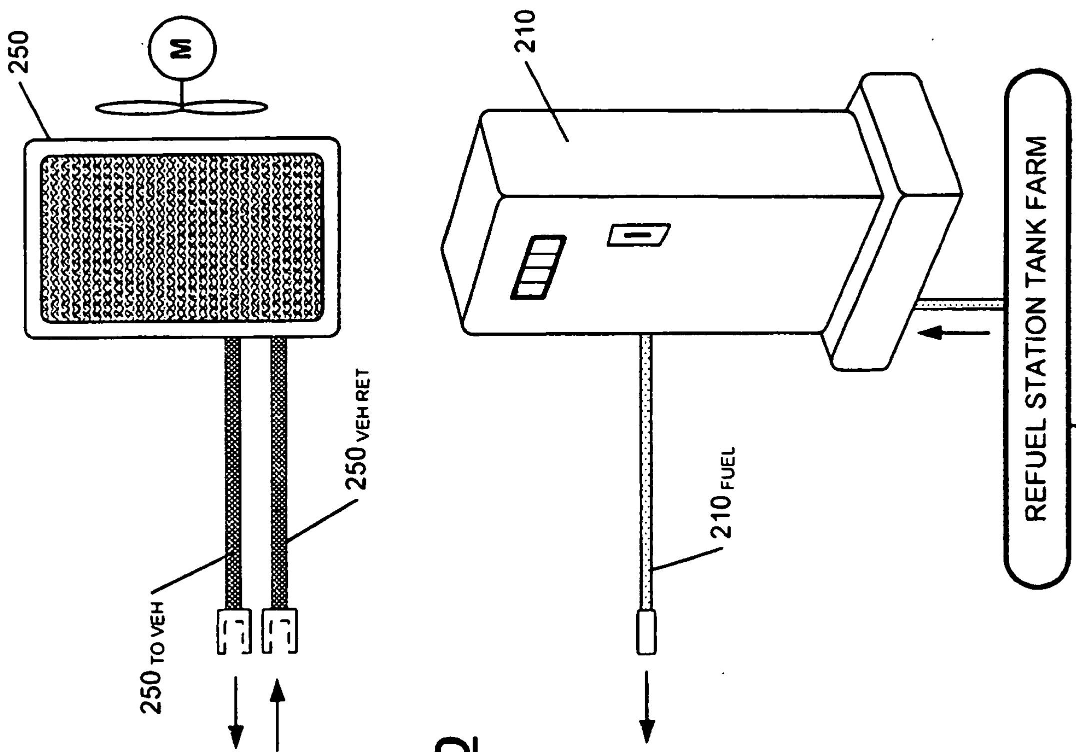


FIGURE 2D

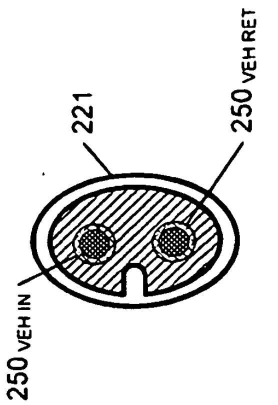


FIGURE 2E

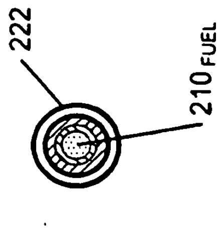


FIGURE 2F

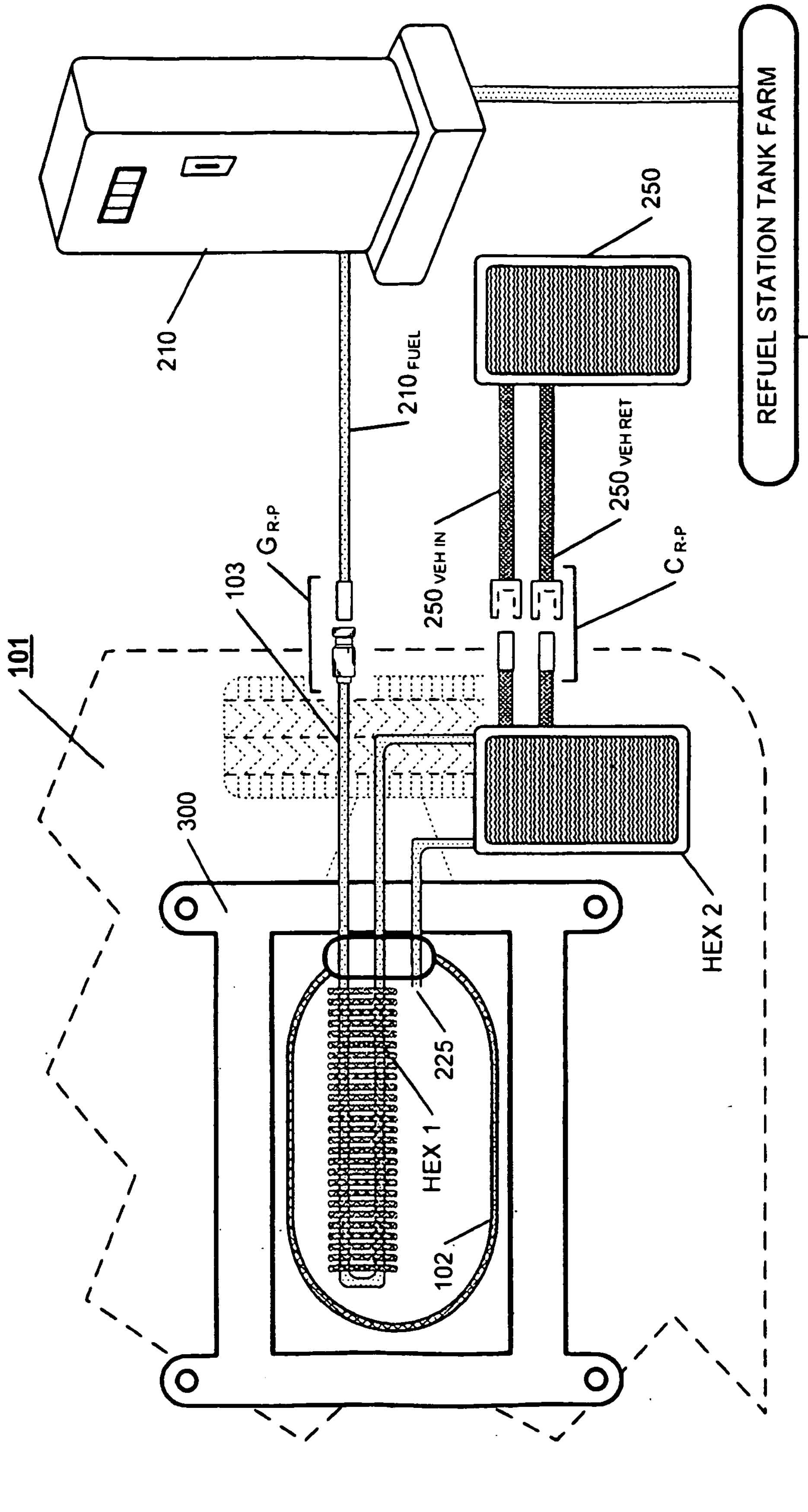
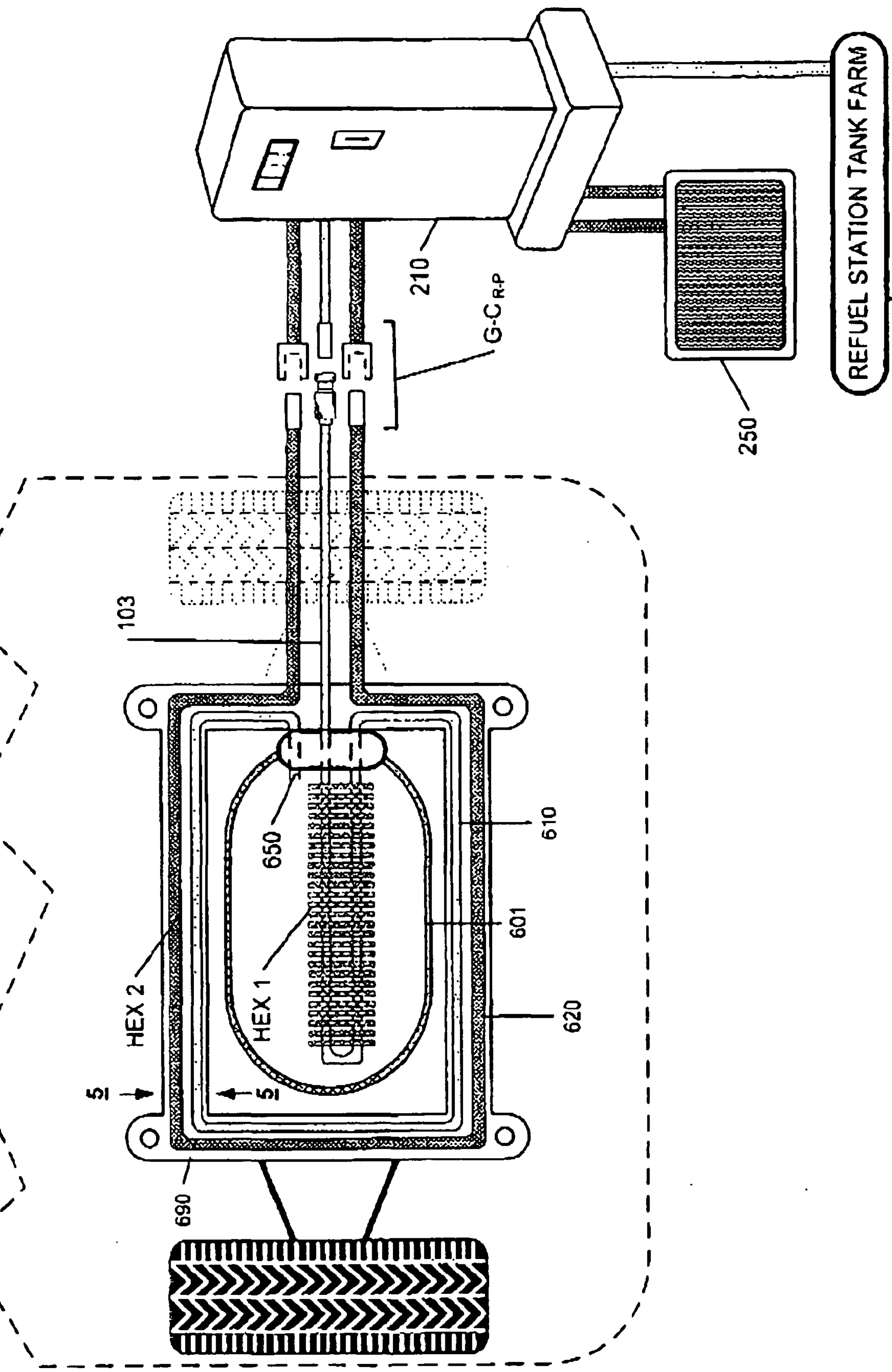

210
210 FUEL
250
REFUEL STATION TANK FARM
205
G R-P
103
250 VEH IN
250 VEH RET
C R-P
101
300
HEX 2
225
HEX 1
102

FIGURE 3

FIGURE 4


REFUEL STATION TANK FARM
205
250
210
G-C R-P
103
650
HEX 1
HEX 2
601
610
620
5
5
690

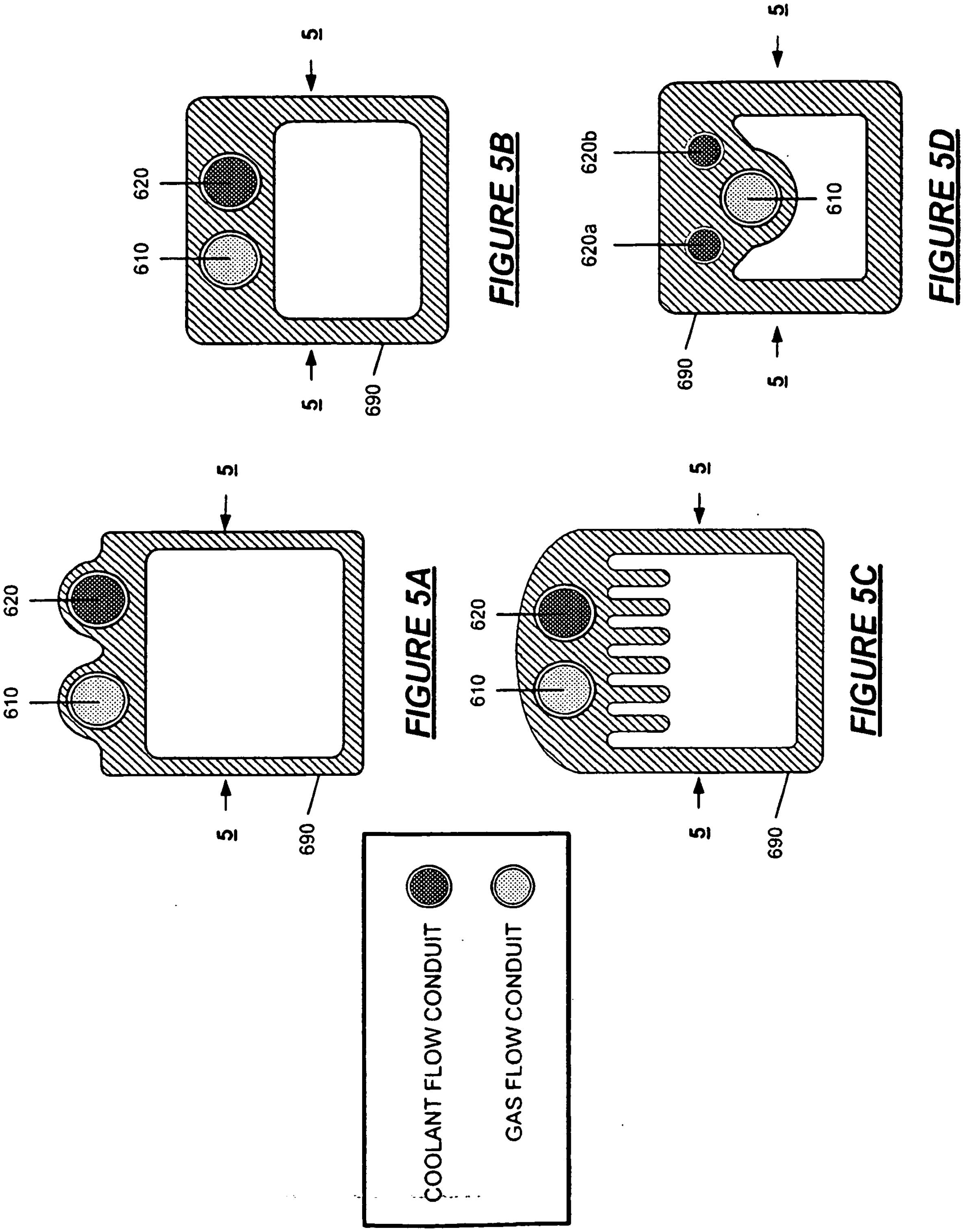


FIGURE 5A

FIGURE 5B

FIGURE 5C

FIGURE 5D

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

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