Title: AMMONIA CANISTER HAVING INTEGRAL ELECTRIC HEATING ELEMENTS

Abstract: A redundant storage and release system having a canister having an exterior housing defining an interior volume, a heating element disposed within the volume of the canister, a supply of redundant material packed within the volume about the heating element, and an outlet positioned on the canister and in fluid communication with the interior volume, is described. An assembly for applying heat and regulating the temperature within an ammonia-containing storage cartridge used in the reduction of NOx in an exhaust stream, is specifically described. In use, the activation of the heating element causes the ammonia-containing material to release ammonia gas, which is discharged from the outlet into a delivery system for a NOx reduction canister. The assembly further comprises a controller for regulating an activation temperature of the heating element in the storage cartridge.
AMMONIA CANISTER HAVING INTEGRAL ELECTRIC HEATING ELEMENTS

TECHNICAL FIELD

[0001] The present system relates to reductant storage and release for use with a vehicle exhaust gas NO\textsubscript{x} reduction system. Specifically, the system relates to an ammonia storage and release system using a storage canister.

BACKGROUND

[0002] Compression ignition engines provide advantages in fuel economy, but produce both NO\textsubscript{x} and particulates during normal operation. New and existing regulations continually challenge manufacturers to achieve good fuel economy and reduce the particulates and NO\textsubscript{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\textsubscript{x} as well. Accordingly, the use of NO\textsubscript{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 in conjunction with an after-treatment device. 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\textsubscript{2}).

[0004] Transporting ammonia as a pressurized fluid, however, can be hazardous if the container bursts caused by 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 many forms, including disks and balls loaded into a metal cartridge or canister. A single cartridge or several cartridges are then loaded into a mantle or other vehicle on-board storage structure and
connected to the appropriate vehicle systems for use. A requisite amount of heat is applied to the cartridges, which then causes the ammonia-containing storage material to release its ammonia gas into an after-treatment device and the exhaust system of a vehicle, for example. Therefore, regulating and maintaining the heat in and around the cartridges is important for consistent and efficient release of ammonia into the exhaust stream, and more effective reduction of NO\textsubscript{x}. An efficient system requires that multiple cartridge system configurations be heated sequentially, with only one cartridge being actively heated at a time. Furthermore, it is desirable to provide heating to the cartridges during all vehicle operations. The disclosed system is easy to use and relatively inexpensive to manufacture and install.

SUMMARY

[0005] There is disclosed herein a device, system and methods, each of which avoids the disadvantages of prior devices, systems and methods while affording additional structural and operating advantages.

[0006] Generally speaking, an ammonia storage and release system comprises a canister having an exterior housing defining an interior volume, a heating element disposed within the volume of the canister, a supply of an ammonia adsorbing/desorbing material packed within the volume about the heating element, and an outlet positioned on the canister and in fluid communication with the interior volume. In use, the activation of the heating element causes solid ammonia to sublimate and the resulting ammonia gas is discharged from the outlet into a delivery system for a NO\textsubscript{x} reduction canister.

[0007] An assembly for applying heat and regulating the temperature within an ammonia-containing storage cartridge used in the reduction of NO\textsubscript{x} in an exhaust stream, is specifically described. The assembly further comprises a controller for regulating an activation temperature of the heating element in the storage cartridge.

[0008] These and other aspects of the invention may be understood more readily from the following description and the appended drawings.
BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic of an exhaust gas NO\textsubscript{x} reduction (EGNR) system incorporating the start-up cartridge and main cartridges of the present system;

[0010] FIG. 2 is a perspective view of the mantel housing containing the main cartridges and the start-up cartridge positioned near but separate from the mantle;

[0011] FIG. 3 is a right side view of the mantle housing;

[0012] FIG. 4 is a left side view of the mantle housing;

[0013] FIG. 5 is a cross-section of an embodiment of the present heating element;

[0014] FIG. 6 is a cross-section of another embodiment of the present heating element;

[0015] FIG. 7 is a cross-section of still another embodiment of the present heating element; and

[0016] FIG. 8 is a schematic illustrating one embodiment of an AFM device in accordance with the present disclosure.

DETAILED DESCRIPTION

[0017] Referring to FIGS. 1-8, there is illustrated a system for storage and delivery of a reductant, such as gaseous ammonia, for use in the reduction of NO\textsubscript{x} in an exhaust gas stream (EGNR). The present flow modulator device, generally designated by the numeral 10, is discussed with respect to ammonia flow control, specifically for controlling the supply of ammonia gas to an after-treatment device 30 (FIG. 1) for use in a compression ignition engine (not shown). As the exhaust system of a vehicle, including that of a diesel engine, is well-known, it will not be described in detail here.

[0018] In the NO\textsubscript{x} reduction system, ammonia gas is delivered to the exhaust stream by way of a fluid tubing 50 connected at one end to an ammonia source 40 and at the other end to an injector 60 positioned within the exhaust stream. As shown in FIGS. 2-4, the ammonia source 40 used for ammonia dosing in the exhaust stream includes a first or start-up unit 12 and a mantle housing 14 having a main unit 16 comprised of at least one cartridge or canister 17. The ammonia-containing material loaded into the cartridges 17 of units 12 and 16—also referred to herein as the start-up cartridge 12 and main cartridge(s) 17—is generally in a solid form, such as a compressed powder or granules, and may include any suitable shape for packing into the cartridges, including disks, balls, granules, or a tightly-packed powder.
Suitable material for use with the present system include metal-ammine salts, which offer a solid storage medium for ammonia, and represent a safe, practical and compact option for storage and transportation of ammonia. Ammonia may be released from the metal ammine salt by heating the salt to temperatures in the range from 10°C to the melting point of the metal ammine salt complex, for example, to a temperature from 30° to 700°C, and preferably to a temperature of from 100° to 500°C. Generally speaking, metal ammine salts useful in the present device include the general formula M(NH$_3$)$_n$X$_z$, where M is one or more metal ions capable of binding ammonia, such as Li, Mg, Ca, Sr, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, etc., n is the coordination number usually 2-12, and X is one or more anions, depending on the valence of M, where representative examples of X are F, Cl, Br, I, S0$_4^{2-},$ Mo0$_4^{2-},$ P0$_4^{3-}$, etc. Preferably, ammonia saturated strontium chloride, Sr(NH3)Cl$_2$, is used. While embodiments using ammonia as the preferred reductant are disclosed, the invention is not limited to such embodiments, and other reductants may be utilized instead of, or in addition to, ammonia for carrying out the inventions disclosed and claimed herein. Examples of such other, or additional reductants include, but are not limited to, urea, ammonium carbamate, and hydrogen.

As noted above, in order to use the ammonia gas in the treatment of NO$_x$ in an exhaust system, it is necessary to apply a sufficient amount of heat to the cartridges of units 12 and 16, and thus the ammonia-containing material, in order to release the solid ammonia into its useful gaseous form. Previous heat sources have been external to the canister 17, such as a heating jacket.

With reference to FIGS. 5-7, heating of the ammonia adsorbing/desorbing material in cartridges 12, 17 is accomplished through use of an internal heating element 100. The heating element 100 of the present system may be embodied in many different forms. Electric heating elements or heat exchange coils using heated vehicle fluid are two possible heating designs. FIG. 5 shows an electric line 102 feeding a plurality of resistive-heating discs 104 spaced within the canister 17. The discs 102 may be heated simultaneously or individually—i.e., starting at the disc closest to the outlet and moving toward the canister bottom. Another alternative of an electric heating element is shown in FIG. 6, which uses a heating coil 106 extending throughout the canister volume. The coil 106 may be disbursed through the canister 17 in a manner which most effectively heats the ammonia adsorbing/desorbing material.
FIG. 7 illustrates a heat exchange coil 110 running through the canister volume. For example, exhaust gas or other heated vehicle fluids can be diverted to heat the solid ammonia of the canister 17. Again, the heat exchange coil may run in a simple pattern, down and up, or it may be staged to create graduated heating in the solid ammonia bed.

Although not shown, it should be understood that the heating element is connected to a power source (not shown) and control device, such as an electronic control module (ECM) 18 to control the amount of heat generated by the heating element, as well as the duration of heating. Similarly, the heating element 100 may include an integrated temperature detection device (thermistor) and pressure sensors (not shown) for sending appropriate signals to the ECM 18 for monitoring and controlling the heating element, even controlling the sequential heating of multiple elements in the system. In this manner, the heating can be controlled within predefined limits, such that it does not damage surrounding components or even the ammonia-containing material within the cartridges.

However, as hot vehicle fluids would not be available at vehicle start-up and electrical heating can take time to reach a critical temperature, these ammonia release systems may require a supplemental heat source at cold starts and other such times.

Accordingly, during the initial start-up of an engine when there is insufficient heated fluids generated to activate the ammonia-containing material, especially material stored in the cartridges 17 of main unit 16 within the mantle housing 14, the start-up unit 12 is used. That is, in order to jump-start the release of ammonia gas into the after-treatment device 30 and the exhaust stream, the smaller first or start-up unit 12 is positioned separately from the mantle 14 containing the cartridges 17 of main unit 16. Because of its significantly smaller size than that of the main cartridges 17, the first or start-up cartridge 12 can be heated quickly after receiving the appropriate signals from the vehicle's electronics system including the electronic control module (ECM) 18 and Peripheral Interface Module (PIM) 20, which are transmitted to the heating device. In this manner, the start-up cartridge 12 can start releasing ammonia gas into an after-treatment device 30 and the exhaust stream practically from the initial start-up of the engine, while the main unit 16 is more slowly readied. The flow of ammonia gas from the start-up unit 12 and the main unit 16 is directed through the ammonia flow modulator 10.

As shown in FIG. 8, the flow modulator 10 comprises a housing 42 having an inlet 44 for each of the start-up unit 12 and main unit 16, an outlet 46, passages 48 which connect the
inlets 44A,B to the outlet 46, and a control valve 52. The passage 48B from the inlet of the main unit intersects the passage 48A from the start-up unit before or upstream of the control valve 52. A check valve 54 may be used to prevent backflow from the start-up unit passage 48A into the main unit passage 48B. Also, a pressure release valve 56 may be positioned to bypass the control valve 52 to prevent damaging the precision orifice of the control valve 52.

[0027] The ammonia flow modulator 10 also contains a plurality of circuits and sensors which are designed to facilitate the flow of a sufficient amount of ammonia gas to the exhaust after-treatment device 30. Each passage 48 may include a pressure sensor 62 and/or a temperature sensor 64 to monitor incoming ammonia gas characteristics. An effluent pressure sensor 65 may be positioned downstream of the control valve 52 as well. A controller 70 is preferably coupled to each of the sensors (pressure and temperature) and valves, including the control valve 52 and pressure release valve 56, to orchestrate proper ammonia delivery from each of the start-up unit 12 and the main unit 16.

[0028] Once the ammonia gas is completely released from the ammonia-containing material contained within the start-up unit 12, and the system temperature has reached a sufficient level to activate the cartridges 16 of the main unit 16, the start-up unit 12 can be replenished with ammonia for subsequent use. Positioning the start-up unit 12 outside of the mantle 14 containing the main unit 16, maximizes the heat loss from the start-up unit 12, and also prevents it from being affected by the heat generated from the main unit 16. Once the cartridge 12 cools to a certain level where the ammonia gas is no longer released from the ammonia-containing material, the material within the unit 12 can be replenished. Replenishing the ammonia-absorbing material can be accomplished in any number of ways, including re-directing a partial flow of ammonia gas released from the main unit cartridges 17 due to the drop in temperature to the start-up cartridge, or replenishing by an outside, exterior source of ammonia gas or liquid, or by any other suitable means.

[0029] In addition, by enclosing the main unit 16 within a mantle housing 14, it is possible to control and maintain the activating temperature required to release the ammonia gas from the material contained within the cartridge or cartridges. The housing 14 acts to minimize the loss of heat to the ambient temperature. Minimizing the temperature loss provides a more efficient and consistent release of ammonia gas from the ammonia-containing material within the main cartridge 17 to an after-treatment device 30.
The start-up cartridge 12 is preferably positioned outside of the mantle housing 14 containing the main cartridges 17 in such a manner that the start-up cartridge is able to cool down quickly without being influenced by any heat generated from the main cartridge unit. In this manner, the ammonia-containing material in the start-up cartridge 12 can be replenished quickly once the cartridge is cooled below the temperature required for sublimation of the solid ammonia to ammonia gas.

Regeneration of the start-up cartridge 12 can be accomplished by directing ammonia gas from the main cartridges 17. Quick regeneration of the start-up cartridge permits it to be ready immediately for the next time the engine is started. The method further comprises a step of maintaining an activating temperature inside the mantle 14 for sufficient release of ammonia gas from the ammonia-containing material within the main cartridge to the after-treatment device 30. In this manner, the method provides for a consistent flow of ammonia into the exhaust stream, and thus, a more efficient and consistent reduction of NOx.
CLAIMS

What is claimed is:

1. A reductant storage and release system comprising:
   a canister having an exterior housing defining an interior volume;
   a heating element disposed within the volume of the canister;
   a supply of reductant material packed within the volume about the heating element; and,
   an outlet positioned on the canister and in fluid communication with the interior volume;
   wherein the activation of the heating element causes solid ammonia to sublimate and the
   resulting ammonia gas is discharged from the outlet.

2. The reductant storage and release system of Claim 1, wherein the heating element is
electric.

3. The reductant storage and release system of Claim 1, wherein the heating element is a
length of tubing filled by hot engine exhaust gas.

4. The reductant storage and release system of Claim 1, wherein the outlet comprises a
valve for controlling the release of ammonia gas.

5. The reductant storage and release system of Claim 2, wherein the electric heating element
comprises a resistance heating element positioned within a central part of the volume.

6. The reductant storage and release system of Claim 5, wherein the electric heating element
further comprises a series of heating plates interspersed with the reductant material.

7. The reductant storage and release system of Claim 2, wherein the electric heating element
connects to a heating jacket positioned to contact an exterior surface of the canister.

8. The reductant storage and release system of Claim 4, further comprising a controller for
controlling the heating element and the outlet valve.

9. The reductant storage and release system of Claim 1, wherein the canister housing
comprises a double-wall.

10. An ammonia storage and release system comprising:
a double-walled canister having an interior volume;
an electric heating element disposed within the volume of the canister;
a controller for activating the heating element;
a supply of ammonia adsorbing/desorbing material packed within the volume about the heating element; and
an outlet positioned on the canister and having a valve in fluid communication with the interior volume;

wherein the activation of the heating element by the controller causes the ammonia adsorbing/desorbing material to release ammonia gas which is discharged from the outlet through the valve.

11. The ammonia storage and release system of Claim 10, wherein the electric heating element further comprises a series of heating plates interspersed with the ammonia adsorbing/desorbing material.

12. The ammonia storage and release system of Claim 11, wherein the electric heating element connects to a heating jacket positioned to contact an exterior surface of the canister.
CLAIMS

What is claimed is:

1. An a reductant storage and release system comprising:

   a canister having an exterior housing defining an interior volume;
   a heating element disposed within the volume of the canister;
   a supply of reduclani material packed within the volume about the heating element; and,
   an outlet positioned on the canister and in liquid communication with the interior volume;

   wherein the activation of the heating element causes solid ammonia to sublime and the
   resulting ammonia gas is discharged from the outlet, wherein the healing element is electric.

2. The reductant storage and release system of Claim 1, wherein the healing element is a
   length of tubing filled by hot engine exhaust gas.

3. The reductani storage and release system of Claim 1, wherein the outlet comprises a
   valve for controlling the release of ammonia gas.

4. The reductani storage and release system of Claim 1, wherein the electric heating element
   comprises a resistance heating element positioned within a central part of the volume.

5. The reductani storage and release system of Claim 4, wherein the electric healing element
   further comprises a series of heating plates interspersed with the reductani material

6. The reductani storage and release system of Claim 1, wherein the electric heating element
   connects to a heating jacket positioned to contact an exterior surface of the canister.
7. The rcduetanl storage and release system of Claim 3, further comprising a controller for controlling the healing element and the oullel valve.

8. The rcduetanl storage and release system of Claim 1, wherein the canister housing comprises a double-wall.

9. An ammonia storage and release system comprising:
   a double-walled canister having an interior volume;
   an electric healing element disposed within the volume of the canister;
   a controller for activating the healing element;
   a supply of ammonia adsorbing/desorbing material packed within the volume about the healing element; and
   an outlet positioned on the canister and having a valve in fluid communication with the interior volume;
   wherein the activation of the heating element by the controller causes the ammonia adsorbing/desorbing material to release ammonia gas which is discharged from the outlet through the valve.

10. The ammonia storage and release system of Claim 9, wherein the electric heating element further comprises a series of healing plates interspersed with the ammonia adsorbing/desorbing material.

11. The ammonia storage and release system of Claim 10, wherein the electric heating element connects to a heating jacket positioned to contact an exterior surface of the canister.
international application no.

INTERNATIONAL SEARCH REPORT
INTERNATIONAL SEARCH REPORT
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01N 3/00 (201.2.01)
USPC - 60/282

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): F01N 3000 (2012.01)
USPC: 60/282

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

IPC(8): F01N 3000 (2012.01)
USPC: 60/272, 282-293

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

PubWEST; PGPB, USPT, EPAB, JPAB; Google Scholar; Google Patent; Search Terms: NH.sub.3 ammonia adsorpt desorpt resorpt tube canister housing heater resistance valve check ball controller computer cool shell canister wall liquid solid fuel pellet powder particulate granule solenoid steel metal reaction

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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</thead>
<tbody>
<tr>
<td>US 201/0005267 A1 (Lambert et al.) 13 January 2011 (13.01.2011) para. [0002] through [03181], Fig. 1-31</td>
<td>1, 3, 4, 8 and 9</td>
</tr>
<tr>
<td>US 2010/0062296 A1 (Johannessen) 11 March 2010 (11.03.2010) para. [0030] through [0092], Fig. 1, 2</td>
<td>2, 5-7 and 10-12</td>
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<tr>
<td>US 2006/0112636 A1 (Chellappa et al.) 01 June 2006 (01.06.2006) entire document</td>
<td>1-12</td>
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Further documents are listed in the continuation of Box C.

- Special categories of cited documents:
  - "A" Document defining the general state of the art which is not considered to be of particular relevance
  - "E" Earlier application or patent but published on or after the international filing data
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06 JUN 2012

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