United States Patent

Davis

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[54] FUEL VAPOR RECOVERY APPARATUS

[72] Inventor: **Edwin R. Davis,** 2020 Beverly Plaza 0213, Long Beach, Calif. 90815

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[52] **U.S. Cl.** ..... **62/54,** 55/88, 220/85 VR

[51] **Int. Cl.** **F17c 13/12**

[58] **Field of Search** ..... 62/55, 45, 50, 54; 55/88, 89; 220/85 VR, 85 VS

[56] **References Cited**

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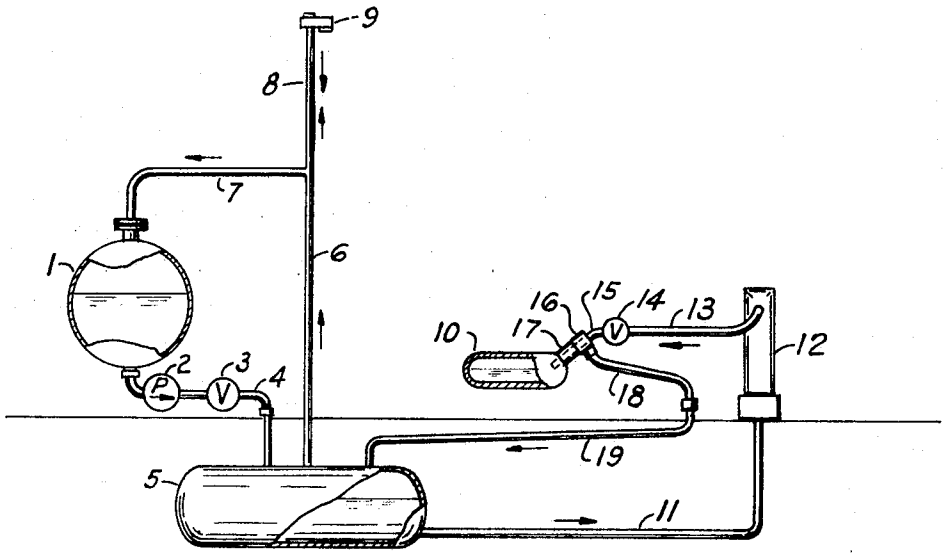
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Primary Examiner—Meyer Perlin
Assistant Examiner—Ronald C. Capossela
Attorney—Fulwider, Patton, Rieber, Lee and Utecht

[57] **ABSTRACT**

A fuel recovery apparatus including a service station storage tank and a fuel transfer line for connection with a truck tank. Condenser means is provided for receiving vapor expelled from the storage tank during filling thereof and the condensed fuel is returned to the storage tank in liquid form. A vapor return conduit may be provided for cycling the expelled vapor back to the ullage in the truck tank during emptying thereof.

9 Claims, 6 Drawing Figures



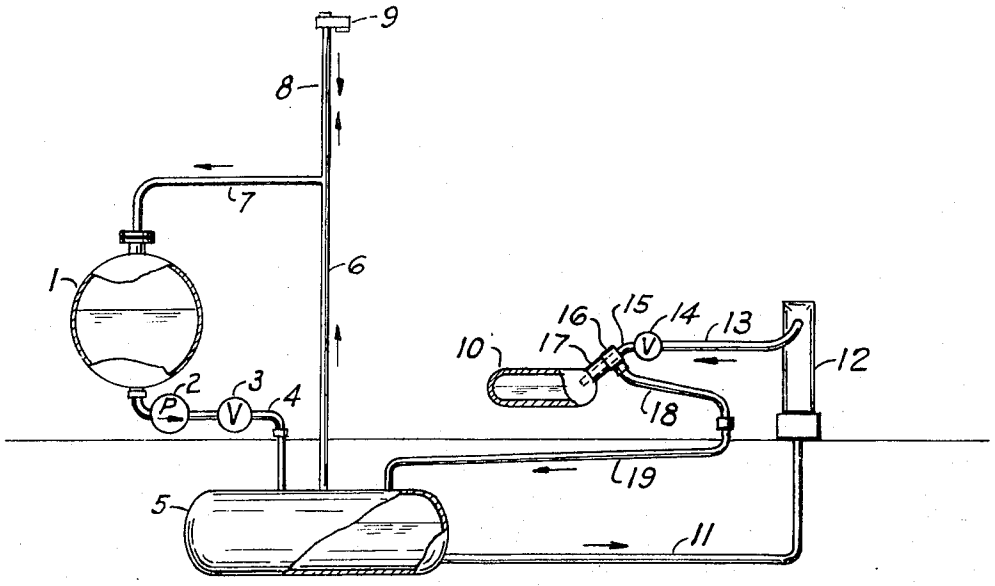


FIGURE 1

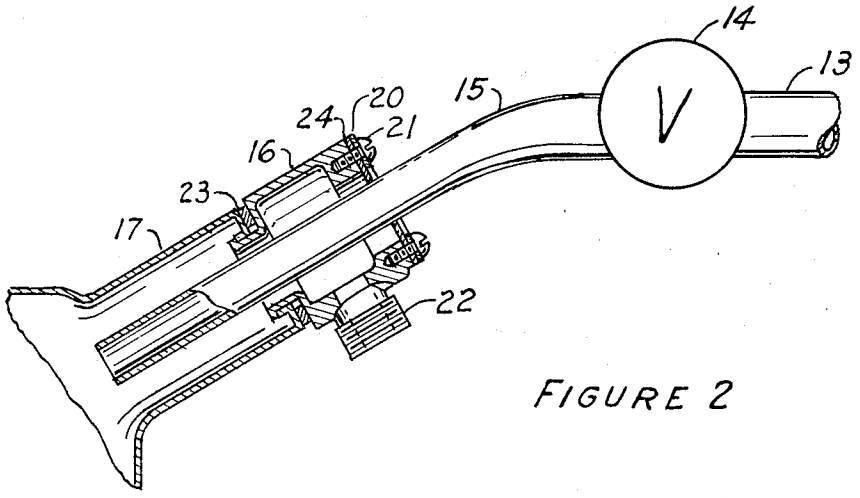


FIGURE 2

INVENTOR.
Edwin R. Davis
BY Edwin R. Davis

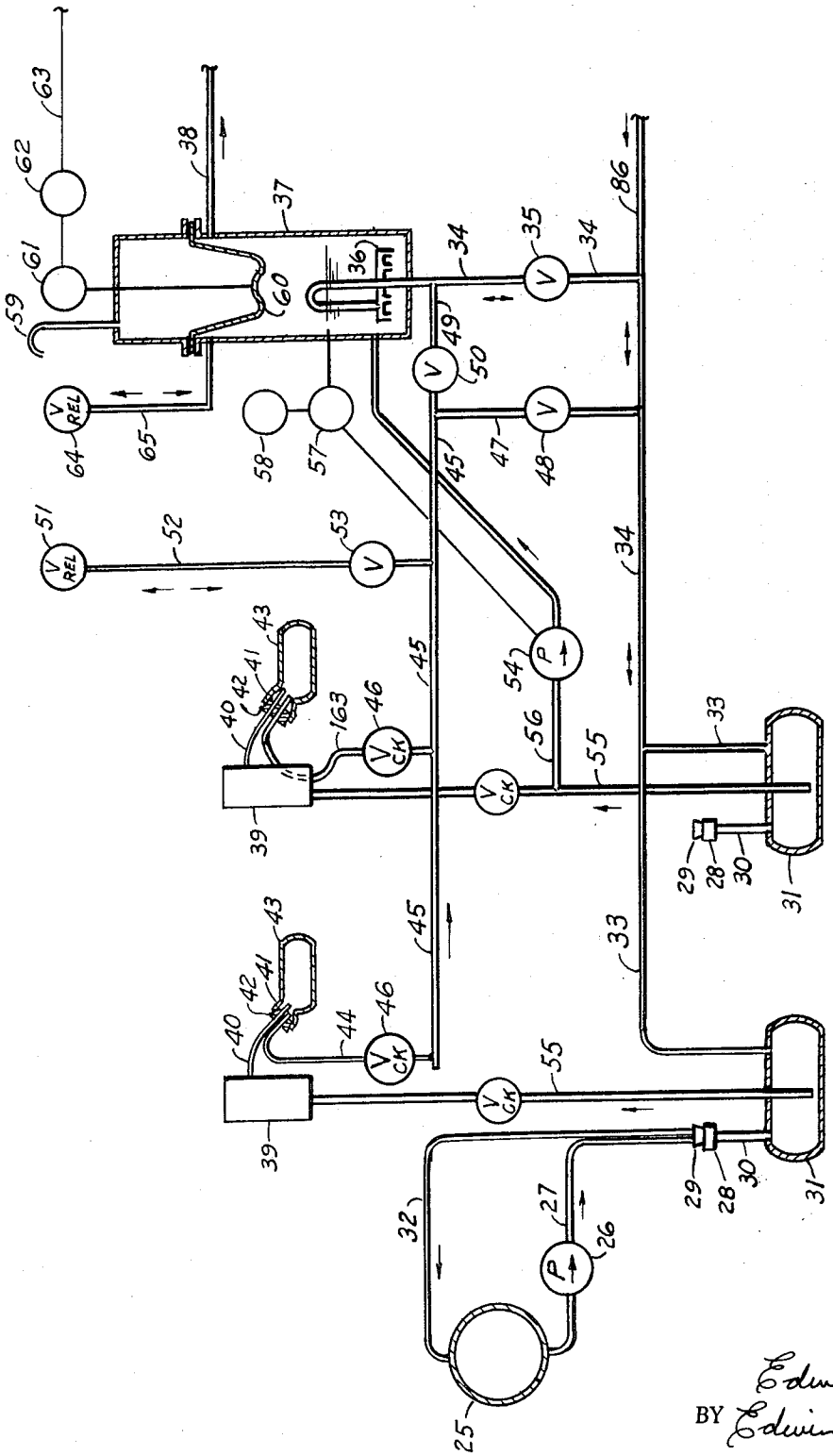


FIG. 3

INVENTOR.
Edwin R. Davis
BY Edwin R. Davis

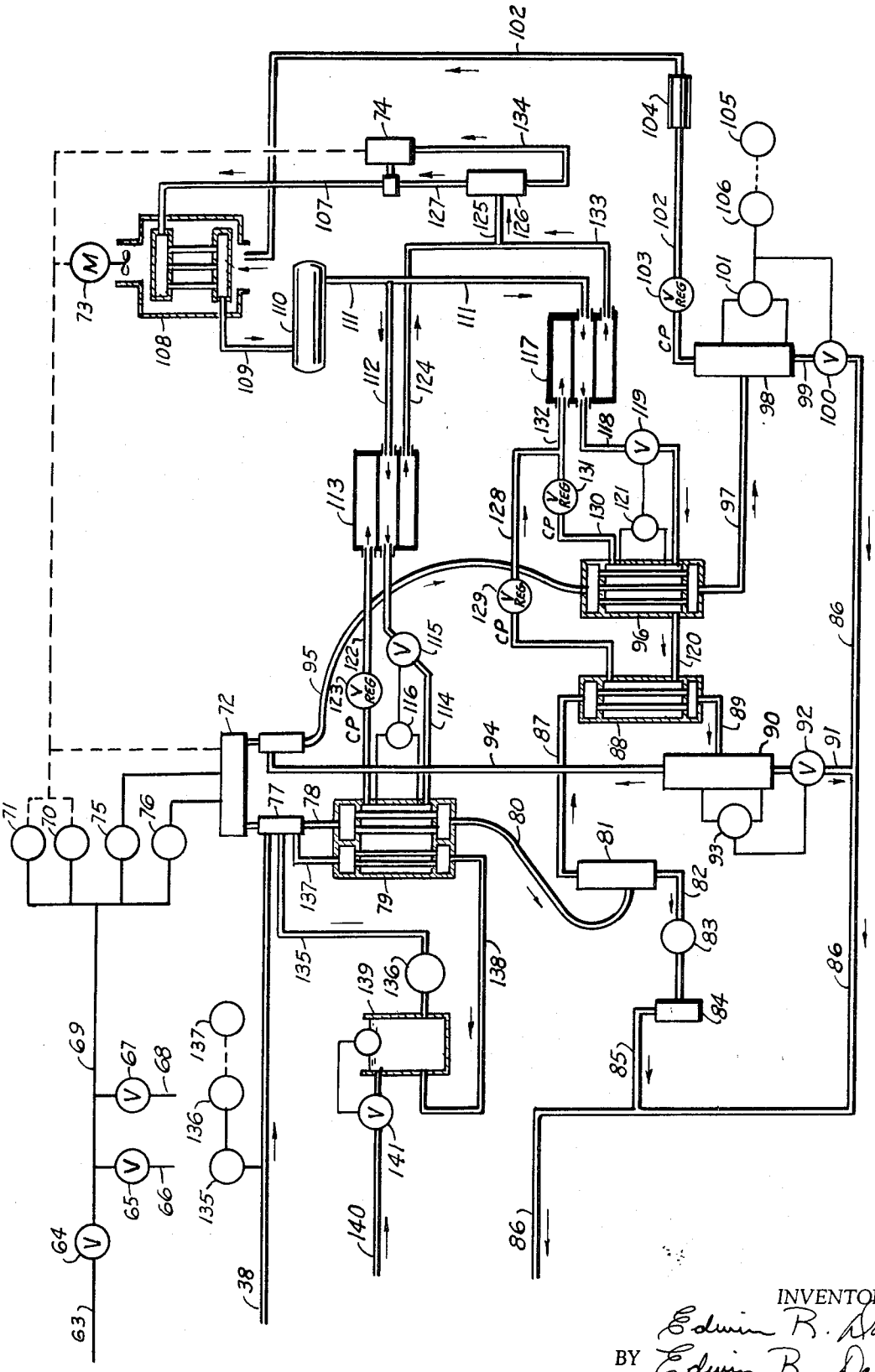


FIG. 4

INVENTOR.
Edwin R. Davis
BY Edwin R. Davis

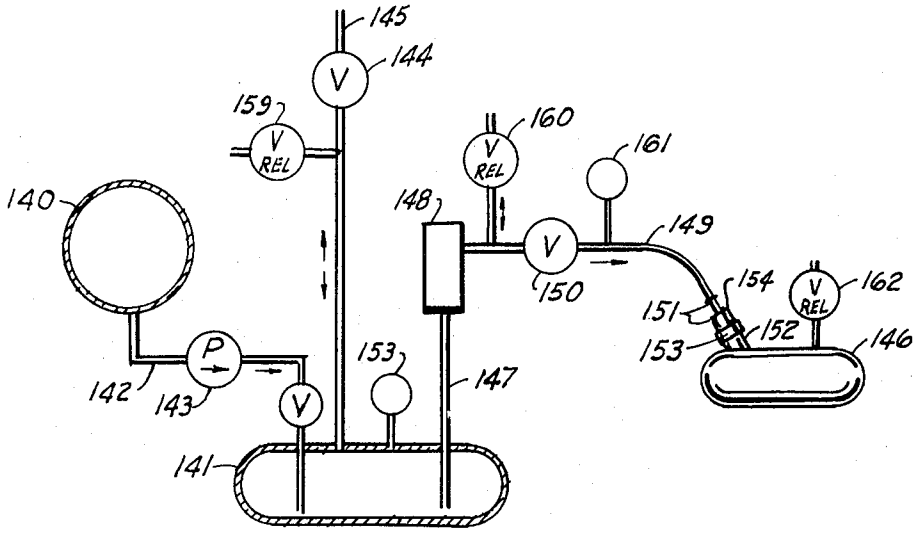


FIG. 5

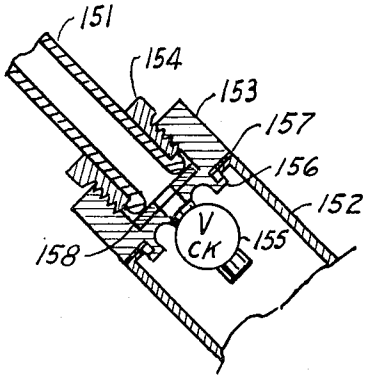


FIG. 6

INVENTOR.
Edwin R. Davis
BY Edwin R. Davis

FUEL VAPOR RECOVERY APPARATUS

This invention relates to a vapor emission prevention and vapor conservation system for automobile gasoline service stations which will prevent or reduce the emission of hydrocarbon vapors to the atmosphere from such stations.

The emission of unburned hydrocarbon vapors to the atmosphere is recognized as a major source of air pollution and is a contributory factor in the formation of "smog." When gasoline is pumped into automobile gas tanks the liquid displaces vapors which flow out of the filling spout to the atmosphere. These vapors contain large amounts of hydrocarbon. Liquid often overflows from these tanks or splashes out at the conclusion of filling and falls to the ground where it vaporizes to the atmosphere. When gasoline is pumped into the station underground storage tanks from tank trucks to provide gasoline supply to the station pumps, the liquid displaces vapors which flow out of the filling spout or out of the tank vent line to the atmosphere. These vapors contain large amounts of hydrocarbon.

The object of this invention is to prevent the emission to the atmosphere of the principal part of vapors from all of these sources incident to gasoline service station operations and to recover the principal part of the hydrocarbons contained in these vapors and return them in liquid form to the storage tanks, the recovered liquid also having an economic value. The general method provides for gathering such vapors and liquids into a collecting and balancing system which returns part of them to space made available by displaced liquids in the system and collects all vapors in excess of these amounts in a vapor surge chamber where they are drawn off and the hydrocarbon content is then reduced to liquid by compression and condensation in a special mechanical refrigeration system, after which it is returned to storage. Essentially hydrocarbon-free vapors, or air, is then discharged from this system to the atmosphere. When gasoline is withdrawn from the service station storage tank and pumped into a motor vehicle gasoline tank, the principal volume of vapors and liquids displaced from the motor vehicle tank will be conveyed by the vapor balancing system to the service station storage tank because the volume of liquid transferred from the service station storage tank to the motor vehicle gasoline tank being filled is substantially equal to the volume of vapors displaced from the motor vehicle gasoline tank being filled. It is known that the volume of vapors displaced from a tank being filled with a volatile liquid, such as gasoline, may be greater than the liquid entering the tank. These excess vapors are generated due to bubbling, splashing and agitation of the liquids. These excess vapors are collected in a surge chamber. When gasoline is introduced into the station underground storage tanks from gasoline tank trucks, the principal volume of vapors displaced from the station underground storage tanks will be conveyed by the vapor balancing system back to the gasoline tank truck because the volume of liquid transferred from the gasoline tank trucks to the station underground storage tanks being filled is substantially equal to the volume of vapors displaced from the station underground storage tank being filled. Excess generated vapors are collected in a surge chamber. All such excess vapors are drawn off, compressed and the hydrocarbon content condensed in a special mechanical refrigeration system and returned to storage.

Another object of this invention is to provide a means, suitable for installation in new or existing service stations at little cost, which will prevent the emission of volatile vapors from the fuel supply tanks of such service stations by closing or eliminating the vents of said fuel supply tanks. Then, when liquid is introduced into such a closed-vent tank, it is necessarily injected at a pressure which will compress the vapors within the tank to provide room for the entering liquid. This increased pressure will then cause sufficient vapors to condense until the vapors in the tank reach equilibrium, at which time the pressure within the tank will equal the vapor pressure of the liquid at the temperature existing. When liquid is withdrawn from such a closed-vent tank, the increased vapor space will cause a transient lowering of the pressure within the tank, the lower pressure inducing evaporation of liquid in the tank sufficient to return the pressure to the equilibrium state. It is essential that no air be introduced into such closed-vent tanks during operation because its low boiling point will prevent its condensation. Therefore, a manually operated vent is essential to vent air which may exist within the tank at start-up or after cleaning or maintenance.

Other objects will be apparent from the description, drawings and appended claims.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a fuel vapor recovery apparatus embodying the present invention;

FIG. 2 is a detailed view, in enlarged scale and partially broken away, of an adaptor fitting included in the apparatus shown in FIG. 1;

FIG. 3 is a schematic view of a second embodiment of the fuel vapor recovery apparatus of the present invention;

FIG. 4 is a vapor condensing apparatus which may be utilized with the fuel vapor recovery apparatus shown in FIG. 3;

FIG. 5 is a schematic view of a modification of the apparatus shown in FIG. 1; and

FIG. 6 is a sectional view of a modification of the adaptor shown in FIG. 2.

In the drawings, FIG. 1 is a diagram of one arrangement illustrating a simplified, vapor emission prevention system, which, for economy, omits the vapor surge, compression, refrigeration and related components, but which substantially curtails vapor emissions.

To fill the service station tank 5, the gasoline delivery truck 1, discharges gasoline via the pump 2, valve 3 and disconnectable line 4 into the service station tank 5. Vapors displaced from the service station tank 5, exit via line 6, and a volume of vapor substantially equal to the volume of liquid leaving the truck tank 1, enters the truck tank 1, via the disconnectable line 7. If the vapor volume rate flowing through line 6 differs from the liquid volume rate flowing out of the gasoline truck tank 1, the differential volume leaves or enters the system from or to the atmosphere via line 8 and the vacuum pressure relief valve 9. To fill the motor vehicle fuel tank 10, gasoline flows from the service station tank 5, via line 11, to the service station metering pump 12, thence to the motor vehicle fuel tank 10, via line 13, valve 14 and filling spout 15, which is inserted through the fuel tank vapor-hose connector 16. Vapors displaced from the motor vehicle fuel tank 10, flow through the inlet nozzle 17, entering the vapor-hose connector 16 via the space around the outside of the filling spout 15, thence flowing through the vapor hose 18 and the sloping line 19, to the service station tank 5. If the volume flow rate of vapors entering the service station tank 5, differs from the volume flow rate of liquid leaving said tank 5, the differential volume leaves or enters the system from or to the atmosphere via line 6, line 8 and vacuum pressure relief valve 9.

FIG. 2 is a fragmentary diagrammatic view showing the vapor hose connector 16, assembled to the motor vehicle fuel tank inlet nozzle 17, and the inserted filling spout 15. An essential feature of the vapor hose connector 16, is that the configuration of that portion connecting to the gasoline tank nozzle 17, closely duplicates the corresponding configuration of a standard motor vehicle gasoline tank cap, thereby providing a convenient, vapor-tight attachment of said connector to nozzle 17. The gasket 23, may be attached to the vapor hose connector 16. The center hole in the flexible diaphragm 24, is sized to closely fit around the inserted filling spout 15, thereby preventing the escape of vapors to the atmosphere. The annular retaining ring 20 and screws 21, provide support and fastening for said flexible diaphragm 24. The vapor-hose connection thread 22 is integral with the vapor-hose connector 16.

FIGS. 3 and 4 in the drawings are diagrammatic flow diagrams of one embodiment of the invention, FIG. 3 showing the vapor balancing and excess vapor collection system, and FIG. 4 showing the vapor compression and refrigeration system.

In FIG. 3, gasoline is pumped from the gasoline tank truck 25 by the truck pump 26 through the truck hose 27 to the tank filling connection 28, hose 27 being connected by the special vapor recovery connection 29. Gasoline then gravitates down the filling line 30 to the storage tank 31. Rising liquid level in gasoline storage tank 31 then forces vapor, in equal volume to counter flow, up filling line 30 thence via line 32 to the vapor space in gasoline tank truck 25. Vapor recovery line 32 may be integral with gasoline unloading hose 27 or may be part of the fixed service station equipment. The vapors having been prevented from discharging to the atmosphere, as is commonly the case, are removed with the truck to gasoline truck loading terminal where the vapor is then recovered by facilities existing at said terminal. In addition to these vapors, excess vapors are generated in the process of filling gasoline storage tank 31 due to bubbling, splash, agitation and/or temperature change of the liquids. These excess vapors tend to build up the pressure in underground gasoline storage tanks 31 and gasoline tank truck 25, thereby causing flow of this excess vapor through vapor balancing line 33, line 34 containing valve 35, and distributor 36 into vapor enricher and surge tank 3/. These vapors are discharged through vapor distributor 36 up through a liquid consisting of regular grade or other gasoline, thereby becoming enriched to a point well above the explosive range and are thereafter accumulated in tank 37 until, at a predetermined vapor accumulation, they exit via line 38, which connects to the vapor recovery compression and condensing system shown diagrammatically in FIG. 4. Gasoline service station pumps 39 are used for the purpose of filling motor vehicle fuel tanks 43 with gasoline. Gasoline is pumped from the gasoline service station pumps 39 through the filling hose 40 to filling nozzle 41, being connected thereto by fuel tank hose connector 42, one form of which is shown in FIG. 2. Rising liquid level in the motor vehicle fuel tank 43 forces vapor in equal volume to counterflow up through filling nozzle 41, thence through hose connector 42 and respective hoses 44 and 163 to line 45. Liquids tending to splash from nozzle 41 will either run back into motor vehicle fuel tank 43 or through respective hoses 44 and 163 to line 45. Vapors and liquids in line 45 flow to tanks 31 via lines 45, 47, 34 and 33, line 47 including an automatic drain valve 48 for dumping liquid into line 34 and retaining vapor. Check valves 46 prevent backflow through hoses 44 and 163. Hoses 44 and 163 may be integral with or separate from hose 40. Hose 163 is located partially within the gasoline pump outer housing.

Excess vapors generated in the process of filling motor vehicle fuel tanks flow through line 49 containing valve 50 to line 34, there joining the vapor stream flowing to tank 37 as hereinbefore described.

Partial condensation of vapors in tanks 31 because of a reduction in temperature will reduce the pressure therein causing vapors to flow from vapor surge tank 37 to tanks 31. If the volume of vapors in tank 37 is insufficient to meet this demand, the reduced pressure in the system will open vacuum/pressure relief valve 51 allowing air to enter the system via line 52 containing valve 53, thereby protecting the system from being subjected to a partial vacuum which its components cannot withstand.

Vapor surge tank 37 provides vapor surge volume to reduce cycling frequency of the vapor compression and condensing system, FIG. 4, and to reduce the size requirement of this latter system otherwise dependent on maximum load incurred while unloading gasoline tank trucks 25, to underground gasoline storage tanks 31.

Pump 54 transfers gasoline from gasoline pump suction line 55 via line 56, to tank 37. Liquid level in tank 37 is controlled by level controller 57 actuating pump 54. High liquid level in tank 37 is indicated by high level alarm 58. Emergency pressure or vacuum conditions are relieved by vacuum pressure relief valves 51 and 64 which open at predetermined settings to admit air or vent vapor to the atmosphere. The part of tank 37 not containing hydrocarbon vapors is vented to the atmosphere by line 59.

Vapor surge tank 37 can be by-passed by opening valve 48 in line 47 and closing valves 35 and 50.

The volume of vapors in surge tank 37 controls the vapor compression and refrigeration system shown in FIG. 4. Although alternate methods of sensing the volume of vapors in surge tank 37 may be used, in FIG. 3 the position of flexible diaphragm 60 actuates level transmitter 61, which, through controller 62, transmits a controlling signal via control line 63 to the compression, refrigeration system, shown in FIG. 4.

In FIG. 4, by closing valve 64 in control line 63 and opening either valve 65 in air line 66, or valve 67 in vent line 68, the air signal in line 69 can be manually controlled, over-riding the automatic signal from control line 63, and providing for starting the compression refrigeration system immediately when starting to unload truck 25 into tanks 31.

When valve 64 is open and valves 65 and 67 are closed, the variable pressure pneumatic signal in line 69 represents the volume of vapors in vapor surge tank 37, shown in FIG. 3.

At predetermined set points, pressure switches 70 and 71 will respectively start and stop vapor compressor 72, air-cooled condenser fan motor 73 and refrigeration compressor 74.

At predetermined set points pneumatic relays 75 and 76 will respectively half-load and full-load vapor compressor 72.

When vapor compressor 72 is operating, vapors from vapor surge tank 37, shown in FIG. 3, flow via line 38 to the low pressure cylinder 77 of vapor compressor 72 where it is compressed, then discharged through line 78 to cooler 79 where part of the gasoline and water vapors are condensed. Condensate and vapors then flow through line 80 to liquid vapor separator 81. Liquids exit separator 81 via line 82 containing automatic liquid draining valve 83 to dryer 84 where water is removed, thence via line 85 to liquid collecting line 86. All liquids collected in line 86 return to storage tanks 31 via lines 86, 34 and 33. Vapors exit separator 81 via line 87 to chiller 88 where additional gasoline vapors are condensed. Condensate and vapors flow through line 89 to liquid vapor separator 90. Liquids exit separator 90 via line 91 containing control valve 92, which is controlled by level controller 93, to liquid collecting line 86. Vapors exit separator 90 via line 94 to the high pressure stage of vapor compressor 72 where they are compressed and discharged through line 95 to cooler/chiller 96 where additional gasoline vapors are condensed. The liquid and vapor mixture flows from cooler chiller 96 through line 97 to vapor/liquid separator 98. Liquids exit separator 98 via line 99 containing control valve 100, which is controlled by level controller 101, to liquid collecting line 86. Vapors which are substantially free of hydrocarbons are vented to atmosphere from separator 98 via line 102, which contains back-pressure regulating valve 103 and silencer 104 and which terminates in the air stream of a cooler 108.

Unduly high level in separator 98 is indicated by high-level alarm 105 which is actuated by pressure switch 106.

Refrigeration compressor 74 discharges refrigerant gas through line 107 to condenser 108. Liquid refrigerant flows through line 109 to accumulator tank 110, thence through lines 111 and 112, heat exchanger 113 and line 114 which contains control valve 115 to cooler 79. Liquid level in cooler 79 is controlled by level controller 116, controlling valve 115.

Similarly, liquid refrigerant flows through line 111, heat exchanger 117, line 118 containing control valve 119 to cooler/chiller 96. Balance line 120 provides a flow path for liquid refrigerant to chiller 88. Liquid level in chiller 88 and cooler/chiller 96 is controlled by level controller 121 controlling valve 119.

Vaporized refrigerent flows from cooler 79 via line 122 containing back-pressure regulating valve 123 to heat exchanger 113, thence via lines 124 and 125 to vapor/liquid separator 126 and line 127 to the suction of refrigeration compressor 74.

Similarly, vaporized refrigerant flows from chiller 88 through line 128 containing back-pressure regulating valve 129, and from cooler/chiller 96 through line 130 containing back-pressure regulating valve 131, thence through line 132 to heat exchanger 117, thence via lines 133 and 125 to vapor/liquid separator 126, thence via line 127 to the suction of the refrigeration compressor 74.

Liquids from separator 126 flow to the crankcase of refrigeration compressor 74 via line 134.

Cooling water flows to vapor compressor 72 via line 135 containing pump 136, thence via line 137 to cooler 79, thence via line 138 to surge tank 139. Make-up water is supplied through line 140 containing float-operated valve 141 which controls the liquid level in surge tank 139.

In FIG. 5, another embodiment of this invention is shown wherein vapors in the service station supply tank 141, and optionally in motor vehicle tanks 146, are kept under pressure equal to the vapor pressure of the gasoline fuel, thereby providing a closed system with no vents normally open to the atmosphere, so that all hydrocarbon vapors are contained and not permitted to escape to the atmosphere.

In FIG. 5, fuel from truck tank 140 is pumped into service station supply tank 141 via line 142 using truck pump 143. As liquid enters tank 141, vapors therein are compressed into a smaller vapor space causing a transient state of higher pressure and higher temperature. During this transient state, heat is transferred from the compressed vapors to the surroundings and the pressure in the vapors decreases until, at the end of said transient state, the temperature and pressure reach an equilibrium, at which time the pressure in tank 141 equals the vapor pressure of the fuel therein at the temperature prevailing in said tank 141.

Valve 144 in vent line 145 is normally closed, being used for emergency venting of air at startup after tank 141 has been opened for any reason. It is essential that air not be permitted to accumulate in tank 141 or in the entire closed system because, due to the low condensation temperature of liquid air, no condensation of air would occur in the system. Therefore, a much higher pressure would occur in tank 141 during the transient state occuring when liquid enters said tank 141. Pressure indicator 153 on tank 141 therefore would indicate the presence of an unduly high amount of air in the system due to some malfunction, and the need to purge the system of air by opening valve 144 and filling tank 141 with liquid, thereby forcing all vapors and air out vent line 145.

Motor vehicle fuel tank 146 is filled from tank 141 via line 147, metering pump 148 and hose 149, containing valve 150 and terminating in filling spout 151, which is inserted in fuel tank filling nozzle 152 through filling hose adapter 153.

FIG. 6 is a diagrammatic fragmentary view of filling spout 151 attached to adapted 153 by connector 154, and showing adapter 153 with integral check valve 155, adapter 153 being attached to fuel tank filling nozzle 152 by means of lugs 156. Gaskets 157 and 158 are attached to adapter 153, using cement or other suitable means.

Pressure/vacuum relief valve 159 prevents over or under pressuring the system upstream from pump 148 and pressure/vacuum relief valve 160 prevents over or under pressuring the system downstream from pump 148. Pressure indicator 161 will show a high pressure reading if air is in tank 146 when it is being filled, thereby indicating that air should be displaced from said tank 146. To exhaust air from a motor vehicle tank 146, the adapter 153 is removed, the tank 146 is filled with fuel displacing all vapors, and adapter 153 is replaced.

During operation of the motor vehicle, vacuum/pressure relief valve 162, which may optionally be connected to tank 146 or adapter 153, prevents under or over pressure of fuel tank 146. Pressure transmitter 135 senses low pressure in the suction line 38 of vapor compressor 72 and, at a predetermined set point, pressure transmitter 136 actuates low pressure alarm 137 to indicate an unduly low pressure in line 38.

I claim:

1. Fuel vapor recovery apparatus comprising:
- a first fuel tank;
- a fuel transfer line for connecting a second fuel tank with said first tank to prevent loss of fuel vapor during transfer of fuel to said first tank;
- condenser means for condensing fuel vapor;
- a vapor conduit for connecting the upper portion of said first tank with the inlet to said condenser means;
- a liquid line connecting the condenser means outlet with said first tank;
- sensing means for sensing the production of fuel vapor in said first tank and responsive to the production of a predetermined amount thereof to produce a signal; and
- control means connected with said sensing means and said condenser and responsive to said signal to operate said condenser whereby the vapor expelled from said first tank during filling thereof may be condensed by said condenser and returned to said first tank.

2. Fuel vapor recovery apparatus as set forth in claim 1 that includes:
- a surge tank interposed between said tank and condenser means and including volume control means for applying a substantially constant pressure to the vapor received therein; and
- pressure control means responsive to a predetermined pressure for admitting flow from said surge tank to said condenser means at said predetermined pressure whereby vapor received therein from said first tank during filling thereof may be stored in said surge tank for subsequent return to said first tank when drainage thereof creates ullage.

3. Fuel vapor recovery apparatus as set forth in claim 1 wherein:
- said condenser means includes a first stage compressor connected with said first tank for compressing said vapor to a selected pressure, a first stage refrigeration unit connected with said first stage compressor for cooling said vapor to a selected temperature, a separator connected with said first stage refrigeration unit for separating the liquid fuel from the vapor, a second stage compressor connected with the vapor outlet of said separator for compressing said vapor to a relatively high pressure, and a second stage refrigeration unit connected with said second stage compressor for cooling said vapor to a relatively low temperature to precipitate liquid fuel therefrom.

4. Fuel vapor recovery apparatus as set forth in claim 1 that includes:
- a vapor line for connecting the upper portion of said first tank with the upper portion of said second tank whereby vapor being expelled from said first tank during filling thereof may be returned to the ullage of said second tank.

5. Fuel vapor recovery apparatus as set forth in claim 1 that includes:
- means interposed between said storage tank and condenser for saturating the vapor being expelled from said storage tank below the ignition point thereof.

6. Fuel vapor recovery apparatus as set forth in claim 2 wherein:
- said volume control means includes a moveable member forming one wall of said surge tank and pressure responsive means for positioning said moveable wall to maintain said substantially constant pressure.

7. Fuel vapor recovery apparatus as set forth in claim 3 that includes:
- a refrigeration system for cooling said first and second stage coolers, said system including a refrigerant condenser; and
- means for exhausting the vapor from said second stage chiller in heat exchange relationship with said refrigerant condenser.

8. Fuel vapor recovery apparatus comprising:
- a first fuel tank;
- a fuel transfer line for connecting a second fuel tank with said first tank to prevent loss of fuel vapor during transfer of fuel to said first tank;
- condenser means for condensing fuel vapor;
- a vapor conduit for connecting the upper portion of said first tank with the inlet to said condenser means;
- a liquid line connecting the condenser means outlet with said first tank;
- a surge tank in said vapor circuit;
- control means responsive to a predetermined pressure in said surge tank for admitting flow from said surge tank to

said condenser means at said predetermined pressure whereby vapor received therein from said first tank during filling thereof may be stored in said surge tank for subsequent return to said first tank when drainage thereof creates ullage and when said predetermined pressure is reached said condenser means will be actuated.

9. Fuel vapor recovery apparatus as set forth in claim 8 wherein:

said surge tank includes a movable wall for being moved by pressure build up in said surge tank to increase the volume of said surge tank.

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