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**"CONDENSING A VAPOUR FROM A STREAM OF AIR"**

THE PRESENT INVENTION relates to a condenser and a method for condensing a vapour from a stream of air.

It is envisaged that a condenser and a method embodying the present invention will find particular application in condensing volatile organic compounds from a stream of air in order to recover such compounds and/or to control their emission into the atmosphere, for example, from storage tanks and during drumming and distillation operations.

The amount of volatile organic compounds that are inadvertently emitted into the atmosphere is thought to be over 200 million tonnes per year, on a global basis. Many of these compounds are toxic, and it is not desirable for the compounds to be emitted into the environment. Examples of volatile organic compounds that may be inadvertently emitted are petroleum and petro-chemical products such as benzene, chloroform, ethyl benzene, styrene, toluene, xylene, methyl chloride, formaldehyde, pyridine, acetone and iso-propyl alcohol. Many states, throughout the world, have set up regulations or standards relating to the emission of volatile organic compounds.

Known condensers for condensing volatile organic compounds are arranged to operate permanently at a temperature above 0°C, since otherwise ice may form on the surface of the condenser and thereby reduce the heat transfer and the condensation efficiency. The efficiency with which such condensers remove volatile organic compounds from air containing such compounds is accordingly quite low.

The present invention seeks to provide a condenser and method which enables volatile organic compounds to be condensed out of a stream of air more efficiently than is possible using conventional condensers.

Accordingly, in one aspect, the present invention provides a condenser for condensing a vapour from a stream of air containing said vapour, the condenser

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comprising a housing, an air inlet pipe for introducing a stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, and coolant supply means for supplying coolant to the condenser arrangement through a coolant supply pipe and for removing coolant from the condenser arrangement through a coolant outlet pipe, in which condenser a sensor is provided to sense the temperature of the air at the outlet of the condenser arrangement and the coolant supply means is responsive to signals from the sensor to adjust the flow rate and/or temperature of the coolant supplied to the condenser arrangement to maintain the sensed temperature just above the freezing point of the condensate formed by the condenser arrangement.

In another aspect, the invention provides a condenser for condensing a vapour from a stream of air, the condenser comprising a housing, an air inlet pipe for introducing the stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, a coolant supply pipe for supplying coolant to the condenser arrangement, and a coolant outlet pipe for removing coolant from the condenser arrangement, the housing having a condensate outlet for discharging condensate formed in the housing by the condenser arrangement and an air outlet for directing the stream of air to the exterior of the housing, in which condenser the condenser arrangement comprises an outlet manifold connected to the coolant outlet pipe, and a plurality of coolant pipes positioned to be exposed to the stream of air through the condenser arrangement and connected in parallel between the coolant supply pipe and the outlet manifold.

Preferably, the housing is of elongate form, and the outlet manifold comprises an elongate conduit extending substantially axially of the housing, the said coolant pipes forming a plurality of substantially helical turns surrounding said manifold

Conveniently, the condenser arrangement comprises a hollow sleeve located

substantially coaxially within the housing with an inlet end of the sleeve connected to the air inlet pipe and an outlet end of the sleeve open to the interior of the housing, the sleeve receiving the manifold and the coolant pipes therein.

Advantageously, the sleeve is formed of a thermally conductive material, and the air outlet pipe is positioned adjacent the air inlet pipe, so that air flowing out of the housing flows adjacent the exterior of the sleeve before flowing to the exterior of the housing through the air outlet.

According to a further aspect of the invention, there is provided a condenser for condensing a vapour from a stream of air, the condenser comprising a housing, an air inlet pipe for introducing the stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, a coolant supply pipe for supplying coolant to the condenser arrangement, and a coolant outlet pipe for removing coolant from the condenser arrangement, the housing having a condensate outlet for discharging condensate formed in the housing by the condenser arrangement and an air outlet for directing the stream of air to the exterior of the housing, in which condenser the condenser arrangement comprises one or more coolant pipes connected between the coolant supply pipe and the coolant outlet pipe, said coolant pipes being surrounded by a sleeve which has an inlet end connected to the air inlet pipe and an outlet end open to the interior of the housing, the air outlet being located so that, in use, air flowing out of the housing flows past the exterior of the sleeve before flowing through the air outlet to the exterior of the housing.

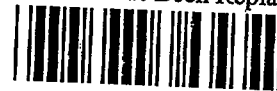
Conveniently the sleeve is made of a thermally conductive material and there is contact between one or more of said coolant pipes and said sleeve.

Advantageously said coolant pipes describe a plurality of helical turns within said sleeve.

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Preferably, the condenser arrangement comprises a plurality of said coolant pipes connected in parallel between said coolant supply pipe and said coolant outlet pipe.

Desirably, a sensor is provided to sense the temperature within the condenser.

The sensor may be a thermocouple, an electrical conductivity sensor, or any other suitable sensor.

Advantageously, the condenser is associated with a coolant re-processing unit controlled by signals from the sensor.

The invention also provides a method of condensing a volatile vapour from a stream of air containing said vapour, the method comprising the steps of introducing the stream of air containing said vapour into a housing, directing the stream of air through a condenser arrangement within the housing, supplying coolant to the condenser arrangement means to cool the stream of air and condense said vapour, discharging the cooled air and condensate from the housing, and adjusting the flow rate and/or temperature of the coolant supplied to the condenser arrangement in response to signals from a temperature sensor within the condenser to maintain the temperature sensed by the sensor just above the freezing point of the condensate.

According to yet another aspect, the invention provides a condenser for condensing a vapour from a stream of air, the condenser comprising a generally vertical housing, an air inlet pipe at the upper end of the housing for introducing a stream of air into the interior of the housing, an air outlet adjacent the upper end of the housing to direct a flow of air to the exterior of the housing, a sleeve formed from conductive material and extending substantially coaxially within the housing with an inlet end of the sleeve connected to the air inlet pipe and an outlet end of the sleeve open to the interior of the housing, and a condenser arrangement received in the sleeve, the condenser arrangement comprising a coolant outlet manifold in the form of an elongate conduit received substantially axially within the sleeve, a coolant outlet pipe connected to the manifold, and

a plurality of coolant pipes connected in parallel between a coolant supply pipe and the manifold, the coolant pipes defining a plurality of substantially helical turns around the exterior of the manifold, the condenser being such that, in use, air introduced into the housing through the air inlet flows through the sleeve past the coolant pipes, and subsequently enters the interior of the housing where it flows past the exterior of the sleeve before flowing to the exterior of the housing through the air outlet.

In order that the invention may be more readily understood, and so that further features thereof may be appreciated, the invention will now be described, by way of example, with reference to the accompanying drawings in which

FIGURE 1 is a sectional view of a condenser in accordance with the invention; and

FIGURE 2 is a block diagram illustrating a condensing system incorporating the condenser of Figure 1.

Referring initially to Figure 1, a condenser embodying the invention for condensing volatile organic compounds comprises a housing 1 of generally elongate cylindrical form, the housing being provided with support brackets 2 and 3 which may be used to support the housing 1 in a vertical position, as shown.

At the upper end of the housing 1, a pipe 4 projects vertically from the upper end of the housing 1 to constitute an inlet for a flow of air containing the vapour of a volatile organic compound which is to be condensed. The pipe 4 extends sealingly into the housing 1 and merges into an enlarged diameter vertical sleeve 5 which extends axially within the housing 1. The sleeve 5 is formed of a thermally conductive material and has an open lower end 6 disposed within the housing 1.

A condensed vapour discharge pipe 7 ascends vertically from the lowest part of the housing 1 and communicates with the interior 8 of the housing.

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The upper part of the side wall of the cylindrical housing 1 is provided with a horizontally extending outlet pipe 9 which communicates with the interior 8 of the housing, and which constitutes an outlet for a flow of air containing residual vapours of light volatile organic compounds.

Received within the sleeve 5 is a condenser tube assembly 10 which comprises a plurality of coolant pipes 11 coiled around a centrally located cylindrical conduit 12. In the illustrated embodiment of the invention, there are three coolant pipes 11 which are wound around the exterior of the conduit 12 to form a plurality of substantially helical turns 13 about the exterior of the conduit 12. The coolant pipes 11 are formed of a thermally conductive material and the outermost helical turns are in contact with the sleeve 5.

A coolant supply pipe 14 enters the lower end of the housing 1 and is connected to the lower ends of the three coolant pipes 11 via a flow distributor 15 formed at the upper end of the supply pipe 14. The upper ends of the coolant pipes 11 are connected to the upper end of the conduit 12 which constitutes an outlet manifold for the coolant pipes 11. The coolant pipes are thus connected "in parallel" between the supply pipe 14 and the manifold 12. The lower end of the conduit 12 is connected to a coolant outlet pipe 16 which emerges from the lower end of the housing 1.

A sensor 17 is provided which is located in the region of the lower end of the coolant pipes 11. In the illustrated embodiment, the sensor 17 is located on the pipe 14 near the distributor 15. The sensor 17 is adapted to sense the temperature of the air that has passed through the condenser assembly 10, and may, for example, comprise a thermocouple, an electrical conductivity sensor, or a combination of such sensors. As will become clear from the following description, the sensor is provided to detect when the cooling effect provided by the condenser, in use, reduces the temperature of the air flowing through the condenser to a temperature below the freezing point of the vapour to be condensed.

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In use of the condenser illustrated in Figure 1, a coolant is introduced to the coolant supply pipe 14, as indicated by the arrow 18. The coolant flows through the flow distributor 15 into each of the three coolant pipes 11, where it flows through the helical turns 1. The coolant then flows into the outlet manifold constituted by the conduit 12 and leaves the condenser through the coolant outlet pipe 16, as indicated by the arrow 19. This flow of coolant through the condenser thus reduces the temperature of the coolant pipes 11, the sleeve 8 and the conduit 12.

The coolant discharged from the coolant outlet 16 may then be re-cooled, using an appropriate cooling arrangement, before being re-introduced to the condenser.

Air, containing a volatile organic compound vapour to be condensed, is introduced to the condenser, through the air inlet pipe 4, as indicated by arrow 20. The air enters the sleeve 5 at its upper end and is cooled as it flows downwardly, as indicated by the arrows 21, between the adjacent turns of the coiled coolant pipes in the space between the sleeve 5 and the conduit 12, so that the volatile organic compound vapour condenses out of the air. The cooled air and condensate emerge from the open lower end 6 of the sleeve 5 into the interior 8 of the housing 1. The condensate falls, under the influence of gravity, to the bottom of the housing 1 where it is removed through the discharge pipe 7, as indicated by arrow 22. The cooled air emerging from the lower end of the sleeve 5 changes its direction of flow, as indicated by arrow 23, and flows upwardly through the space between the sleeve 5 and the housing 1, as indicated by arrows 24, cooling the sleeve 5 as it goes. Upon reaching the upper end of the housing 1, the air, which is purged of the condensate but which may still contain small amounts of light volatile organic compounds, is discharged through the air outlet pipe 9, as indicated by the arrow 25.

It is believed that use of a plurality of coolant pipes connected in parallel between the inlet pipe 14 and the outlet manifold, constituted by the conduit 11, achieves an even temperature distribution and a high heat transfer efficiency. The provision of the multitude of helical turns causes a high turbulence in the air flowing downwardly within the sleeve

8, which enhances the heat transfer. The use of the distributor 15 and the manifold, constituted by the conduit 11, to distribute and receive the flow of coolant through three coolant pipes connected in parallel acts to balance the flow rate in each pipe, and the use of a plurality of coolant pipes, in parallel, minimises the flow resistance in the coolant flow circuit.

It is also to be appreciated that the provision of the air outlet pipe 9, at a position such that the cooled air flows past the exterior of the sleeve 5 before leaving the interior of the housing 1, ensures that the incoming air is, at least to a certain extent, pre-cooled before encountering the coolant pipes 11.

Additionally it is to be appreciated that, by using the central conduit 12 as a manifold to receive the coolant from the coolant pipes 11 at a position within the sleeve 5 immediately adjacent the air inlet pipe 4 and feed it directly.

A condenser for condensing a vapour from a stream of air containing said vapour, the condenser comprising a housing, an air inlet pipe for introducing a stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, and coolant supply means for supplying coolant to the condenser arrangement through a coolant supply pipe and for removing coolant from the condenser arrangement through a coolant outlet pipe, in which apparatus a sensor is provided to sense the temperature of the air at to the coolant outlet pipe 16, and by enclosing the conduit and the surrounding coolant pipes 11 in the sleeve 5, cooling load loss from the coolant pipes 11 is obviated.

Referring now to Figure 2 of the accompanying drawings, the condenser housing 1 is illustrated, in a schematic form.

From Figure 2 it can be seen that the condensate outlet pipe 7 is connected to a condensate storage tank 27. _____

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Also from Figure 2 it can be seen that the coolant outlet pipe 16 is connected to a coolant supply means in the form of a coolant re-processing unit 28 which supplies re-processed coolant to the coolant supply pipe 14. The re-processing unit 28 comprises a pump 29 and a cooler 30. The cooler 30 may comprise a conventional refrigeration unit. The arrangement is such that the pump 29 is adapted to pump coolant from the coolant outlet pipe 16 through the cooler 30 to the coolant supply pipe 14.

The coolant re-processing unit 28 receives control signals, through a line 31, from the sensor 17. The temperature of coolant and/or the flow rate of coolant is adjusted so that the temperature of air leaving the condenser is slightly above the freezing point of the vapour to be condensed. It is to be appreciated that traditional condensation is carried out with a coolant temperature of above 0°C. However, when handling air which contains organic compound vapour, the freezing point of the condensate, due to the miscibility of the solvent vapour with any moisture present in the air, will be lowered from 0°C to a lower temperature, which may be as low as -4°C, or even as low as -8°C. The extent of the depression of the freezing point below 0°C will depend upon the identity of the solvent, the relative humidity of the air, and the concentration of the organic vapour. However, by utilising the arrangement as described above with reference to Figure 2, the effective cooling power of the condenser may be adjusted so that an optimum condensing effect is achieved. Of course, if freezing does occur, the flow path for air through the condenser will become at least partially blocked, and also the heat transfer between the air and consequently the condensation efficiency will be reduced.

By utilising a condenser as described, the emission of vapour to the atmosphere may be minimised, and vapour which is condensed may be re-used, thus reducing operating costs.

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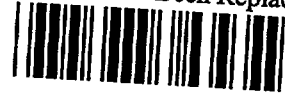
CLAIMS

1. A condenser for condensing a vapour from a stream of air containing said vapour, the condenser comprising a housing, an air inlet pipe for introducing a stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, and coolant supply means for supplying coolant to the condenser arrangement through a coolant supply pipe and for removing coolant from the condenser arrangement through a coolant outlet pipe, in which condenser a sensor is provided to sense the temperature of the air at the outlet of the condenser arrangement and the coolant supply means is responsive to signals from the sensor to adjust the flow rate and/or temperature of the coolant supplied to the condenser arrangement to maintain the sensed temperature just above the freezing point of the condensate formed by the condenser arrangement.
2. A condenser according to claim 1 wherein the condenser arrangement comprises an outlet manifold connected to the coolant outlet pipe, and a plurality of coolant pipes positioned to be exposed to the stream of air through the condenser arrangement and connected in parallel between the coolant supply pipe and the outlet manifold.
3. A condenser according to Claim 2 wherein the housing is of elongate form, and the outlet manifold comprises an elongate conduit extending substantially axially of the housing, the said coolant pipes forming a plurality of substantially helical turns surrounding said manifold.
4. A condenser according to Claim 3 wherein the condenser arrangement comprises a hollow sleeve located substantially coaxially within the housing with an inlet end of the sleeve connected to the air inlet pipe and an outlet end of the sleeve open to the interior of the housing, the sleeve receiving the manifold and the coolant pipes therein.
5. A condenser according to Claim 4 wherein the sleeve is formed of a thermally



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conductive material, and the air outlet pipe is positioned adjacent the air inlet pipe, so that air flowing out of the housing flows adjacent the exterior of the sleeve before flowing to the exterior of the housing through the air outlet.

6. A condenser according to Claim 1 wherein the condenser arrangement comprises one or more coolant pipes connected between the coolant supply pipe and the coolant outlet pipe, said coolant pipes being surrounded by a sleeve which has an inlet end connected to the air inlet pipe and an outlet end open to the interior of the housing, the air outlet being located so that, in use, air flowing out of the housing flows past the exterior of the sleeve before flowing through the air outlet to the exterior of the housing.

7. A condenser according to Claim 6 wherein the sleeve is made of a thermally conductive material and there is contact between one or more of said coolant pipes and said sleeve.

8. A condenser according to Claim 6 or 7 wherein said coolant pipes describing a plurality of helical turns within said sleeve.

9. A condenser according to any one of Claims 6 to 8 wherein the condenser arrangement comprises a plurality of said coolant pipes connected in parallel between said coolant supply pipe and said coolant outlet pipe.

10. A condenser according to any preceding Claim wherein the sensor comprises a thermocouple.

11. A condenser according to any preceding Claim wherein the sensor comprises an electrical conductivity sensor.

12. A condenser for condensing a vapour from a stream of air, the condenser comprising a housing, an air inlet pipe for introducing the stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air





inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, a coolant supply pipe for supplying coolant to the condenser arrangement, and a coolant outlet pipe for removing coolant from the condenser arrangement, the housing having a condensate outlet for discharging condensate formed in the housing by the condenser arrangement and an air outlet for directing the stream of air to the exterior of the housing, in which condenser the condenser arrangement comprises an outlet manifold connected to the coolant outlet pipe, and a plurality of coolant pipes positioned to be exposed to the stream of air through the condenser arrangement and connected in parallel between the coolant supply pipe and the outlet manifold.

13. A condenser according to Claim 12 wherein the housing is of elongate form, and the outlet manifold comprises an elongate conduit extending substantially axially of the housing, the said coolant pipes forming a plurality of substantially helical turns surrounding said manifold.

14. A condenser according to Claim 13 wherein the condenser arrangement comprises a hollow sleeve located substantially coaxially within the housing with an inlet end of the sleeve connected to the air inlet pipe and an outlet end of the sleeve open to the interior of the housing, the sleeve receiving the manifold and the coolant pipes therein.

15. A condenser according to Claim 14 wherein the sleeve is formed of a thermally conductive material, and the air outlet pipe is positioned adjacent the air inlet pipe, so that air flowing out of the housing flows adjacent the exterior of the sleeve before flowing to the exterior of the housing through the air outlet.

16. A condenser for condensing a vapour from a stream of air, the condenser comprising a housing, an air inlet pipe for introducing the stream of air into the interior of the housing, a condenser arrangement located in the housing and connected to the air inlet pipe so that the stream of air flows through the condenser arrangement into the interior of the housing, a coolant supply pipe for supplying coolant to the condenser



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arrangement, and a coolant outlet pipe for removing coolant from the condenser arrangement, the housing having a condensate outlet for discharging condensate formed in the housing by the condenser arrangement and an air outlet for directing the stream of air to the exterior of the housing, in which condenser the condenser arrangement comprises one or more coolant pipes connected between the coolant supply pipe and the coolant outlet pipe, said coolant pipes being surrounded by a sleeve which has an inlet end connected to the air inlet pipe and an outlet end open to the interior of the housing, the air outlet being located so that, in use, air flowing out of the housing flows past the exterior of the sleeve before flowing through the air outlet to the exterior of the housing.

17. A condenser according to Claim 16 wherein the sleeve is made of a thermally conductive material and there is contact between one or more of said coolant pipes and said sleeve.
18. A condenser according to Claim 16 or 17 wherein said coolant pipes describing a plurality of helical turns within said sleeve.
19. A condenser according to any one of Claims 16 to 18 wherein the condenser arrangement comprises a plurality of said coolant pipes connected in parallel between said coolant supply pipe and said coolant outlet pipe.
20. A condenser according to any one of Claims 12 to 19 wherein a sensor is provided to sense the temperature within the condenser.
21. A condenser according to Claim 20 wherein the sensor comprises a thermocouple.
22. A condenser according to Claim 20 or 21 wherein the sensor comprises an electrical conductivity sensor.
23. A method of condensing a volatile vapour from a stream of air containing said vapour, the method comprising the steps of introducing the stream of air containing said



vapour into a housing, directing the stream of air through a condenser arrangement within the housing, supplying coolant to the condenser arrangement means to cool the stream of air and condense said vapour, discharging the cooled air and condensate from the housing, and adjusting the flow rate and/or temperature of the coolant supplied to the condenser arrangement in response to signals from a temperature sensor within the condenser to maintain the temperature sensed by the sensor just above the freezing point of the condensate.

24. A condenser for condensing a vapour from a stream of air, the condenser comprising a generally vertical housing, an air inlet pipe at the upper end of the housing for introducing a stream of air into the interior of the housing, an air outlet adjacent the upper end of the housing to direct a flow of air to the exterior of the housing, a sleeve formed from conductive material and extending substantially coaxially within the housing with an inlet end of the sleeve connected to the air inlet pipe and an outlet end of the sleeve open to the interior of the housing, and a condenser arrangement received in the sleeve, the condenser arrangement comprising a coolant outlet manifold in the form of an elongate conduit received substantially axially within the sleeve, a coolant outlet pipe connected to the manifold, and a plurality of coolant pipes connected in parallel between a coolant supply pipe and the manifold, the coolant pipes defining a plurality of substantially helical turns around the exterior of the manifold, the condenser being such that, in use, air introduced into the housing through the air inlet flows through the sleeve past the coolant pipes, and subsequently enters the interior of the housing where it flows past the exterior of the sleeve before flowing to the exterior of the housing through the air outlet.

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