

[54] **VAPOR EMISSION CONTROL SYSTEM AND METHOD**

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[51] Int. Cl. **B01d 53/04**

[58] Field of Search 55/88, 89, DIG. 30, 255, 55/256, 179, 387; 141/44, 45; 261/122

[56] **References Cited**

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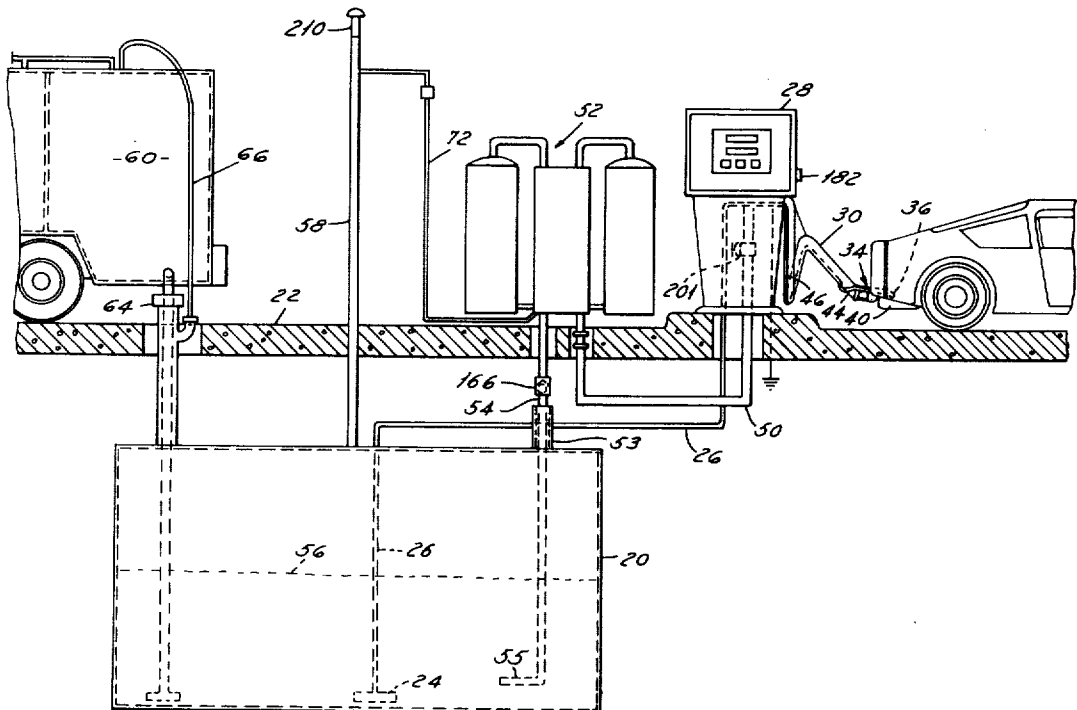
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Primary Examiner—Charles N. Hart
Attorney, Agent, or Firm—Burton & Parker

[57] **ABSTRACT**

A vapor emission control system for gasoline stations and the like recovers escaping gases or vapors at the connection between the filling hose nozzle and the end of the filler neck of an automobile gas tank by creating an annular inrushing atmospheric air curtain at the open end of the filler neck which sweeps escaping vapors into a vapor return line and delivers the same for disposal. The disposal may involve either burning of the vapors, or the vapors may be returned to and taken up in gasoline for use in subsequent automobile refueling. The vapors may be taken up by the gasoline by first separating them from any atmospheric air with which they have been mixed and then passing them through microscopic passageways of the labyrinth immersed in liquid gasoline.

4 Claims, 11 Drawing Figures



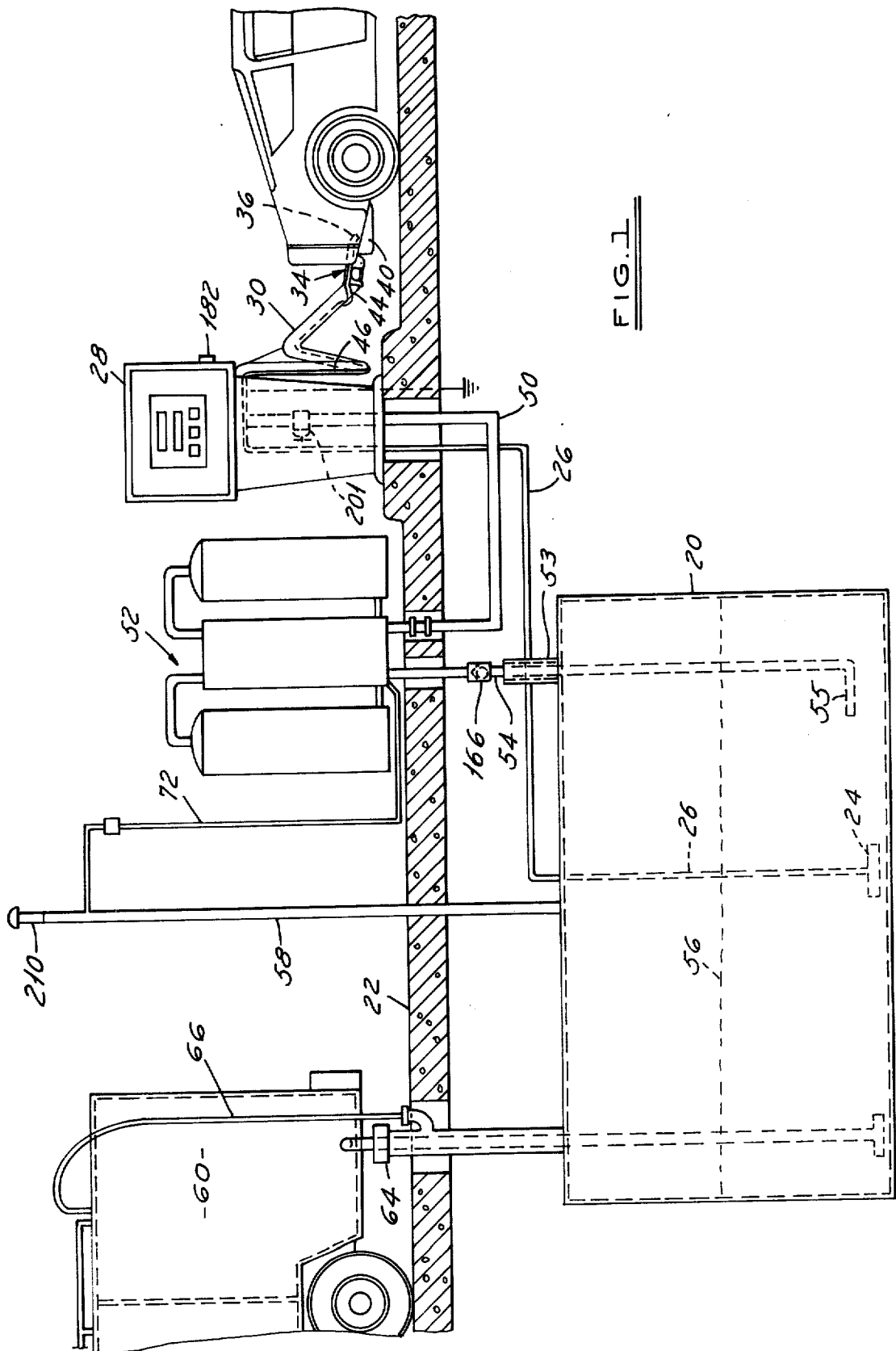


FIG. 2

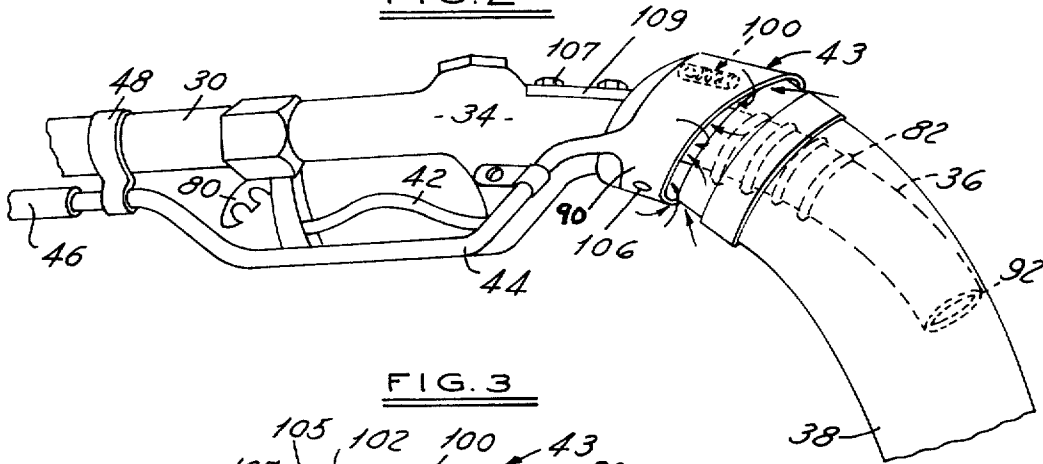


FIG. 3

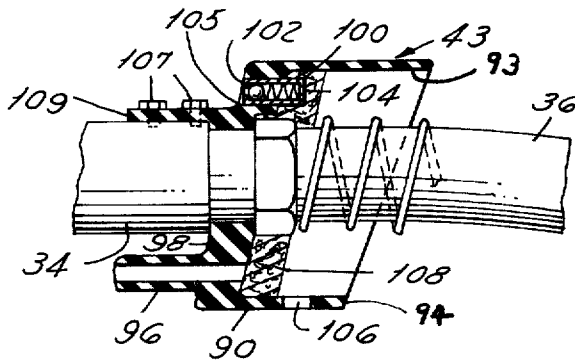


FIG. 4

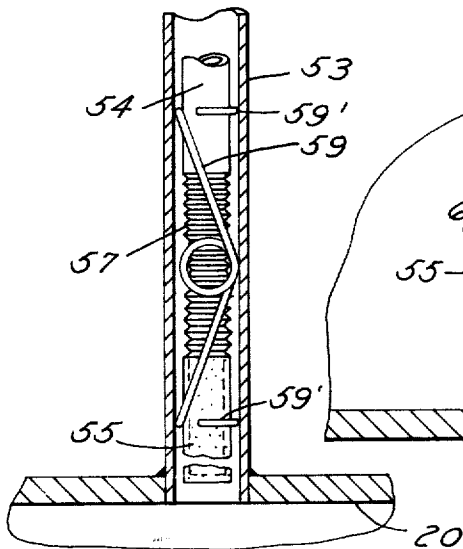


FIG. 5

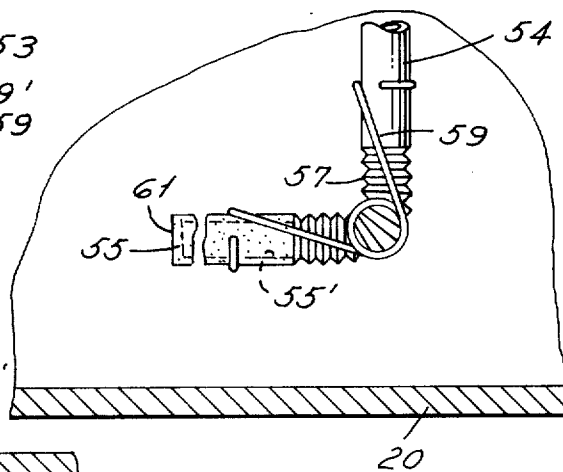
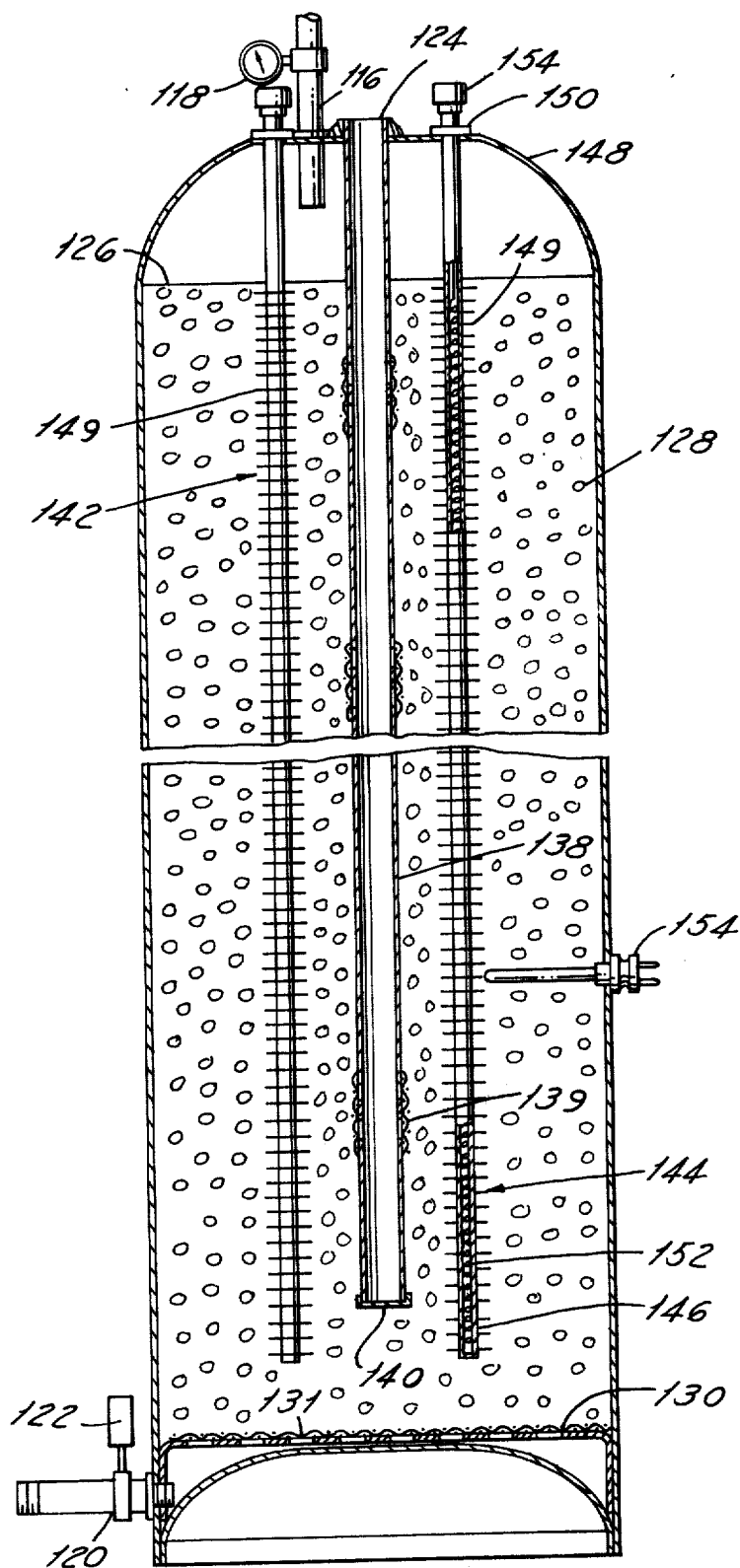


FIG. 6



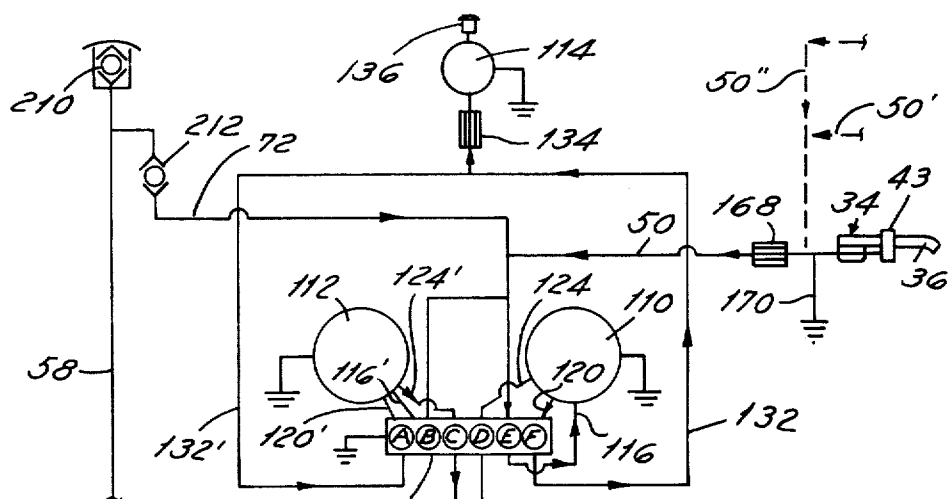


FIG. 7

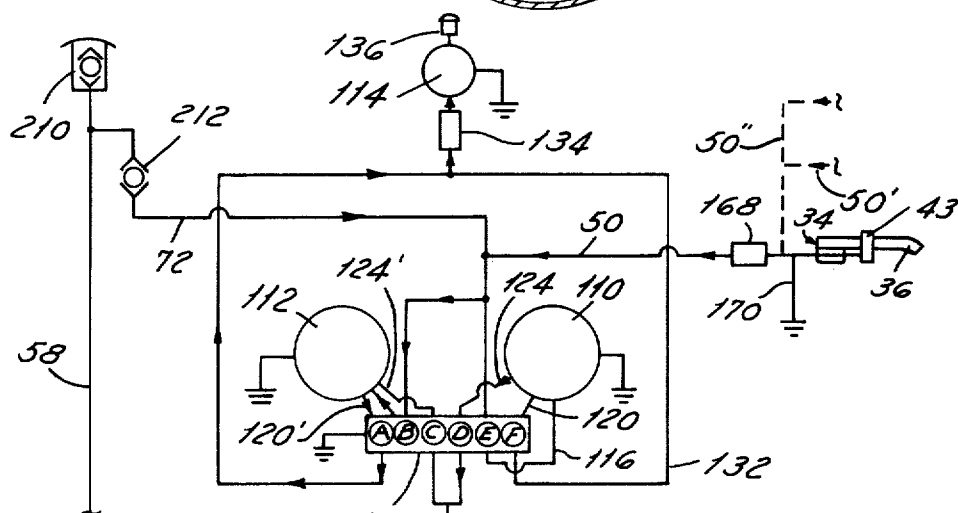
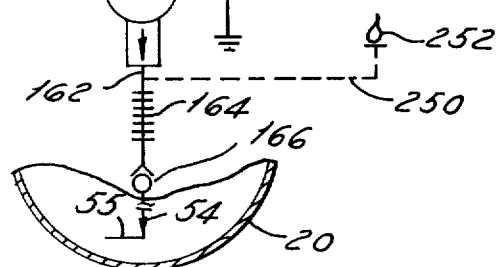


FIG. 8

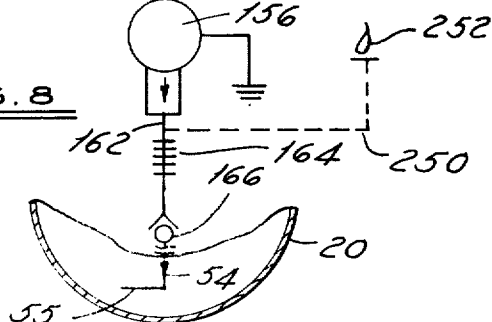


FIG. 9

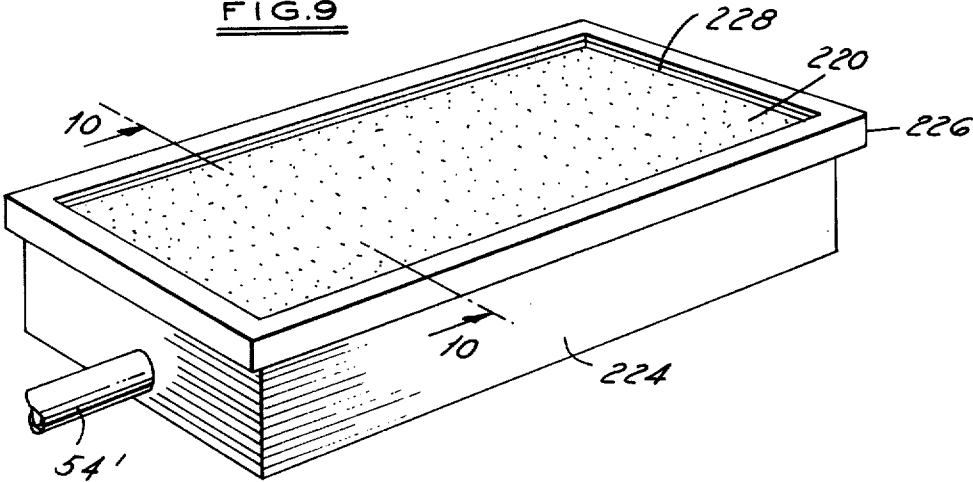


FIG. 10

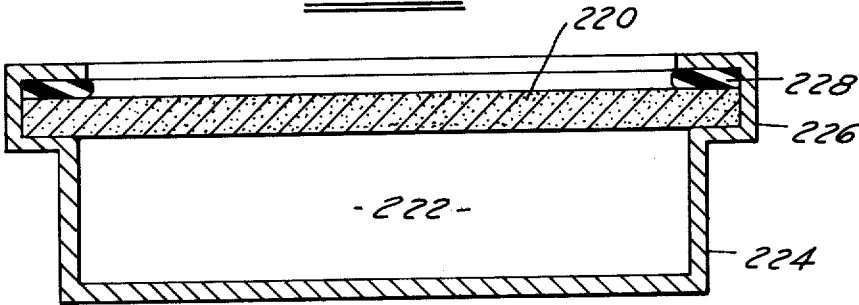
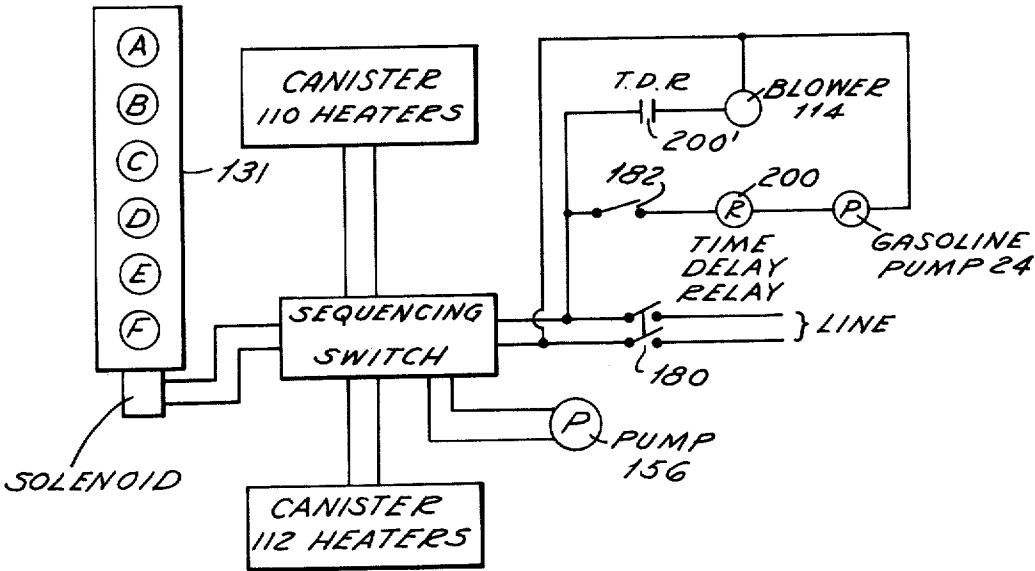


FIG. 11



VAPOR EMISSION CONTROL SYSTEM AND METHOD

FIELD OF INVENTION

This invention relates to equipment for preventing the escape to atmosphere of gases and vapors from volatile fuels and the like during transfer of such liquids. The invention is particularly, though not exclusively, adapted for use in the delivery of gasoline from gasoline station storage tanks to automobile, boat, airplane and the like gas tanks, and from gasoline distribution centers into the tank trucks.

BACKGROUND AND OBJECTS OF THE INVENTION

It has been estimated by some who have studied air pollution by gasoline vapors resulting from automobile refueling at gasoline stations that approximately 31.4 pounds of liquid gasoline in vapor form is lost on the average each day to the atmosphere from the refueling operations at a single gasoline station pumping 60,000 gallons of gasoline per month. Heretofore a number of solutions have been proposed, and in my own prior U.S. Pat. No. 3,581,782 I show a system for preventing the escape of these air polluting vapors. Further attention to this problem has led me to certain conclusions and further developments as hereinafter set forth.

First, because of the lack of standardization of automobile gas tank filler necks, the concept of a fuel nozzle which will make a mechanically fluid-tight seal with the automobile gas tank filler neck, such as suggested in the following patents, appears impractical:

French Patent No. 1,292,909;

U.S. Pat. No. 2,908,299;

U.S. Pat. No. 3,289,711;

U.S. Pat. No. 3,543,484;

U.S. Pat. No. 3,672,180

Second, the sometimes haphazard practices of service station attendants requires a vapor control system which will function to prevent vapor escape even when the fill nozzle has not been fully inserted into the automobile gas tank filler neck.

Third, the necessary modification of existing gasoline station equipment to adapt vapor recovery or control systems thereto should be minimal to reduce the cost thereof.

Fourth, the vapors recovered during the refueling of automobiles or the like should be economically stored in a form such that the same can be utilized in subsequent refueling of automobiles.

SUMMARY OF THE INVENTION

My invention solves each of the foregoing problems, and possesses certain other advantages which will be apparent during the ensuing description. In general, the system includes a vapor collector at the fill hose nozzle which creates an annular inrushing curtain of atmospheric air around the nozzle pipe at the entrance or open end of the automobile gas tank filler neck with the result that as gasoline enters the automobile gas tank from the fill nozzle, gasoline vapors escaping back out of the filler neck are swept into the collector so that they do not escape to the atmosphere. The collector is connected to a vapor return line which communicates with a source of subatmospheric pressure whereby an atmospheric air flow is induced into the collector to create the aforesaid annular air curtain. Means are pro-

vided for limiting the vacuum created between the collector and the end of the automobile tank filler neck.

The collector may or may not fit in sealed relation with the filler neck of the automobile gas tank, depending on the size of the collector in relation to the filler neck and how far into the filler neck the gas station attendant inserts the nozzle, but the design of the collector is such that the aforementioned air curtain will serve to function when the collector is spaced slightly from the open end of the filler neck.

In the embodiment disclosed herein, the collected vapors are returned through the vapor return line to means for separating the vapors from the atmospheric air with which they are mixed. Such means comprises at least two sorbing canisters, one of which is in its sorbing cycle and receives the vapors and stores them. The other canister is in a desorbing cycle during which stored vapors are drawn therefrom and either returned to and taken up in gasoline stored in the gas station storage tank for subsequent delivery to automobiles, or the vapors may be burned.

In the embodiment disclosed herein, when the vapors are drawn from the canister in the de-sorbing cycle, they are passed directly to a device I refer to as a sparger which is located within and adjacent the bottom of the gasoline storage tank. The sparger comprises a labyrinth of microscopic passageways immersed in the liquid gasoline in the tank. The vapors are caused to pass into and through these passageways and are taken up in the gasoline. As a result of experimentation with butane gas recovery in gasoline I believe substantially all of the gasoline vapors returned to the gasoline can be taken up therein using the sparger.

DESCRIPTION OF DRAWINGS

FIG. 1 schematically illustrates a refueling station embodying my invention;

FIG. 2 is a perspective view of a fuel delivery nozzle provided with my vapor collector showing the nozzle pipe inserted in typical fashion in a tank to be refueled;

FIG. 3 is a cross-sectional view through the vapor collector;

FIG. 4 shows a sparger being inserted down through a breather pipe or the like of a fuel storage tank;

FIG. 5 shows the sparger positioned in the tank;

FIG. 6 shows one of the vapor filtering canisters;

FIGS. 7 and 8 are schematic diagrams of the alternate sorbing and de-sorbing cycles of the vapor filtering canisters;

FIG. 9 is a perspective view of a modified form of sparger;

FIG. 10 is a cross-sectional view taken on the line 10-10 of FIG. 9; and

FIG. 11 is a schematic diagram of the control system.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS

Overall System

FIG. 1 shows in schematic form the essential components of an automobile gas station embodying the invention. The invention may also be incorporated with marine refueling stations, aircraft refueling, or any other refueling or volatile liquid transfer system to which those skilled in the art might wish to adapt it. As shown, a volatile liquid fuel storage tank 20 located beneath the surface 22 of the gas station is provided with a conventional fuel delivery system including fuel

pump 24, a discharge pipe 26 leading from the tank 20 to a dispensing stand or pedestal 28, and from thence by hose 30 to a nozzle 34 having a nozzle pipe 36 for insertion in the gas tank filler neck 38 of the automobile gasoline tank 40.

With the pump 24 in operation, squeezing the nozzle trigger 42, shown in FIG. 2, will cause gasoline to be pumped from the tank 20 to the automobile tank 40 through the nozzle pipe 36 and filler neck 38.

Mounted on the nozzle is a vapor collector 43 which communicates with the upstream end of a vapor return line 44 which includes a flexible hose section 46 which is secured to the hose 30 in any suitable fashion as by clips or the like 48. The hose portion 46 of the vapor return line enters the dispensing stand 28 and communicates with vapor return line portion 50 which terminates at means 52 for separating the gasoline vapors from a mixture of such vapors and atmospheric air which have been drawn into the vapor return line at the collector 43. The vapor return line portion 50 may be concealed as by extending down through the bottom of the stand 28 and thence underground to the separator and thereafter back up through the surface of the gas station to the separator. The separator is schematically shown in FIG. 1 and described in greater detail in FIGS. 6, 7 and 8 hereafter.

Following separation of the vapors from the atmospheric air, the vapors are either delivered therefrom for return to the fuel storage tank 20, or if desired may be burned. In the FIG. 1 system the vapors are added to and taken up by the fuel in the storage tank 20. The vapors are returned to the tank through the line 54 which extends down into the storage tank 20 terminating near the bottom thereof substantially as shown in FIG. 1. The lower end of the line 54 is provided with a sparger 55 shown and described in greater detail in connection with FIGS. 4, 5, 8 and 9 whose function is to cause the vapors to be taken up in the gasoline in the tank 20. The liquid level of the fuel in tank 20 is indicated at 56. The underground tank 20 is also provided with an atmospheric vent line 58.

Also shown in FIG. 1 is a representation of a fuel delivery tank truck 60 having a fuel delivery hose 62 connected to an inlet fitting 64 leading to the tank 20 and a vapor return line 66 leading from the fitting back to the truck.

The vent line 58 extends above the tank truck 60 so that in the event the tank is overfilled, raw fuel will not escape from the vent line. A vapor recovery and vent line 72 extends from the vent line 58 at a point above the top of the tank truck to the separator means 52 for purpose hereinafter explained.

Within the schematic representation of the separator means 52 there is a vacuum pump or blower for creating a subatmospheric pressure condition in the vapor return line 50 and hose portion 46 and portion 44 whereby vapors and atmospheric air are drawn into the vapor return line at the collector 43 for delivery to the separator means. Atmospheric air separated from the vapors is vented to the atmosphere at the separator means 52. Also within the schematic representation of the separator means 52 there is a vacuum pump compressor for stripping the vapors during the de-sorb cycle and delivering the vapors to the storage tank or for burning.

Collector means

FIG. 2 represents a conventional nozzle for the end of a gasoline delivery hose such as will be found in typical automobile gas stations. In addition to the on-off trigger 42, the nozzle may include a trigger-holding catch 80 which the gas station attendant may engage with the trigger so that he can leave the nozzle unattended while the automobile tank is being filled and a fuel level sensing element 82 associated with the nozzle pipe 36 senses the fuel level and through mechanism well understood by those skilled in the art (and not disclosed herein) serves to automatically shut off the nozzle and flow of gasoline therethrough when the tank 40 is filled or substantially so.

My invention is intended to be adaptable to existing gasoline stations with a minimum of reconstruction of the station equipment, and to this end the collector 43, as shown in FIGS. 2 and 3, comprises a cup-shaped boot 90 which is slipped over the nozzle pipe and retained in place by any suitable means. I have disclosed the boot as being disposed between the nut 105, which holds the nozzle pipe 36 in the nozzle 34, and the nozzle body. A pair of screws 107, which extend through a portion 109 of the boot, additionally serve to secure the boot to the nozzle. The boot is so arranged that its cup shape is aligned co-axially with the nozzle pipe 36 and is spaced from but opens toward the fuel discharge end 92 thereof. The boot is formed of a gas and oil resistant rubber type flexible material, such as Buna-N rubber, or neoprene with a Shore durometer of 45 ± 5 . Other suitable materials will occur to those skilled in the art. The rim 93 of the cup-shaped collector may, if desired, be angled as shown in FIG. 3 so that the rim will closely overlie the open end of the gas tank filler neck or opening when the nozzle pipe is inserted in the filler neck and left unattended by the attendant. It will be noted that the nozzle pipe, by virtue of its curvature, tends to wedge in the filler neck with the nozzle being inclined at an angle to the open end of the filler neck. In some cases the boot or collector may effect a partial or complete mechanical seal with the open end of the filler neck depending upon the relative sizes of the boot and filler neck and how far into the filler neck the attendant has inserted the nozzle pipe. In FIG. 2 the edge 94 of the rim 93 of the cup-shaped collector is shown as having a nipple portion 96 which opens through the radial wall 98 of the cup shape and the vapor return tube may be pressed over such nipple and secured thereto.

Means are provided at the collector to prevent excessive vacuum being created therewithin and imposed upon the automobile gas tank (which might tend to cause implosion or inward collapse thereof) should the rim 93 of the collector make a mechanically tight seal with the open end of the filler neck. Such means comprises a pressure responsive check valve assembly 100 comprising a ball check valve 102 held against a seat by a spring 104 such that upon the pressure within the collector dropping below a predetermined point, the atmospheric pressure against the ball 102 will unseat it allowing atmospheric air to enter the collector. In addition, a weep hole 106 may be provided in the rim of the collector to admit atmospheric air thereinto and allow water or the like to drain therefrom. It is preferred that the vacuum developed within the collector not exceed

2.5 to 3 inches of water column, and the check valve is set to limit the vacuum to this degree.

Diffuser means **108** in the form of a fine screen with a clutch weave of 50×250 and a particle migration size of 60 microns is disposed within the collector to restrict dust particles from entering the vapor return line and also to act as a flame arrester and also for the purpose of distributing the subatmospheric pressure created by the vapor return line substantially uniformly around the inside of the cup shape. The diffuser may comprise a multitude of layers of monel screen wire. Instead of monel wire the diffuser may be made of other materials such as aluminum, glass threads or the like and will resemble steel wool. Should liquid fuel splash back out of the filler neck and into the collector, the diffuser will serve to cause such liquid fuel to vaporize as the inrushing atmospheric air passes through the diffuser, and thereby raw liquid fuel is prevented from entering the vapor return line and being returned to the separator.

The volume of air pulled through the vapor return tube should be, for a conventional gasoline station nozzle having a collector **43** of the character disclosed, on the order of 2 to 3 cubic feet per minute at a vacuum of 2 to 3 inches of water column, which will exceed the volume of gasoline delivered per minute by the nozzle. By virtue of the cup shape of the collector and the distribution of vacuum substantially uniformly therewithin by the diffuser, an annular inrushing air curtain or stream is formed around the nozzle pipe and between the rim of the collector and the filler neck when the nozzle pipe is inserted therein, such inrushing air curtain being illustrated by the arrows in FIG. 2. Such air curtain will entrain any vapors escaping back out of the filler neck **38** and carry them through the vapor return line to the separator means **52**. Consequently a mechanically tight seal with the filler neck **38** is not required as in the prior art as any vapors will be swept into the collector and prevented from escaping to the atmosphere.

Air and vapor separator

In the overall broad concept of the vapor recovery system herein disclosed any suitable means for separating the gasoline vapors from atmospheric air may be employed. The reason for this separation is to enable only the return of the gasoline vapors to the underground fuel storage tank. These vapors comprise the so-called light ends of the gasoline which vaporize during the automotive gas tank filling operation and comprises about 60 percent butane, with the balance being primarily methane, hexane, pentane and the like. If atmospheric air is also returned to the storage tank **20** along with the vapors, the air which is essentially immiscible in the gasoline, will bubble to the surface and cause vaporization of the light ends of the gasoline in the tank above the liquid level and will also result in an undesirable buildup of air pressure in the tank.

As disclosed herein, the separator means **52** includes a pair of vapor sorbing and de-sorbing canisters **110** and **112** shown in FIGS. 7 and 8, a vacuum pump or blower **114** and a control system for opening and closing canister control valves and de-sorbing heaters in the canisters. One of the canisters, namely canister **110**, is shown in FIG. 6 and a description thereof will suffice for both. Corresponding portions, lines, etc. of canister **112** are indicated by primed reference numerals. The canister is a tank-like air-tight receptacle having an air

and vapor mixture inlet or inlet line **116**, which may be provided with a vacuum gauge **118**, an air outlet or outlet line **120**, also provided with a vacuum gauge **122**, and a vapor outlet or outlet line **124**. The canister is filled to the level **126** with suitable vapor sorbing and desorbing material such as a molecular sieve of Zeolite or active carbon (activated charcoal) **128**. A foraminous partition **130** covered by a fine mesh screen **131** supports the sorbing material and allows air to pass therethrough and out the outlet **120**. Outlet **120** is connectible through valve **F** of the solenoid actuated multiple valve assembly **131** shown in FIG. 7, with a suction line **132** leading from valve **F** through a flame arrester **134** to the pump **114** which exhausts to atmosphere through a vent **136**. The pump **114**, when solenoid valve **F** is open during the sorbing cycle for the canister **110**, as shown in FIG. 7, will therefore draw a vacuum through the outlet **120** on the canister and in consequence on the air and vapor mixture inlet **116** and create the subatmospheric condition in the collector **43** which creates the annular inrushing vapor-entraining air stream at the nozzle.

The vapor outlet **124** connects with a vapor collecting foraminous tube **138**, which is surrounded by a fine mesh screen **139**. The tube extends into the sorbing bed **128**. The tube is closed as at **140** at its lower end. Upon application of a pressure differential across the tube, vapors de-sorbed by the bed enter the tube and travel upwardly and out the outlet **124**.

Desorption of vapors from the bed **128** is accomplished by heating the bed to approximately 220° to 230° F. and drawing a vacuum thereon of from 28 inches to 27 inches of mercury. This is carried out by a plurality of electric heaters **142** and **144**, as many being provided as may be found necessary in accordance with the size of the charcoal bed. Each heater includes an outer tubular metal casing **146** closed at its lower end and extending up through the top **148** of the canister and sealed therein as at **150**. If desired the tubes may be provided with fins **149**. A helical resistance heating wire **152** extends down into the tube with the ends of the wire terminating in a terminal block **154** on the upper end of the tube for connection to a source of electric current. The wire is electrically insulated from the tube **146** in any suitable fashion that will also provide good heat conductivity, such as a magnesium oxide powder. One typical heating wire was rated at 8 watts per inch, with the heater providing a total of 1250 watts at 240 volts. A thermally responsive switch **154** in the heater circuits may be provided for limiting the temperature rise in the sorbing bed **128** during desorbing.

The vacuum is drawn on the sorbing bed by a vacuum pump **156**, schematically shown in FIGS. 7 and 9, whose intake line **158** connects through a flame arrester **160** with the valves **C** and **D** of valve assembly **131**. Valves **C** and **D** respectively connect with the vapor outlets **124** and **124'** of canisters **110** and **112**. The compression pressure side of vacuum pump **156** connects to a line **162** which may be provided with cooling fins **164**, and line **162** connects to the sparger vapor return line **54** through a one-way vapor check valve **166** which prevents vapor in the tank from backing up into the pump **156** when the same is not operating.

Valves **B** and **E** of the multiple valve assembly **131** connect as shown in FIGS. 7 and 8 with the vapor re-

turn line 50 and respectively with the inlets 116' and 116 of canisters 112 and 110. Valve A connects outlet 120' with pump 114 through line 132'. In FIG. 7 valves A, B and D are closed and C, E and F are open, while in FIG. 8 the reverse condition obtains. The arrows are the communication lines in FIGS. 7 and 8 and indicates flow and direction.

A flame arrester 168 is schematically shown in FIGS. 7 and 8 in the air and vapor mixture return line 50. In addition, such line is grounded, as indicated at 170, as is each canister, the pumps 114 and 156, and the solenoid actuated multiple valve assembly 131.

Control System

The solenoid valve assembly 131 comprises a plurality of valves A-F, each having an inlet and an outlet to which the fluid conducting lines are connected as shown in FIGS. 7 and 8. The valves are actuated to one valving condition by energization of a solenoid and spring returned to the opposite valve condition upon de-energization of the solenoid.

In FIG. 11 there is shown a control system for operating the vapor recovery system heretofore described. Suitable sequencing switch mechanism is connected to the solenoid of the valve assembly 131, the heaters for canisters 110 and 112, and the vacuum pump 156 to control operation of these devices in a determined sequence hereinafter explained. A master on-off switch 180 supplied current to the sequencing switch and devices controlled thereby, and also to the gasoline pump 24 and blower 114, through the conventional switch 182 on the pedestal.

In a typical operation, closure of switch 180, as for example when the service station attendant arrives to open the station for business in the morning, will start the sequencing switch which will in turn energize the system for de-sorbing of canister 112 and sorbing by canister 110 as shown in FIG. 7. In the sequence controlled by the sequencing switch, the valves A, B and D are closed and valves C, E and F are open, and the heaters in canister 112 are energized. Following a short time delay to allow the heaters in canister 112 to heat the sorbing bed, such as ten minutes, the sequencing switch will energize the vacuum pump 156 to draw a vacuum on the canister 112 and strip the sorbed vapors therefrom through outlet 124', through valve C, flame arrester 160, the pump 156, the cooling tube 162, valve 166 and finally to the sparger 55 where the vapors are taken up by the gasoline in the tank 20. The vacuum pump and heaters will remain energized for a predetermined period of time to strip vapors from the sorbing bed, such as 25 minutes, and then the sequencing switch will deenergize the heaters and after the sorbing bed has cooled somewhat the sequencing switch deenergizes the vacuum pump. During energization of the heaters, the temperature of the sorbing bed is thermostatically controlled by a suitable thermostat switch in the heater leads.

During the foregoing de-sorb cycle of canister 112, canister 110 is in condition for sorbing vapors. When the service station attendant in the typical operation of refueling an automobile removes the nozzle from its hanger on the pedestal 28, he resets the gallonage delivery meter and closes switch 182, see FIGS. 1 and 11, which energizes a time delay relay 200 and starts the pump 24 to deliver gasoline from tank 20 to the nozzle. Contacts 200' of the relay are thereupon closed ener-

gizing the blower 114 to create a partial vacuum in canister 110 and vapor and air mixture inlet 116, valve E and the vapor return line 50, 46 and within the collector 43. Such subatmospheric pressure creates the aforementioned annular inrushing atmospheric air curtain around the nozzle pipe 36 to collect the vapors escaping back out the automobile gas tank filler neck 38 as gasoline is pumped into the tank through nozzle pipe 36. When the nozzle is shut off and removed from the filler neck, and the pedestal switch 182 is opened, the time delay relay will continue to energize the blower 114 until a determined time period expires to thereby clear the vapor collector 43 and return line of any residual fuel vapors, and then the blower 114 is shut off until the next vehicle is to be refueled and the operation repeats.

The length of time the sequencing switch holds canister 110 in the foregoing described sorbing cycle will be adjusted in accordance with the average gallonage pumped by the station. For example, canister 110 may be on the sorbing cycle for 3 1/2 hours and then the sequencing switch will energize the solenoid of the valve assembly 31, to open valves A, B and D and close valves C, E and F to establish the condition shown in FIG. 8 wherein canister 110 is on the de-sorb cycle and canister 112 is on its sorbing cycle, during which the foregoing description with the opposite canisters repeats.

It is to be understood that the control system of FIG. 11 is merely representative of one system that will operate the separator means 52 to draw in the vapors through the collector 43, cause separation thereof from the air, and deliver them to the sparger. Different or more sophisticated control systems may be visualized by those skilled in the art without departing from the essential concept disclosed herein.

In multiple pedestal or multiple delivery nozzle gas stations, which are more often found than a single nozzle station schematically represented by the solid lines of FIGS. 7 and 8, the vapor return lines for a plurality of nozzles are connected together so that when one nozzle is in use to refuel one vehicle, air is being pulled into the collectors of the other nozzles as well. For example, in FIGS. 7 and 8, phantom lines 50' and 50'' are shown which extend from their nozzles (not shown) to the vapor line 50 for communication of all three with the separator means 52. By this arrangement a larger volume of air is pulled across a sorbing bed thereby helping to cool it or keep it cool during sorption and also further insuring that any residual vapors around nozzles not being used are drawn into the sorbing bed. In the event it is desired to open only the vapor return line associated with the nozzle being used, each vapor return line may have a solenoid valve 201 as shown in FIG. 1, which is normally closed but opens when the pedestal switch 182 for its pedestal is closed. If desired during warm atmospheric conditions suitable cooling means may be provided for cooling the sorbing bed 128 during the sorbing cycle.

Vent System

In FIGS. 1, 7 and 8 the storage tank is shown vented to the atmosphere through vent line 58 which is topped by a control valve 210 of any suitable character which will establish communication with the atmosphere if the pressure in tank 20 exceeds 1 p.s.i.g. or if the pressure in the tank drops below 1 oz. gauge of vacuum. Be-

tween these limits, viz. 1 p.s.i.g. and 1 oz. of vacuum, the valve is closed. This valve will protect the tank 20 against pressures or vacuum conditions which might be injurious to it. Line 72 leads from the vent pipe 58 to the separator means 52 as shown in FIGS. 1, 7 and 8. It is provided with a valve 212 which closes to prevent flow from the pipe 58 to the collector as soon as the pressure between line 58 and valve 212 drops below zero and is opened between zero and $\frac{1}{2}$ p.s.i.g. and is closed when the pressure exceeds $\frac{1}{2}$ p.s.i.g. Valve 212 serves to allow sorbing of vapors escaping from the tank 20 through line 58, but prevents drawing a vacuum on the tank. Closure of the valve above $\frac{1}{2}$ p.s.i.g. will prevent saturation of the sorbing bed by vapors during tank filling by the tank truck 60.

Sparger

In FIG. 1 the sparger 55 is mounted on the lower end of a pipe 54 which is secured to the tank and extends vertically down thereinto. The sparger 55 extends horizontally from pipe 54 approximately 5 inches to 6 inches from the bottom of the tank which will be above any water that may collect in the bottom of the tank and which will also provide for a current in the gasoline to sweep fresh gasoline beneath and upwardly around the sparger during the sparging action. The sparger may be connected to the pipe 54 by a flexible elbow 57 with a spring 59 having looped ends 59' engaged with the pipe 54 and sparger 55 to hold the sparger horizontal as shown in FIG. 5. The flexible elbow 57 and spring 59 enable the sparger and pipe to be straightened out so that they can be inserted down through a top opening in the tank represented by the pipe-like structure 59 in FIGS. 1 and 4, and once the sparger is below the tank opening it will be biased by the spring to its horizontal position.

The function of the sparger is to dissolve the light ends of the gasoline, or vapors, in the gasoline contained in the tank 20. The term "dissolve" as used herein is intended to mean that the vapors are taken up by the gasoline to become a part thereof so that the gasoline is effectively enriched by the vapors and they will be burned as fuel by vehicles subsequently refueled from the tank 20.

I have discovered that when the vapors are caused to pass through a sparger of the construction herein described, which is immersed in the gasoline, substantially all of the vapors (on the order of 99 percent thereof) are dissolved in the gasoline. Essentially the sparger comprises a labyrinth of microscopic passageways. The vapors are caused to enter these passageways and are forced therethrough. During experimentation with the sparger, visual observation seems to indicate that a portion of the vapors are dissolved in the gasoline while in the microscopic passageways, and the balance dissolve either at the exit ends of the passageways or during rising of small bubbles of the vapors toward the free surface of the gasoline.

The sparger structure shown in FIGS. 4 and 5 comprises a sintered metal tube having an interior bore 51 closed at its end 61 and communicating at its opposite end with the interior of the elbow 57 and thence the pipe 54. This sparger, for a typical installation, is 24 inches long, $1\frac{1}{4}$ inches in diameter with a $\frac{1}{8}$ inch wall thickness. The powdered metal in a preferred embodiment is stainless steel with a porosity of 40 microns, which is to say that some of the passageways are 40 mi-

crons in size and there will be many of a smaller size. The vapors are delivered from the compression side of the vacuum pump 156 through line 54 to the sparger 55. On the order of 9.8 pounds of vapor may be expected to be stripped from a charcoal sorbing bed of 140 pounds of charcoal during a 20 minute de-sorbing period (7 percent desorption) of a typical canister that might be utilized in a service station, and this vapor would be delivered to the sparger during such 20 minute period. The rate at which the vapors are delivered to the sparger would appear to have a bearing on the effectiveness of the dissolving of the vapors in the gasoline. The pressure on the vapors must of course be sufficient to overcome the static head of the gasoline in the tank measured at the level of the sparger so that the vapors are forced through the sparger. It would appear that the rate of delivery of the vapors will be dependent upon the porosity of the sparger and the external surface area thereof exposed to the gasoline. Satisfactory results have been obtained, viz. 99 percent recovery of the vapors in the gasoline, where the flow rate equals approximately 0.49 pounds of vapors per minute and the sparger has a $\frac{1}{8}$ inch wall thickness of 40 micron porosity and an area exposed to the gasoline of 93.56 square inches, and is located at least 6 inches below the free surface of the gasoline. Greater flow rates may be possible with the same porosity, wall thickness and area, if the sparger is located farther beneath the free surface of the gasoline, or if a greater flow of gasoline is created around the sparger, but for application in the typical automotive gas station, the foregoing would appear to be preferable.

Upon delivery of the vapors to the sparger, which is of course immersed in the cool gasoline in the tank, the vapors enter the labyrinth of tortuous microscopic passageways and are cooled in such passageways and diffused into the gasoline and are thereby taken up by the gasoline. I am not certain at this time whether the greater portion of the diffusion of the vapors into the gasoline occurs within the passageways or at the outer ends thereof at the outside surface of the sparger, but visual observation seems to indicate that a considerable portion of the vapors diffuse into the gasoline within the microscopic passageways of the sparger. However, vapor bubbles also appear at the outside surface of the sparger but disappear almost instantly and therefore are diffused into the gasoline. Other bubbles appearing on the outside of the sparger begin to rise in the gasoline and create a current flow of unsaturated fresh gasoline around the sparger and such bubbles for the most part dissolve before reaching the free surface of the gasoline. Such current flow of unsaturated gasoline around the sparger may also be attributable to the discharge of gasoline (into which vapors have been diffused) from the microscopic passageways of the sparger.

In one example, a tubular sintered stainless steel sparger was provided having a 40 micron porosity, an O.D. of $\frac{3}{8}$ inch, an I.D. of $\frac{1}{8}$ inch and a length of 0.23 inches. This sparger was immersed horizontally in 3.25 gallons of Amoco Premium gasoline in a test vessel, the sparger being disposed between 11 inches and 13 inches below the free surface of the gasoline. The temperature of the gasoline was 77° F.

Into the sparger butane gas was delivered at a temperature of 77° F. and a flow rate of 250 cc/min. A rotameter type flow meter capable of measuring flow

rates as low as 5 cc/min was connected to the outlet of the test vessel above the free surface of the gasoline and no exit flow was measurable on the flowmeter over a period of 4 hours during which the butane was delivered at the rate of 250 cc/min. At the end of this period a more sensitive soap film flow meter was used and the exit flow was determined to be 2.47 cc/min. Recovery of the butane in the gasoline was therefore on the order of 99 percent. At the time of this measurement the amount of butane added to the gasoline was about 50 grams/gallon. Such a concentration is well above that which would develop as a result of vapor return to a typical storage tank such as shown in FIG. 1 during vapor recovery. It has been estimated that the maximum due to return is on the order of 10 to 20 grams of butane and other light ends per gallon of stored gasoline. Therefore typical recovery under field conditions should be equal to or better than 99 percent.

Based on visual observations during the foregoing example, it appeared that the greater portion of the vapor is taken up by the gasoline within the passageways of the sparger. While some vapor bubbles appeared on the exterior surface of the sparger, few appeared to break the free surface of the gasoline.

In FIGS. 9 and 10 I show a modified form of the sparger which provides an upwardly facing sintered metal plate 220 of a 40 micron porosity which extends over a plenum chamber 222 formed in a box-like structure 224, with the vapor delivery line 54' entering one end thereof. The box may be formed of stainless steel sheet metal having an upper rim 226 folded as shown and with a gasket 228 overlying the plate to seal the plate and box structure together. This sparger structure when immersed in the gasoline with the plate disposed horizontally and facing upwardly will tend to prevent coalescing of any vapor bubbles escaping from the plate into the gasoline, and therefore improve the effectiveness of the sparging action. It is estimated that with a sparger of either of the foregoing construction, but preferably of that of FIGS. 9 and 10, the sparging action will provide a 99 percent recovery of the vapors in the gasoline even when the free surface of the gasoline drops to 6 inches above the sparger.

Burning of Vapors

Should it be desired to burn the vapors rather than return them to the storage tank 20, the vapors may be passed through a line 250, shown in phantom to indicate this optional arrangement, and led to a burner 252 of any suitable construction.

What is claimed is:

1. The method of recovering fuel vapors emanating from refueling of a tank with volatile liquid fuel and returning them to stored liquid fuel for subsequent refueling use, comprising:

entraining the vapors in an atmospheric air stream as they are generated during refueling of the tank, collecting the vapor-entrained air stream, separating the vapors from the atmospheric air stream,

and passing the vapors through a labyrinth of microscopic passageways immersed in stored liquid fuel to dissolve substantially all the vapors therein.

2. The method of recovering fuel vapors emanating from refueling of a tank with a volatile liquid fuel, comprising:

entraining the vapors in an atmospheric air stream as they are generated during refueling of the tank, collecting the vapor-entrained air stream, separating the vapors from the atmospheric air stream,

and passing the vapors through a labyrinth of microscopic passageways immersed in the liquid fuel to dissolve them therein without volatilizing said stored fuel.

3. A vapor recovery system for refueling stations comprising, in combination:

a storage tank for liquid fuel,

refueling means for delivering liquid fuel from the storage tank to a tank to be refueled,

collection means for collecting fuel vapors generated during refueling of a tank by said refueling means,

separating means connected to said collecting means for separating fuel vapors from a mixture of such vapors and air,

means for venting the storage tank to the atmosphere,

dissolving means connected to said separating means and to said storage tank for dissolving vapors and returning them to the storage tank, said dissolving means comprised of a labyrinth of microscopic passageways immersed in the liquid fuel,

and means connecting the upper part of said tank above liquid fuel therein with said separating means for delivering fuel vapors and air from the storage tank to the separator means upon a predetermined increase in pressure in the tank.

4. The method of recovering fuel vapors emanating from refueling of a tank with a volatile liquid fuel, comprising:

collecting the vapors as they are generated during refueling of the tank,

separating the vapors from atmospheric air with which they may be mixed,

and passing the vapors through a labyrinth of microscopic passageways immersed in the liquid fuel to dissolve substantially all of them therein and without increasing the volatilization of the stored liquid fuel.

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