

[54] **METHOD AND APPARATUS FOR
PREVENTING LOSS OF HYDROCARBONS
TO ATMOSPHERE**

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VR, 85 VS**

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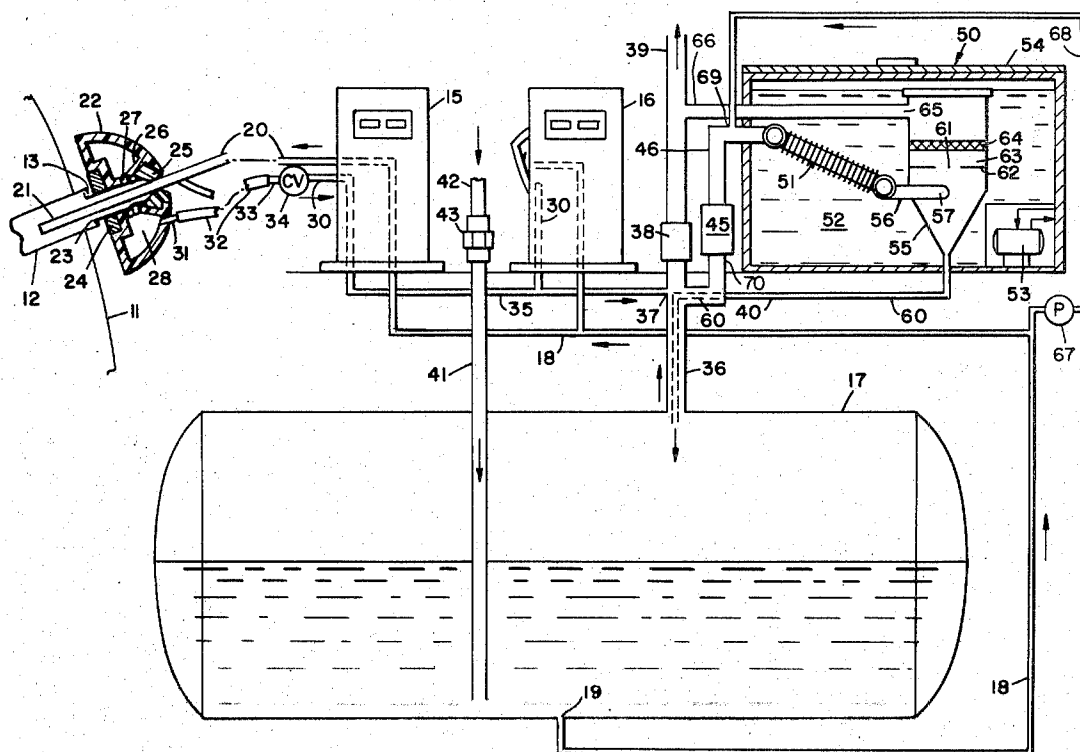
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ABSTRACT

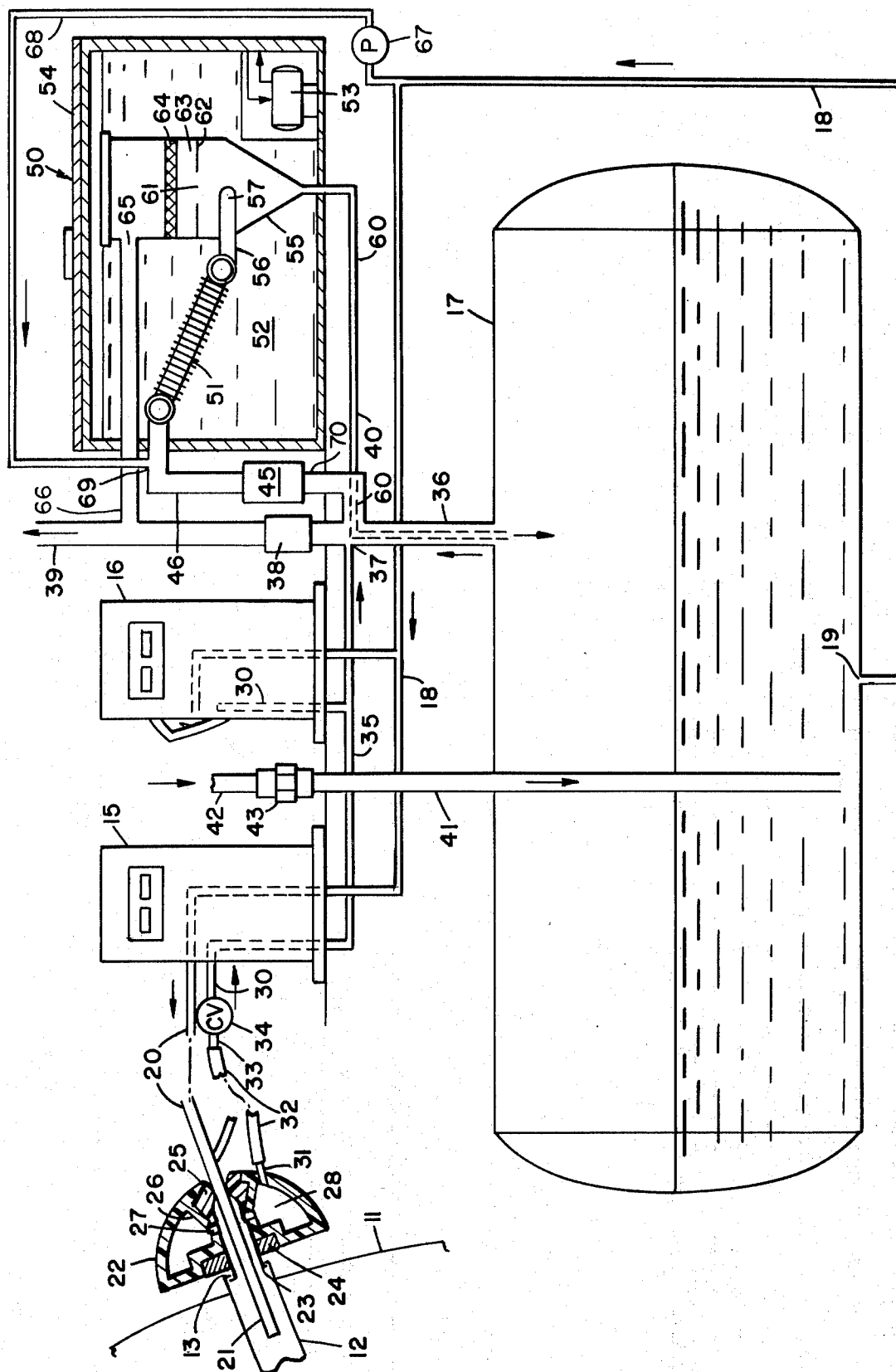
A self-contained vapor recovery system for gasoline service stations and for similar applications. Displaced hydrocarbon gases are collected at the point of entry when a vehicle's fuel tank is being filled, or when the service station's main storage tanks are receiving a fresh loading of gasoline. These vapors are collected under controlled pressure conditions, dehydrated, and passed through a refrigerated condensation or absorption zone, and the recovered liquid is returned to the service station's storage tankage, preferably below the liquid level there. The essentially hydrocarbon-free gas, now mainly air, is discharged into the atmosphere. The invention not only helps conserve a valuable natural resource, the petroleum from which the gasoline is made, but also alleviates air pollution or smog formation, since unburned hydrocarbons in the earth's atmosphere react under the influence of sunlight with nitrogen oxides and carbon monoxide from any source of combustion, to form a typical smog blanket. Being compact, the apparatus occupies little valuable space in a service station; and it requires less power than conventional apparatus.

17 Claims, 1 Drawing Figure



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METHOD AND APPARATUS FOR PREVENTING LOSS OF HYDROCARBONS TO ATMOSPHERE

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 289,757, filed Sept. 15, 1972, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to the field of prevention of air pollution. Specifically, it relates to a method of and apparatus for preventing loss of gasoline fractions when filling automobile fuel tanks and when refilling service station storage tanks. It is an improvement on the invention disclosed in my co-pending application Ser. No. 109,226 filed Jan. 25, 1971 now U.S. Pat. No. 3,763,901.

When a motorist stops to refuel, he may take, typically, about 7½ U.S. gallons, which means that 7½ gallons of gasoline vapor and air are displaced during the refueling. Additionally, there is at least an equal evaporation loss due to agitation of the fuel, which may be warmer than the ambient temperature. This means that 15 gallons of vapor or two cubic feet of vaporized gasoline and air are vented to the atmosphere.

Recent California laws limit vapor pressure of gasoline seasonally, so that "summer grade," by area and date, may not exceed 9 pounds Reid vapor pressure at 100° F. This lower vapor pressure and the evaporation control systems on late-model automobiles have reduced losses when filling automobile tanks, and the lower vapor pressure has helped to reduce losses when filling tanks for storage in stations. The late-model cars commonly use a charcoal canister to absorb and store gasoline vapors from the fuel-tank and carburetor until their use as fuel is permissible. Thus, loss in filling automobile tanks has been substantially reduced to about 0.5 gallons or less per 1,000 gallons transferred, but this is additive to other losses in the filling station — the other main loss occurring when filling main storage tanks, where loss is in the range of 1-3 gallons per 1,000 gallons transferred. Thus, typical overall loss is at least 2 or more gallons per 1,000, amounting to 5,500 grams or more per 1,000 gallons transferred. Under California law, permissible total auto emissions of hydrocarbons are 3.2 grams per mile in 1972, dropping to 0.4 grams in 1975-76 for all autos sold in the U.S.A. under the 1970 Clean Air Act, both figures based on current test procedures.

It is apparent that controls will have to be placed on the handling of gasoline at service stations and at bulk distribution centers to meet the stringent standards set by the 1970 Clean Air Act.

It is well known that "smog," now a major problem in most metropolitan areas, is presently attributable about 60 percent or more to the automobile population. Excluding CO₂, automobile exhausts and evaporation losses contribute about 68,000,000 tons daily to the 142,000,000 tons of pollutants entering the nation's atmosphere daily. Automobiles powered by internal combustion engines emit into the atmosphere unburned hydrocarbons, nitrogen oxides, and carbon monoxide, which in various combinations react in the atmosphere under the influence of sunlight, causing a typical smog blanket.

the device of this invention, if installed at all service stations where auto gasoline tanks are filled and used according to the method of this invention, should substantially help in lowering the total quantity of hydrocarbons in the air. It would also help conserve a valuable natural resource—the petroleum from which gasoline is made. Additionally, over a period of time, savings at the service stations due to reduced losses of gasoline should pay for the necessary equipment.

SUMMARY OF THE INVENTION

Briefly, a preferred form of my invention comprises a combination of the following elements:

1. A tight seal at the automobile gasoline tank filler-pipe with a screw cap of same size and similar in nature to the gasoline tank cap, fitted with a gasket and sealed with a partial turn. A delivery hose for gasoline is centered in this sealing device, and vents in its release the vented vapors into an enclosed annular space. This annular space is connected by a vapor delivery line leading to a condenser unit. In order to prevent air entry or vapor loss when a pump is not in use, as would be the case especially in multiple-pump stations, each delivery line is equipped with a check-valve to permit flow of vapors only in the direction of the condenser unit.

2. A pressure relief valve, in each main storage tank ventline to the atmosphere, which may be set to open at a desired predetermined pressure differential, such as 0.5-2.5 psig. Elements (1) and (2) provide vapor-tight means for preventing the displaced or evaporated hydrocarbons from the tanks from entering the atmosphere. 3. A vapor collection system comprising lines from each pump, and from a point or points just upstream of the main storage tank pressure relief valves (element 2), this system leading to the condenser unit.

4. A condenser unit comprising (a) a vapor dissicator, (b) a low temperature zone, similar to a conventional chest or horizontal household-freezer and capable of maintaining a desired low temperature, which will vary with the air and light hydrocarbon content of the vapor and may be in the range of about 0° F. to about -40° F., (c) a coolant bath maintained well below the most volatile commonly-used hydrocarbon in gasoline, normal butane, which boils at 31° F., the coolant bath being large enough to provide a "heat sink" for preventing undesirably high temperature during short overload periods of perhaps 10 minutes while a truck and trailer load of gasoline, usually 5,000 to 10,000 gallons, is unloaded into the main storage tanks, (d) a condenser, preferably finned as in an automobile radiator and immersed in the coolant bath, the condenser discharging into (e) a small cyclone-separator to provide additional cooling and condensation and to create, by high entry velocity, a separation force greater than that of gravity, sufficient to force condensed hydrocarbon liquid out the bottom of the cyclone cones and to release air, other gas and hydrocarbon mist at relatively low velocity through a vertical cylindrical disengaging zone above but within the cyclone-separator vessel, and (f) a demister pad of steel-wool or similar material in said cylindrical section to agglomerate any entrained hydrocarbons present as a mist, returning said liquid hydrocarbons by gravity to the separation zone of the cyclone-separator, while venting air, substantially free of hydrocarbons, from said cylindrical section into the atmosphere.

5. A flexible tube or conduit for the condensed liquid hydrocarbons, placed within the vapor-venting system of the storage tank or tanks, and to return therein the liquid hydrocarbon condensate from the bottom of the cyclone vessel to storage.

The above combination thus (1) prevents the gasoline vapor displaced by liquid during filling from escaping into the atmosphere, (2) prevents gasoline from evaporating into the atmosphere during filling, (3) collects essentially all the displaced and evaporated vapor and condenses it into liquid form, and (4) recovers the liquid. The invention thus prevents both pollution of the atmosphere and waste of valuable gasoline.

Other objects and advantages of the invention will appear from the following description of some preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a diagrammatic view in elevation and partly in section of a gasoline vapor recovery system embodying the principles of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the system of this invention, all lines carrying hydrocarbons and all connections are vapor tight; so the condensing system may be operated at a slight pressure, preferably at about 0.5 to 2.5 psig.

Thus, a tight seal is made between the automobile's filling tube and the spout of the filling station hose, when the automobile's gasoline tank is being filled. This tight seal may be made by any one of the means therefor shown in co-pending patent application Ser. No. 109,226 filed Jan. 25, 1971, or the structure shown in the drawing of the present application may be used.

Here, the automobile has a body 11 and a filler tube 12 leading to its gasoline tank, not shown, and having a filler spout or inlet 13.

Each gasoline pump 15, 16 at the filling station is connected to a main storage tank 17 for its grade or type of gasoline by a pipe 18 leading from an outlet 19 at the bottom of the tank 17. A hose 20 leads from the pump 15, and its outlet end or nozzle 21 is placed in the filler tube 12.

A vapor-tight, preferably transparent cup 22 serves as a vapor collection device. It has a screw cap 23 which may be the same size as and similar in nature to the tank cap (not shown) of the tube 12. The screw cap 23 is provided with a gasket 24, and the connection can then be sealed by a partial turn, just as when putting a gasoline tank cap in place. The cup 22 may be made from a suitable hard transparent plastic, such as rigid polyethylene, and (although a similar device may be secured to the hose 20) in this instance it may be placed on the filler tube 12 independently of and before the delivery hose nozzle 21 is inserted in the tube 12. Thus the cup 22 has a flexible gasket 25 made from gasoline-resistant material such as neoprene or nitrile rubber, Viton plastic, or the like; the gasket 25 is annular and is so shaped and sized that it readily accepts the nozzle 21 and forms a vapor-tight fit around it.

The cup 22 thus has an inner tubular wall 26 having openings 27 therethrough leading into an annular space 28, and gasoline and air from the automobile tank are displaced by gasoline during filling and flow from the tube 12 through the openings 27 into the enclosed

space 28, where the vapors are temporarily collected.

The invention calls for conveying this mixture of air and gasoline vapor away from the cup 22 by a vapor-collection tube 30. For this purpose, the tube 30 may be connected to an outlet 31 from the space 28 by a length of plastic tubing 32 having a quick connector 33. In order to prevent the venting of vapors to the air from the vapor-collection line 30, a check valve 34 is provided at the end of the line 30 to allow flow of vapor only into the line 30.

A main collection line 35 collects vapor from all the lines 30 and from a vent line 36 leading up from the upper end of the main storage tank 17, which joins the line 35 at a juncture 37 a short distance below a pressure relief valve 38 with a stack 39. A line 40 combines the vapors from the lines 35 and 36. The vent line 36 accommodates the displaced air and vapors when the tank 17 is being filled, its inlet line 41 then being joined to the gasoline delivery truck's line 42 by a vapor-tight union 43. Thus, the vent line 36 transmits to the main vapor-collection line 35 both the displacement vapors from filling, those resulting from agitation, and those resulting from the "breathing" induced by temperature changes. The pressure relief valve 38 may be set to open at a predetermined pressure differential, such as 1.0 psig. If the pressure exceeds the predetermined setting, the collected vapors are vented directly to the air through the line 39 in order to prevent the tanks and so on from damage or rupture.

The line 40 leads to a desiccant vessel 45, where the mixture of air and gasoline vapor is de-moisturized. The vessel 45 may contain any effective desiccant, such as silica gel, anhydrous calcium sulfate ("Drierite"), calcium chloride, molecular sieves. This drying is important since the condensing or absorption system is to operate below the freezing point of water, and solidified hydrocarbon hydrates or ice would plug the lines.

The dried mixture of air and vapors passes from the desiccant vessel 45 by a conduit 46 to a condenser unit 50, where it flows first into a finned heat-exchanger tube 51 immersed in a bath 52 of a suitable liquid coolant. A preferred coolant is a 50 percent solution of ethylene glycol in water. The bath 52 is kept in the range of about 0° F. to -40° F., by a refrigerating unit 53, which may be like that of a household freezer and has a chest or housing 54. The finned heat-exchanger tube 51 is preferably placed in a downwardly slanting position in the bath 52 in order to provide a thermo-syphon circulation of the contained coolant. However, if desired, the coolant may be mechanically agitated to improve the heat transfer rate. Here, the gasoline vapors condense and become liquid.

The chilled effluent from the tube 51 flows into a cyclone separator 55 via a line 56 and a tangential inlet 57. The cyclone separator 55 is fully immersed in the bath 52. The inlet velocities are substantial when the main tank 17 is being filled and is appreciable when an automobile's tank is being filled. For example, gasoline is normally sent into the main tank 17 at a rate of about 400 to 450 gallons per minute, so that vapor velocities into the tangential inlet 57 may be about 60 feet per second or more; moreover, the radius of the cyclone 55 is necessarily small, so that the separating force between the air and the liquid condensate is great, typically 200 or more times the force of gravity.

The condensed liquid collects in the bottom of the cyclone separator 55 and leaves it through a conduit 60, which flows back into the main storage tank 17. A convenient way to do this is to employ hydrocarbon-resistant flexible tubing and to place the conduit 60 inside the vapor lines 40 and 36, insofar as is practicable.

The substantially hydrocarbon-free air leaves the cyclone separator 55 via a central orifice 61 in a horizontal plate 62 and flows into a low-velocity chamber 63. The orifice 61 occupies, preferably, about 8 percent to 25 percent of the area of the plate 62. As insurance against loss of some liquid as mist, the low-velocity chamber 63 may contain a de-mister pad 64 of suitable material, such as stainless steel wool, which agglomerates any mist into droplets. Thus, substantially dry, clean air, free of condensate, leaves the chamber 63 through an outlet 65 and passes by a conduit 66 to the vent stack 39.

"Winter grade" gasoline presently has no legal vapor-pressure limit, hence may be expected to contain more normal butane than "summer grade" gasoline. Some refiners may even see fit to add some propane or isobutane, should these hydrocarbons be in excess of other needs. The presence of such additional light hydrocarbons in a vapor which is mostly air may result in equilibrium condensation temperature as low as about -40°F. for 90 percent hydrocarbon recovery as liquid. While such operating temperatures pose no special problems other than use of a proper refrigerant, including the Freon-type compound monochlorodifluoro methane known as Refrigerant 502, ammonia, or propane and do not effect refrigeration horsepower requirements appreciably, it may be desirable to inject a small amount of tank gasoline into the tank vapors before they enter the condenser-liquid recovery unit. This enables a somewhat higher coolant temperature for 90 percent hydrocarbon recovery or, alternately, a greater recovery at a given temperature, by taking advantage of the combination absorption and higher equilibrium temperature effects. Unless a large amount of gasoline is injected, the refrigeration load increase is small. An economical amount is about 1 to 3 mols of gasoline per mol of total hydrocarbons in the vapor.

To accomplish this, a pump 67 may take suction on the tank gasoline in line 18 whenever the pressure at a sensor 70 exceeds a predetermined figure, as when a main storage tank is being filled. The pump 67 discharges the tank gasoline through a line 68 into the vapor line 46 at a point 69 just before the vapors enter the condenser 51. In tanks using a submersible pump to supply the gasoline-dispensing pumps, the pressure sensor 70 would actuate this submersible tank pump and supply the gasoline into the line 68.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. A method for preventing pollution of the atmosphere by hydrocarbon vapors, comprising:
 - closing off the space between a tank to be filled and a filling hose from access to the atmosphere during the filling of the tank,

collecting the gasoline vapors and air displaced from said tank during filling of said tank by liquid gasoline and also collecting additional gasoline vapors evaporated during said filling of the tank, de-moisturizing the collected vapors, and air, condensing the de-moisturized vapors to liquid form with some of the condensed gasoline vapors still dispersed in the air, and

introducing the air and condensed vapors tangentially into a cyclone-separation zone maintained at a temperature between about 0°F. and about -40°F. at an entrance velocity such that the centrifugal force imparted is substantially greater than the force of gravity,

completing the condensation to at least 90 percent of the hydrocarbons boiling at and above about 31°F. and separating the hydrocarbon liquid from the air by said centrifugal force.

2. The method of claim 1 having the additional steps of injecting about one to three mols of tank gasoline per mol of total hydrocarbons present in the vapor, into the vapors entering the condensing system, to absorb part of the hydrocarbons.

3. The method of claim 1 having the additional steps of

de-misting the air and any condensed hydrocarbon contained therein after said separating by agglomerating the mist into droplets of liquid, and returning said droplets to the separation portion of the cyclone zone by gravity.

4. The method of claim 3, including injecting about one to three mols of tank gasoline per mol of total hydrocarbons present in the vapor, into the vapors entering the condensing system.

5. The method of claim 3 having the additional steps of

conducting the condensed hydrocarbon liquid from the bottom of the cyclone-separator vessel to storage, and

venting the air and other gas to the atmosphere.

6. The method of claim 1 having the additional steps of

conducting the condensed hydrocarbon liquid at the bottom of the cyclone separator to storage, and venting the air and other gas from the top of the cyclone separator to the atmosphere.

7. Apparatus for preventing pollution of the atmosphere by hydrocarbon vapors, comprising:

means for closing off the space between a tank to be filled and a filling hose from access to the atmosphere during the filling of the tank,

means for collecting the gasoline vapors and air displaced from said tank during filling thereof by liquid gasoline and also for collecting any additional gasoline vapors evaporated during said filling of the tank,

means for de-moisturizing the collected vapors, and air,

means for condensing the collected vapors to liquid form, with some of the condensed gasoline vapors still being dispersed in the air, and

a cyclone separator having a tangential inlet introducing the air and condensed vapors at an entrance velocity such that the centrifugal force imparted is substantially greater than the force of gravity, means for maintaining the condensed vapors in said cyclone separator in their condensed state so that

condensation is completed to 90 percent or more of all hydrocarbons boiling at and above about 31° F., and so that the hydrocarbon liquid is separated from the air by said centrifugal force.

8. The apparatus of claim 7 having means for injecting tank gasoline into the vapors before said vapors enter said means for condensing.

9. The apparatus of claim 7 having means for de-misting the air and any condensed hydrocarbon contained therein after separation by agglomerating the mist into droplets of liquid, and

means for returning said droplets to said cyclone separator by gravity.

10. The apparatus of claim 9 having means for conducting condensed hydrocarbon liquid at the bottom of the cyclone separator to storage, and

means for venting the air and other gas to the atmosphere.

11. The apparatus of claim 7 having means for conducting the condensed hydrocarbon liquid at the bottom of the cyclone separator to storage and

means for venting the air and other gas from the top of the cyclone-separator vessel to the atmosphere.

12. Apparatus for preventing loss of hydrocarbons to air when filling a depleted automobile gasoline tank and when filling the fuel-dispensing tank of the service station, comprising

a gasoline storage tank,

vapor-collecting means for collecting the hydrocarbon vapors and air displaced from the automobile gasoline tank during filling under slight pressure,

drying means connected to said vapor-collecting means for demisting said collected vapors and air,

condensing means connected to said drying means for condensing not less than 90 percent of the hydrocarbons boiling at and above about 31° F. to liquid form, said condensing means comprising a housing containing refrigerated coolant, and a heat exchanger and a cyclone-separator vessel both immersed in said refrigerated coolant, said cyclone-separator vessel imparting a centrifugal separating force greater than that of gravity and having a separation zone,

a liquid collector at the bottom of the cyclone-separator zone,

conduit means connected to said liquid collector for conducting said liquid hydrocarbon condensate to said storage tank, and

means connected to said vapor zone for venting the air and any other gas present from the top of said cyclone-separator vessel to the atmosphere.

13. The apparatus of claim 12 having means for injecting tank gasoline into the vapors before said vapors enter said condensing means.

14. The apparatus of claim 12 having means for collecting vapors and air displaced in filling said storage tank connected to said vapor-collecting means,

bypass venting means connected to said means for collecting vapors and air to said vapor-collecting means, and

check valve means in said bypass venting means holding a pressure in said collected vapors of about 0.5-2.5 psig before venting.

15. The apparatus of claim 12 wherein said vessel has a cylindrical vapor zone within and above said separation zone of said cyclone separator wherein the linear velocity is relatively low, and

a de-mister pad placed horizontally in said vapor zone wherein air, gas and any condensed hydrocarbon vapor present as fine mist are caused to pass, thereby agglomerating said mist into liquid droplets,

said liquid droplets returning by gravity into the separation zone of the cyclone-separator vessel.

16. The apparatus of claim 12 wherein said vapor-collecting means comprises a housing providing an annular space and secured to a gasoline filling hose adjacent to its nozzle and having means for attachment to the filling spout of said automobile gasoline tank in the same manner as the cap normally closing said spout.

17. The apparatus of claim 16 having a vapor line from said housing and check-valve means in said vapor line for closing off said vapor-collecting means when no vehicles are being refueled.

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