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Declarations under Rule 4.17:

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[Continued on next page]

(54) **Title**: STATUS INDICATOR FOR AMMONIA CARTRIDGE

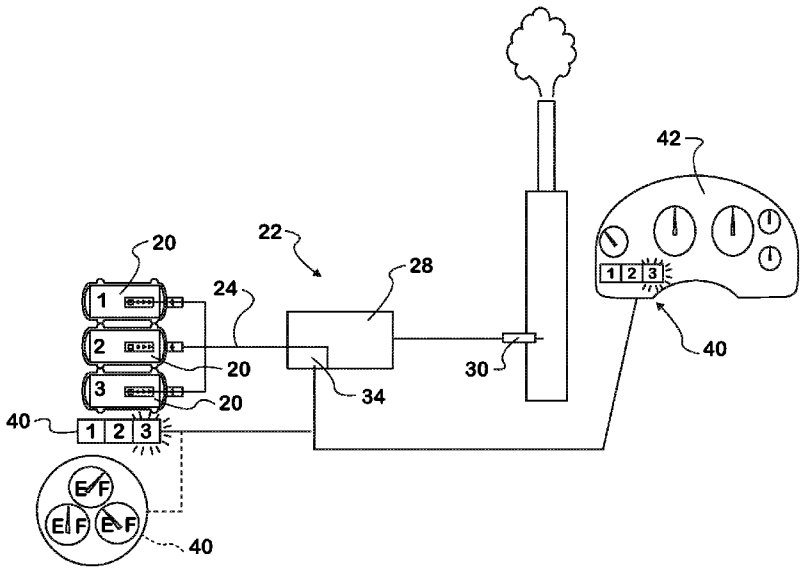

FIG. 2

(57) **Abstract**: Systems and methods for tracking and indicating a status for the deliverable ammonia in an ammonia canister used in an exhaust gas after-treatment system are disclosed. An on-board system provides a visual display to indicate either generally or specifically the fill-status of each of a plurality of loaded ammonia canisters, while a separate canister system is able to be periodically updated while on-line and, using a memory device such as a RFID tag, carry the updated fill-status even when it is removed from the vehicle system. The residing memory device can be read off-line to determine the ammonia fill-status. Metering of the ammonia flow allows real-time monitoring and updating of the canister status.

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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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— *with international search report (Art. 21(3))*

STATUS INDICATOR FOR AMMONIA CARTRIDGE

TECHNICAL FIELD

[0001] The present device and methods relate to status indicators for containers. More specifically, the device and methods relate to content status indicators, such as "full" or "empty," for ammonium cartridge canisters (or cartridges) used on internal combustion engines for exhaust gas after-treatment systems.

BACKGROUND

[0002] Compression ignition engines provide advantages in fuel economy, but produce both NO_x and particulates during normal operation. New and existing regulations continually challenge manufacturers to achieve good fuel economy and reduce the particulates and NO_x emissions. Lean-burn engines achieve the fuel economy objective, but the high concentrations of oxygen in the exhaust of these engines yields significantly high concentrations of NO_x as well. Accordingly, the use of NO_x reducing exhaust treatment schemes is being employed in a growing number of systems.

[0003] One such system is the direct addition of ammonia gas to the exhaust stream. It is an advantage to deliver ammonia directly in the form of a gas, both for simplicity of the flow control system and for efficient mixing of reducing agent, ammonia, with the exhaust gas. The direct use of ammonia also eliminates potential difficulties related to blocking of the dosing system, which are cause by precipitation or impurities, e.g., in a liquid-based urea solution. In addition, an aqueous urea solution cannot be dosed at a low engine load since the temperature of the exhaust line would be too low for complete conversion of urea to ammonia (and CO_2).

[0004] Due to its caustic nature, transporting ammonia as a pressurized liquid can be hazardous if the container bursts, as the result of an accident, or if a valve or tube breaks. In the case of using a solid storage medium, the safety issues are much less critical since a small amount of heat is required to release the ammonia and the equilibrium pressure at room temperature can be—if a proper solid material is chosen—well below 1 bar. Solid ammonia can be provided in the form of disks or balls loaded into a cartridge or canister. The canisters are then loaded into a mantle or other storage device and secured to the vehicle for use. Appropriate heat is applied to the canisters, which then causes the ammonia-containing solid storage material to release ammonia gas into the exhaust system of a vehicle, for example.

[0005] However, eventually the ammonia in a canister is depleted and must be recharged or replaced. Unfortunately, there are no systems in place which are capable of indicating the fill-status of a canister. This short-coming requires a plurality of canisters to be used in a vehicle system in order to provide a level of redundancy. Further, the canisters are typically changed on a regular basis, regardless of the fill-level, to avoid the possibility of ammonia depletion during engine operation. The result is sometimes the carrying of too much ammonia to provide the desired redundancy, and sometimes the removal and replacement of partially-filled ammonia canisters with full canisters to avoid depletion. Such conditions and procedures may increase the possibility of an accidental ammonia release.

[0006] Thus, the present system and methods provide for fill-status indication on-board vehicles and on individual canisters. The system and methods facilitate proper scheduling of removal and replacement of ammonia canisters as well as providing real-time ammonia loads for canisters. These and other problems are addressed and resolved by the disclosed systems and method of the present application.

SUMMARY

[0007] There is disclosed herein a system and method, each of which avoids the disadvantages of prior systems and methods while affording additional structural and operating advantages.

[0008] An ammonia delivery system generally comprising at least one canister containing a supply of ammonia in solid form, an exhaust gas after-treatment system having an ammonia injector fluidly coupled to the at least one canister, a controller for metering flow of ammonia to the injector, and a status indicator electronically connected to the controller for indicating a fill-status of the at least one canister is disclosed.

[0009] In an embodiment of the disclosed system, the status indicator comprises an LED. In another embodiment, the status indicator comprises a series of LEDs. In another embodiment, the status indicator comprises an analog display. And, in still another embodiment, the status indicator comprises a digital display.

[0010] In various of the disclosed embodiments, the status indicator signals when the supply of ammonia reaches a predetermined level, such as empty or nearly-empty.

[0011] A method for delivering ammonia to a exhaust gas after-treatment system is also disclosed. Generally speaking, the method comprises the steps of heating a first supply of solid ammonia stored in a first canister to produce an ammonia gas, transporting the ammonia gas from the first canister to an ammonia injector coupled to an exhaust gas after-treatment

system, metering the ammonia gas as it is transported to the ammonia injector, calculating a remaining supply of solid ammonia in the first canister, and indicating a status of the remaining supply of solid ammonia in the first canister.

[0012] As with the disclosed system, the step of indicating a status of the remaining supply in different embodiments of the method may include activating an LED, activating a series of LEDs, operating an analog or digital display, and operating another type of visual display.

[0013] In addition, a method for tracking solid ammonia level in an ammonia canister used for an exhaust gas after-treatment system is also disclosed. The method comprises the steps of attaching a memory storage device to an ammonium canister, determining the volume of solid ammonium in the canister, storing information relevant to the determined volume in the memory storage device, and periodically updating the information on the memory storage device.

[0014] In an embodiment of the tracking method, a further step of metering the use of the ammonia after the step of storing the information may be employed. The information may comprise a value corresponding to the amount of solid ammonium remaining in the canister or the amount used.

[0015] In an embodiment of the tracking method, the memory storage device comprises an RFID tag.

[0016] Finally, a solid ammonium canister status system is also disclosed. Generally speaking, the canister status system comprises a solid ammonium canister having stored therein a supply of solid ammonium, a memory storage device affixed to the canister, wherein the memory storage device contains information relevant to the volume of solid ammonium stored in the canister, a metering device for tracking the amount of ammonium delivered from the canister over a period of time, and an input device for periodically updating the memory storage device based on the amount of ammonium delivered from the canister as tracked by the metering device.

[0017] In embodiments of the canister status system, the memory storage device comprises an RFID tag, the input device comprises an RFID reader/writer electronically coupled to the metering device, and the metering device comprises an ammonium flow module.

[0018] These and other aspects of embodiments of the invention are described in the following detailed description and shown in the appended drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a schematic overview of an ammonia storage and delivery system working in conjunction with a vehicle engine system, exhaust gas after-treatment system and the vehicle electronics;

[0020] FIG. 2 is a schematic illustrating an embodiment of the present on-board fill-status indicator system;

[0021] FIG. 3 is a schematic illustrating a partial cross-section of an ammonia canister and an embodiment of the present canister fill-status indicator system;

[0022] FIG. 4 is a color picture illustrating a particular embodiment of the indicator system used in a three cartridge array; and,

[0023] Appendix.

DETAILED DESCRIPTION

[0024] With reference to FIGS. 1-4 and the Appendix, the embodiments of the system and methods are described to one of skill in the relevant art. Generally speaking, an ammonia delivery system, designated with the reference number 10 in the figures, typically works in conjunction with an internal combustion engine 12, an exhaust gas after-treatment system 14, and vehicle electronics 16.

[0025] In an embodiment of the ammonia delivery system 10, a canister 20 containing a supply of ammonia in solid form is loaded into a carrier and secured in place. The canister 20 is connected to a metering system 22 via special tubing 24 and a special connector 26 to prevent leakage of the ammonia. In most systems, a plurality of canisters will be used to provide greater travel distance between recharging. However, the current system works sufficiently with a single canister, for some applications and as desired or necessary. A heating jacket (not shown) is typically used around the canister to bring the solid ammonia to a sublimation temperature.

[0026] Once converted to a gas, the ammonia is metered at the ammonia flow module (AFM) 28 and directed to an exhaust gas after-treatment system 14 having an ammonia injector 30, as shown in FIG. 1. The AFM 28 includes a controller 34 for metering flow of ammonia to the injector. By "metering" it is meant that the controller 34 controls ammonia flow (rate and duration) and stores information about such details including the amount of ammonia required by the exhaust gas after-treatment system 14, the amount of ammonia being delivered, the canister providing the ammonia, the starting volume of deliverable

ammonia in the canister, and other such data which may be relevant to determining the amount of deliverable ammonia in each canister. The information may be monitored on a periodic or continuous basis. When the controller 34 determines that the amount of deliverable ammonia is below a predetermined level, a status indicator 40 electronically connected to the controller 34 is activated. The indicator 40 may be used to generally indicate a status of the canister 20, such as, for example, "Full" or "Empty" (see FIG. 4, for example) or it may be used to indicate a specific amount of remaining deliverable ammonia.

[0027] In an embodiment for indicating a general threshold level of ammonia, the status indicator is preferably a single LED or other such simple visual indicator capable of signifying two separate conditions (e.g., on and off). The predetermined threshold level may be "empty" or it may be, for example, when only 10% of deliverable ammonia remains. In a similar embodiment, the status indicator may include a series of LEDs (or other such visual indicators) to indicate ranges or a decreasing series of different threshold levels of deliverable ammonia remaining—e.g., 80%, 50%, 20%, etc. For more acute concerns, the status indicator may use an analog or digital display of remaining ammonia, much like a fuel gauge on a vehicle operates.

[0028] The visual indicator 40 may be mounted in proximity to the canister storage area to better advise those individuals charged with recharging and replacing empty canisters, and/or the indicator 40 may be mounted within the vehicle cab as part of the instrument cluster 42. When a first canister registers as "empty" or when it is removed from the canister mounting, the controller 34 automatically switches to a second supply of solid ammonium in a second canister.

[0029] In another feature of an embodiment of the present system, a method for tracking the solid ammonia level in the ammonia canister 20 may be used on each canister, as illustrated in FIG. 3. That is, after a canister is removed from the vehicle's ammonia storage and delivery system, the remaining ammonia in the subject canister can be readily determined. Generally speaking, the method comprises attaching a memory storage device to each ammonia canister, determining the volume of solid ammonia in the canister, storing information relevant to the determined volume in the memory storage device and periodically updating the information on the memory storage device as the ammonia is used.

[0030] As with the system 10 previously described, the method further comprises metering the use of the ammonia after the step of storing the information. The system controller 34 previously described is suitable for such metering and information storage. However, the controller 34 remains with the vehicle when the ammonia canisters are

removed and, therefore, cannot suitably operate to make such information available for a removed canister. Instead, the memory storage device 50 affixed to the ammonia canister comprises an RFID tag which can be read by a conventional RFID reader 52.

[0031] When a canister 20 is connected to the vehicle's ammonia storage and delivery system 10, an RFID reader/writer in the metering system 22 can frequently update the information stored on the RFID tag 50 as ammonia is depleted. As the controller 34 determines information about each coupled canister 20, the RFID reader/writer can easily write such information to the individual RFID tag 50 on each canister. Periodically or continuously updating the information merely comprises the steps of calculating the amount of solid ammonium remaining in the canister based on the flow rate and duration metered by the controller 34 and then storing a value relevant to the calculated amount on the memory storage device, i.e., the RFID tag 50.

[0032] In an embodiment of the canister volume tracking method, each solid ammonium canister 20 comprises a memory storage device (e.g., RFID tag) 50 affixed to the canister 20, wherein the memory storage device contains information relevant to the volume of solid ammonium stored in the canister. The vehicle components include a metering device for tracking the amount of ammonium delivered from the canister over a period of time, and an input device (e.g., RFID reader/writer) for periodically updating the memory storage device based on the amount of ammonium delivered from the canister 20 as tracked by the metering device 22.

[0033] Before the canister 20 is removed from the vehicle, the memory storage device 50 is updated with current ammonia load information. Then, a conventional handheld RFID reader 52 may be used at canister drop-off locations to determine the fill-status of each canister 20.

1. An ammonia delivery system comprising:

at least one canister containing a supply of ammonium in solid form;

an exhaust gas after-treatment system having an ammonia injector fluidly coupled to the at least one canister;

a controller for metering flow of ammonia to the injector;

a status indicator electronically connected to the controller for indicating a status of the at least one canister.

2. The ammonia delivery system of Claim 1, wherein the status indicator comprises an LED.

3. The ammonia delivery system of Claim 1, wherein the status indicator comprises a series of LEDs.

4. The ammonia delivery system of Claim 1, wherein the status indicator comprises an analog display.

5. The ammonia delivery system of Claim 1, wherein the status indicator comprises a digital display.

6. The ammonia delivery system of Claim 1, wherein the status indicator signals when the supply of ammonia reaches a predetermined level.

7. The ammonia delivery system of Claim 2, wherein the LED lights when the supply of ammonia reaches a predetermined level.

8. The ammonia delivery system of Claim 3, wherein the series of LEDs light when the supply of ammonia reaches each of a plurality of predetermined levels.

9. The ammonia delivery system of Claim 1, wherein the controller calculates a status of the supply of ammonia based on an initial volume, a controlled flow rate and a measured time of flow.

10. A method for delivering ammonia to a exhaust gas after-treatment system, the method comprising the steps of:

heating a first supply of solid ammonia stored in a first canister to produce an ammonia fluid;

transporting the ammonia fluid from the first canister to an ammonia injector coupled to an exhaust gas after-treatment system;

metering the ammonia fluid as it is transported to the ammonia injector;

calculating a remaining supply of solid ammonia in the first canister; and

indicating a status of the remaining supply of solid ammonia in the first canister.

11. The method of Claim 10, wherein the step of metering the ammonia fluid comprises the steps of controlling a flow rate of the fluid ammonia and tracking the flow time of the fluid ammonia.

12. The method of Claim 10, wherein the step of indicating a status of the remaining supply comprises the step of activating an LED.

13. The method of Claim 10, wherein the step of indicating a status of the remaining supply comprises the step of activating a series of LEDs.

14. The method of Claim 10, wherein the step of indicating a status of the remaining supply comprises the step of operating an analog display.

15. The method of Claim 10, wherein the step of indicating a status of the remaining supply comprises the step of operating a visual display.

16. The method of Claim 15, wherein the visual display is an LED.

17. The method of Claim 15, wherein the visual display is a series of LEDs.

18. The method of Claim 15, wherein the visual display is analog.

19. The method of Claim 15, wherein the visual display is digital.

20. The method of Claim 10, further comprising the step of switching to a second supply of solid ammonium in a second canister when the indicated status of the remaining supply of solid ammonium in the first canister reaches a predetermined level.

21. A method for delivering ammonia to a exhaust gas after-treatment system, the method comprising the steps of:

heating a supply of solid ammonium to produce an ammonia fluid;

transporting the ammonia fluid to an ammonia injector coupled to the exhaust gas after-treatment system;

continuously metering the ammonia fluid as it is transported to the ammonia injector;

periodically calculating a remaining supply of solid ammonium;

continuously indicating a status of the remaining supply of solid ammonium.

22. A method for tracking solid ammonia level in an ammonia canister used for an exhaust gas after-treatment system, the method comprising the steps of:

attaching a memory storage device to an ammonium canister;

determining the volume of solid ammonium in the canister;

storing information relevant to the determined volume in the memory storage device;

periodically updating the information on the memory storage device.

23. The method of Claim 22, further comprising the step of metering the use of the ammonia after the step of storing the information.

24. The method of Claim 22, wherein the information comprises a value corresponding to the amount of solid ammonium remaining in the canister.

25. The method of Claim 22, wherein the memory storage device comprises an RFID tag.

26. The method of Claim 23, wherein the step of periodically updating the information comprises the steps of calculating the amount of solid ammonium remaining in the canister and storing a value relevant to the calculated amount on the memory storage device.

27. The method of Claim 26, wherein the memory storage device comprises an RFID tag.

RECTIFIED SHEET (RULE 91)

28. A solid ammonium canister status system comprising:

a solid ammonium canister having stored therein a supply of solid ammonium;

a memory storage device affixed to the canister, wherein the memory storage device contains information relevant to the volume of solid ammonium stored in the canister;

a metering device for tracking the amount of ammonium delivered from the canister over a period of time; and

an input device for periodically updating the memory storage device based on the amount of ammonium delivered from the canister as tracked by the metering device.

29. The solid ammonium canister status system of Claim 28, wherein the memory storage device comprises an RFID tag.

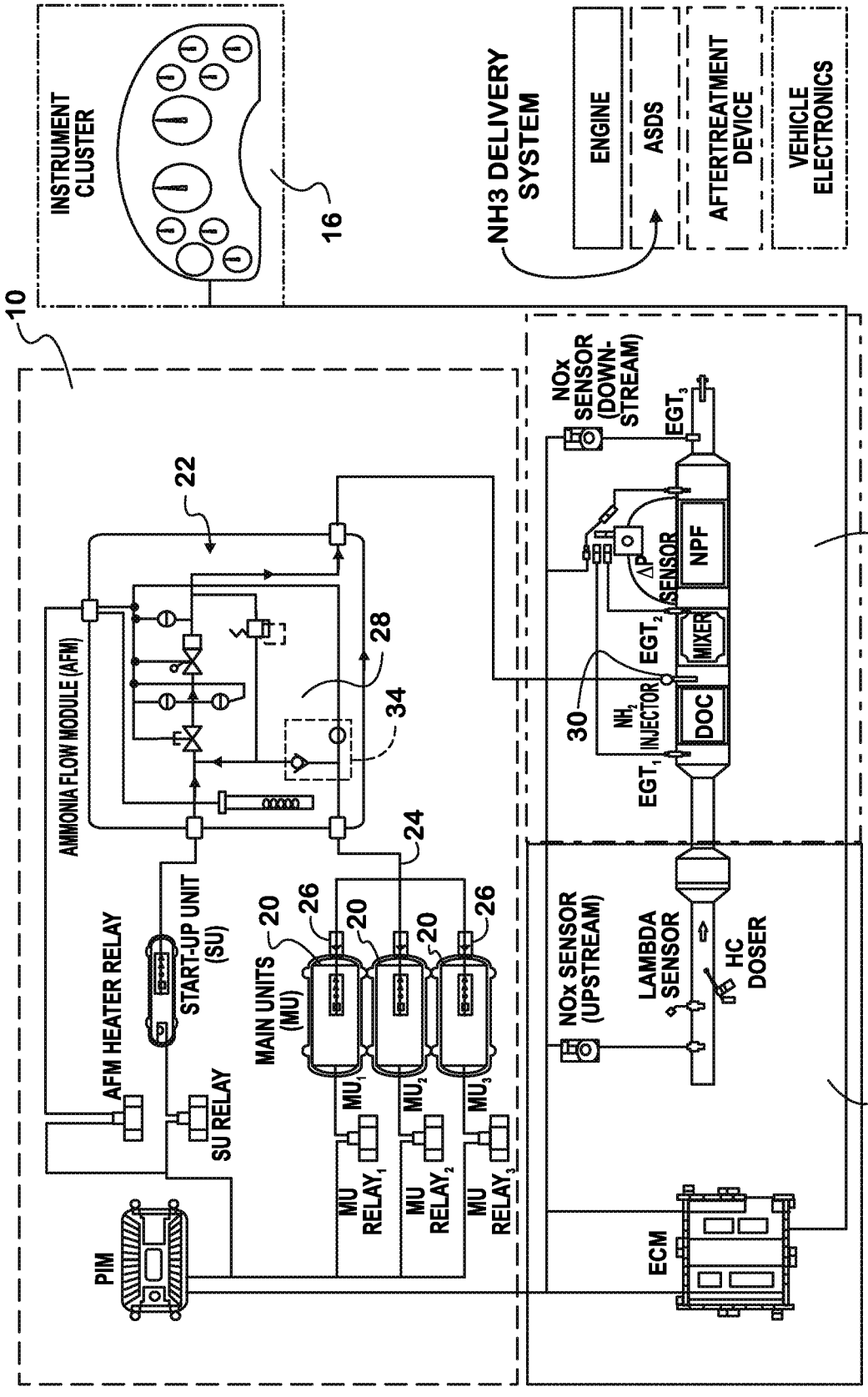
30. The solid ammonium canister status system of Claim 29, wherein the input device comprises an RFID reader/writer electronically coupled to the metering device.

31. The solid ammonium canister status system of Claim 28, wherein the metering device comprises an ammonium flow module.

32. The solid ammonium canister status system of Claim 31, wherein the ammonium flow module controls flow of fluid ammonium from the canister.

33. The solid ammonium canister status system of Claim 31, wherein the memory storage device comprises an RFID tag.

34. The solid ammonium canister status system of Claim 33, wherein the input device comprises an RFID reader/writer electronically coupled to the metering device.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16
NH3 DELIVERY SYSTEM
ENGINE
ASDS
AFTERTREATMENT DEVICE
VEHICLE ELECTRONICS
10
NOx SENSOR (DOWN-STREAM)
EGT3
22
28
34
NPF
ΔP SENSOR
EGT2
MIXER
30
NH2 INJECTOR
DOC
EGT1
14
AMMONIA FLOW MODULE (AFM)
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AFM HEATER RELAY
START-UP UNIT (SU)
SU RELAY
MAIN UNITS (MU)
20
26
MU1
MU2
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HC DOSER
PIM
ECM
12

FIG. 1

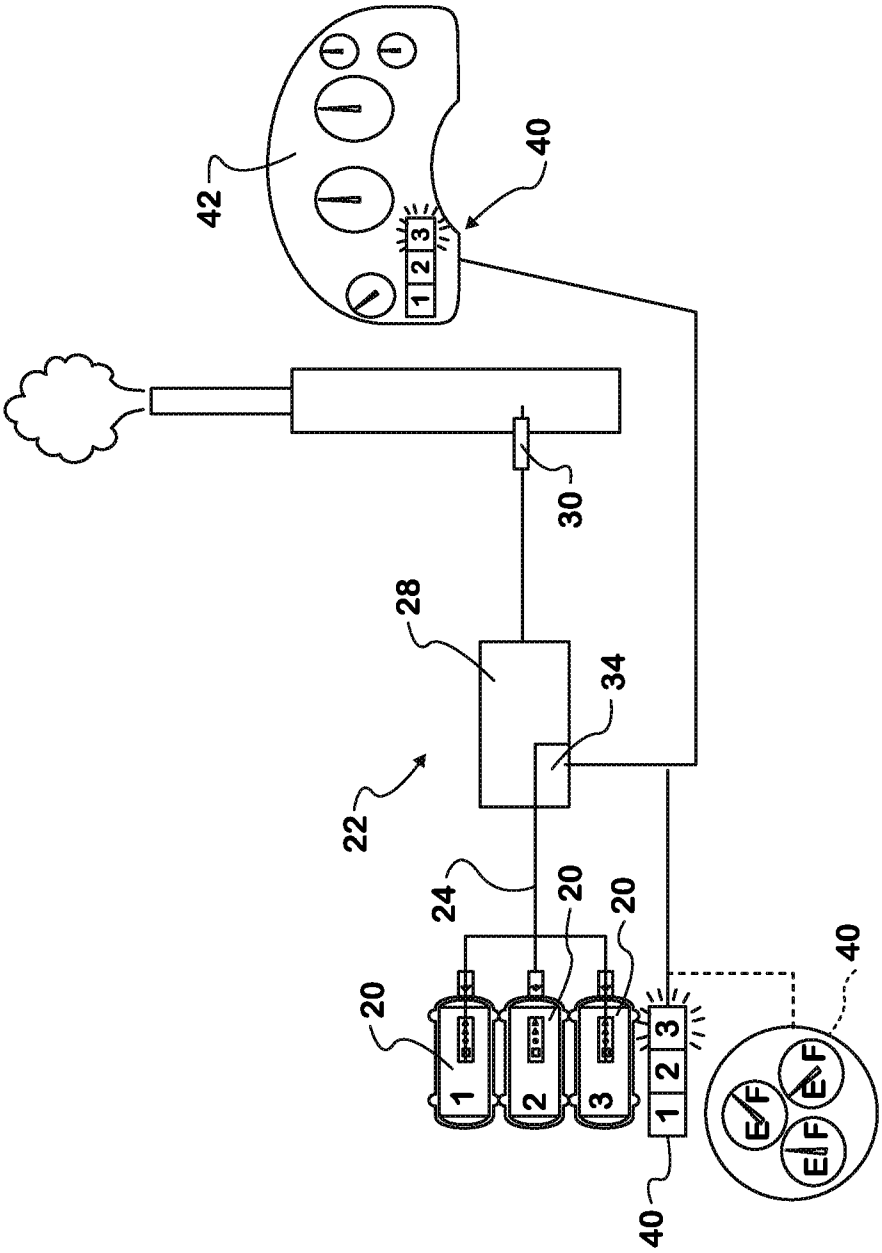

FIG. 2

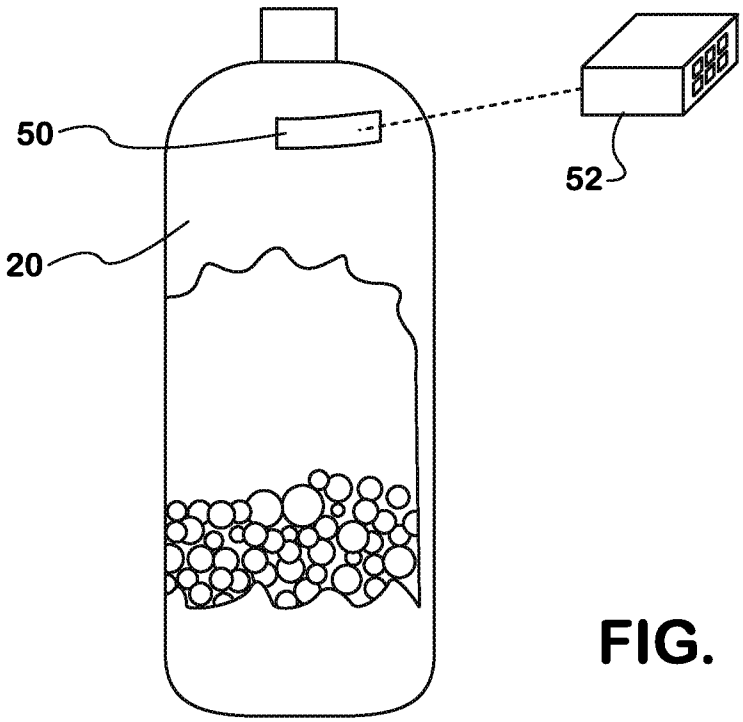

FIG. 3

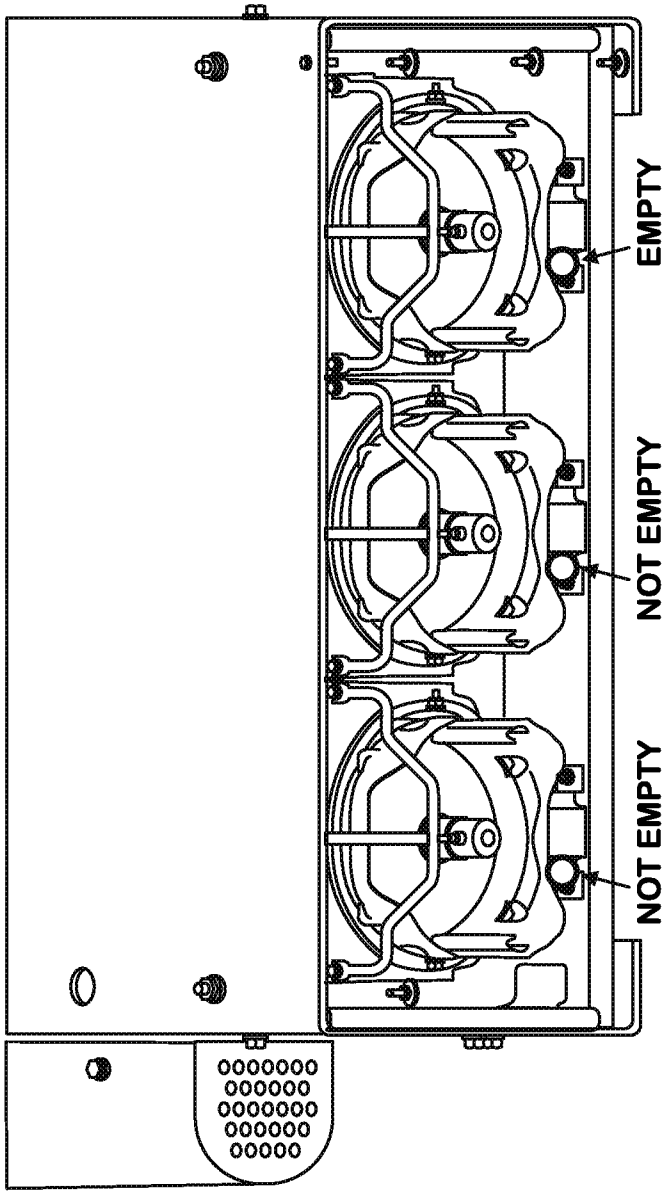

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/49094

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 53/56 (2011.01)
USPC - 60/295; 137/12; 206/.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) -- B01D 53/56 (2011.01)
USPC -- 60/295; 137/12; 206/.7

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) -- B01D 53/56; B01D; F17C; G05D; H01M (2011.01)
USPC -- 60/286, 295, $; 137/12; 206/.7

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB,USPT,USOC,EPAB,JPAB); USPTO; Espacenet; Google Patents; Google Scholar; Google -- AMMONIA AMMONIUM CANISTER CONTAINER DISPLAY$ EMPTY EXHAUST FULL HEAT$ INDICAT$ LED LIGHT LIQUIF$ NOx RFID SOLID STATUS TANK VEHICLE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0293927 A1 (Johannessen et al.) 25 November 2010 (25.10.2010) para [0006]; [0007]; [0008]; [0016]; [0019]; [0052]; [0059]; [0062]	1-20,21A,21B,22-33
Y	US 2006/0145880 A1 (Chi et al.) 06 July 2006 (06.07.2006) [0008]; [0014]; [0020];	1-20,21A,21B,22-33
Y	US 2009/0314798 A1 (Hovinen et al.) 24 December 2009 (24.12.2009) para [0002]; [0026]; [0058]; [0127]; [0131]; [0137]	9,11,20,21A,21B,22-33
A	US 2008/0220721 A1 (Downie et al.) 11 September 2008 (11.09.2008) para [0013]; [0032]	2-8;12-19;24-26;28-33
A	US 2008/0241033 A1 (Nazri) 02 October 2008 (02.10.2008) Figs 1-3; abstract	1-20,21A,21B,22-33
A	US 2008/0058680 A1 (Lee et al.) 06 March 2008 (06.03.2008) para [0055]	2-8;12-19;24-26;28-33

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" 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
11 JAN 2012

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