

DESCRIPTION

METHOD AND DEVICE FOR RECOVERING HYDROCARBON VAPOR

5

Technical Field

The present invention relates to a method and device for recovering hydrocarbon vapor contained in a gas such as air discharged from storage facilities when the storage facilities such as storage tank is filled with liquid hydrocarbon such as gasoline or on account of expansion of the liquid hydrocarbon in accordance with temperature.

10

Background Art

In filling a barge, lorry, and a storage tank with liquid hydrocarbon such as gasoline, kerosene and light oil, a gas containing hydrocarbon vapor (vapor generated by volatilization of a part of the components of the liquid hydrocarbon) is discharged from the container since the gas phase and the liquid phase are displaced inside the container or the gas such as air is expanded in accordance with the temperature change. The concentration of the hydrocarbon vapor in the exhaust gas reaches 30% during summer.

20

Recently, the discharge of the hydrocarbon vapor has come to be restricted. For instance, according to restriction in Pollution Prevention Ordinance of Japanese prefectures, the concentration is defined as 5 to 8% and the removal rate is defined as 80-90%. Further strict restriction is defined for toxic air pollutant.

25

Conventionally, in order to recover hydrocarbon vapor within the exhaust gas from the storage tank, following methods have been proposed.

(1) After adsorbing the hydrocarbon vapor using a removal equipment filled with activated carbon, the adsorbed hydrocarbon is desorbed by heated steam;

30

(2) After adsorbing the hydrocarbon vapor using a removal equipment filled with silica gel or zeolite, the adsorbed hydrocarbon is desorbed by decompression; and

(3) Membrane separation method.

35

On the other hand, in order to improve the recovering efficiency of the above conventional recovering methods of hydrocarbon, following invention has been proposed (Japanese Patent Laid-Open Publication No.

Hei 10-156127).

In the invention, after the exhaust gas containing high-concentration benzene is brought into contact with pre-cooled heavy oil or benzene to partially remove the benzene vapor in a scrubber, the benzene vapor is adsorbed and removed by an adsorber filled with adsorbent. In order to desorb the benzene from the adsorbent, the adsorber is decompressed by a vacuum pump etc. while being heated by a heated coil with the steam flowing thereinside. The desorbed benzene is returned to the scrubber, thereby being condensed and recovered.

According to the above invention, since the benzene vapor is adsorbed after partially recovering the benzene vapor, the benzene can be removed nearly completely, and the desorbed benzene can be easily post-processed.

However, though the adsorber is heated by the heated coil having steam flowing thereinside in desorbing the benzene from the adsorbent, such indirect heating method is inefficient. Further, since the adsorbent such as silica gel is low in thermal conductivity and respective particles are in point-contact, thermal transfer of the adsorbent filled layer becomes extremely low.

Further, since adsorption and desorption are switched approximately in several minutes in an ordinary pressure and temperature swing adsorption (PTSA), the distance capable of increasing the temperature is limited to several centimeters around the surface of the heating coil within the time period. Accordingly, many heating coil has to be provided, so that excess space is required in the adsorber and temperature of the adsorbent layer becomes uneven, thus increasing loss of heating steam.

Disclosure of the Invention

An object of the present invention is to provide a recovering method and device of a hydrocarbon capable of efficiently recovering the hydrocarbon vapor from a gas containing hydrocarbon vapor.

A method for recovering hydrocarbon vapor according to an aspect of the present invention includes the steps of: first step for cooling and condensing a gas containing the hydrocarbon vapor by a cooling means to remove a part of the hydrocarbon vapor; second step for, by a heating means, heating the gas after removing a part of the hydrocarbon vapor to raise temperature thereof; and third step for feeding the gas with raised

temperature to an adsorbing means filled with an adsorbent to adsorb and remove the hydrocarbon vapor.

The temperature of the gas after being processed by the first step preferably exceeds freezing point of contained components and is preferably set low around the freezing point.

The temperature may preferably be as low as possible for increasing condensation amount to decrease the concentration of the hydrocarbon vapor in the gas and reduce the load applied to post-process, so that the size of an adsorber as the adsorbing means can be reduced. For instance, when the benzene is main component of the hydrocarbon vapor, since the freezing point of benzene is 5.5°C, the temperature is preferably 6 to 20°C, more preferably 6 to 10°C.

The above first step efficiently removes, for instance, high boiling impurity generated by coal cracking such as toluene, xylene, trimethylbenzene, coumarone and indene contained in crude or light oil having benzene as the main component, especially naphthalene as a sublimation solid, by decreasing vapor pressure caused by being cooled and being solved into benzene.

The temperature of the gas after being heated in the second step is preferably 5 to 30°C higher than the temperature after being processed in the first step. More preferably the temperature is 10 to 20°C higher.

The temperature is set as the above because immediate condensation or solid precipitation are resulted when the temperature is further lowered at an intermediate piping or adsorber or by heat radiation in winter since the hydrocarbon vapor has reached saturation at the cooled temperature. Such phenomenon results in choking of piping, malfunction of switching valve, and increase in pressure loss of adsorber.

On the contrary, the temperature of the gas after the first step can be increased by the second step, so that saturation ratio of the hydrocarbon vapor can be reduced in order to prevent condensation in the piping etc. The temperature of the downstream adsorbing device can be raised, thus facilitating desorption and recovery after adsorption. Further, since the concentration of the hydrocarbon vapor is lowered, the load during the subsequent third step can be reduced, thus reducing the size of the adsorber and the vacuum pump.

On the other hand, the temperature of the adsorbent in the adsorber is raised by adsorbing the hydrocarbon vapor and is lowered by desorption

thereof. When the adsorbed amount is several percent, the temperature fluctuates within several degrees range. Accordingly, if the gas containing saturated hydrocarbon vapor of is introduced when the temperature of the adsorbent is lowered immediately after completion of process for desorbing the hydrocarbon vapor from the adsorbent without heating and temperature-raising operation of the second step, the hydrocarbon can be condensed or solid content can be precipitated at the inlet of the adsorbers. On the contrary, when the temperature of the introduced gas is too high, adsorbable capacity can be decreased, thus deteriorating adsorption efficiency.

The adsorbent filled in the adsorbing means in the third step may be general adsorbent such as silica gel, zeolite, alumina gel and activated carbon. Silica gel, zeolite and alumina gel may preferably be used in view of safety.

More preferably, the adsorbent may be silica gel processed by high-temperature baking or with hydrophobic agent or high silica zeolite with silica/alumina ratio of 80 or more. This is because hydrophobic adsorbent that hardly adsorbs water but adsorbs hydrocarbon is preferable since separating water from the recovered oil is necessary once the adsorbent adsorbs water in the gas.

The adsorbing means is an adsorber, for instance.

The hydrocarbon vapor is adsorbed and removed by the adsorbent in the third step, so that clean gas can be discharged.

Incidentally, the adsorbent in which the hydrocarbon etc. is adsorbed is recovered by desorbing the hydrocarbon etc. by decompression. Vacuum degree in desorbing process is preferably 60Torr or less in absolute pressure. More preferably 25Torr or less in absolute pressure. With low absolute pressure, the hydrocarbon vapor can be easily desorbed. When desorption of the hydrocarbon etc. is insufficient, the hydrocarbon vapor is difficult to be adsorbed in the subsequent adsorbing process, thus deteriorating removal efficiency of the hydrocarbon vapor.

On the other hand, the concentration of the hydrocarbon vapor desorbed from the adsorbent is extremely high, which can be easily condensed by cooling and is recovered as liquid. The cooling may be conducted using general heat exchanger (tube-type, plate-type etc.). The residual low-concentration hydrocarbon vapor without being condensed is mixed with the material gas at the inlet of the device to be processed without being discharged to the outside of the device.

As an alternative recovering method of the hydrocarbon vapor, the hydrocarbon vapor may be recovered by being brought into contact with cooled light oil, kerosene, gasoline and recovered oil, where the hydrocarbon vapor is cooled and condensed or resolved therein. The residual
5 low-concentration hydrocarbon vapor without being condensed or resolved may be mixed in the material gas at the inlet of the device as in the above.

Further, the desorbed hydrocarbon vapor may be recovered by being cooled and condensed after being mixed with the gas in the first step containing the hydrocarbon vapor.

10 The gas from which the hydrocarbon vapor is to be recovered may be inactive gas such as nitrogen as well as ordinary air, so that the present invention can be applied for various gases discharged from production and storage facilities of liquid hydrocarbon as a source of the hydrocarbon vapor.

In the recovering method of the present invention, the condensed
15 liquid hydrocarbon may preferably be used in the first step, the cooled liquid hydrocarbon being brought into contact with the gas containing the hydrocarbon vapor for cooling and condensing the hydrocarbon vapor in the gas.

Since the condensed liquid hydrocarbon is used, efficient recovery is
20 possible.

In the recovering method of the present invention, a thermal medium for heating the gas after removing a part of the hydrocarbon vapor in the second step may preferably be warm water.

Steam as the thermal medium is not suitable, because insufficient
25 heating or abnormal rise in temperature can be resulted in changing the flow rate of the process gas on account of large temperature difference against the process gas. On the other hand, when warm water is used as the thermal medium, such problem is not caused. Incidentally, there is no problem in using warm water prepared by heating water by steam through a heat
30 exchanger.

In the recovering method of the present invention, in the third step, after the gas with raised temperature in the second step is supplied to the adsorber to adsorb the hydrocarbon vapor with the adsorbent, the inside of the adsorber may preferably be decompressed while reversely flowing a
35 clean gas into the adsorber, whereby the hydrocarbon is desorbed from the adsorbent.

Accordingly, since partial pressure of the hydrocarbon vapor is

lowered by reversing the clean gas from the outlet side of the adsorber toward inside thereof in desorbing the hydrocarbon from the adsorbent, the hydrocarbon etc. can be more easily desorbed from the adsorbent.

At this time, the hydrocarbon is more likely to be desorbed as with
5 the flow rate of the clean gas. However, when the flow rate is simply increased, the concentration of the hydrocarbon vapor in the desorbed gas is decreased, so that the hydrocarbon vapor is difficult to be recovered by the subsequent cooling and condensation. Therefore, an optimum value should be set for the flow rate of the clean gas, which is preferably one fifth to one
10 fiftieth of the flow rate of the process gas introduced into the adsorber in adsorbing process, more preferably, one tenth to one twentieth.

In the recovering method of the present invention, a plurality of adsorbers may preferably be used in the third step, the adsorbers continuously processing while being alternately switched between an
15 adsorbing process and a desorbing process.

The adsorbers may preferably be switched within an hour, more preferably in ten minutes. In order to decrease temperature change of the adsorbent layer by reducing the change in adsorption amount of the hydrocarbon, short time switching is preferable.

20 In general, the adsorption heat is exothermic reaction. When the temperature is raised, adsorption becomes difficult to occur (desorption is enhanced), on the other hand, when the temperature is lowered, adsorption is enhanced (desorption becomes difficult to occur). Accordingly, the adsorption of the hydrocarbon vapor results in increase in the temperature of
25 the adsorbent, thus making further adsorption of the hydrocarbon vapor difficult. On the other hand, in the desorbing process, the temperature is lowered when the hydrocarbon vapor is desorbed, so that further desorption of the hydrocarbon vapor becomes difficult. In other words, the adsorbing and desorbing process accompanies phenomenon for canceling the effect of
30 the process itself. In order to reduce the above effect, switching time between the adsorbing process and desorbing process is preferably shortened.

In the recovering method of the present invention, the hydrocarbon desorbed from the adsorbent in the third step may preferably be mixed with
35 the gas containing the hydrocarbon vapor in the first step to be cooled and condensed before being recovered.

Since the desorbed hydrocarbon is extremely dense and easily

condensable, the hydrocarbon can be easily condensed and recovered by being mixed and processed with the gas in the first step. The above method is economically preferable in that it requires only one cooling and condensing/recovering device.

5 A device for recovering a hydrocarbon vapor according to another aspect of the present invention includes: a cooling means for cooling and condensing to remove a gas containing the hydrocarbon vapor so that a part of the hydrocarbon vapor; a heating means for heating the gas after removing a part of the hydrocarbon vapor to raise temperature thereof; and an
10 adsorbing means filled with an adsorbent for adsorbing and removing the hydrocarbon vapor in the gas with raised temperature.

The cooling means may be selected from the following two arrangements according to concentration of the hydrocarbon vapor and allowable pressure loss.

15 When the allowable pressure loss is high, a combination of an ordinary heat exchanger (tube-type, plate-type etc.) and a liquid separator is suitable.

When the allowable pressure loss is low, a scrubber installed with a heat exchanger or a scrubber having external heat exchanger is suitable.

20 The scrubber has a gas-liquid contact zone on the upper side and an accumulator on the lower side thereof, where the liquid on the lower side is drawn out by a pump to be introduced to the upper side to be circulated.

The gas-liquid contact zone is filled with filler such as Raschig ring, which can efficiently bring the gas and the liquid into contact with each
25 other.

The level of the liquid at the accumulator is controlled by a balance between drawn-out amount by the pump and the circulation amount.

A demister is preferably provided to a gas outlet of the scrubber for preventing entrainment.

30 The heating means may be an ordinary heat exchanger such as tube-type and plate-type.

In the recovering device of the present invention, a chiller unit common to a supply source of cooling thermal medium to be supplied to the cooler and a supply source of heating thermal medium to be supplied to the
35 heater may preferably be provided.

With the common chiller unit, the cooling thermal medium and heating thermal medium can be respectively supplied with the single unit,

thus being economical and advantageous with respect to space.

The cooling means and the heating means may alternatively be a freezer or a heater.

5 In the recovering device of the present invention, a plurality of the adsorbing means may preferably be provided for continuous processing by alternately switching an adsorbing process and a desorbing process.

Though the adsorbing means such as an adsorber may be single, a plurality of adsorbers may preferably be provided for continuously conducting adsorbing process while switching adsorbing and desorbing
10 process.

Brief Description of Drawings

Fig. 1 is a general illustration of recovering device of hydrocarbon vapor according to first embodiment of the present invention;

15 Fig. 2 is a general illustration of recovering device of hydrocarbon vapor according to second embodiment of the present invention;

Fig. 3 is general illustration of recovering device of hydrocarbon vapor according to comparative example;

20 Fig. 4 is general illustration of recovering device of hydrocarbon vapor according to another embodiment of the present invention;

Fig. 5 is general illustration of recovering device of hydrocarbon vapor according to still another embodiment of the present invention; and

Fig. 6 is general illustration of recovering device of hydrocarbon vapor according to further embodiment of the present invention.

25

Best mode for Carrying out the Invention

[First Embodiment]

30 A recovering method and device of hydrocarbon vapor according to first embodiment of the present invention will be described below with reference to Fig. 1.

A hydrocarbon vapor recovering device according to the present embodiment has a first heat exchanger 11 connected to an introduction line 10 of a gas (air) including hydrocarbon vapor, a liquid separator 13 connected to the heat exchanger 11 through a gas feeding line 10A, a second
35 heat exchanger 14 connected to the liquid separator 13 through a gas feeding line 12, first and second adsorbers 15 and 16 connected to the second heat exchanger 14 through a gas feeding line 12A having branched downstream

ends, and a vacuum pump 20 connected through a gas feeding line 33A branched from the gas feeding line 12A adjacent to the adsorbers 15 and 16.

A freezer 17 is annexed to the (tube-type or plate-type) first heat exchanger 11.

5 The liquid separator 13 has an accumulator 19 on a downside thereof. A wire-mesh-type demister (not shown) is provided at a gas outlet of the liquid separator 13.

A heater 21 is annexed to the (tube-type or plate-type) second heat exchanger 14. Heating medium of the heat exchanger 14 is warm water.

10 The first and the second adsorbers 15 and 16 have adsorbing bed 22 filled with adsorbent.

First and second valves 23 and 24 are provided to respective gas feeding lines 12 from the second heat exchanger 14 to the first and the second adsorbers 15 and 16.

15 Third and fourth valves 25 and 26 are provided to the gas feeding line 33A branched from the gas feeding line 12A.

Clean gas discharge line 31 is connected to respective heads of the first and the second adsorbers 15 and 16, the respective lines 31 being provided with fifth and sixth valves 27 and 28.

20 Clean gas feeding line 32 for reversing a clean gas (clean air) is connected to the line 31 between the fifth and the sixth valves 27 and 28 and the heads of the adsorbers 15 and 16, the line 32 having seventh and eighth valves 29 and 30.

A return line 33 for returning the desorbed hydrocarbon vapor is provided between the vacuum pump 20 and the introduction line 10 on the upstream of the first heat exchanger 11.

The hydrocarbon vapor is recovered using the recovering device as follows.

Initially, as the first step, the air containing the hydrocarbon vapor is introduced to the first heat exchanger 11 from the introduction line 10, where the air is cooled to condense the hydrocarbon vapor. The cooled and condensed hydrocarbon and the air are supplied to the liquid separator 13 for liquid separation. The condensed part of hydrocarbon vapor is accumulated and recovered in the accumulator 19. On the other hand, the air containing residual hydrocarbon vapor is supplied from an outlet to the second heat exchanger 14.

Next, as the second step, warm water is used as a heating medium to

heat the air after a part of the hydrocarbon vapor being removed to increase temperature thereof.

Subsequently, as the third step, the temperature-raised air is supplied to the first adsorber 15 or the second adsorber 16, where the hydrocarbon vapor is adsorbed and removed by the adsorbent.

Adsorbing process and desorbing process are alternately switched by switching the valves 23, 24, 27 and 28 in the first and the second adsorbers 15 and 16, thereby continuously processing the hydrocarbon vapor.

During desorbing process, the inside of the adsorbers 15 and 16 are decompressed by the vacuum pump 20 to reverse the clean air from the clean air feeding line 32, so that the hydrocarbon is desorbed from the adsorbent.

The desorbed hydrocarbon returns to the inlet side of the heat exchanger 11 and is mixed with the air containing the hydrocarbon vapor, which is cooled and condensed to be recovered by repeating the aforesaid first and subsequent steps.

[Second Embodiment]

A recovering method and device of hydrocarbon vapor according to second embodiment of the present invention will be described below with reference to Fig. 2.

The hydrocarbon vapor recovering device according to the present embodiment has a scrubber 36 connected to an introduction line 10 of a gas (air) containing the hydrocarbon vapor, a first heat exchanger 11 provided in between lower portion and upper portion of the scrubber 36 through a liquid hydrocarbon circulation line 39, a second heat exchanger 14 connected to the scrubber 36 through a gas feeding line 12, first and second adsorbers 15 and 16 connected to the second heat exchanger 14 through a gas feeding line 12A with branched downstream end, and a vacuum pump 20 connected through a gas feeding line 33A branched from the gas feeding line 12A around the adsorbers 15, 16.

The scrubber 36 has a gas-liquid contact zone 37 on an upper portion thereof and an accumulator 38 on a lower portion thereof. The gas-liquid contact zone 37 is filled with filler such as Raschig ring. A wire-mesh type demister (not shown) is provided on a gas outlet of the scrubber 36.

The liquid hydrocarbon circulation line 39 has one end connected to the accumulator 38 side of the scrubber 36 and the other end inserted to an upper side of the gas-liquid contact zone 37 inside the scrubber 36, the other

end having a liquid hydrocarbon spreader 41. A circulation pump 42 is provided on the circulation line 39 between the accumulator 38 and the first heat exchanger 11.

5 The other components of the device such as the first heat exchanger 11, the second heat exchanger 14, the first and the second adsorbers 15 and 16, the vacuum pump 20 are the same as the aforesaid first embodiment.

The process for recovering the hydrocarbon vapor using the recovering device is as follows.

10 Initially, as the first step, the air containing hydrocarbon vapor is supplied from the introduction line 10 to the scrubber 36 so that the air is cooled to condense the hydrocarbon vapor, thus generated liquid being accumulated in the accumulator 38. In cooling and condensing the air, the liquid hydrocarbon of the accumulator 38 is partially circulated through the
15 circulation line 39, which is cooled by the first heat exchanger 11 to be supplied to the inside of the scrubber 36, so that the liquid hydrocarbon and the air are brought into contact at the gas-liquid contact zone 37.

Subsequent second and the third steps are the same as the aforesaid first embodiment.

20 Incidentally, though the freezer 17 is annexed to the first heat exchanger 11 and the heater 21 is annexed to the second heat exchanger 14, a common chiller unit may be provided as a supply source of a cooling medium to the first heat exchanger 11 and a supply source of a heating medium to the second heat exchanger.

25 Alternatively, the scrubber may be arranged as follows.

As shown in Fig. 4, the scrubber 36 is provided with a gas-liquid dispersion device 37A such as chimney tray and perforated tray between the gas-liquid contact zone 37 and an introduction port of the circulation line 39. A demister 37B is disposed to an upper portion relative to the introduction
30 port of the circulation line 39. An extraction line 42A extending from a side of the scrubber 36 to the circulation pump 42 is connected to the accumulator 38, the extraction line 42A having intake end facing downwardly and a vortex breaker 42B provided therearound, the vortex breaker 42B being composed of a radially disposed plurality of plate
35 members.

The gas-liquid dispersion device 37B enables further contact between the liquid component returned from the circulation line 39 and the gas

component rising through the gas-liquid contact zone 37, thus enhancing recovery of the liquid component. Since the demister 37B is disposed, mist liquid component can be removed from the gas going out to the tower-head gas feeding line 12. Further, since the vortex breaker 42B is disposed, the swirl and gas swallowing in sucking out the liquid accumulated in the accumulator 38 from the extraction line 42A can be prevented.

Specific design of the gas-liquid dispersion device 37A, the demister 37B and the vortex breaker 42B may be arranged in any manner used in known plant technique.

As shown in Fig. 5, approximate U-shaped scrubber 36A may be used. In the figure, an introduction line 10 is connected to the head of one of the approximate U-shaped scrubber 36A (shown in the left side) and a circulation line 39 is connected to a slightly lower portion relative to the head. A gas-liquid dispersion device 37A is disposed to a slightly lower portion relative to the connecting portion of the circulation line 39, and a gas-liquid contact zone 37 is disposed thereunder. A gas feeding line 12 is connected to the head of the other scrubber (shown in right side), and a demister 37B is disposed thereunder. The arrangement of the scrubber 36A is the same as shown in the above-described Fig. 4 except for wider bottom.

Such approximate U-shaped scrubber 36A can also separate the hydrocarbon vapor contained in the gas from the introduction line 10 and the circulation line 39, thereby drawing out the hydrocarbon-vapor-desorbed gas from the gas feeding line 12 to be accumulated in the accumulator 38.

Though the above-described respective embodiments process the gas containing hydrocarbon vapor from a single introduction line 10, the gas containing hydrocarbon vapor from a plurality of gas source may be processed. In this arrangement, a structure for avoiding complex pollution (contamination) caused by backflow between the respective gas sources may preferably added.

In Fig. 6, two-systems of introduction lines 10L and 10H are connected to the scrubber 36A. The introduction line 10L is connected to the head in the same manner as the introduction line 10 of Fig. 5. The introduction line 10H is connected between the gas-liquid connecting portion 37 and the gas-liquid dispersion device 37A of the scrubber 36A.

The gas source supplied to the introduction line 10H has more dense or pure accumulated liquid than the gas source supplied to the introduction line 10L. For instance, the introduction line 10L is connected to an exhaust

port of crude benzene tank, and the introduction line 10H is connected to an exhaust port of pure benzene tank.

In this case, if the introduction line 10H is simply connected to the scrubber 36A, since the low-purity benzene component is introduced into the scrubber 36A, the low-purity benzene component can be reversed to the pure benzene tank through the introduction line 10H, thus lowering the benzene purity inside the tank.

Accordingly, a seal pot 10P is disposed to the introducing portion of the introduction line 10H, where the contents liquid (pure benzene here) of the gas source connected through the introduction line 10H is accumulated therein. And an end of the introduction line 10H is dipped in the liquid inside the seal pot 10P.

Accordingly, the backflow from the introduction line 10H can be prevented.

Incidentally, the plurality of gas source may not be of the same type, but may be of different type such as gasoline and benzene as long as the substance to be recovered is overlapped.

Specific experiments conducted according to the above-described respective embodiments will be described below.

[Experiment 1]

In the first embodiment, following specific method and device were used.

Flow rate of the air containing the high-concentration hydrocarbon vapor to be processed (referred to as material gas hereinafter) was 10m^3 , and the concentration of the hydrocarbon vapor was 20vol%. The components of the hydrocarbon vapor in the air were as in the following Table 1.

(Table 1)

Type of hydrocarbon	Pentane	Benzene	Toluene	Xylene	Trimethylbenzene	Indene	Naphthalene
Concentration (vol%)	2.5	15.0	1.5	0.5	0.2	0.1	0.2

Initially, after the material gas and the desorbed gas from the outlet of the vacuum pump 20 was joined and was cooled by the tube-type first heat exchanger 11 to be partially condensed, which was introduced to lateral type liquid separator 13 to separate gas phase and liquid phase.

The temperature of the gas after being cooled by the first heat exchanger 11 was 10°C . The recovered liquid hydrocarbon amounted to

3.9kg/hr.

Subsequently, the gas discharged from the liquid separator 13 was introduced to the tube-type second heat exchanger 14 to be heated for increasing temperature thereof. The temperature of the gas after being
5 heated by the heat exchanger 14 was 30°C.

Next, the temperature-increased gas was supplied to one of the two adsorbers 15 to adsorb and remove the hydrocarbon vapor by the adsorbent. The used adsorbent was silica gel [silica gel CARiACT Q-3 (tradename) manufactured by Fuji Silysia Chemical Ltd.] after being hydrophobically
10 treated by baking for four hours at 500°C. The inlet and outlet valves 23, 24, 27 and 28 of the two adsorbers 15 and 16 were switched at every five minutes to alternately conduct adsorption and desorption.

The concentration of the hydrocarbon vapor in the gas at the outlet of the adsorbers 15 and 16 was 30ppm. The components of the hydrocarbon
15 vapor were as shown in following Table 2.

(Table 2)

Type of hydrocarbon	Pentane	Benzene	Toluene	Xylene	Trimethylbenzene	Indene	Naphthalene
Concentration (vol%)	0.002	0.001	0	0	0	0	0

The desorbing process of the hydrocarbon from the adsorbent in the adsorbers 15 and 16 was conducted by decompressing the inside of the adsorbers 15 and 16 by the vacuum pump 20. The desorption pressure at
20 the time was 25Torr according to absolute pressure. The desorption was conducted while the clean air was reversed from the outlet of the adsorbers 15 and 16 toward the inside thereof through the clean air feeding line 32 at a flow rate of 1m³/hr.

The desorbed gas from the outlet of the vacuum pump 20 was joined
25 with the material gas of the introduction line 10, which was cooled and condensed by the first heat exchanger 11 to be recovered.

The temperature of the adsorbent in adsorbing process and desorption process was measured by a thermocouple inserted in the adsorbers 15 and 16, which was maximum of 35°C in adsorption and minimum of 25°C in
30 desorption.

During the operation, the pressure loss of the adsorbers 15 and 16 was substantially the same at 20mmH₂O. Though the adsorbers 15 and 16 and piping were opened to check after terminating the operation, there was

no abnormality such as condensation of the hydrocarbon vapor.

[Experiment 2]

In the second embodiment, following specific method and device were used.

5 The air containing the high-concentration hydrocarbon vapor to be processed was the same as the Experiment 1.

Initially, the material gas and the desorbed gas from the outlet of the vacuum pump 20 were joined and introduced to the lateral-type scrubber 36. After the liquid of the accumulator 19 of the scrubber 36 was drawn out by
10 the pump 42 and was cooled by the tube-type first heat exchanger 11, the liquid was introduced to the upper portion of the scrubber 36 to contact with the material gas, thereby condensing the hydrocarbon vapor in the material gas. The temperature of the gas after being cooled by the heat exchanger 11 was 10°C.

15 The gas phase and liquid phase after gas-and-liquid contact were desorbed, whereby the gas was drawn out from the upper portion of the scrubber 36 and the liquid was recovered in the accumulator 38 at the lower portion. The recovered liquid hydrocarbon vapor amounted to 3.9kg/hr.

Subsequently, the gas drawn out from the scrubber 36 was introduced
20 to the plate-type second heat exchanger 14 to heat and increase temperature thereof. The temperature of the gas after being heated by the second heat exchanger 14 was 25°C.

Next, the temperature-raised gas was supplied to one of the adsorbers 15, where the hydrocarbon vapor was adsorbed and removed by the
25 adsorbent. The used adsorbent was silica gel [silica gel CARiACT Q-3 (tradename) manufactured by Fuji Silysia Chemical Ltd.] after being hydrophobically treated by baking for four hours at 500°C. The inlet and outlet valves 23, 24, 27 and 28 of the two adsorbers 15 and 16 were switched at every five minutes to alternately conduct adsorption and desorption.

30 The concentration of the hydrocarbon vapor in the gas at the outlet of the adsorbers 15 and 16 was 30ppm. The components of the hydrocarbon vapor were as shown in following Table 3.

(Table 3)

Type of hydrocarbon	Pentane	Benzene	Toluene	Xylene	Trimethyl-benzene	Indene	Naphthalene
Concentration (vol%)	0.002	0.001	0	0	0	0	0

The desorbing process of the hydrocarbon from the adsorbent in the adsorbers 15 and 16 was conducted by decompressing the inside of the adsorbers 15 and 16 by the vacuum pump 20. The desorption pressure at the time was 20Torr according to absolute pressure. The desorption was
5 conducted while the clean air was reversed from the outlet of the adsorbers 15 and 16 toward the inside thereof through the clean air feeding line 32 at a flow rate of $0.5\text{m}^3/\text{hr}$.

The desorbed gas from the outlet of the vacuum pump 20 was joined with the material gas of the introduction line 10, which was cooled and
10 condensed by the scrubber 36 to be recovered.

The temperature of the adsorbent in adsorption and desorption was measured by a thermocouple inserted in the adsorbers 15 and 16, which was maximum of 30°C in adsorption and minimum of 20°C in desorption.

During the operation, the pressure loss of the adsorbers 15 and 16
15 was substantially the same at 20mmHg . Though the adsorbers 15 and 16 and piping were opened to check after terminating the operation, there was no abnormality such as condensation of the hydrocarbon vapor.

[Comparison 1]

As shown in Fig. 3, the device according to the present comparison
20 was the device of the second embodiment except that the second heat exchanger 14 was not provided and a heater 46 having a heating coil 45 with steam flowing therein was provided to the adsorbers 15 and 16.

The air containing the high-concentration hydrocarbon vapor was the same as the Experiment 1.

25 Initially, the material gas and the desorbed gas from the outlet of the vacuum pump 20 were joined to be introduced into the lateral-type scrubber 36. After the liquid of the accumulator 38 of the scrubber 36 was drawn out by the pump 42 and was cooled by the tube-type first heat exchanger 11, the liquid was introduced to the upper portion of the scrubber 36 to bring into
30 contact with the material gas to condense the hydrocarbon vapor in the material gas. The temperature of the gas after being cooled by the heat exchanger 11 was 10°C .

The gas phase and liquid phase after gas-and-liquid contact were separated, whereby the gas was drawn out from the upper portion of the scrubber 36 and the liquid was recovered in the accumulator 38 at the lower
35 portion. The recovered liquid hydrocarbon vapor amounted to $3.9\text{kg}/\text{hr}$.

Subsequently, the gas drawn out from the scrubber 36 was introduced

to the other adsorber 15, where the hydrocarbon vapor was adsorbed and removed by adsorbent. The used adsorbent was silica gel [silica gel CARiACT Q-3 (tradename) manufactured by Fuji Silysia Chemical Ltd.] after being hydrophobically treated by baking for four hours at 500°C. The inlet and outlet valves 23, 24, 27 and 28 of the two adsorbers 15 and 16 were switched at every five minutes to alternately conduct adsorption and desorption.

The concentration of the hydrocarbon vapor in the gas at the outlet of the adsorbers 15 and 16 was 100 to 200ppm, which tended to gradually increase. The components of the hydrocarbon vapor after a week were as shown in following Table 4.

(Table 4)

Type of hydrocarbon	Pentane	Benzene	Toluene	Xylene	Trimethylbenzene	Indene	Naphthalene
Concentration (vol%)	0.12	0.06	0.02	0	0	0	0

The desorbing process of the hydrocarbon from the adsorbent in the adsorbers 15 and 16 was conducted by decompressing the inside of the adsorbers 15 and 16 by the vacuum pump 20. The desorption pressure at the time was 20Torr according to absolute pressure. The desorption was conducted while the clean air was reversed from the outlet of the adsorbers 15 and 16 at a flow rate of 0.3m³/hr.

The desorbed gas from the outlet of the vacuum pump 20 was joined with the material gas at the inlet of the device, which was cooled and condensed by the scrubber 36 to be recovered.

The temperature of the adsorbent in adsorption and desorption was measured by a thermocouple inserted in the adsorbers 15 and 16, which was maximum 15°C in adsorption, and minimum of 10°C and maximum of 40°C in desorption, which was greatly dispersed within the adsorbers 15 and 16.

During one-week operation, the pressure loss of the adsorbers 15 and 16 was 20 to 30mmH₂O, which was gradually increased. The adsorbers 15 and 16 and piping were opened to check after terminating the operation to find condensation of the hydrocarbon vapor on the lower part of the adsorbers 15 and 16 and around the valve at the intermediary of the piping.

Industrial Availability

The present invention can be suitably used for preventing dispersion

and recycling of the hydrocarbon vapor discharged from a storage tank etc. of storage facility or refining facility of liquid hydrocarbon such as gasoline and for recovering and recycling thereof.

Claims

1. A method for recovering hydrocarbon vapor, comprising the steps of:
first step for cooling and condensing a gas containing the
5 hydrocarbon vapor by a cooler to remove a part of the hydrocarbon vapor;
second step for, by a heater, heating the gas after removing a part of
the hydrocarbon vapor to raise temperature thereof; and
third step for feeding the gas with raised temperature to an adsorber
filled with an adsorbent to adsorb and remove the hydrocarbon vapor.
10
2. The method for recovering the hydrocarbon vapor according to claim
1, wherein the condensed liquid hydrocarbon is used in the first step, the
cooled liquid hydrocarbon being brought into contact with the gas containing
the hydrocarbon vapor for cooling and condensing the hydrocarbon vapor in
15 the gas.
3. The method for recovering the hydrocarbon vapor according to claim
1, wherein a heating medium for heating the gas after removing a part of the
hydrocarbon vapor in the second step is warm water.
20
4. The method for recovering the hydrocarbon vapor according to claim
1, wherein, in the third step, after the gas with raised temperature in the
second step is supplied to the adsorber to adsorb the hydrocarbon vapor with
the adsorbent, the inside of the adsorber is vacuumized to reverse a clean gas
25 into the adsorber, whereby the hydrocarbon is desorbed from the adsorbent.
5. The method for recovering the hydrocarbon vapor according to claim
4, wherein a plurality of adsorbers are used in the third step, the adsorbers
continuously processing while being alternately switched between an
30 adsorbing process and a desorbing process.
6. The method for recovering the hydrocarbon vapor according to claim
4, wherein the hydrocarbon desorbed from the adsorbent in the third step is
mixed with the gas containing the hydrocarbon vapor in the first step to be
35 cooled and condensed before being recovered.
7. A device for recovering a hydrocarbon vapor, comprising:



a cooler for cooling and condensing to remove a gas containing the hydrocarbon vapor so that a part of the hydrocarbon vapor;

a heater for heating the gas after removing a part of the hydrocarbon vapor to raise temperature thereof; and

5 an adsorber filled with an adsorbent for adsorbing the hydrocarbon vapor in the gas with raised temperature.

8. The device for recovering a hydrocarbon vapor according to claim 7, further comprising a chiller unit common to a supply source of thermal
10 medium to be supplied to the cooler and a supply source of thermal medium to be supplied to the heater.

9. The device for recovering a hydrocarbon vapor according to claim 7, wherein a plurality of the adsorbers are provided for continuous processing
15 by alternately switching an adsorbing process and a desorbing process.

