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- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

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(54) Title: METHOD FOR FILLING AN AMMONIA CARTRIDGE

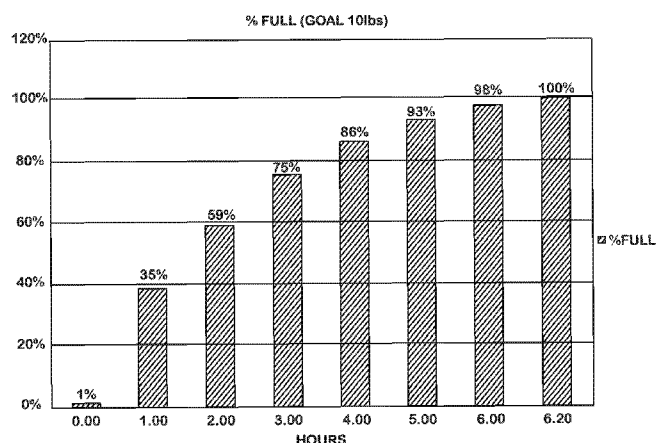


FIG. 1

(57) Abstract: A method for filling a cartridge with ammonia (NH₃) that is used to treat nitrogen oxides in exhaust gas that are created by the internal combustion of fossil fuels. The method includes supplying a predetermined amount of vapor NH₃ to an inner region of the cartridge. An absorption material in the cartridge absorbs the vapor NH₃, during which time the absorption material generally begins to solidify together. After a substantial portion of the absorption material has solidified together, the supply of NH₃ vapor may be discontinued. The filling process of the cartridge may then be completed by supplying the cartridge with liquid NH₃. The solidification of the absorption material before the supply of the liquid NH₃ may assist in preventing damage to the cartridge typically caused by the elevated temperatures and associated forces generated when the absorption material absorbs NH₃.



WO 2012/170769 A1

METHOD FOR FILLING AN AMMONIA CARTRIDGE

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61,494,921, filed June 9, 2011, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Combustion engines may employ emission controls or systems that are configured to reduce the amount of nitrogen oxides (NO_x), such as nitrogen dioxide, present in the engine's exhaust gas. One aspect of controlling such emissions includes injecting ammonia (NH₃) into an exhaust gas that is generated by the combustion of a fossil fuel, such as, for example, diesel fuel, petroleum, and gasoline. The NH₃ may be injected into the exhaust gas in dosing amounts or rates for converting NO_x in the exhaust gas into at least nitrogen. NH₃ used in the conversion of NO_x may be stored in, and supplied from, a cartridge. An engine control unit or module may control the release of the NH₃ from the cartridge and into the exhaust stream. However, over time, and through usage, the quantity of NH₃ stored in the cartridge is depleted, which eventually requires that the cartridge be replaced and/or refilled. However, filling a cartridge with NH₃ can be time consuming and expensive.

[0003] Typically, an inner region of the cartridge includes an absorption material that absorbs the NH₃, such as, for example, a compacted or compressed powder, including strontium chloride (SrCl₂), among others. However, the absorption of NH₃ by strontium chloride results in an exothermic reaction, which produces a significant amount of heat in the cartridge. Accordingly, when liquid NH₃ is introduced into a cartridge that has a relatively large quantity the strontium chloride that is in a condition to react with the NH₃, the temperatures and forces generated by the exothermic reaction can cause the cartridge to swell and/or deform. Accordingly, expensive measures are typically taken to significantly cool the exterior of the cartridge while also using fixtures that resist deformation of the cartridge.

[0004] To avoid damage to the cartridge created by the heat generated during the above-mentioned exothermic reaction, NH_3 is typically supplied to the cartridge as a vapor. By providing NH_3 as a vapor, the NH_3 may be more gradually introduced into the cartridge than would typically be achieved if the NH_3 were supplied in a liquid state. Additionally, the NH_3 vapor may encounter strontium chloride that is available to absorb the NH_3 at a slower rate. Thus, the use of NH_3 vapor limits the elevated temperature and forces inside the cartridge due to the exothermic reactions that may otherwise damage the cartridge.

[0005] Using NH_3 vapor to fill such cartridges typically takes a relatively long time, and thus can be costly. Further, over time, the strontium chloride that remains available to absorb NH_3 may be located at positions that are more difficult, or require more time, for the vapor NH_3 to reach. For example, Figure 1 illustrates a chart for the amount of time necessary to fill a 35 pound cartridge having strontium chloride with about 10 pounds of useable NH_3 using NH_3 vapor and minimal cartridge cooling. As shown, during the first three hours, the strontium chloride absorbs approximately 75% of the desired weight of useable NH_3 , or approximately 7.5 pounds. However, filling the cartridge with the remaining 25%, or 2.5 pounds, of NH_3 requires approximately an additional 3.8 hours. Such delay may be at least partially attributable to the slow time it takes vapor NH_3 to reach areas or pockets in the cartridge, such as areas against a wall of the cartridge, that contain strontium chloride that is still able to absorb NH_3 .

[0006] Figure 2 illustrates a similar result for re-filling two cartridges containing strontium chloride, which may already have some residual NH_3 , with approximately 10 pounds of NH_3 . The cartridges in this example have initial weights of 27.87 and 28.12 pounds, respectively. As shown, approximately 75% of the weight gain in the cartridge from the absorption of NH_3 occurs during the approximately the first 3.5 hours, with the re-filling of the remaining 25% of NH_3 taking another approximately 3.5 hours.

SUMMARY

An aspect of the illustrated embodiment is a method for filling a cartridge with ammonia used to treat NO_x in engine exhaust. The method includes supplying an inner region of the cartridge with a vapor NH₃ until a predetermined level of the vapor NH₃ has been absorbed by an absorption material in the cartridge. The method also includes supplying the inner region of the cartridge with a liquid NH₃ until a predetermined level of liquid NH₃ has been supplied to the cartridge.

[0007] Another aspect of the illustrated embodiment is a method for filling a cartridge with ammonia used to treat NO_x in engine exhaust that includes supplying an inner region of the cartridge with a vapor NH₃ until a predetermined amount of the vapor NH₃ has been supplied to the cartridge. The method further includes, subsequent to the supply of the predetermined level of vapor NH₃, supplying the inner region the cartridge with a liquid NH₃ until a predetermined amount of NH₃ has been supplied to the cartridge.

[0008] A further aspect of the illustrated embodiment is method for filling a cartridge with ammonia used to treat NO_x in engine exhaust that includes Initiating a supply of substantially NH₃ vapor to an inner region of the cartridge. The method also includes determining the amount of NH₃ vapor that has been supplied to the cartridge or absorbed by the absorption material. Further, the supply of NH₃ vapor to the cartridge is discontinued after a predetermined amount of NH₃ vapor has been supplied to the cartridge or absorbed by the absorption material in the cartridge. A vacuum is also pulled in the cartridge to provide a negative pressure in the cartridge that will assist in later supplying liquid NH₃ to the cartridge. The method further includes initiating a supply of substantially liquid NH₃ to an inner region of the cartridge. Additionally, the amount of liquid NH₃ supplied to the cartridge is determined. The supply of liquid NH₃ to the cartridge is discontinued after a predetermined amount of liquid NH₃ has been supplied to the cartridge.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 illustrates a bar chart of an example of the number hours required to fill an approximately 35 pound cartridge having strontium chloride with about 10 pounds of useable NH_3 using NH_3 vapor.

[0010] Figure 2 charts the weight and time to fill two separate 35 pound cartridges having strontium chloride with 10 pounds of useable NH_3 using NH_3 vapor.

[0011] Figure 3 illustrates a system for filling a cartridge with NH_3 according to the illustrated embodiment.

[0012] Figure 4 illustrates a cross sectional view of a cartridge for use with the system illustrated in Figure 3.

[0013] Figure 5 illustrates a flow chart for filling cartridges with both vapor and liquid NH_3 that will be used by emission control systems according to the illustrated embodiment.

DETAILED DESCRIPTION

[0014] For illustrative purposes, Figure 3 shows a system 100 for filling a cartridge 102 with NH_3 according to the illustrated embodiment. As shown, the system 100 includes at least one cartridge 102 and at least one tank 104, 106 containing liquid NH_3 . In the illustrated embodiment, a first tank 104 containing liquid NH_3 may be operably connected to a heater 108 that is controlled by a controller 110. The heater 108 is configured to elevate the temperature of the liquid NH_3 in the first tank 104 so that at least a portion of the liquid NH_3 in the first tank 104 is converted into vapor NH_3 .

[0015] The flow or release of either vapor or liquid NH_3 from the first and second tanks 104, 106, respectively, may be controlled by valves 112a, 112b, such as, for example shut-off valves. When the valve 112a for the first tank 104 is in the open position, NH_3 vapor may be allowed to flow, or be drawn, out of the first tank 104 and into a supply line, hose, or tube 111.

Similarly, when the valve 112b for the second tank 106 is in the open position, liquid NH_3 may be allowed to flow, or be drawn, out of the second tank 106 and into a supply line 111.

[0016] The system 100 may include a vacuum 116 that is operably connected to the system 100. When a vacuum valve 118 is in an open position, operation of the vacuum 116 creates a negative pressure in the system 100 that may be used to draw NH_3 vapor and/or liquid from the first and/or second tanks 104, 106, respectively. Further, the vacuum 116 may be used to draw a negative vacuum in the cartridge 102 that may assist in delivering the NH_3 vapor and/or liquid to the cartridges 102 through the supply lines 111.

[0017] The flow of NH_3 in the supply lines may also be controlled and/or regulated by various ancillary valves that are positioned along the supply lines 111. For example, the system 100 may include one or more shut-off, check, and/or pressure relief valves, among other flow controls. Additionally, the condition of the NH_3 flowing, or entering into, the supply lines 111 may be monitored, such as, for example, through the use of pressure, flow, and/or temperature transducers that are positioned along the supply lines 111. Further, as shown in Figure 3, vapor NH_3 from the first tank 104 may pass through a filter 114 that may remove contaminants and/or debris from the vapor NH_3 .

[0018] The system 100 may also include one or more heating jackets 122 that, when operated, are used to convert liquid NH_3 to vapor NH_3 and/or to ensure that, when desired, the NH_3 is in a vapor state. Heat used to convert liquid NH_3 to a vapor may be provided to the heating jacket 122 by a heater 124, such as, for example, a steam or electric heater. According to the illustrated embodiment, flow of NH_3 to, and through, the heating jacket 122, may be controlled by a shut-off valve 120.

[0019] NH_3 that passes through the heating jacket 122 may flow to, or be drawn into, a cartridge 102 that contains an absorption material that can absorb NH_3 , such as, for example, strontium chloride. Figure 4 illustrates a side cross sectional view of a cartridge 102. As shown, the cartridge 102 includes an upper wall 140, a lower wall 142, and a side wall 146 that generally

define an inner region 149 of the cartridge 102. The cartridge 102 also includes an inlet 148 and a diffuser tube 150. The inlet 148 may be operably connected to a supply line 111 such that NH_3 may flow from the supply line 111, through the inlet 148, and through the diffuser tube 150. The diffuser tube 150 may have a plurality of openings along the length of the diffuser tube 150 that allow for the release of the vapor or liquid NH_3 from different locations along the diffuser tube 150. The cartridge 102 illustrated in Figure 4 also includes an absorption material 152 that is used to absorb the NH_3 entering into the inner region 149, and which will later release the absorbed NH_3 for the treatment of NO_x in exhaust gases.

[0020] As previously discussed, the absorption of NH_3 by absorption materials 152 such as strontium chloride may occur via an exothermic reaction that produces heat that can cause swelling of, and related damage to, the cartridge 102. Additionally, such heat may interfere with the flow of NH_3 into the cartridge 102. Accordingly, at least a portion of the cartridge 102 may be cooled by the placement of the cartridge 102 in a cooling unit 126. The cooling unit 126 may be supplied with cold fluid, such as, for example, chilled air, water, or refrigerant, among others, by a chiller 128. Such cold fluid may be delivered from the chiller 128 to the cooling unit 126 by a coolant line 130, and returned from the cooling unit 126 to the chiller 128 through a return line 132.

[0021] Figure 5 illustrates a flow chart for filling cartridges 102 with vapor and liquid NH_3 for use in emission control systems according to the illustrated embodiment. At step 205, the cartridges 102 may be placed in the cooling unit 126 of the system 100. At step 210, the cartridge 102 may then be connected to the supply manifold, such as, for example, the inlet 148 of the cartridge 102 being connected to a supply line 111. However, according to certain embodiments, the cartridge 102 may be connected to the supply manifold prior to being placed in a cooling unit 126. The cooling unit 126 may be supplied with cold fluid from the chiller 128 at any number of times during the filling process, such as, for example, before or after the supply of vapor NH_3 and/or liquid NH_3 to the cartridge 102 has been initiated.

[0022] At 215, a supply of vapor NH_3 for the cartridge 102 is initiated. For example, at least one valve is opened so that vapor NH_3 may flow from the first tank 103 and into the cartridge 102. More specifically, according to certain embodiments, the shut-off valve 112a for the tank 104 that is used to supply NH_3 vapor may be opened, as well as shut-off valve 120 for the heating jacket 122, if not already in an opened position. The controller 110 may also operate the heater 108 such that at least a portion of the liquid NH_3 in the tank 104 is converted into NH_3 vapor. NH_3 vapor may then be allowed to flow to one or more cartridges 102. As previously discussed, before reaching the cartridge 102, the NH_3 may flow through a heating jacket 122 that is configured to ensure that the NH_3 flowing into the cartridge 102 is in a vapor state.

[0023] NH_3 vapor may then flow into the cartridge 102 and be dispensed in the inner region 149 of the cartridge 102 through the diffuser tube 150. At step 220, the amount of vapor NH_3 absorbed in the cartridge 102, such as by the quantity of NH_3 supplied to and/or absorbed by strontium chloride in the inner region 149, may be determined. In the illustrated embodiment, the amount of NH_3 vapor delivered into the cartridge 102 may be sufficient to substantially solidify together the compressed powdered absorption material 152 so that, in further steps in which liquid NH_3 is delivered into the cartridge 102, the solidified condition of the absorption material 152 may assist in preventing damage to the cartridge 102, such as, for example, damage due to swelling in the cartridge 102. The quantity of absorbed vapor NH_3 may be determined in a number of different ways. For example, the current weight of the cartridge may be compared with a prior cartridge weight 102, such as, for example, before or shortly after the system 100 began supplying vapor NH_3 into the cartridge 102. Alternatively, the weight of the cartridge 102 may be determined at various intervals to determine changes in the rate at which the vapor NH_3 is being absorbed inside the cartridge 102. Alternatively, vapor NH_3 may be supplied to the cartridge for a predetermined time limit. For example, NH_3 vapor may be supplied to the cartridge for a pre-determined time period that is predicted to allow the cartridge 102 to absorb a pre-determined amount of useable NH_3 , or more specifically, 10 pounds of NH_3 that may be later released from the cartridge during the treatment of exhaust gases.

[0024] For example, if 10 pounds of NH_3 is to be absorbed by the absorption material 152 in the cartridge 102, such as by strontium chloride, vapor NH_3 may be supplied to the cartridge 102 until the weight of the cartridge 102 indicates that approximately 75% of the desired 10 pounds, or 7.5 pounds, of NH_3 has been absorbed by the absorption material 152. As previously mentioned, according to certain embodiments, a change(s) in the weight of the cartridge 102 may be used to indicate whether or when 7.5 pounds of NH_3 has been absorbed by the absorption material 152, such as, for example, by a comparison of a cartridge weight after the filling process has begun with an initial cartridge weight taken before or around the time the filling process begins. According to other embodiments, NH_3 vapor may be supplied to the cartridge 102 for a predetermined time period based on when a predicted amount of the 75% of the useable NH_3 will be absorbed. For example, information shown in Figure 1 may be used to predict that vapor NH_3 should be supplied to the cartridge for approximately 3 hours, at which time approximately 75% of the useable NH_3 is expected to have been absorbed by the absorption material 152. These percentages and times however are for purposes of illustration, and may be varied based on a number of circumstances, including, for example, the desired time period for filling a cartridge, the amount of ammonia that is to be absorbed, and permissible temperature levels created by the exothermic reaction that occurs when the absorption material 152 absorbs the NH_3 , among other factors.

[0025] After the predetermined amount of NH_3 vapor has been absorbed by the absorption material 152, then at step 225, the supply of vapor NH_3 to the cartridge 102 is discontinued. For example, according to certain embodiments, a valve that supplies vapor NH_3 to the cartridge 102 may be closed. Moreover, in the system illustrated in Figure 3, the shut-off valve 112a for the first tank 104 may be moved to a closed position. At step 230, the vacuum 116 may be operated to create a negative pressure in the cartridge 102. At step 235, a supply of liquid NH_3 for the cartridge 102 may be initiated. For example, according to certain embodiments, one or more valves may be opened so as to allow liquid NH_3 from the second tank 106 to flow to the cartridge 102. Moreover, in the system 100 illustrated in Figure 3, the shut-off

valve 112b for the second tank 106 may be moved to an open position that allows liquid NH_3 to flow out of the tank 106. Further, the negative pressure created by the operation of the vacuum 116 may at least assist in drawing the liquid NH_3 in the supply lines 111 from the second tank 106 into the cartridge 102.

[0026] At step 240, the amount of liquid NH_3 in the cartridge 102 that has been absorbed by the absorption material 152 and/or the amount of liquid NH_3 in the cartridge 102 may be determined. Similar to the vapor NH_3 , the quantity of liquid NH_3 in the cartridge 102 and/or the amount of liquid NH_3 or the total amount of NH_3 absorbed by the absorption material may be determined in a number of different ways. For example, the current weight of the cartridge 102 may be compared with a prior cartridge weight 102, such as, for example, before or shortly after the system 100 begins supplying vapor NH_3 into the cartridge 102 and/or the weight of the cartridge 102 when the supply of vapor NH_3 ceased and/or the supply of liquid NH_3 began. Alternatively, liquid NH_3 may be supplied to the cartridge for a predetermined time limit. For example, liquid NH_3 may be supplied to the cartridge for a pre-determined time period that is predicted to allow the cartridge to receive and/or the absorption material to absorb a pre-determined amount of useable NH_3 . Further, the time period for which liquid NH_3 is to be absorbed by the absorption material 152 does not necessarily mean the cartridge 102 needs to remain connected to the system 100. Moreover as the vapor and liquid NH_3 are released from the diffuser tube 150 and into the absorption material 152, typically most of the saturation of the absorption material 152 at least initially occurs around the proximity to the diffuser tube 150. Therefore, the regions or areas of the absorption material 152 that are not yet saturated with NH_3 may be located remotely from the diffuser tube 150. Thus, liquid NH_3 may need time to reach portions of the absorption material 152 that are remote from the diffuser tube 150, such as, for example, absorption material 152, or pockets thereof, that are along the side wall 144 or lower wall 144 of the cartridge 102. However, this absorption can occur after both the liquid NH_3 has been delivered to the inner region 149 and the cartridge 102 has been disconnected to a supply line 111, and more specifically, disconnected from the system 100.

[0027] Using the prior example where 75% of the 10 pounds of useable NH_3 is to be supplied to the absorption material 152 inside the cartridge 102 by vapor NH_3 , the remaining 25% of useable NH_3 may be supplied by liquid NH_3 . Unlike the use of vapor NH_3 for this remaining 25%, which as shown in the example illustrated in Figure 1 required an additional 3.8 hours, the use of liquid NH_3 allows the remaining 25% to be supplied to the cartridge 102 in a relatively significantly shorter time period, such as, for example, in one hour. Further, by first using the vapor NH_3 , the compressed powdered absorption material 152 is allowed to generally solidify together, which may aid in preventing swelling and/or deforming of the cartridge 102 caused by the exothermic reaction created by the introduction of liquid NH_3 into the cartridge 102. Further, as there is less unsaturated NH_3 in the cartridge 102 available to react with the NH_3 , the overall force generated by the reaction of the absorption material 152 with the liquid NH_3 may be minimal.

[0028] Once the cartridge 102 has received the desired amount of liquid NH_3 and/or a desired amount of liquid NH_3 has been absorbed by the absorption material 152, then at step 245 the supply of NH_3 to the cartridge 102 is discontinued. For example, the valve 112b for the second tank 104 may be moved from an open position to a closed position so that liquid NH_3 no longer flows through the supply lines 111 and to the cartridge 102. As previously discussed, the cartridge 102 may be detached from the system 100 with the an amount of liquid NH_3 in the inner region 149 needed to complete the filling process even if all of the liquid NH_3 has not yet been absorbed by the absorption material 152. This is because even when removed from the system 100, the liquid NH_3 in the cartridge 102 will continue to be absorbed by absorption material 152 that is not yet saturated with NH_3 and/or is still capable of absorbing NH_3 . However, with vapor NH_3 , as the vapor contains less NH_3 than the liquid NH_3 , a cartridge 102 being completely filled using NH_3 vapor could not be disconnected from the system 100 and still achieve the goal amount of NH_3 in the cartridge 102 unless the disconnect happened around the same time as the goal amount of NH_3 had been absorbed by the absorption material 152 in the inner region 149 of the cartridge.

Claims

1. A method for filling a cartridge with ammonia used to treat NO_x in engine exhaust comprising:

supplying an inner region of the cartridge with a vapor NH₃ until a predetermined level of the vapor NH₃ has been absorbed by an absorption material in the cartridge; and

supplying the inner region of the cartridge with a liquid NH₃ until a predetermined level of liquid NH₃ has been supplied to the cartridge.

2. The method of claim 1, further including the steps of measuring a first weight of the cartridge, measuring a second weight of the cartridge, and comparing the first and second weights to determine if the predetermined level of vapor NH₃ has been absorbed by the absorption material.

3. The method of claim 2, further including the steps of measuring a third weight of the cartridge and comparing the second and third weights to determine if the predetermined level of liquid NH₃ has been supplied to the cartridge.

4. The method of claim 1, further including the step of measuring the time period during which the cartridge has been supplied with vapor NH₃ to determine whether the predetermined level of vapor NH₃ has been absorbed by the absorption material.

5. The method of claim 4, further including the step of measuring the time period during which the cartridge has been supplied with liquid NH₃ to determine whether the predetermined level of liquid NH₃ has been supplied to the cartridge.

6. A method for filling a cartridge with ammonia used to treat NO_x in engine exhaust comprising:

supplying an inner region of the cartridge with a vapor NH_3 until a predetermined amount of the vapor NH_3 has been supplied to the cartridge; and

subsequent to the supply of the predetermined level of vapor NH_3 , supplying the inner region the cartridge with a liquid NH_3 until a predetermined amount of NH_3 has been supplied to the cartridge.

7. The method of claim 6, further including the steps of measuring a first weight of the cartridge, measuring a second weight of the cartridge, and comparing the first and second weights to determine if the predetermined amount of vapor NH_3 has been supplied to the cartridge.

8. The method of claim 7, further including the steps of measuring a third weight of the cartridge and comparing the second and third weights to determine if the predetermined amount of liquid NH_3 has been supplied to the cartridge.

9. The method of claim 6, further including the step of measuring the time period during which the cartridge has been supplied with vapor NH_3 to determine whether the predetermined amount of vapor NH_3 has been supplied to the cartridge.

10. The method of claim 9, further including the step of measuring the time period during which the cartridge has been supplied with liquid NH_3 to determine whether the predetermined amount of liquid NH_3 has been supplied to the cartridge.

11. A method for filling a cartridge with ammonia used to treat NO_x in engine exhaust comprising:

initiating a supply of substantially NH_3 vapor to an inner region of the cartridge;

determining the amount of NH_3 vapor supplied to the cartridge or the amount of NH_3 vapor absorbed by an absorption material in the inner region of the cartridge;

discontinuing the supply of NH_3 vapor to the cartridge after a predetermined amount of NH_3 vapor has been supplied to the cartridge or absorbed by the absorption material;

pulling a vacuum in the cartridge;

initiating a supply of substantially liquid NH_3 to an inner region of the cartridge;

determining the amount of liquid NH_3 supplied to the cartridge; and

discontinuing the supply of liquid NH_3 to the cartridge after a predetermined amount of liquid NH_3 has been supplied to the cartridge.

12. The method of claim 11, wherein the predetermined amount of vapor supplied to the cartridge is an amount to substantially solidify the absorption material together.

13. The method of claim 11, wherein the predetermined amount of vapor NH_3 supplied to the cartridge is approximately 75% of the total weight of NH_3 that is to be absorbed by the absorption material from the combination of the supplied vapor and liquid NH_3 .

14. The method of claim 11, wherein the predetermined amount of vapor NH_3 supplied to the cartridge is determined by the step of monitoring the overall weight gain of the cartridge from the supply of vapor NH_3 to the inner region.

15. The method of claim 11, wherein the supply of liquid NH_3 is discontinued before at least a portion of the liquid NH_3 supplied to the inner region has been absorbed by the absorption material.

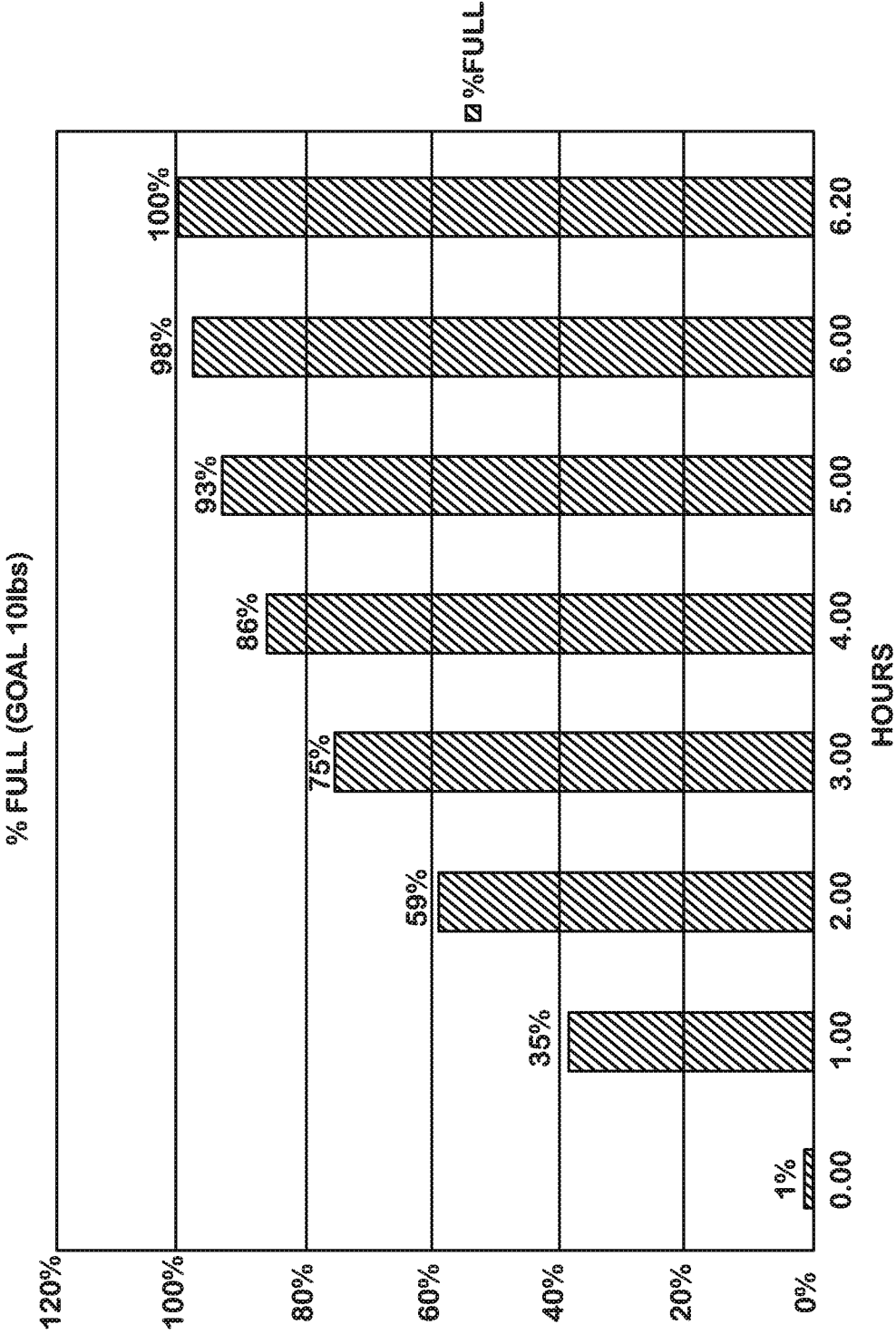


FIG. 1

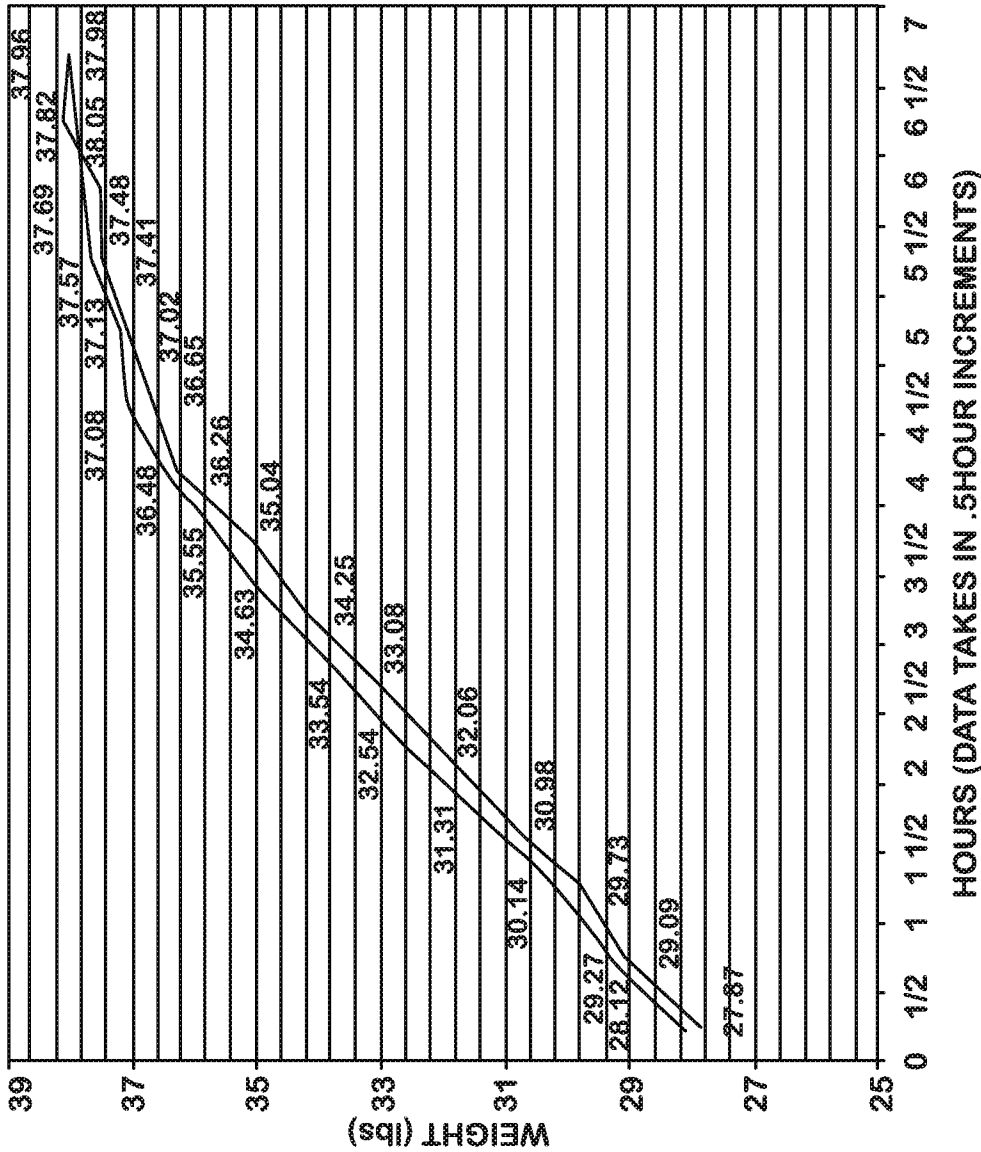
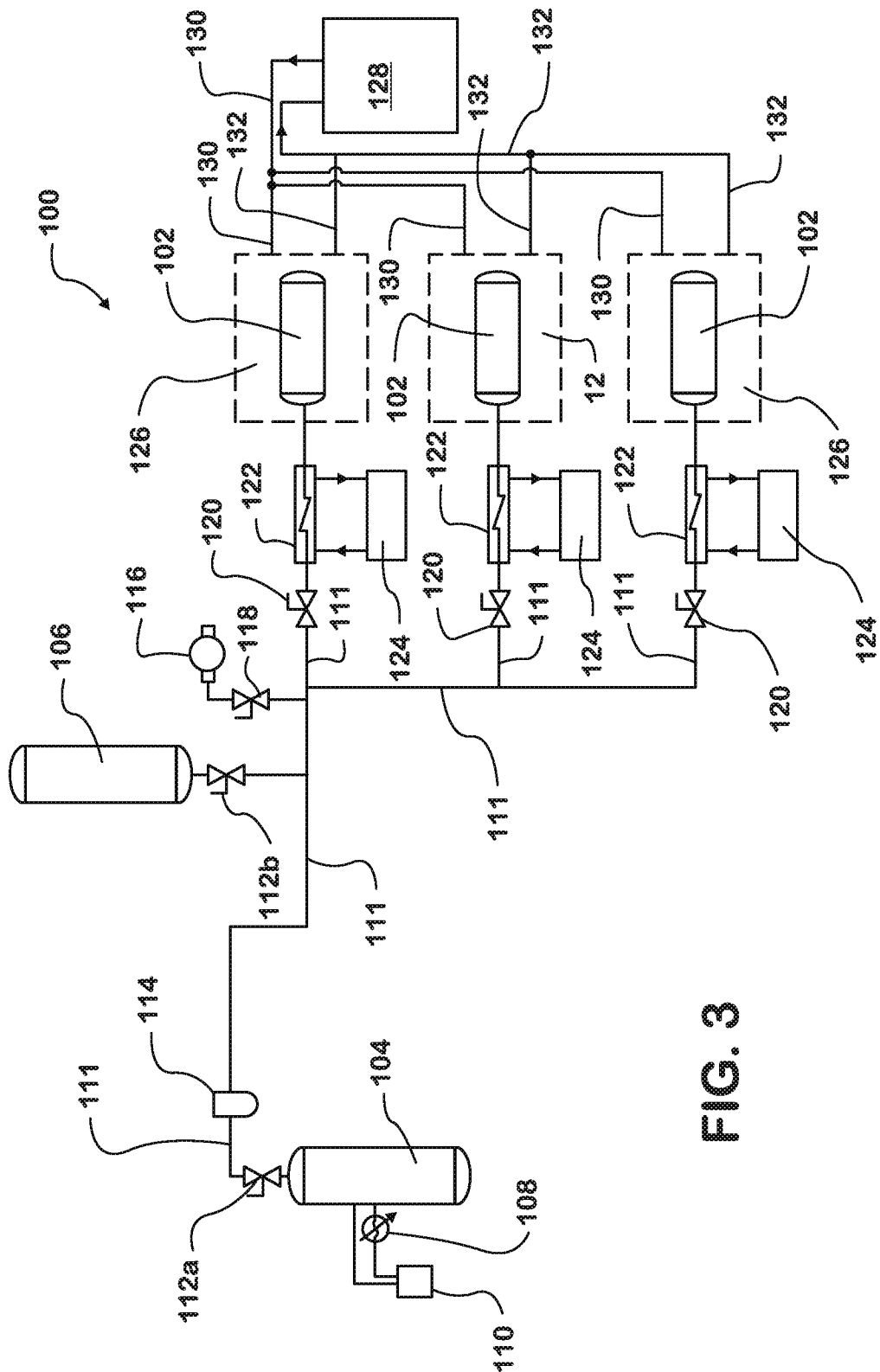
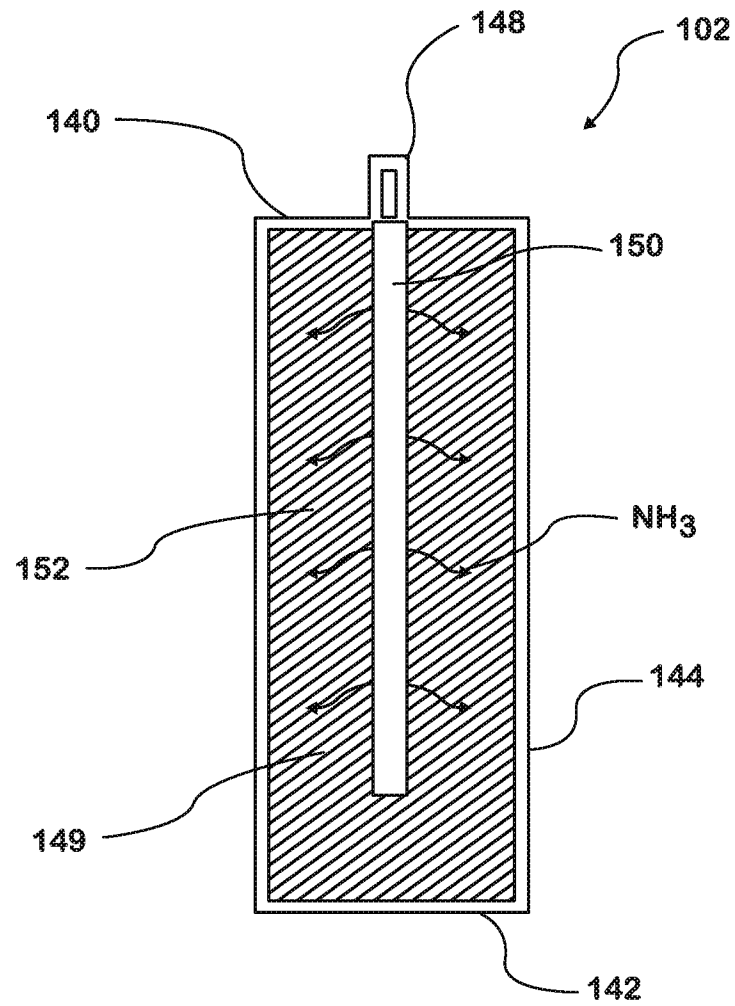


FIG. 2



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**FIG. 4**

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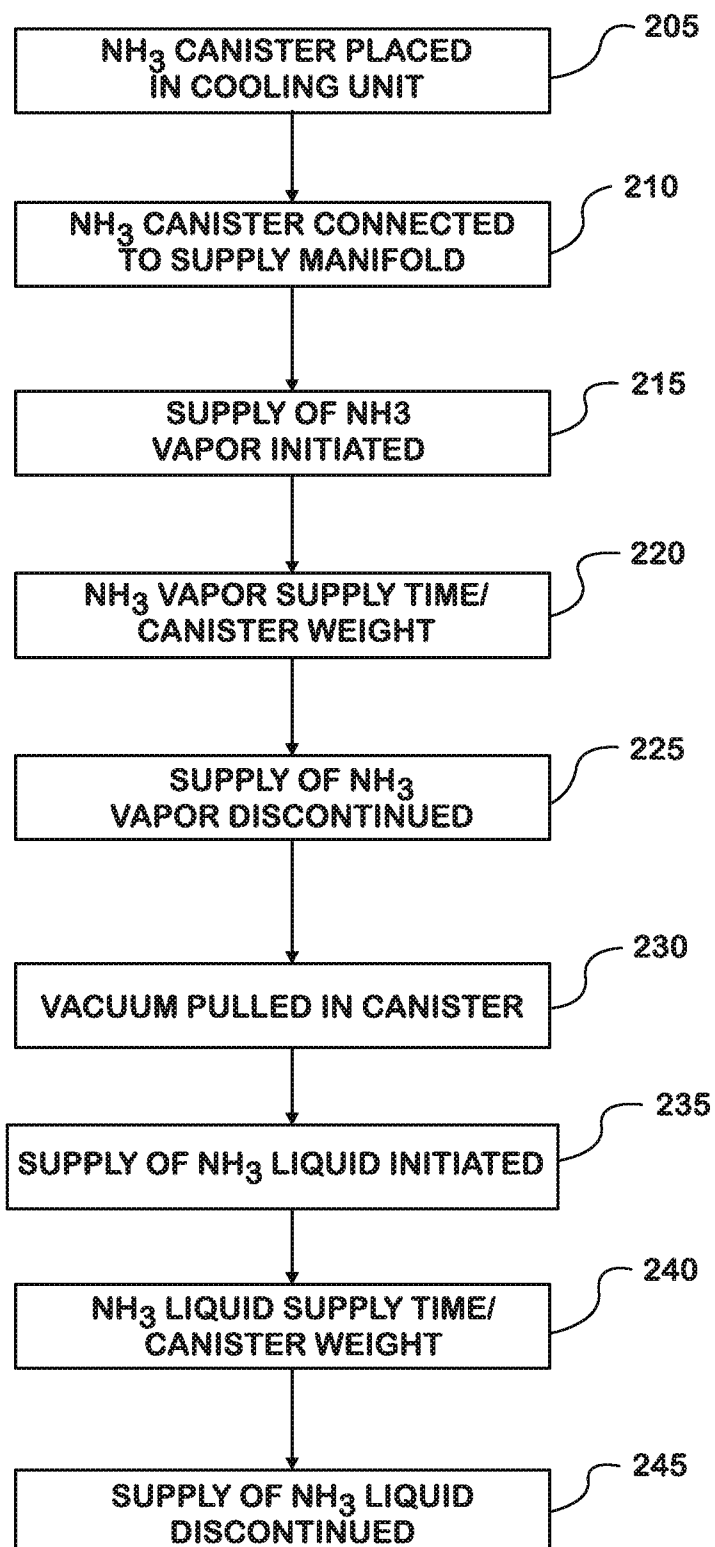


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/041480

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B65D 81/26 (2012.01)

USPC - 206/0.7

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - B65D 81/26; F17C 11/00, 13/00; H01M 8/18 (2012.01)

USPC - 206/0.5, 0.6, 0.7, 204

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0266475 A1 (JOHANSEN et al) 21 October 2010 (21.10.2010) entire document	1-15
Y	WO 2010/025947 A1 (SVAGIN et al) 11 March 2010 (11.03.2010) entire document	1-15
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"&" document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

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