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(54) **VENTING OF ON-BOARD VEHICLE EMISSIONS TREATMENT SYSTEM**

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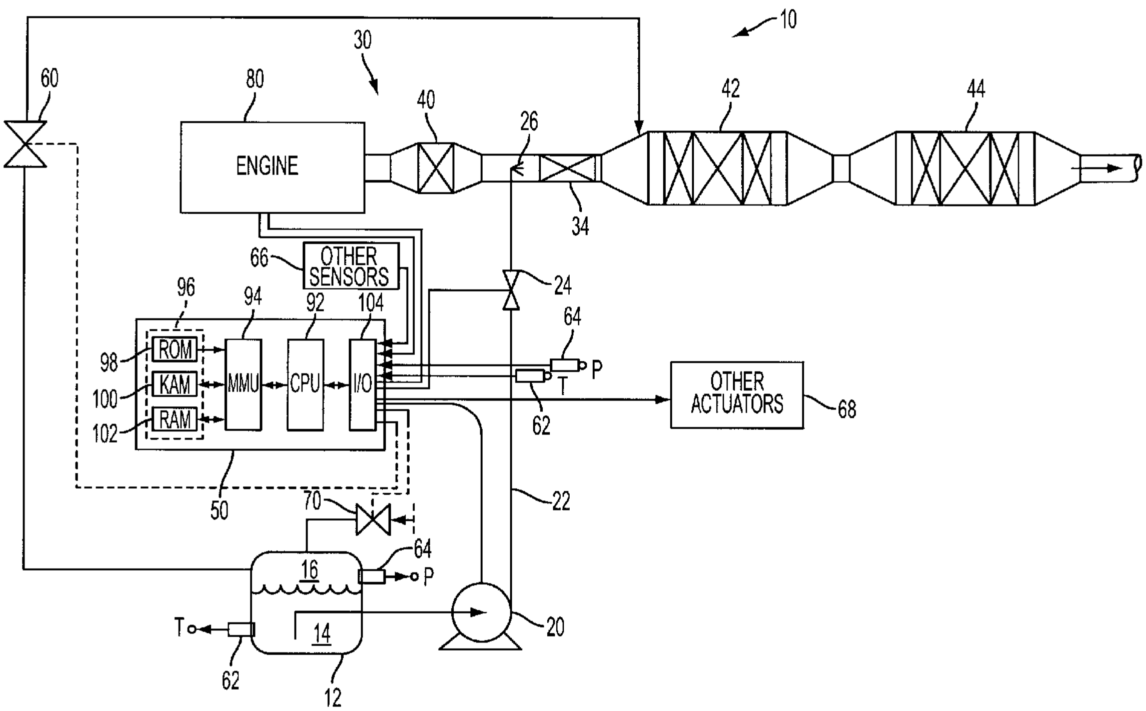
(57) **ABSTRACT**

A system and method for controlling venting of an on-board vehicle emissions treatment substance storage and distribution system that selectively dispenses an emissions treatment substance from a storage tank on the vehicle to an exhaust system of the vehicle include selectively coupling the storage tank to the exhaust system when pressure in the storage tank exceeds a predetermined pressure associated with the exhaust system. The invention may also include selectively coupling the storage tank to atmosphere when a pressure differential between the storage tank and atmosphere exceeds a predetermined pressure differential.



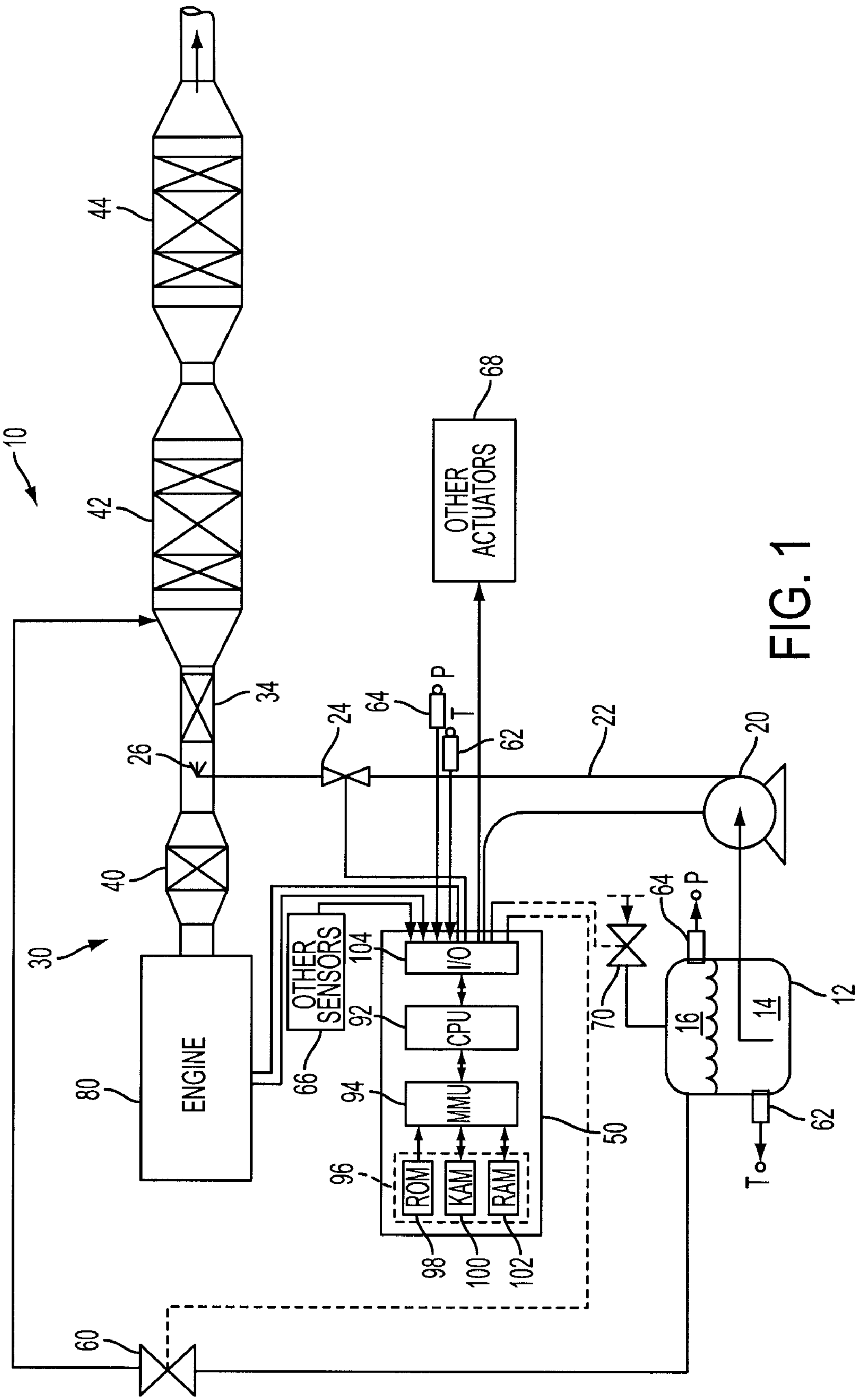

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FIG. 1

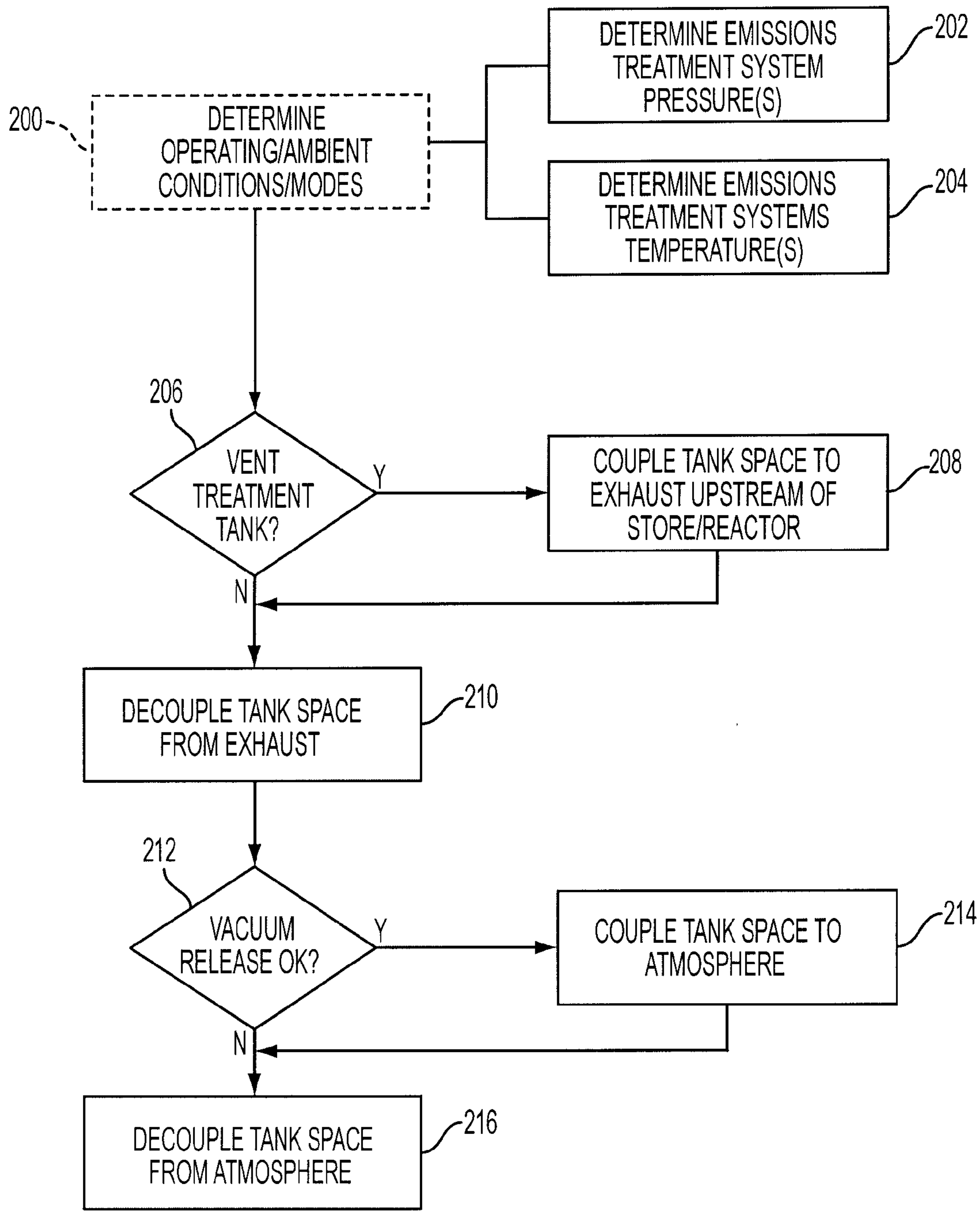
200
DETERMINE OPERATING/AMBIENT CONDITIONS/MODES
DETERMINE EMISSIONS TREATMENT SYSTEM PRESSURE(S)
202
DETERMINE EMISSIONS TREATMENT SYSTEMS TEMPERATURE(S)
204
206
VENT TREATMENT TANK?
Y
N
COUPLE TANK SPACE TO EXHAUST UPSTREAM OF STORE/REACTOR
208
DECOUPLE TANK SPACE FROM EXHAUST
210
212
VACUUM RELEASE OK?
Y
N
COUPLE TANK SPACE TO ATMOSPHERE
214
DECOUPLE TANK SPACE FROM ATMOSPHERE
216

FIG. 2

VENTING OF ON-BOARD VEHICLE EMISSIONS TREATMENT SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to systems and methods for controlling venting of an on-board emissions treatment system of a vehicle.

[0003] 2. Background Art

[0004] Various types of vehicle emission control systems introduce one or more substances directly or indirectly to the engine via the fuel supply, air/fuel intake, exhaust, or directly to an engine cylinder or emissions control device, such as a catalyst. For example, substances acting as reducing agents or reductants, such as aqueous urea or hydrocarbons (other than fuel) may be used in lean air/fuel ratio engine applications including diesel engines in combination with lean NOx catalysts (or selective catalytic reduction (SCR)) to treat nitrous oxide feedgas emissions. These substances generally require a storage and distribution system separate from the primary fuel storage and distribution system.

[0005] Liquid urea selective catalytic reduction (SCR) is a method of mobile exhaust aftertreatment particularly suited for diesel engines for treating oxides of nitrogen (NOx) emissions. In a representative liquid urea SCR application, a urea solution, typically 33% urea in water, is stored on board the vehicle and metered or dosed by a pump and injector into the exhaust where it decomposes by thermal hydrolysis to ammonia and carbon dioxide. Ammonia then reacts over the SCR catalyst to reduce NOx compounds to nitrogen, oxygen, and water before being released to atmosphere.

[0006] Urea stored on-board the vehicle poses unique technical challenges. For example, when subjected to temperatures common for underbody exhaust components, urea stored in the tank may begin to decompose and release ammonia to the air space above the liquid. In an open vented tank system, some ammonia, which is lighter than air, may travel up and out the tank vent. Because ammonia has a pungent odor that most humans can detect in concentrations as low as 5-20 ppmv, it is desirable to minimize or eliminate ammonia escaping from the emissions treatment system. Prior art approaches have employed a selectively operable fan to introduce air into the reductant storage tank or to remove vapors from the tank as disclosed in US2003/0213234 and WO2005/028826, for example.

SUMMARY OF THE INVENTION

[0007] A system and method for controlling venting of an on-board vehicle emissions treatment substance storage and distribution system that selectively dispenses an emissions treatment substance from a storage tank on the vehicle to an exhaust system of the vehicle include selectively coupling the storage tank to the exhaust system when pressure in the storage tank exceeds a predetermined pressure associated with the exhaust system. The invention may also include selectively coupling the storage tank to atmosphere when a pressure differential between the storage tank and atmosphere exceeds a corresponding predetermined pressure differential. The emissions treatment substance storage tank may be coupled to the exhaust system upstream of a catalyst that may store ammonia or facilitate its decomposition to reduce or eliminate ammonia escaping from the vehicle.

[0008] Embodiments of the present invention include an on-board emissions treatment system having a first valve for selectively coupling a vehicle emissions treatment substance storage tank to a vehicle exhaust system when pressure in the storage tank exceeds a predetermined threshold. A passive one-way check valve may be used with a predetermined crack or opening pressure selected to be above the highest anticipated exhaust system pressure to allow selective venting of the storage tank while reducing or eliminating exhaust flow into the storage tank. Alternatively, a computer controlled solenoid valve may be used to selectively couple the storage tank to the vehicle exhaust system based on current engine, vehicle, and/or ambient operating conditions. A second check valve or solenoid valve may be used to selectively couple the storage tank to atmosphere to reduce or eliminate vacuum and associated vacuum lock in the emissions treatment storage and distribution system.

[0009] The present invention provides a number of advantages. For example, the present invention provides a passive control for venting a vehicle emissions treatment system to provide storage and/or treatment of any vapors before being released to atmosphere. The present invention reduces or eliminates detectable odor associated with the release of untreated vapors from a vehicle emissions treatment system. In addition, the invention provides an alternative to open venting without inducing vacuum lock in the emission treatment system.

[0010] The above advantages and other advantages and features of the present invention will be readily apparent from the following detailed description of the preferred embodiments when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a block diagram illustrating one embodiment of a system or method for controlling venting of an on-board vehicle emissions treatment system according to the present invention; and

[0012] FIG. 2 is flow chart illustrating operation of one embodiment of a system or method for controlling venting of an on-board emissions treatment system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0013] As those of ordinary skill in the art will understand, various features of the present invention as illustrated and described with reference to any one of the Figures may be combined with features illustrated in one or more other Figures to produce embodiments of the present invention that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. However, various combinations and modifications of the features consistent with the teachings of the present invention may be desired for particular applications or implementations.

[0014] Referring now to FIG. 1, a block diagram illustrating one embodiment of a system or method for controlling an on-board vehicle emissions treatment system according to the present invention is shown. System **10** includes an emissions treatment substance storage tank **12** mounted on a vehicle (not shown). Storage tank **12** may be used to store an emissions treatment substance **14**, which may include, but is not limited to various reducing agents or reductants such as aqueous urea, hydrocarbons (other than the primary fuel), etc. Storage tank **12** may be a single or multiple wall storage tank having a generally rigid exterior and may optionally include an interior bladder that contains emissions treatment substance **14**. However, the present invention is independent of the particular type of storage tank **12**. Storage tank **12** includes a vapor/air space **16** that varies in volume relative to the quantity of emissions treatment substance **14** in tank **12**. A fill pipe (not shown) extends from storage tank **12** and terminates at a filler neck adapted for receiving a filling nozzle to add emissions treatments substance **14** to storage tank **12**.

[0015] Pump **20** is fluidly coupled to storage tank **12** and in communication with controller **50**, which controls operation of pump **20**. During operation, pump **20** pumps emissions treatment substance **14** from tank **12** to pressurize a supply line **22**. A dosing or metering valve **24** is selectively controlled by controller **50** in response to current operating conditions or parameters of exhaust system **30** and/or engine **80** to deliver emissions treatment substance **14** via a corresponding nozzle or injector **26** to exhaust system **30** upstream of a mixing element or mixer **34**, which mixes exhaust flow from engine **80** with injected emissions treatment substance **14**. Exhaust system **30** includes various emissions control/treatment devices that may include a pre-oxidation catalyst **40**, a selective catalytic reduction (SCR) catalyst **42**, and a diesel particulate filter (DPF) **44**, for example. Of course, the presence and/or sequence of particular emissions treatment/control devices may vary depending upon the particular type of fuel, engine control strategy, and other factors affecting a particular application or implementation and the present invention is independent of the particular types or sequence of emissions treatment/control devices.

[0016] As also illustrated in FIG. **1**, system **10** includes a venting valve **60** disposed between storage tank **12** and exhaust system **30**. Venting valve **60** opens to selectively fluidly couple space **16**, preferably above a maximum level of emissions treatment substance **14**, of storage tank **12** to exhaust system **30** when pressure in storage tank **12** exceeds a predetermined pressure, such as a pressure associated with exhaust system **30**, for example. Venting valve **60** closes to decouple space **16** of storage tank **12** from exhaust system **30** when pressure in exhaust system **30** is greater than pressure within storage tank **12**. In one embodiment, venting valve **60** is implemented by a passive mechanical valve that operates solely in response to the pressure in storage tank **12** to open when the pressure in tank **12** exceeds a predetermined pressure and to close when the pressure in tank **12** is less than the predetermined pressure. For example, a passive one-way mechanical valve may be implemented by a spring-biased ball check valve that has a selected opening or crack pressure associated with the spring constant and aperture size. The opening or crack pressure of venting valve **60** may be selected or determined based on the maximum anticipated pressure in exhaust system **30** so that valve **60** opens only when tank pressure exceeds exhaust pressure to prevent the flow of exhaust into tank **12**. In an alternative embodiment, venting valve **60** is implemented by an active/controllable valve, such as a solenoid valve, in communication with controller **50** and may be electrically, pneumatically, or electromagnetically actuated in response to one or more vehicle and/or ambient operating conditions, modes, and/or parameters. For example, an active venting valve **60** may be selectively operated directly or indirectly in response to a temperature sensor **62** and/or pressure sensor **64**, which may trigger operation of venting valve **60** directly, or may communicate with a dedicated or general purpose controller **50** that actuates venting valve **60** in response to signals received from sensors **62**, **64**, and/or other sensors **66** and/or other actuators **68**.

[0017] In the representative embodiments illustrating the present invention, space **16** of storage tank **12** is vented to exhaust system **30** via selective fluid coupling facilitated by venting valve **60**. Fluid coupling of space **16** to exhaust system **30** directs vapors away from the vehicle, particularly during filling of emissions treatment substance storage tank **12**. While venting of tank **12** away from an associated filling tube (not shown) according to the present invention reduces or eliminates detection of odor during filling of tank **12** by vehicle operators/occupants, additional benefits of the invention may be provided by venting tank **12** to a device that can decompose or store the vapor for future treatment to reduce or eliminate vapor escape from system **10**. In the representative embodiment illustrated in FIG. **1**, tank **12** is selectively coupled to exhaust system **30** upstream of a vapor storage/decomposition device implemented by SCR catalyst **42**. Depending upon the current operating temperature of SCR catalyst **42**, vapor from tank **12** will react with exhaust flow from engine **80** in exhaust system **30**, or may be stored by SCR catalyst **42** and subsequently reacted when a suitable operating temperature is reached. For example, if valve **60** opens while engine **80** is operating or has just been shut off and SCR catalyst **42** has reached an appropriate operating temperature, vapor from tank **12** will be reacted with exhaust constituents in SCR catalyst **42**. If valve **60** opens based on pressure in tank **12** exceeding a predetermined pressure threshold due to refilling of substance **14**, or due to increasing temperature of tank **12** when SCR catalyst **42** is below operating temperature, vapor is stored by SCR catalyst **42** for subsequent reaction.

[0018] As also illustrated in FIG. **1**, system **10** may include a vacuum release valve disposed between storage tank **12** and atmosphere. Vacuum release valve **70** selectively couples atmosphere to space **16** of storage tank **12** when a pressure differential between atmosphere and storage tank **12** exceeds a predetermined level or threshold. Vacuum release valve **70** closes to decouple space **16** of storage tank **12** from atmosphere when the differential pressure is below the predetermined threshold. Vacuum release **70** may be implemented by a passive one-way mechanical device that operates solely in response to the pressure differential between storage tank **12** and atmosphere, or may be actively controlled by a sensor or controller, such as pressure sensor **64** or controller **50**, for example, in response to one or more operating conditions, modes, and/or parameters. In one embodiment, a vacuum release device **70** is implemented by a mechanical device such as a spring-biased check valve that allows air to enter space **16** while preventing vapor egress from space **16** of tank **12** to atmosphere. Preferably, the opening or cracking pressure of vacuum release valve or device **70** is selected to allow air to enter space **16** when even a small pressure differential, such as ⅓ psig is present to avoid vacuum lock of pump **20**. Those of ordinary skill in the art will recognize that various other types of valves or flow control devices may be used depending upon the particular application to provide the features and advantages of the present invention that may include but are not limited to mechanically, electrically, magnetically, electromagnetically, or pneumatically actuated valves, for example.

[0019] As those of ordinary skill in the art will appreciate, system **10** includes various conventional sensors **66** and actuators **68** in addition to those specifically illustrated in FIG. **1** to control system **10**. Various sensors and actuators may communicate with at least one dedicated or general-purpose controller **50** that includes a microprocessor **92**, also called a central processing unit (CPU), in communication with a memory management unit (MMU) **94**. MMU **94** controls movement of data and/or instructions among various computer readable storage media **96** and communicates data to and from CPU **92**. The computer readable storage media preferably include volatile and nonvolatile or persistent storage in read-only memory (ROM) **98**, keep-alive memory (KAM) **100**, and random-access memory **102**, for example. KAM **100** may be used to store various engine and/or ambient operating variables while CPU **92** is powered down. Computer-readable storage media **96** may be implemented using any of a number of known memory devices such as PROMs (programmable read-only memory), EPROMs (electrically PROM), EEPROMs (electrically erasable PROM), flash memory, or any other electric, magnetic, optical, or combination memory devices capable of storing data, some of which represent executable instructions, used by CPU **92** in controlling system **10**. Computer-readable storage media **96** may also include floppy disks, CD-ROMs, hard disks, and the like depending upon the particular application. CPU **92** communicates with the sensors and actuators via an input/output (I/O) interface **104**. Interface **104** may be implemented as a single integrated interface that provides various raw data or signal conditioning, processing, and/or conversion, short-circuit protection, and the like. Alternatively, one or more dedicated hardware or firmware chips may be used to condition and process particular signals before being supplied to CPU **92**. Some controller architectures do not contain an MMU **94**. If no MMU **94** is employed, CPU **92** manages data and connects directly to ROM **98**, KAM **100**, and RAM **102**. Of course, the present invention could utilize more than one controller **90** or more than one CPU **92** to provide system control and each controller **90** may contain multiple ROM **98**, KAM **100**, and RAM **102** coupled to MMU **94** or CPU **92** depending upon the particular application.

[0020] FIG. **2** is a flow chart illustrating operation of a system or method for controlling venting of an on-board vehicle emissions treatment substance storage and distribution system according to one embodiment of the present invention. As those of ordinary skill in the art will appreciate, the diagram of FIG. **2** generally represents a control process or logic, some of which may be implemented by any one or more of a number of known processing strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various steps or functions illustrated may be performed in the sequence illustrated, in parallel, or in some cases omitted. Likewise, the order of processing is not necessarily required to achieve the features and advantages of the invention, but is provided for ease of illustration and description. Although not explicitly illustrated, one of ordinary skill in the art will recognize that one or more of the illustrated steps or functions may be repeatedly performed depending upon the particular processing strategy or implementation.

[0021] Steps of the process performed by a controller may be implemented primarily in software executed by a microprocessor-based controller that may be dedicated to controlling the emissions treatment system, or may also be used to control the engine and/or vehicle. Of course, these steps may be implemented in software, hardware, or a combination of software and hardware depending upon the particular application. When implemented in software, the control logic is preferably provided in a computer-readable storage medium having stored data representing instructions executed by a computer or controller to control the system. The computer-readable storage medium or media may be any of a number of known physical devices which utilize electric, magnetic, and/or optical devices to temporarily or persistently store executable instructions and associated calibration information, operating variables, and the like.

[0022] Block **200** represent of FIG. **2** represents optionally determining operating and/or ambient parameters associated with the engine, vehicle, and/or emissions treatment system and may include determining pressure(s) **202** and/or temperature(s) **204** associated with an emissions treatment system including an emissions treatment substance storage tank and/or one or more exhaust system components, such as catalysts. Temperature(s) and/or pressure(s) may be measured by corresponding sensors and/or inferred based on one or more operating modes, conditions, or parameters. Of course, for implementations using a passive flow control device for selective coupling of the emissions treatment storage tank, this step is unnecessary. Block **206** generally represents a determination of whether to vent the emissions treatment substance storage tank in response to current operating conditions or modes. If block **206** determines that venting of the tank is desired, block **208** actuates one or more flow control devices to selectively couple the on-board vehicle emissions treatment substance storage tank to the exhaust system of the vehicle in response to at least one operating condition and/or parameter. For example, the selective coupling may be performed by actuating a solenoid valve in response to operating and/or ambient conditions as determined by corresponding sensors and/or actuators. Alternatively, selective coupling represented by block **208** may be performed by a mechanical device operating solely in response to one or more operating conditions, such as temperature and/or pressure within the emissions treatment substance storage tank and/or exhaust system. Depending upon the particular application and implementation, the selective coupling may be performed in response to a predetermined pressure or pressure differential exceeding a predetermined threshold with the threshold based on an absolute or differential pressure associated with the exhaust system of the vehicle to reduce or eliminate exhaust flow into the storage tank. As also generally represented by block **208**, a space above the maximum fluid fill level of the storage tank is preferably selectively connected to the exhaust system upstream of a treatment device capable of storing and/or treating vapors exiting the emissions treatment substance storage tank. In one embodiment, vapors from the emissions treatment substance storage tank are selectively introduced to the exhaust system upstream of an

SCR catalyst and downstream of the emissions treatment substance injector and mixing device.

[0023] If block **206** determines that current operating conditions and/or mode are not favorable or do not require tank venting, the system and method decoupling the storage tank from the exhaust system in response as represented by block **210**. This step or function may include controlling one or more devices to decouple or block flow between the storage tank and exhaust system. For example, the system or method may decouple the storage tank space from the exhaust system when the storage tank pressure is below a predetermined pressure or pressure differential that may be selected to include hysteresis for actively controlled valve applications.

[0024] As also illustrated in FIG. **2**, the present invention may include a determination for selectively coupling the emissions treatment substance storage tank to atmosphere as represented by block **212**. If current operating conditions and/or operating mode are suitable for vacuum release, then the emissions treatment substance storage tank is coupled to atmosphere as represented by block **214**. Operating conditions may include ambient and/or system temperature(s) and/or pressure(s), operating state of pump **20**, engine **80**, and the like.

[0025] Preferably, a vacuum release device operates in response to a pressure differential between the storage tank and atmosphere to couple the storage tank to atmosphere and allow air to enter the storage tank and to subsequently decouple the storage tank from atmosphere as represented by block **216** to stop vapor egress from the storage tank to atmosphere.

[0026] Although described with reference to coupling and decoupling the storage tank space to the exhaust system and/or atmosphere, those of ordinary skill in the art will recognize that these features of the invention may be stated differently as controlling egress of vapors from the storage tank while allowing ingress of air to prevent vacuum lock of an associated emissions treatment system pump.

[0027] As such, the present invention provides a passive or active control for venting a vehicle emissions treatment system to provide storage and/or treatment of any vapors before being released to atmosphere. The present invention reduces or eliminates detectable odor associated with the release of untreated vapors from a vehicle emissions treatment system. In addition, the invention provides an alternative to open venting without inducing vacuum lock in the emission treatment system.

[0028] While the best mode for carrying out the invention has been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.

1. A method for controlling an on-board vehicle emissions treatment system that selectively dispenses an emissions treatment substance from a storage tank to an exhaust system of the vehicle, the method comprising:

selectively coupling the storage tank to the exhaust system in response to pressure in the storage tank exceeding a predetermined pressure associated with the exhaust system and decoupling the storage tank from the exhaust system otherwise to reduce or eliminate backflow of exhaust into the storage tank.

2. The method of claim 1 wherein the exhaust system includes a catalyst and wherein the step of selectively coupling comprises selectively coupling a portion of the storage tank above a maximum level of the emissions treatment substance to the exhaust system upstream of the catalyst to selectively deliver vapors from the storage tank to the exhaust system.

3. The method of claim 1 wherein the predetermined pressure associated with the exhaust system corresponds to a maximum anticipated exhaust pressure and wherein the step of selectively coupling comprises positioning a passive valve between the storage tank and the exhaust system that operates solely in response to a pressure differential across the valve to open when the pressure in the storage tank exceeds the predetermined pressure and to close when the pressure in the storage tank is less than the predetermined pressure.

4. The method of claim 1 wherein the step of selectively coupling comprises positioning a one-way valve between the storage tank and the exhaust system wherein the one-way valve opens when the pressure in the storage tank exceeds the predetermined pressure.

5. The method of claim 1 wherein the step of selectively coupling comprises controlling a solenoid valve disposed between the storage tank and the exhaust system such that the solenoid valve opens when the pressure in the storage tank exceeds the predetermined pressure associated with the exhaust system.

6. The method of claim 1 further comprising selectively coupling the storage tank to atmosphere when a pressure differential between the storage tank and atmosphere exceeds a predetermined pressure differential.

7. The method of claim 6 wherein the step of selectively coupling the storage tank to atmosphere comprises positioning a one-way valve between the storage tank and atmosphere, the one-way valve opening when the pressure differential between the storage tank and atmosphere exceeds the predetermined pressure differential to provide air from atmosphere to the storage tank, and closing when the pressure differential between the storage tank and atmosphere is less than the predetermined pressure differential to prevent vapor egress from the storage tank.

8. The method of claim 6 wherein the step of selectively coupling the storage tank to atmosphere comprises controlling a solenoid valve positioned between the storage tank and atmosphere to selectively provide air to the storage tank.

9. An on-board vehicle emissions treatment system that selectively dispenses an emissions treatment substance from a storage tank on the vehicle to an exhaust system of the vehicle, the emissions treatment system comprising:

a venting valve disposed between the storage tank and the exhaust system, the venting valve selectively coupling the storage tank to the exhaust system when pressure in the storage tank exceeds a predetermined pressure associated with the exhaust system, and decoupling the storage tank from the exhaust system otherwise to reduce or eliminate exhaust backflow toward the storage tank.

10. The emissions treatment system of claim 9 further comprising:

a vacuum release valve disposed between the storage tank and atmosphere, the vacuum release valve selectively coupling atmosphere to the storage tank when a pressure differential between atmosphere and the storage tank exceeds a predetermined level and decoupling the storage tank from atmosphere otherwise.

11. The emissions treatment system of claim 10 wherein the vacuum release valve operates solely in response to the pressure differential between the storage tank and atmosphere.

12. The emissions treatment system of claim 9 wherein at least one of the venting valve and the vacuum release valve comprises a solenoid valve, the emissions treatment system further comprising:

a controller in communication with the at least one valve for selectively controlling the valve in response to current operating conditions.

13. The emissions treatment system of claim 9 wherein the venting valve operates solely in response to a pressure differential between the storage tank and the exhaust system.

14. The emissions treatment system of claim 9 further comprising:

a catalyst disposed downstream of an internal combustion engine, wherein the venting valve selectively couples the storage tank to the exhaust system upstream of the catalyst.

15. The emissions treatment system of claim 9 wherein the venting valve opens when the pressure in the storage tank exceeds a maximum exhaust pressure associated with operation of an internal combustion engine of the vehicle.

16. A computer readable storage medium having stored data representing instructions executable by a computer to control an emissions treatment system of a vehicle, the emissions treatment system selectively dispensing an emissions treatment substance from a storage tank on the vehicle to an exhaust system of the vehicle, the emissions treatment system including a conduit with a controllable valve disposed between the storage tank and the exhaust system for selectively venting vapors from the storage tank to the exhaust system, the computer readable storage medium comprising:

instructions for controlling the valve to open in response to pressure in the storage tank exceeding exhaust system pressure to reduce or prevent backflow of exhaust into the storage tank.

17. The computer readable storage medium of claim 16 wherein the predetermined pressure corresponds to a maximum anticipated exhaust pressure to prevent exhaust from entering the storage tank when the valve is open.

18. The computer readable storage medium of claim 16 wherein the emissions treatment system includes a controllable vacuum release valve and wherein the computer readable storage medium comprises instructions for controlling the vacuum release valve in response to atmospheric pressure exceeding pressure of the storage tank by a predetermined amount.

19. The computer readable storage medium of claim 16 further comprising instructions for periodically opening the valve to deliver vapor from the storage tank to the exhaust system.

20. The computer readable storage medium of claim 16 further comprising instructions for opening the valve in response to temperature of at least one exhaust system component.

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