

[54] VAPOR RECOVERY WITH AMBIENT COOLING

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[58] Field of Search..... 62/54; 220/85 VR, 85 VS; 55/88, 89, 90, 93, 94, 64, 65

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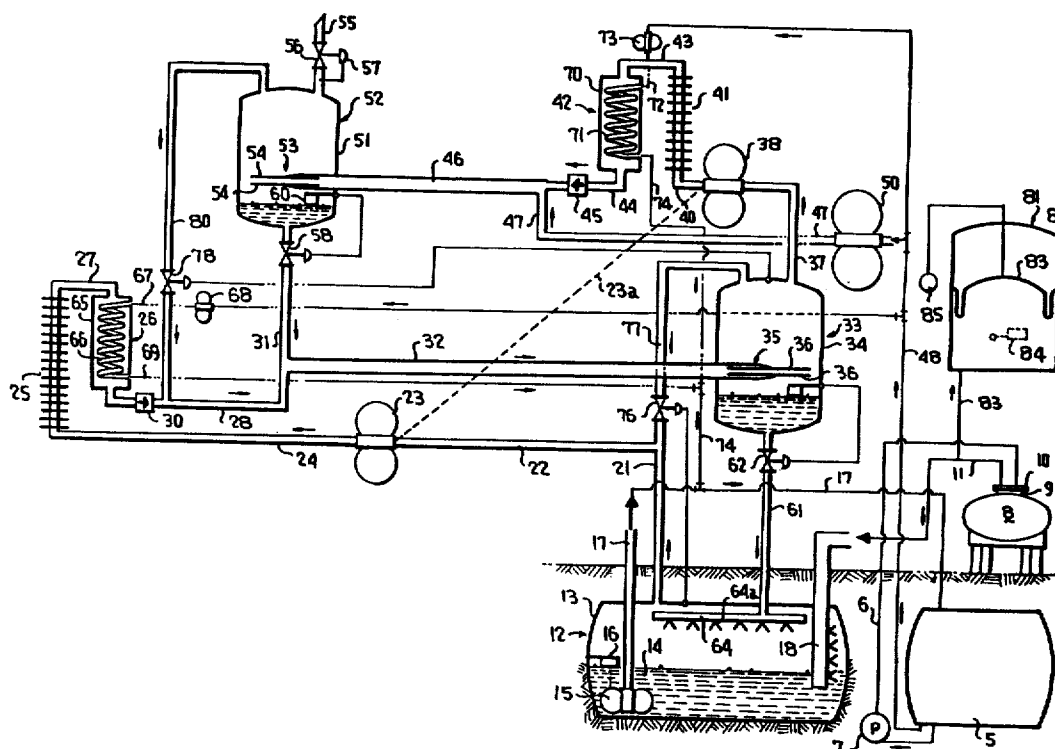
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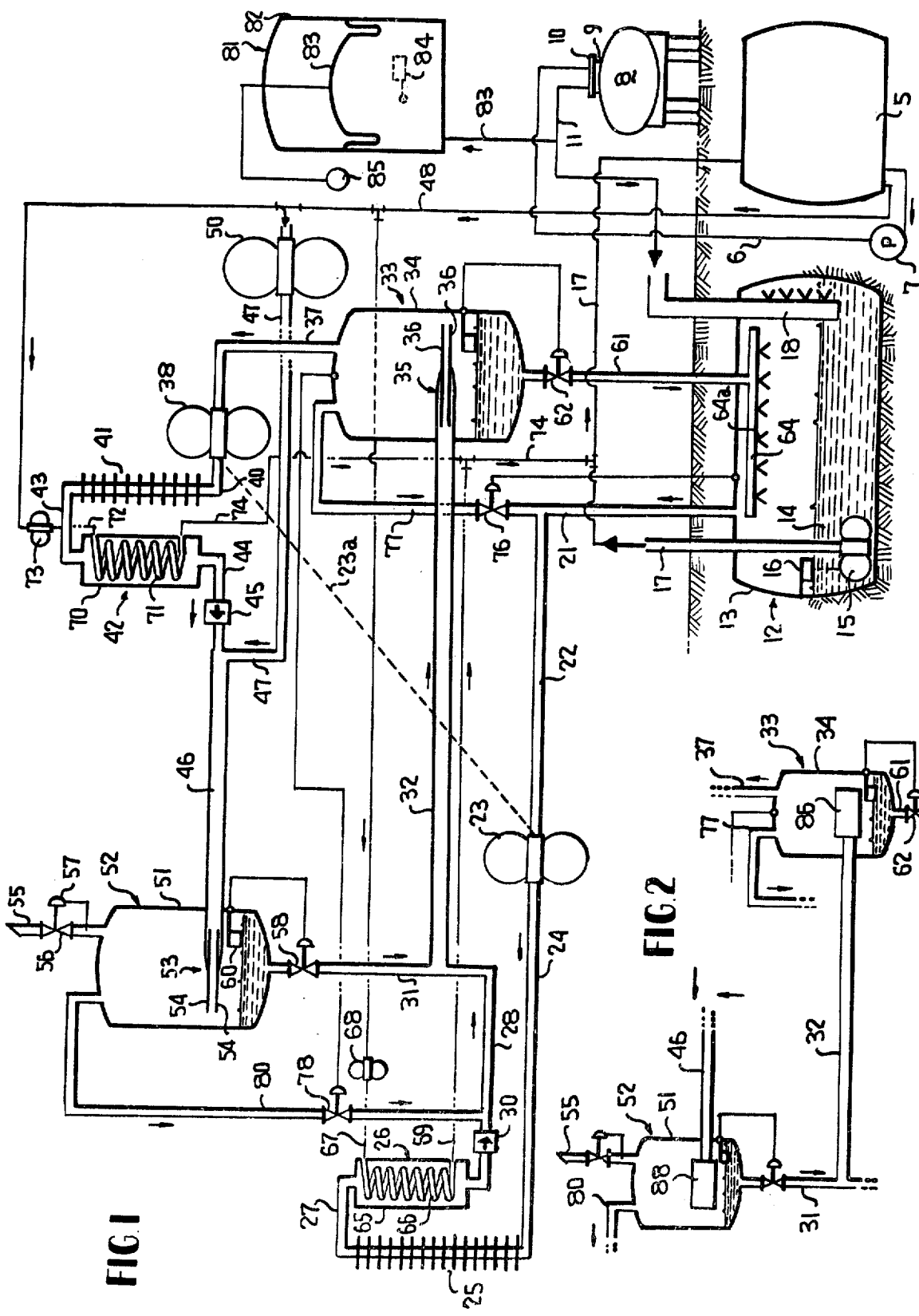
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ABSTRACT

This disclosure relates to a low cost system for recovering vapors of volatile liquids, such as gasoline, and liquifying the same without the use of refrigeration; that is, by utilizing only ambient cooling. Liquid is employed as a heat exchange medium and two absorber-separators operating at different pressures are used whereby relatively great efficiency is obtained. The system may also provide means for maintaining flow of gases through the required compressors when there is little or no recovered vapor being introduced into the system and/or when vapor pressures in the absorber-separators is low to thereby protect the compressors against damage due to cavitation.

25 Claims, 4 Drawing Figures





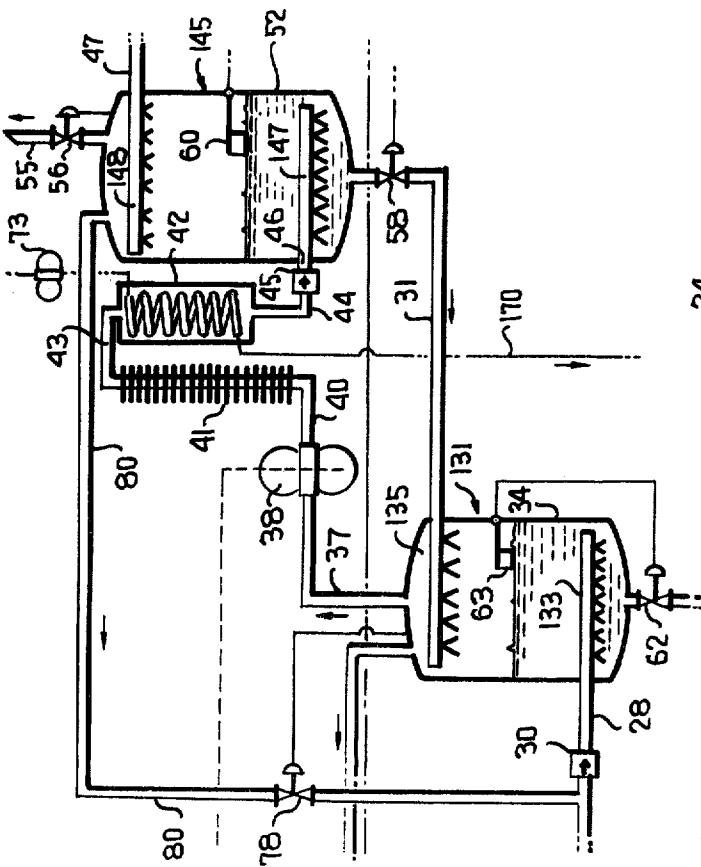


FIG. 3

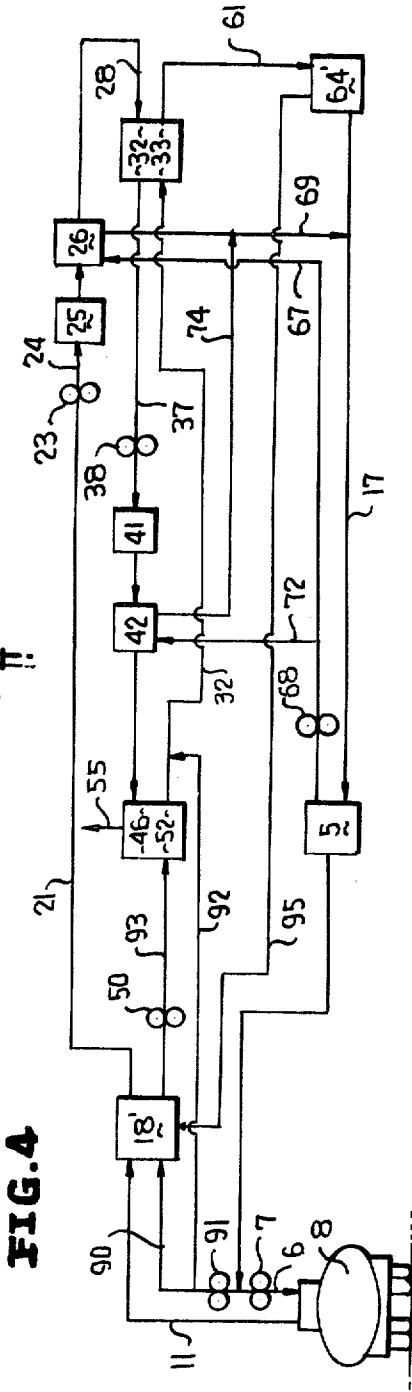


FIG. 4

VAPOR RECOVERY WITH AMBIENT COOLING

BACKGROUND OF THE INVENTION

It is well known that the loss into the atmosphere of vapors of highly volatile liquids, such as hydrocarbon fuel, not only presents an ecology problem, but also results in the loss of large quantities of valuable liquid. Such losses may occur through venting of storage tanks and also during the filling of tanks, such as fuel tank trucks.

In the past, vapor recovery systems have been developed by others, as for example, the system disclosed in U.S. Pat. No. 2,849,150, to Albert H. Tompkins, Jr. These prior systems are complex and expensive. Thus, to provide a satisfactory system corresponding to that of the Tompkins patent requires operating pressures of 200 psig or more, which in turn requires costly two stage reciprocating type compressors that must be operated at constant speed.

To improve efficiency, other systems have been made so as to operate at a low temperature. This requires incorporation of refrigeration units which greatly increase the cost.

SUMMARY OF THE INVENTION

The present invention provides a high efficiency vapor recovery system without refrigeration which is of a simply construction and economical to construct and operate. It utilizes two absorber-separator units arranged in series with recovered vapor being supplied to the absorber-separator under different pressures whereby maximum efficiency is obtained. Moreover, the maximum pressure of vapor delivered to the absorber-separator is sufficiently low, as for example, 165 psig, whereby relatively inexpensive rotary compressors may be used instead of the more costly reciprocating compressors.

Another feature of the invention is that the pressures within the two absorber-separators are materially different, as for example, 50 psi in the first absorber-separator and 150 psig in the second absorber-separator.

Only ambient cooling is utilized for the cooling of vapor passing from the compressor to the absorber-separators. This is accomplished by passing the compressed vapor through a finned tube or an equivalent structure. Also, the compressed vapor may be cooled by means of a heat exchanger utilizing the volatile liquid as a coolant.

Compressors are normally designed to operate at a predetermined maximum efficiency. However, in vapor recovery systems the supply of vapor is not constant, and as a result, the availability of gas to the inlets of the compressors may fluctuate. Therefore, the present system provides for automatic recirculation of gas to the compressor inlets to avoid starving of the compressors and consequent damage thereto.

This invention also provides a combined saturator-flash separator which is preferably disposed underground for aiding in maintaining the vapors at relatively low temperature. The saturator-flash separator receives vapor direct from a source and saturates the same for circulation through the system in explosion proof condition. The saturator-flash separator also is utilized as a final step wherein liquified vapor is sprayed to effect a flash separation of air which may be entrained therein.

Yet another feature of the invention is that the reclaimed liquid is sequentially passed from a second stage absorber-separator to a first stage absorber-separator and then to the saturator-flash separator from which all reclaimed liquid is pumped back to the supply tank.

DESCRIPTION

FIG. 1 is a diagrammatic view of one embodiment of the invention.

FIG. 2 is a diagrammatic view of a modified portion of the system of FIG. 1.

FIG. 3 is a diagrammatic view of another modified portion of FIG. 1.

FIG. 4 is a diagrammatic view of another form of the invention.

The vapor recovery system of FIG. 1 is particularly adapted for use in filling gasoline tank trucks. Gasoline from storage tank 5 is delivered through supply line 6 by a pump 7 to tank truck 8.

To collect gasoline vapor displaced from tank 8 during the filling operation and to prevent discharge of the same to atmosphere, a vent line 11 extends from a cover 10 to convey the vapor to a saturator-flash separator 12. The latter includes a tank 13 which is preferably located underground and has a predetermined amount of liquid gasoline 14 therein. Locating tank 13 underground minimizes formation of an explosive mixture in the tank in cold climates, the vapor within the tank remaining too rich to become explosive. The liquid level within tank 13 is maintained by a pump 15 which is controlled by a float 16 and connected to a line 17 extending to supply tank 5.

Vent line 11 includes a vertical portion 18 within tank 13 adjacent a wall thereof and having openings 20 facing such wall. Incoming vapor is sprayed through opening 20 against the tank wall to saturate the same so as to render it non-explosive. Tank 13 also serves to collect any liquid entrained in the vapor received from truck tank 8.

Saturated vapor exits from tank 13 through a line 21 which is connected to a line 22 leading to a rotary compressor 23 that is capable of compressing the vapor to approximately 50 psig. Compressor 23 is preferably the first stage of a multiple stage compressor of which compressor 38 is the second stage, the connection between the two being indicated by the dotted line 23a. Compressed gases (vapor and air) pass from compressor 23 through line 24 into a finned tube 25 which is exposed to ambient air and which is utilized to cool the compressed gases which, of course, have become heated due to compression thereof by compressor 23.

In some cases such cooling by ambient air is sufficient. However, the system may include a secondary cooler 26 connected to finned tubing 25 by line 27 and to a tube 32 by a line 28 that includes a check valve 30. Tube 32 receives vapor from line 28 and liquid gasoline from line 31 and therefore has two phase flow therein, that is, liquid and gas. Tube 32 serves as a first absorber of a combination first stage absorber-separator 33 that includes a tank 34. Absorber tube 32 extends into the tank 34 and at its end has a laminar flow and impingement separator nozzle 35 that includes two spaced circular disks 36 connected to tube 32 and closely spaced from the vertical wall of tank 34. Liquid and gas flow from tube 32 between disks 36 and impinge against the wall of the tank 34 to effect separation of liquid from

the gas. The liquid falls to the bottom of tank 34 and the gas rises to the top from which it passes through line 37 at about 50 psig pressure to second stage rotary compressor 38 which compresses the gas to a pressure of about 150 psig. A line 40 leads from compressor 38 to a finned tube 41 wherein ambient air cools the heated compressed gas. If ambient temperature conditions are not proper for the necessary cooling of the gas by finned tube 41, the gas may be passed through another cooler 42 connected to tube 41 by a line 43 and to a second stage absorber tube 46 by a line 44 having a check valve 45 therein.

A liquid supply line 47 connects absorber tube 46 with supply tank 5 by way of a line 48 and a pump 50. Thus flow in absorber tube 46 is also two phase. Tube 46 connects to tank 51 and serves as a second stage absorber of a combination second stage absorber-separator generally designated 52. Absorber tube 46 terminates in a laminar flow and impingement separator nozzle 53 that includes parallel circular disks 54 attached to line 46 and which functions in the same manner as nozzle 35.

The second stage absorber-separator 52 liquifies substantially all the gasoline vapor entering from tube 44 so that the gas separated by nozzle 53 from liquid is substantially all air. This gas is exhausted to the atmosphere through a line 55 and a relief valve 56 having a pressure actuated element 57 whereby a predetermined pressure of about 150 psig is maintained within tank 51. Liquid gasoline from nozzle 53 drops to the bottom of tank 51 where it is maintained at a predetermined level by means of a valve 58 controlled by a float 60 which opens to discharge excess liquid from tank 51 via tube 31.

Tank 34 has a drain line 61 controlled by a valve 62 actuated by a float 63 for discharging excess liquid from tank 34 into a flash separator tube 64 within tank 13. Tube 64 has a series of downwardly facing openings 64a through which liquid gasoline from tank 34 is sprayed to effect flash separation of gas entrained therein.

Vapor coolers 26 and 42 are conventional shell and tube heat exchangers but are herein illustrated as coils 66 and 71 respectively mounted within housings 65, 70. Relatively cool liquid from supply tank 5 is supplied to coil 66 through line 67 by a pump 68, line 67 being connected to the liquid supply line 48. Liquid passing out of coil 66 is returned to the tank 5 by lines 69, 74 and 17.

Relatively cool liquid is supplied to cooler housing 70 from tank 5 via line 72, pump 73 and line 48 and is returned to tank 5 via lines 74 and 17.

Processing System Using Vapor Holder

For installations in which a relatively small amount of vapor is to be collected over a period of time, it is advantageous to include a vapor holder 81 in the system. The vapor holder includes a tank 82 having a diaphragm 83 to keep vapor separated from air in the tank. When the system is shut down or flow into the system exceeds the capacity of the compressor 23, vapor from tank 8 flows from line 11 through line 83 into the tank 82 below the diaphragm 83.

When the supply of vapor is low, the diaphragm 83 will move downwardly and trip control switch 84 to shut down the system. Thereafter, vapor flowing from tank 8 will enter vapor holder 81 and cause diaphragm

83 to move upwardly. When the diaphragm 83 moves upwardly to a predetermined height, switch 85 will be tripped to restart the system. Because switch 84 closes down the system when the supply of incoming vapor is low, it is not necessary to recirculate vapors through line 77, as mentioned below, when vapor holder 81 is in the system.

On-Line Processing

For some installations it is possible to use on-line processing, that is, continuous operation with vapor holder 81 omitted. With on-line operation, when vapor flow from tank truck 8, or a plurality of similar trucks, is not sufficient to meet the demands of compressor 23, the gas pressure within tank 13 will open valve 76 to permit vapor in tank 34 to flow through lines 77 and 22 to the inlet of compressor 23 and back to tank 34 via lines 24, 25, 27, 28 and 32. This circulation will continue until sufficient vapor enters tank 13 from tank 8 to raise the pressure in tank 13 to shut valve 76.

In the event the supply of gases to the compressor 38 should become reduced to a predetermined level, pressure within tank 34 will drop and open valve 78 to permit gas in tank 51 to flow to the inlet of compressor 38 via lines 80, 28, 32 and 37. Gases thus flowing out of tank 51 through tube 80 will be primarily air and when mixed in line 28 with gasoline vapor flowing into this line from the saturator-flash separator 12 via lines 21, 22, 24 and 27 may result in an explosive mixture. However, through introduction of liquid from tank 51 into line 32 via line 31 the gases entering line 32 from line 28 becomes saturated and non-explosive.

Absorbers 32 and 46 also serve as gas aftercoolers. If the absorbers were not used as aftercoolers the compressor inlet temperatures could experience a boot strapping effect, particularly when the system is running at a low throughput relative to the compressor.

FIG. 2 Form

FIG. 2 illustrates a slight modification of a portion of the system of FIG. 1. In FIG. 1 the absorbers 32 and 46 are illustrated as having associated therewith laminar flow and impingement separators 33 and 52 respectively. The latter are not the only type of separator that may be utilized. Thus, in FIG. 2 separators 33 and 52 are provided with centrifugal separator nozzles 86 and 88. These nozzles may be of any desired construction with the nozzle 86 receiving two-phase flow from absorber 32 and the nozzle 88 receiving two-phase flow from the absorber 46.

FIG. 3 Form

FIG. 3 shows a system utilizing a different type of absorber-separator than absorber-separators 32, 33 and 46, 52 of FIG. 1. Thus in FIG. 3, an absorber-separator 131 comprises a tank 34 which with bubble bar 133 and spray bar 134 comprises an absorber corresponding to absorber 32 of FIG. 1 and with the dead air space 135 serving as a separator corresponding to separation 33 of FIG. 1. Similarly absorber-separator 145 of FIG. 3 comprises a tank 146 which with bubble bar 147 and spray bar 148 comprises an absorber corresponding to absorber 46 of FIG. 1 and with dead air space 52 serving as a separator corresponding to separator 52 of FIG. 1. Alternatively, conventional demisters, not shown, may be used as the separators in lieu of the dead air spaces.

FIG. 4 Form

FIG. 4 shows an optional arrangement in which saturator 18' corresponding to saturator 18 of FIG. 1 and flash separator 64' corresponds to saturator 64 of FIG. 1 are in separate tanks connected by line 95 so that liquid fuel from line 90 used to saturate the vapor in saturator 18' that came from the tank truck via line 11 loses some of its ends within saturator 18'.

This "lead" liquid is then directed via line 93 to second stage absorber-separator 46, 52 to absorb vapor therein and because the fuel in line 93 is lean the absorption of vapor thereby in absorber-separator 46, 52 is more efficient. In this case a line 90 and a pump 91 is added for delivering the liquid fuel from tank 5 to saturator 18' and a bypass line 92 connects line 90 to line 31 for delivering additional liquid from tank 5 directly to the first stage absorber-separator 32, 33 for added cooling capacity. The remaining portion of the system is similar to that of FIG. 1 with like elements having the same reference numerals in the two systems.

Although only preferred embodiments of the invention have been specifically illustrated and described here, it is to be understood that minor variations may be made in the vapor recovery system without departing from the spirit and scope of the invention, as defined by the appended claims.

I claim:

1. A vapor recovery system for recovering volatile liquid vapors, said vapor recovery system comprising a first absorber-separator for receiving collected vapors, first compressor means associated with said first absorber-separator for delivering collected vapors to said first absorber-separator at a first pressure, a second absorber-separator for receiving a vapor-air mixture from said first absorber-separator, second compressor means associated with said second absorber-separator for delivering vapor-air mixture from the first absorber-separator to said second absorber-separator at a second and higher pressure, means for delivering condensed vapors from said first and second absorber-separators to a collection area, and means for utilizing only ambient air for cooling said vapors.

2. The vapor recovery system of claim 1 wherein ambient cooling means are disposed between at least one of said compressor means and that one of said absorber-separators associated therewith.

3. The vapor recovery system of claim 1 wherein said collection area is in the form of a storage tank and cooling means are disposed between at least one of said compressor means and that one of said absorber-separators associated therewith, said cooling means being in the form of an aftercooler having volatile liquids from said storage tank at storage temperature circulating therethrough as a coolant.

4. The vapor recovery system of claim 1 wherein there are means for returning collected vapors as a liquid to said collection area from said second absorber-separator by way of said first absorber-separator.

5. The vapor recovery system of claim 1 together with means for exhausting all air ejected from said system from said second absorber-separator, and means for flowing all collected liquid from said first absorber-separator.

6. The vapor recovery system of claim 1 wherein said system includes a flash separator and means for deliver-

ing liquid to said flash separator from said first absorber-separator.

7. The vapor recovery system of claim 1 wherein said system includes a flash separator receiving liquid from said first absorber-separator, said flash separator including means for delivering vapors from said flash separator to said first compressor means for recirculation through said system.

8. The vapor recovery system of claim 1 wherein said first and second compressors are first and second stages of a single multiple stage compressor.

9. The vapor recovery system of claim 1 wherein ambient cooling means are disposed between each compressor means and that one of said absorber-separators associated therewith.

10. The vapor recovery system of claim 1 together with a flash separator for removing entrapped air from recovered vapor collected as a liquid, and means for returning collected vapor as a liquid to said collection area from said second absorber-separator by way of said first absorber-separator and said flash separator.

11. The vapor recovery system of claim 9 in which each ambient cooling means is in the form of a finned tube.

12. The vapor recovery system of claim 1 wherein collected vapors are returned as a liquid to said collection area from said second absorber-separator by way of said first absorber-separator, the first absorber-separator includes a first separator and also includes a pipe that provides the absorbing function, and said pipe receives liquid from said second absorber-separator and, compressed vapor for delivery to the first separator.

13. The vapor recovery system of claim 1 wherein said collection area is in the form of a storage tank, said second absorber-separator includes a spray head, and means for supplying liquid from said storage tank to said spray head.

14. The vapor recovery system of claim 1 together with a saturator-flash separator for receiving collected vapors and enriching the liquid content thereof prior to delivery thereof to said first compressor, and a liquid line connected to said saturator-flash separator for supplying recovered condensed vapors thereto for the removal of entrapped air.

15. The vapor recovery system of claim 1 together with means for returning collected vapors as a liquid to said collection area from said second absorber-separator by way of said first absorber-separator, and said first absorber-separator having a spray nozzle receiving liquid returning from said second absorber-separator prior to the return thereof to said collection area.

16. The vapor recovery system of claim 15 wherein said second absorber-separator includes a spray nozzle receiving liquid being circulated from said collection area.

17. The vapor recovery system of claim 1 together with a vapor line between said first compressor and said first absorber-separator and a recirculating line between said second absorber-separator and said vapor line for maintaining gas flow through said first absorber-separator to said second compressor.

18. The vapor recovery system of claim 17 wherein a control valve is mounted in said recirculating line, and means responsive to pressure within said first ab-

sorber-separator controlling the actuation of said control valve.

19. The vapor recovery system of claim 1 together with a saturator positioned in advance of said first compressor for saturating collected vapors prior to the delivery thereof to said first compressor, and means connecting said saturator to said first compressor for delivering saturated collected vapors thereto.

20. The vapor recovery system of claim 19 in which there is a vapor line between said saturator and said first compressor, and a vapor recirculating line between said first absorber-separator and said vapor line for recirculating vapor through said first compressor.

21. The vapor recovery system of claim 20 wherein a control valve mounted in said recirculating line, and means responsive to pressure within said saturator controlling the actuation of said control valve.

22. A vapor recovery system comprising a storage tank for volatile liquid, means delivering liquid from said storage tank to a receiving tank, means for directing a mixture of air and vapor of said liquid expelled from said receiving tank to a saturator, means directing a portion of said liquid from said storage tank to said saturator for saturating said air-vapor mixture, means directing said saturated mixture at a relatively low pressure to a first ambient air cooler for cooling said mix-

ture and then to a first absorber separator for absorbing vapor into a portion of said liquid and for separating the absorbed liquid from the remaining air vapor mixture, means directing air-vapor mixture from said first absorber-separator at a relatively high pressure to a second ambient air cooler and then to a second absorber-separator for further absorption of vapor into said liquid and further separation of air and vapor from said absorbed liquid, means directing liquid from said saturator to at least one of said absorber-separators and then to a flash separator for separating out gases entrained therein, and means for returning gases from the flash separator to said saturator and for disposing of the liquid in said flash separator.

23. The system of claim 22 together with means for directing liquid from said second absorber-separator to the first absorber-separator and then to said flash separator.

24. The system of claim 22 together with means for also delivering liquid from said storage tank directly to said second absorber-separator for absorbing vapor therein.

25. The system of claim 22 together with means for returning the liquid from the flash separator to the storage tank.

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