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(54) METHOD AND APPARATUS FOR REDUCING NOX EMISSIONS

(76) Inventors: **Oscar A. Lecea**, Grand Blanc, MI (US); **Joseph G. Ralph**, Owosso, MI (US); **David A. Goulette**, Marine City, MI (US)

Correspondence Address:
Paul L. Marshall
Delphi Technologies, Inc.
M/C 480-410-202
P.O. Box 5052
Troy, MI 48007 (US)

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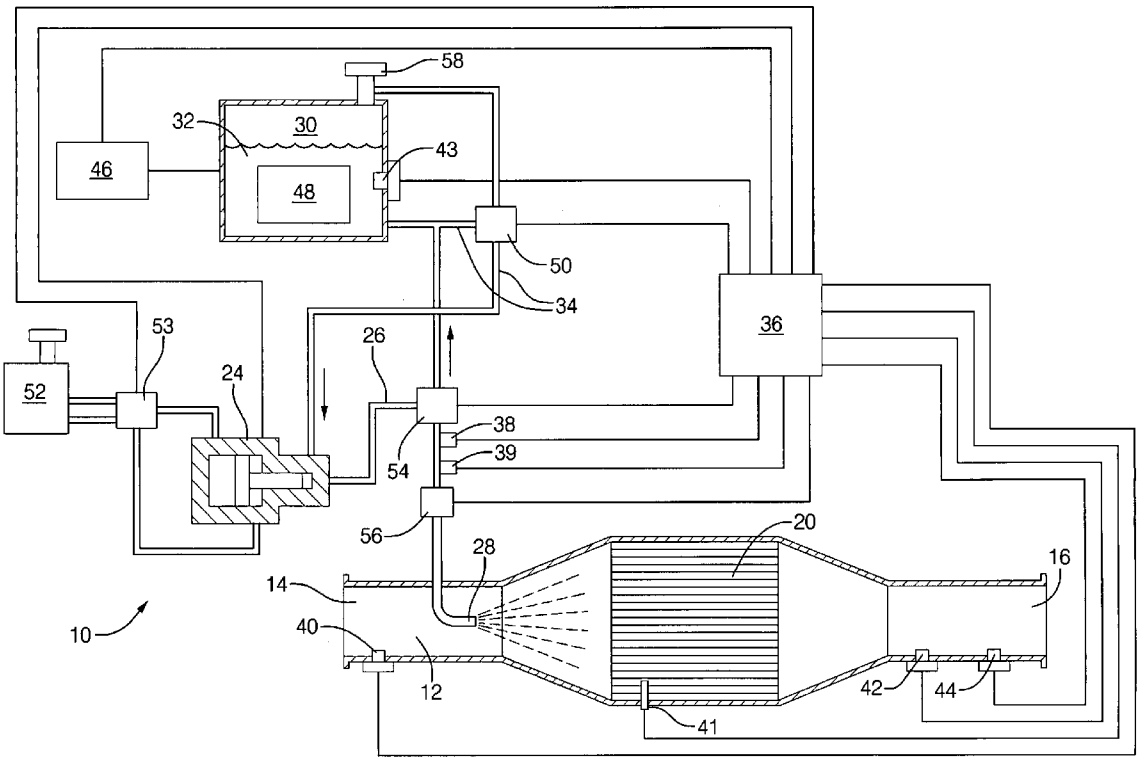
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(57) **ABSTRACT**

In one embodiment, a reductant system comprises: a high pressure reductant pump in operable communication with a power source, wherein the reductant pump comprises a reductant chamber and is capable of pressurizing reductant to a pressure of greater than or equal to 500 psi; a reductant reservoir in fluid communication with the reductant chamber; and an atomizer in fluid communication the reductant chamber. In another embodiment, the reductant system comprises: a reductant pump; system pump in operable communication the reductant pump, a reductant reservoir in fluid communication with the reductant chamber, and an atomizer in fluid communication the reductant chamber. The system pump is configured to provide motive power via a pressurized fluid to the reductant pump, and the system pump is fluidly isolated from a reductant chamber in the reductant pump.



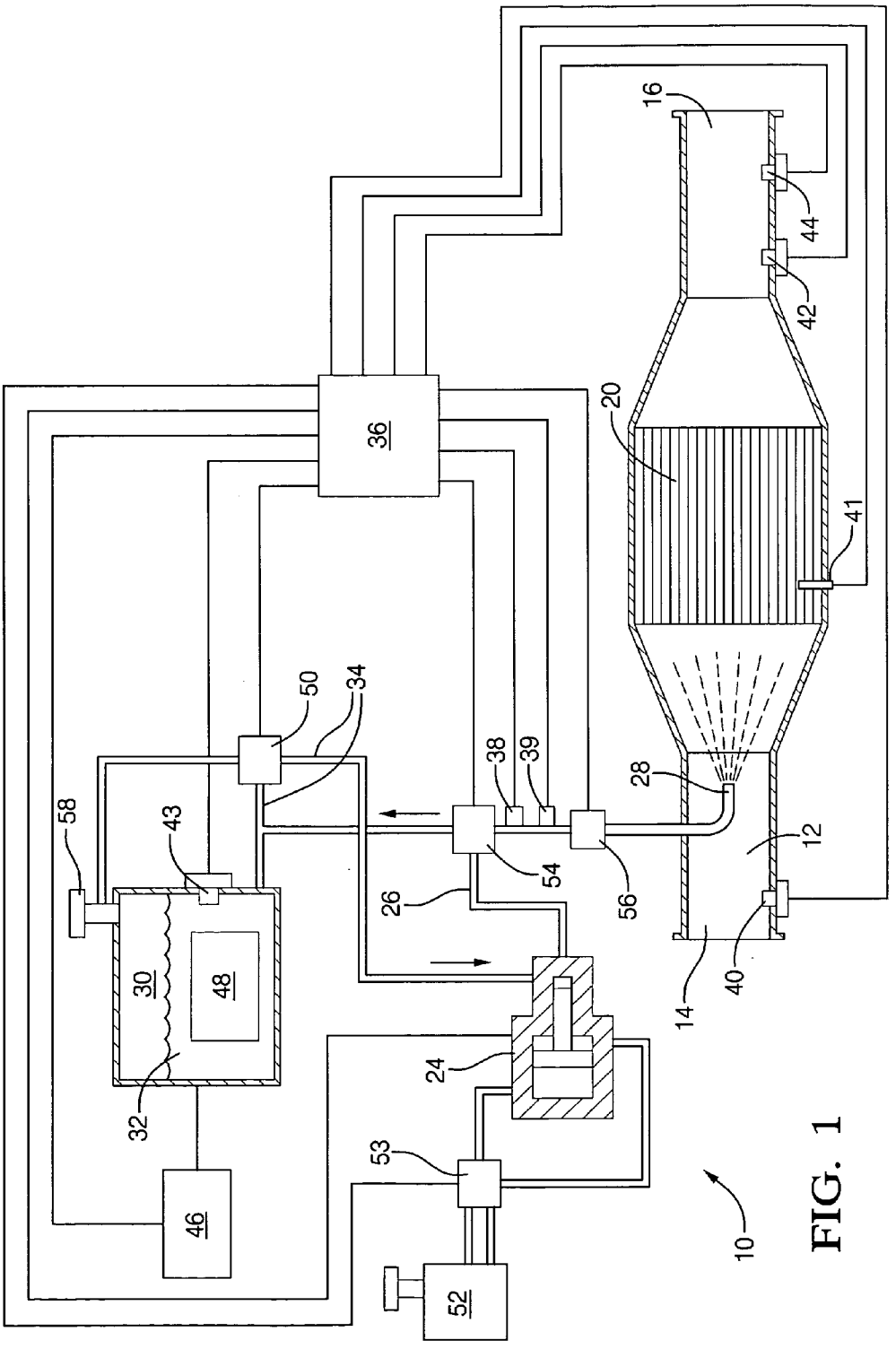

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FIG. 1

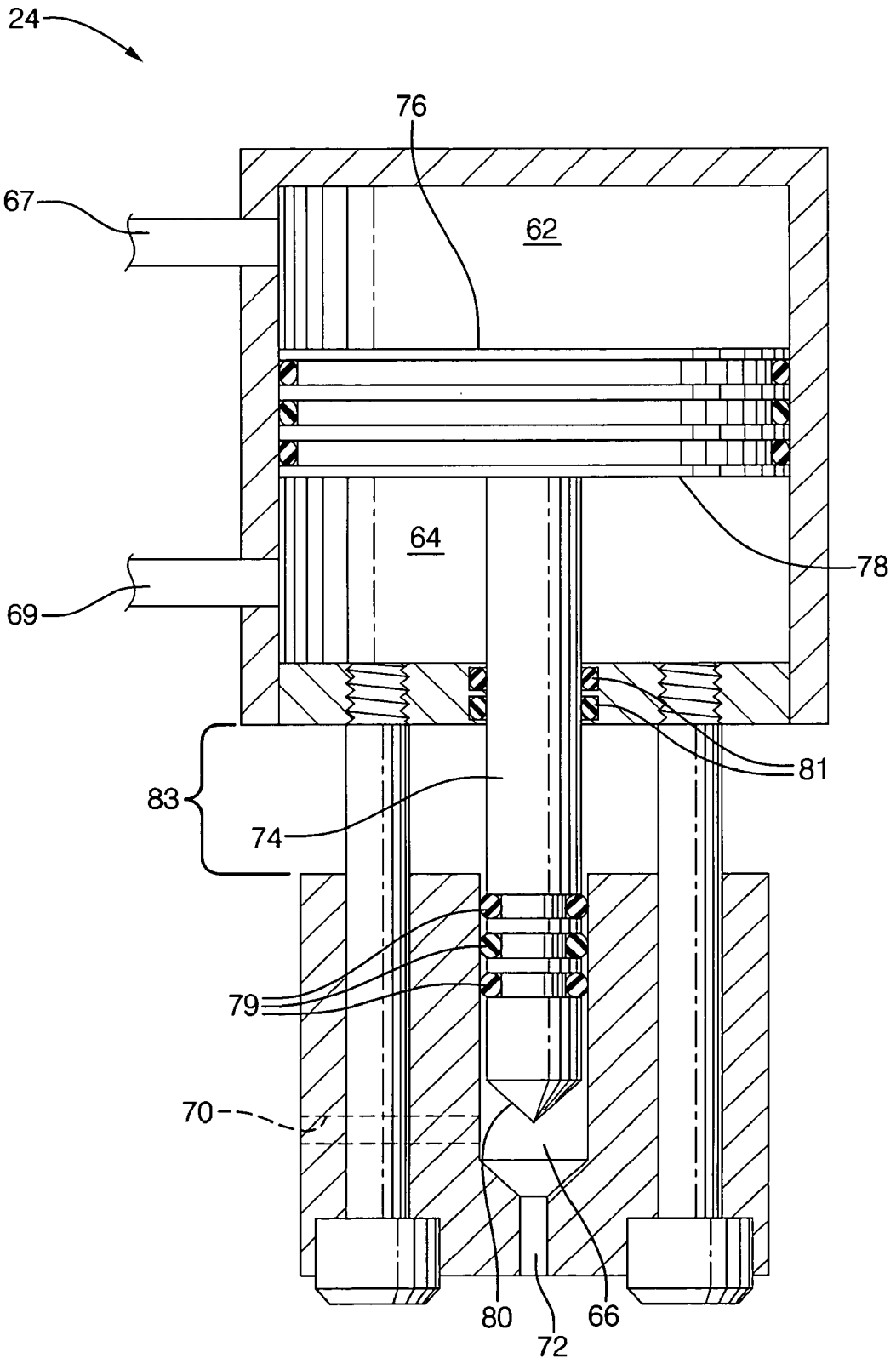


FIG. 2

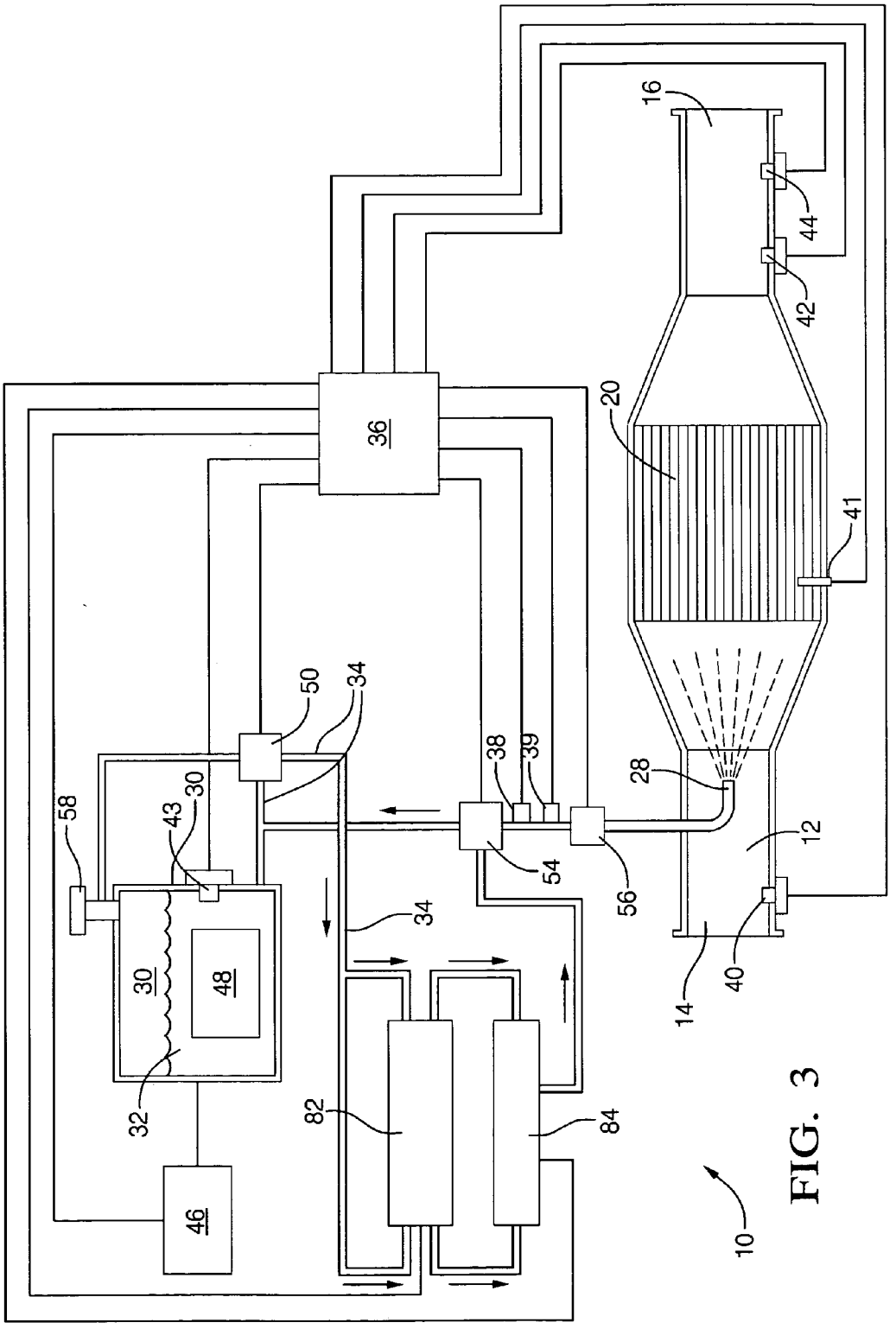

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FIG. 3

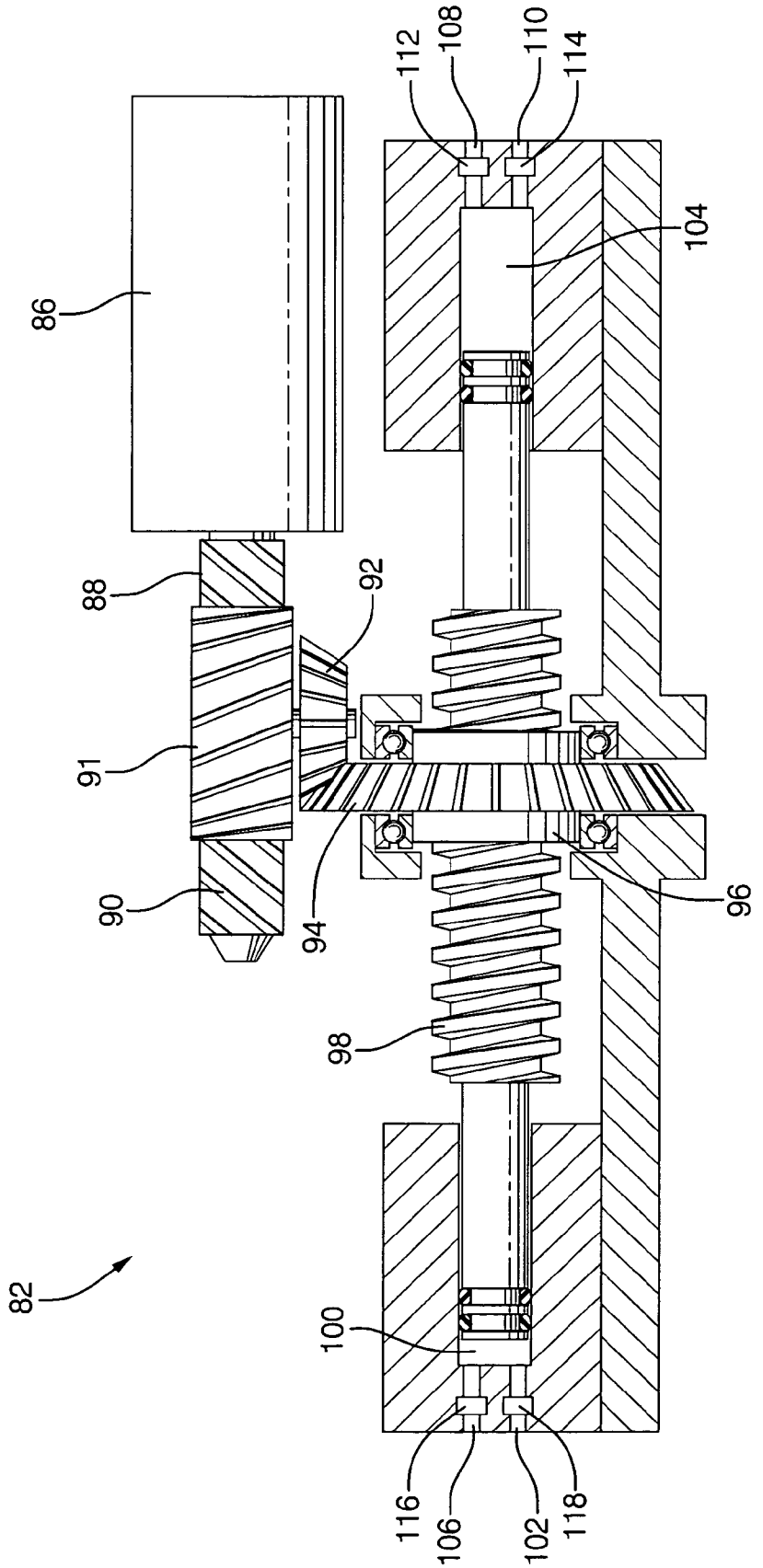


FIG. 4

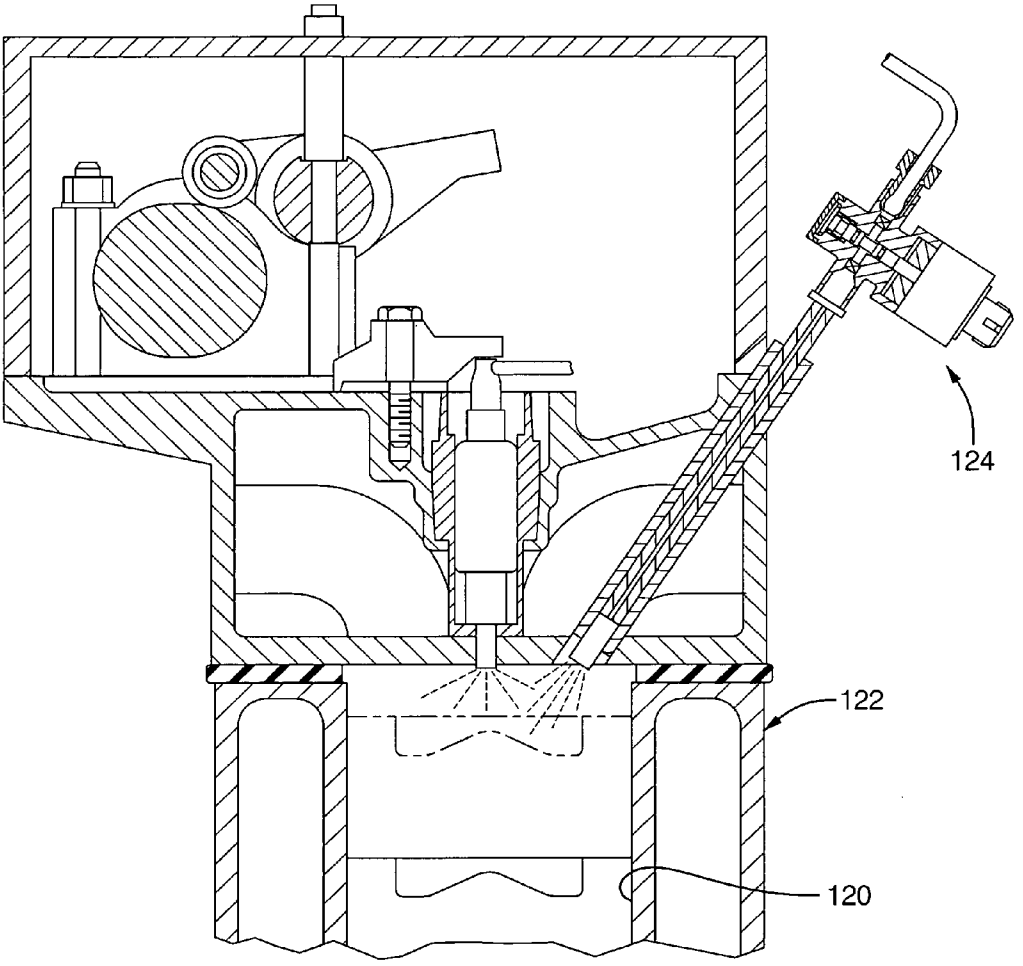


FIG. 5

METHOD AND APPARATUS FOR REDUCING NOX EMISSIONS

TECHNICAL FIELD

[0001] This disclosure relates generally to a method and system for reducing nitrogen oxides (NOx), and more specifically relates to a method and system for reducing NOx emissions from the exhaust gas feedstream.

BACKGROUND

[0002] Internal combustion engines emit undesirable pollutants in their exhaust stream. Those pollutants include NOx such as nitrogen monoxide, nitrogen dioxide. NOx is generated from internal combustion engines such as diesel engines, and large combustion apparatuses such as cogenerators. Accordingly, exhaust systems are coupled to the engine to limit and/or remove the pollutants from the exhaust system. Technologies have been and continue to be developed to attenuate these emissions.

[0003] NOx is cleaned from exhaust gases of internal combustion engines through the use of catalysts. In addition to removing NOx, these catalysts also remove unburned hydrocarbons (HC) and carbon monoxide (CO). When the engine is operated with a lean air/fuel ratio, the catalyst is efficient at removing the HCs and COs because of the extra oxygen in the exhaust gas. However, the extra oxygen tends to inhibit the removal of NOx. Conversely, when the engine is operated with a rich air/fuel ratio, NOx removal efficiency of the catalyst is increased but the HC and CO removal efficiency is decreased.

[0004] In the case of exhaust gas from internal combustion engines operating at stoichiometry (i.e., an air/fuel ratio of nearly balanced stoichiometry for combustion (i.e., about 14.4 and about 14.7) on a mass basis)), NOx is usually removed by using so-called three-way catalysts. (It is noted that stoichiometry (i.e., an air/fuel ratio of nearly balanced stoichiometry for combustion) changes based upon fuel composition, i.e., gasoline, diesel, alcohol, mixtures, etc.) However, in the case of an exhaust gas having a relatively high oxygen concentration, such as those discharged from diesel engines and those discharged from gasoline engines operated lean of stoichiometry, efficient removal of NOx cannot be achieved with the above-described devices. Whereas homogeneous charge engines are able to utilize passive self-contained catalytic reduction techniques as exemplified by the three-way catalyst to control emissions of HC, CO, and NOx, so-called lean-burn engines as exemplified by the compression ignition engine, may have high oxygen content in the exhaust which renders conventional catalysis ineffective. In this case, techniques have been developed to meter an additional chemical reductant or reagent into the exhaust ahead of the reducing catalyst.

[0005] Conventional Selective Catalytic Reduction (SCR) of NOx involves injection of aqueous urea solution into the exhaust system ahead of the SCR catalyst. The dosing system is required to accurately meter the solution into the exhaust system, while being responsive to the engine or after treatment control system. Although various techniques of urea introduction to an exhaust system have been tried, many of these techniques require complex equipment and/or controls. What is needed in the art are improved reductant introduction systems.

BRIEF SUMMARY

[0006] Disclosed herein are reductant pumps, reductant systems, and methods for using reductant systems. In one embodiment, a reductant system, comprises: a high pressure reductant pump in operable communication with a power source, wherein the reductant pump comprises a reductant chamber and is capable of pressurizing reductant to a pressure of greater than or equal to 500 psi; a reductant reservoir in fluid communication with the reductant chamber; and an atomizer in fluid communication the reductant chamber.

[0007] In another embodiment, the reductant system comprises: a reductant pump in operable communication with a power source; system pump in operable communication the reductant pump, a reductant reservoir in fluid communication with the reductant chamber, and an atomizer in fluid communication the reductant chamber. The system pump is configured to provide motive power via a pressurized fluid to the reductant pump, and the system pump is fluidly isolated from a reductant chamber in the reductant pump.

[0008] Yet another embodiment of the reductant system comprises: a reductant pump comprising a motor comprising a rotatable shaft, a pump housing with a first pressurizing chamber, a threaded piston keyed into a pump housing, a first end of the threaded piston comprising a first pressurizing surface in fluid communication with a first pressurizing chamber, and a second end of the threaded piston disposed opposite the first end, the second end comprising a second pressurizing surface in fluid communication with a second pressurizing chamber, and a threaded nut in operable communication with threads on the threaded piston. Rotatable shaft rotation rotates the threaded nut producing axial movement of the threaded piston, and axial movement of the threaded piston in a first direction increases pressure of a first fluid in the first pressurizing chamber and creates a vacuum in the second pressurizing chamber, and wherein axial movement of the threaded piston in a second direction increases pressure of a second fluid in the second pressurizing chamber and creates a vacuum in the first pressurizing chamber.

[0009] In one embodiment the reductant pump comprises: a motor comprising a rotatable shaft; a pump housing with a first pressurizing chamber; a threaded piston keyed into a pump housing, a first end of the threaded piston comprising a first pressurizing surface in fluid communication with a first pressurizing chamber, and a second end of the threaded piston disposed opposite the first end, the second end comprising a second pressurizing surface in fluid communication with a second pressurizing chamber; and a threaded nut in operable communication with threads on the threaded piston. Rotatable shaft rotation rotates the threaded nut producing axial movement of the threaded piston. Axial movement of the threaded piston in a first direction increases pressure of a first fluid in the first pressurizing chamber and creates a vacuum in the second pressurizing chamber, and axial movement of the threaded piston in a second direction increases pressure of a second fluid in the second pressurizing chamber and creates a vacuum in the first pressurizing chamber.

[0010] In one embodiment, the method for providing a reductant to an exhaust system comprises: introducing the reductant to a reductant chamber of a reductant pump;

powering the reductant pump with pressurized fluid from a system pump; pressurizing the reductant; and passing the pressurized reductant through an atomizer and into an exhaust flowpath.

[0011] The above-described and other features will be appreciated and understood by those skilled in the art from the following detailed description, drawings, and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Refer now to the figures, which are exemplary embodiments and wherein like elements are numbered alike.

[0013] **FIG. 1** is a schematic view of one embodiment of a NOx removal system.

[0014] **FIG. 2** is a cross-sectional view of one embodiment of a reductant pump.

[0015] **FIG. 3** is a schematic view of another embodiment of a NOx removal system.

[0016] **FIG. 4** is a cut away schematic view of one embodiment of a reductant pump.

[0017] **FIG. 5** is a schematic view of an in-cylinder embodiment of a NOx removal system.

DETAILED DESCRIPTION

[0018] The use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another, and the terms "a" and "an" herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item. It is noted that this application is described in relation to use in relation to an exhaust stream. This exhaust stream can be any exhaust stream, e.g., a vehicle exhaust stream (such as an automobile, passenger vehicle, truck, or the like), a cogenerator exhaust stream, or the like.

[0019] Disclosed herein is a reductant system, e.g., for injecting reductant (e.g., urea, ammonia, hydrocarbons, or the like) upstream of or into an exhaust treatment device, such as for the removal of NOx from an exhaust stream. Referring now to **FIG. 1**, a schematic illustration of a system **10** is shown. The system **10** can include an exhaust system of a vehicle as well as parts of other vehicle systems, such as the system pump **52**, discussed below. The illustration of **FIG. 1** is provided to explain the apparatus and method of exemplary embodiments and should not be considered as limiting. System **10** comprises an exhaust path **12** having an inlet opening **14** and an outlet opening **16**. Inlet opening **14** is in fluid communication with an exhaust of an engine (not shown) and the outlet **16** opening is in fluid communication with ambient atmosphere.

[0020] Disposed within exhaust path **12** is an exhaust treatment device **20**. The exhaust treatment device **20** may include such treatment devices as, but not limited to: an SCR catalyst, a NOx catalyst, a NOx adsorber, or the like. A reductant pump **24** is positioned to provide a pressurized flow of reductant to an outlet conduit **26**, having an atomizer **28** disposed on one end, in the exhaust path **12**. The reductant may be any material capable of reducing the NOx, such as ammonia, urea, and the like. As used herein the term "urea" is meant to encompass urea in all of its commercial forms, including those containing: ammelide; ammeline; ammonium carbonate; ammonium bicarbonate; ammonium carbamate; ammonium cyanate; ammonium salts of inorganic acids, including sulfuric acid and phosphoric acid; ammonium salts of organic acids, including formic and acetic acid; biuret; cyanuric acid; isocyanic acid; melamine and tricyanourea. Atomizer **28** is positioned to provide an atomized spray of reductant in the exhaust as it flows towards the exhaust treatment device **20**. The spray of reductant in combination with the exhaust treatment device **20** reduces unwanted exhaust emissions. Reductant pump **24** is in fluid communication with a reservoir **30** of reductant **32** via a conduit **34**. In the disclosed embodiments, the reductant is injected into the exhaust path without the need of a carrying medium, such as compressed air.

[0021] An optional heater **46**, with is in thermal communication with the reductant and is for heating the reductant **32**, may be provided to prevent reductant **32** from freezing when exposed to temperatures below the freezing point of the reductant **32**. Additionally or in the alternative, an optional expansion bladder **48** may be located within the reservoir **30**. The expansion bladder will allow the reductant to freeze and expand, without damaging the reservoir.

[0022] In one embodiment, the flow path of the reductant **32** through the system **10** comprises reductant **32** exiting the reservoir **30** through conduit **34**, through a purge solenoid **50**, to the reductant pump **24**. The reductant pump **24** may be powered by a pressurized fluid provided by a system pump **52**, e.g., a fluid that is already present in the system in which the reductant system is employed (e.g., a vehicle system pump, such as power steering fluid, and the like), and the like. A control valve **53** directs the pressurized fluid from the system pump **52** to the reductant pump **24**. The system pump **52** may be, but is not limited to one of the following devices: power steering pump, fuel pump and air compressor. The pressurized fluid therefore may be power steering fluid, fuel, and air, respectively.

[0023] The outlet of the reductant pump **24** is in fluid communication with a purge bypass valve **54** and a solenoid valve **56**. The solenoid valve **56** is controlled by an engine control unit **36** or a separate reductant control unit. Based upon signals received by the engine control unit **36**, it activates the solenoid valve **56** and allows the reductant **32** to travel through the atomizer **28** into the exhaust path **12** ahead of the exhaust treatment device **20**.

[0024] Accordingly, the engine control unit **36** can provide the necessary commands to the various components in the exhaust system to limit NOx emissions. The engine control unit **36** may comprise a microprocessor and associated control algorithm(s). This unit may be in operable communication with various components of the system **10**, such as sensors capable of providing signals indicative of operating parameters. These signals, when applied to the control algorithm(s) cause an appropriate operating signal to be sent to the system components.

[0025] Although, up to now, an exhaust path reductant introduction has been discussed, it should be clear that the disclosed method and apparatus may be adapted for use in an in-cylinder reductant introduction. Therefore, depending on the type of reductant introduction (e.g., exhaust path or in-cylinder), the plurality of sensors may comprise, but are

not limited to, reductant flow temperature sensor(s) **38** (e.g., thermocouple(s)), reductant flow pressure sensor(s) **39**, inlet NOx sensor(s) **40**, catalyst temperature sensor(s) **41**, outlet NOx sensor(s) **42**, ammonia sensor(s) **44**, reductant level sensor(s) (not shown), reductant tank temperature sensor(s) **43**, cylinder pressure sensor(s) (not shown), air mass flow sensor(s) (not shown), humidity sensor(s) (not shown), engine speed sensor(s) (not shown), fuel delivery sensor(s) (not shown), boost pressure sensor(s) (not shown), boost temperature sensor(s) (not shown), cylinder pressure sensor(s), exhaust treatment device temperature sensor(s) (e.g., in thermal communication with the exhaust treatment device), and the like, as well as combinations comprising at least one of the foregoing. Accordingly and through the use of the plurality of sensors, real-time and/or non-real-time post-catalyst monitoring of NOx emissions for NOx reduction confirmation are available.

[**0026**] The engine control unit **36** processes signal(s) selected from the above sensors according to a method for carrying out a control algorithm. The engine control unit **36** makes changes to engine operating conditions according to the method in order to reduce NOx emissions.

[**0027**] The method for carrying out a control algorithm for reducing NOx emissions described above can be embodied in the form of computer-implemented processes and apparatuses for practicing the method. The method can also be embodied in the form of computer program code containing instructions embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, or any other computer-readable storage medium, wherein, when the computer program code is loaded into and executed by a computer and/or controller, the computer becomes an apparatus for practicing the method. Existing systems having reprogrammable storage (e.g., flash memory) can be updated to implement the described method.

[**0028**] The embodiment shown in **FIG. 1** may have an optional reductant purge system comprising the purge bypass valve **54** and purge solenoid **50**. During certain operating conditions, temperatures may get cold enough such that any reductant remaining in the lines of the system **10** may freeze. The purge system will purge the reductant from the lines in the system **10** by directing air from the vent **58** to the pump **24**. The pump **24** compresses the air, which is then used to purge reductant from the system lines. The bypass purge valve **54** may be activated to direct pressurized air through an activated purge solenoid **50** and back into the reservoir **30**, thereby purging the line between the reductant pump **24** and the reservoir **30** of reductant. Similarly the bypass purge valve **54** may be activated to direct pressurized air through the activated solenoid valve **56** and out into the exhaust path **12**, thereby purging the line between the reductant pump **24** and the atomizer **28**. Any small amount of purged reductant left in the exhaust path should not cause any damage upon freezing. Therefore, the atomizer **28** is fluidly isolated from a carrier gas (e.g., air from the environment, air, or the like) during reductant injection (e.g., no carrier gas is needed to introduce reductant to the exhaust path **12**), and may be in fluid communication with a gas (e.g., air) purge during purging. For example, the atomizer preferably has a single input to receive high pressure reductant (e.g., reductant having a pressure of greater than or equal about 500 pounds per square inch (psi)).

[**0029**] **FIG. 2** provides a cross-sectional schematic view of an embodiment of the reductant pump **24**. The pump **24** comprises a pressurizing chamber **62**, a de-pressurizing chamber **64**, and a reductant chamber **66**. The pressurizing chamber **62** has a first port **67** in fluid communication with the control valve **53** (see **FIG. 1**), the depressurizing chamber **64** has a second port **69**, also in fluid communication with the control valve **53**. The reductant chamber **66** has a reductant inlet port **70** in fluid communication with conduit **34**, and a reductant outlet port **72**, in fluid communication with conduit **26**.

[**0030**] A piston **74** may be actuated by pressurized fluid from the vehicle system pump **52**, whereby the piston **74** will pressurize the reductant. The piston **74** has three force transmitting surfaces: a pressurizing surface **76**, a de-pressurizing surface **78** and a reductant pressurizing surface **80**. The pressurizing surface **76** is much larger than the reductant pressurizing surface **80**, thus giving the pressurizing surface **76** a mechanical advantage over reductant pressurizing surface **80**. The piston **74** is shown at or near the top of its stroke in **FIG. 2**. At this point reductant is fed into the reductant chamber **66** via the reductant inlet port **70**. Once the reductant chamber **66** receives the reductant, pressurized liquid is directed by the control valve **53** (see **FIG. 1**) through the first port **67** into the pressurizing chamber **62**. Simultaneously, the control valve **53** also directs the pressurized liquid from the de-pressurizing chamber **64** to a liquid tank (e.g. the system pump **52**) so that the de-pressurizing chamber **64** can release its pressure from the previous cycle (if there was a previous cycle). The pressurized liquid pushes against the pressurizing surface **76** thereby moving the piston **74** down and causing the pressurizing of the reductant in the reductant chamber **66**. Reductant inlet port **70** has a check valve, thereby permitting the pressurizing of the reductant without reductant escaping through port **70**. At or near the bottom of the piston's stroke the reductant outlet port's check valve is opened, and the pressurized reductant exits the chamber **66** via the reductant outlet port **72**. At this point, the control valve **53** directs pressurized liquid into de-pressurizing chamber **64** via second port **69**, simultaneously; the control valve **53** also directs the pressurized liquid from the pressurizing chamber **62** to a liquid tank, which may be associated with the system pump **52** so that the pressurizing chamber **62** can release its pressure. The pressurized liquid pushes up against the de-pressurizing surface **78**, thereby moving the piston up which in turn causes a vacuum to draw reductant into the reductant chamber **66** via inlet port **70** (with the inlet port's check valve open and the outlet port's check valve closed). Once reductant has entered the chamber **66**, the cycle starts again.

[**0031**] Because reductant chamber **66** is separated from pressurizing chamber **62** and de-pressurizing chamber **64**, there is little to no chance of pressurizing fluid leaking into the reductant, or reductant leaking into the pressurizing fluid. If reductant bypasses O-rings **79**, the reductant will merely enter the space **83**, which can be open to the atmosphere (as illustrated), and will not contaminate the fluid from the vehicle system pump **52**. Similarly, if pressurized fluid leaks past O-rings **81**, the fluid will not contaminate the reductant, but will merely enter the space **83**.

[**0032**] The reductant pump **24** should be configured to provide enough reductant to the exhaust path to reduce the NOx emissions. For example, the reductant pump **24** may

have a bore diameter of about 0.25 to about 2 inches (about 0.64 to about 5.1 centimeters), a stroke of about 0.25 to about 2 inches (about 0.64 to about 5.1 centimeters), and a reductant chamber size of approximately about 0.1 to about 2 cubic inches (about 1.6 to about 32.8 cubic centimeters). Of course the disclosed reductant pump may be configured into a variety of different sizes. The size of the reductant pump is dependent on many factors, such as engine size, type, use, and the like.

[0033] **FIG. 3** shows another embodiment of a system. In this embodiment, an electric pump **82** is in fluid communication with the reservoir **30** of reductant **32** via the conduit **34**. The electric pump **82** is in fluid communication with an accumulator **84**. The accumulator is in fluid communication with the atomizer **28** via the solenoid valve **56**. The accumulator **84** dampens pressure fluctuations in the reductant and allows the electric pump **82** to operate intermittently rather than running at all times when reductant is being injected into the exhaust path. The electric pump **82** may be in operable communication with the engine control unit **36** and/or in operable communication with a pressure sensor **39**.

[0034] In another embodiment, the electric pump **82** will only activate when the pressure sensor **39** indicates a reductant pressure below some set point, thus preventing an energy consuming continuous operation of the electric pump **82**. The arrows indicate the flow direction of the reductant from the conduit **34** though the electric pump **82** and the accumulator **84** to the solenoid valve **56**.

[0035] **FIG. 4** shows an embodiment of the electric pump **82**. An electric motor **86** turns a shaft **88**. The shaft **88** may have a worm thread **90** on its outer surface. As the shaft **88** and worm thread **90** rotate, the worm thread turns a worm gear **91**. The worm gear **91** is in operable communication with a first bevel gear **92**, which turns a second bevel gear **94**. A threaded nut **96** is in operable communication with the second bevel gear **94**, and turns with the bevel gear **94**. As the nut **96** turns, it moves a threaded piston **98** in an axial direction represented by the arrow. The embodiment shown may be configured such that when the motor shaft **88** turns clockwise the threaded piston **98** moves to the left, and when the motor shaft **88** turns counter-clockwise the threaded piston moves to the right. Of course the electric pump may be configured such that when the motor shaft **88** turns clockwise the threaded piston **98** moves to the right, and when the motor shaft **88** turns counter-clockwise the threaded piston **98** moves to the left.

[0036] The piston **98** is shown at the end of its left stroke. At this point, the pressurized reductant in the first reductant chamber **100** flows out of a first port (outlet) **102** and into the optional accumulator **84**. As the motor reverses direction and the piston rod begins to move to the right, thus compressing reductant in the second reductant chamber **104**, reductant is drawn from the tank by vacuum caused by the displacement of the piston into the first reductant chamber **100** via the second port (inlet) **106**. The third port (inlet) **108** and fourth port (outlet) **110** each have check valves **112** and **114**, of which **114** is closed during this point in the piston stroke, thus preventing the reductant from returning to the tank and escaping the second chamber **104**. Similarly second port (inlet) **106** has a check valve **116** that is open, and first port (outlet) **102** has a check valve **118** that is closed. Once the piston rod has moved to the right to develop sufficient pressure in chamber **104**, check valve **114** opens and the reductant exits the chamber **104** via fourth port **110** to the accumulator **84**. At the end of the right stroke, the motor reverses direction again, and the piston **98** begins moving to the left whereupon check valve **112** opens, allowing reductant to flow from the reservoir (e.g., tank) **30** into chamber **104**, and check valve **116** closes thus preventing the reductant in chamber **100** from escaping as it is being pressurized. This embodiment of an electric pump using a worm gear advantageously provides a high torque with small power requirements.

[0037] The electric reductant pump **82** can be configured such that it can provide sufficient reductant to the exhaust path to reduce NOx emissions. Thus, in an exemplary embodiment, the bore of the electric reductant pump **82** may be about 0.13 to about 2 inches (about 0.33 to about 5 centimeters), a stroke of about 1 to about 8 inches (about 2.5 to about 20.3 centimeters), and a reductant chamber size of about 0.1 to about 2 cubic inches (about 1.6 to about 32.8 cubic centimeters).

[0038] In addition to the in-exhaust injection of reductant as discussed above with regard to **FIGS. 1-4**, it is possible to inject reductant into the cylinders of the engine, as for example in commonly owned and assigned U.S. Pat. No. 6,679,200 B2, filed Jun. 27, 2002, and issued Jan. 20, 2004. An example of such an application is illustrated in **FIG. 5** wherein a reductant pump **124** is positioned to provide reductant into a cylinder **120** of an engine **122**. Of course, the number of pumps may vary with the number of cylinders requiring reductant. Since the timing of this injection occurs late during the engine expansion stroke, the pump **124** provides an injection pressure high enough to overcome the cylinder pressure. Other known reductant injection systems have only low-pressure capability, and thus far, are unsuitable for in cylinder applications.

[0039] The reductant pumps described herein may be used in conjunction with many different types of atomizers. These include the simple open orifice nozzle, an inward opening closed nozzle, an outward opening top poppet nozzle (e.g., U.S. Pat. No. 4,116,591), a vaporizing nozzle, and many others. The atomizer may be located centrally and axially within the exhaust pipe section, or may be located externally on the exhaust periphery and projecting across the pipe or duct. In all cases, the objective is to select an atomizer appropriate to be the specific system geometry, which will achieve the complete homogeneous mixing of reductant and exhaust gas, and preferably in the shortest possible length. The reductant injection system described here has a wider potential selection of atomizer technologies and geometries that than is available to air-assisted designs. Thus, it can be expected to offer greater application flexibility.

[0040] In an exemplary embodiment, the amount of reductant injected into the exhaust stream would be about 1 part volume of reductant to every 20 parts volume of fuel. Of course this amount of reductant is dependent on various factors, including, but not limited to: the size and type of the engine, types of uses for the engine, and atmospheric conditions. Therefore a possible reductant volume may be about 1 part reductant for every 100 parts of fuel to 1 part of reductant for every 5 parts of fuel.

[0041] Systems without a high pressure pump generally introduce reductant (at a pressure of 35 psi to 50 psi) to an

injector. Air, at a pressure of 50 psi to 100 psi is also introduced to the injector. The air breaks up the reductant to small particles that are introduced to the exhaust stream. Such a system uses a dedicated air compressor that is not always available.

[0042] In contrast, the disclosed reductant system employs a high pressure pump that pressurizes the reductant to a pressure sufficient to atomize the reductant to a desired particle size without the use of a carrier gas. For example, the high pressure pump pressurizes the reductant to a pressure of greater than or equal to about 500 psi, with a pressure of greater than or equal to about 700 psi preferred, and a pressure of greater than or equal to about 900 psi even more preferred. The pressurized fluid, which may be stored in an accumulator, is introduced to an atomizer and injected into an exhaust stream. Since the atomizer receives a high pressure reductant, it can efficiently atomize the reductant without a carrier gas. Hence the atomizer can have a single inlet.

[0043] In the disclosed embodiments, the system may advantageously provide atomized reductant into the exhaust path (e.g., upstream of an exhaust treatment device and/or into an exhaust treatment device) without the need for a separate air supply and air compressor. The disclosed embodiments are lighter and less expensive than the currently used reductant injection systems, because heavy air compressors and heavy air lines able to withstand the pressures of the compressed air are not necessary. Further, in some of the disclosed embodiments, the system may use pressurized fluids from other systems in the automobile, such as power steering fluid, brake fluid, and others. The disclosed embodiments may also be employed for direct injection of reductant into the combustion cylinders.

[0044] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A reductant system, comprising:

a reductant pump in operable communication with a power source, wherein the reductant pump comprises a reductant chamber and is capable of pressurizing reductant to a pressure of greater than or equal to 500 psi;

a reductant reservoir in fluid communication with the reductant chamber; and

an atomizer in fluid communication the reductant chamber.

2. The reductant system of claim 1, wherein the power source is a system pump, wherein the system pump can provide motive power via a pressurized fluid to the reductant pump, and wherein the system pump is fluidly isolated from the reductant chamber.

3. The reductant system of claim 1, wherein the reductant reservoir is in thermal communication with a reductant heater.

4. The reductant system of claim 1, wherein the reductant reservoir comprises an expansion bladder.

5. The reductant system of claim 1, further comprising:

a vent in fluid communication with the reductant reservoir and the reductant chamber; and

a purge bypass valve in fluid communication with the atomizer and the reductant reservoir for directing fluid from the reductant chamber to at least one of the atomizer and the reductant reservoir.

6. The reductant system of claim 1, further comprising a control unit capable of varying an output of the reductant pump in response to a signal from a temperature sensor in thermal communication with an exhaust treatment device.

7. The reductant system of claim 1, further comprising:

a first NOx sensor located upstream of the exhaust treatment device;

a second NOx sensor located downstream of the exhaust treatment device; and

an ammonia sensor located downstream of the exhaust treatment device.

8. The reductant system of claim 1, wherein the reductant pump further comprises:

a piston, the piston comprising a first actuating surface, a second actuating surface, and a reductant pressurizing surface;

wherein the reductant chamber is in fluid communication with an inlet check valve and an outlet check valve, and is in fluid communication with the reductant pressurizing surface;

a first actuating chamber in fluid communication with the first actuating surface and in fluid communication with a first port; and

a second actuating chamber in fluid communication with the second actuating surface and in fluid communication with a second port;

wherein movement of the piston in a direction will increase the pressure of fluid received in the reductant chamber.

9. The reductant system of claim 8, further comprising a spacer chamber disposed between the second actuating chamber and the reductant chamber such that a fluid leaking from the second actuating chamber will escape from the reductant pump and will not enter the reductant chamber, and reductant leaking from the reductant chamber will escape from the reductant pump and will not enter the second actuating chamber.

10. A reductant system, comprising:

a reductant pump;

system pump in operable communication the reductant pump, wherein the system pump is configured to provide motive power via a pressurized fluid to the reductant pump, and wherein the system pump is fluidly isolated from a reductant chamber in the reductant pump;

a reductant reservoir in fluid communication with the reductant chamber; and

an atomizer in fluid communication the reductant chamber.

11. A method for providing a reductant to an exhaust system, comprising:

introducing the reductant to a reductant chamber of a reductant pump;

powering the reductant pump with pressurized fluid from a system pump;

pressurizing the reductant to a pressure of greater than or equal to about 500 psi; and

passing the pressurized reductant through an atomizer and into an exhaust flowpath.

12. The method of claim 11, further comprising introducing the reductant upstream of an exhaust treatment device.

13. The method of claim 11, wherein the pressurized reductant is injected without a carrier fluid.

14. The method of claim 11, further comprising purging a reductant system by

introducing a purge fluid to the reductant chamber;

powering the reductant pump with the pressurized fluid from a system pump;

pressurizing the purge fluid;

purging a flow path between the reductant pump and the atomizer with the pressurized purge fluid; and

purging a flow path between the reductant pump and a reductant reservoir with the pressurized purge fluid.

15. The method of claim 14, comprising purging the reductant system of reductant when an ambient temperature is below a setpoint.

16. The method of claim 14, further comprising pumping the pressurized reductant into an accumulator prior to injecting it into the exhaust flow path.

17. A reductant system, comprising: a reductant pump comprising

a motor comprising a rotatable shaft;

a threaded piston keyed into a pump housing, a first end of the threaded piston comprising a first pressurizing surface in fluid communication with a first pressurizing chamber, and a second end of the threaded piston disposed opposite the first end, the second end comprising a second pressurizing surface in fluid communication with a second pressurizing chamber; and

a threaded nut in operable communication with threads on the threaded piston;

wherein rotatable shaft rotation rotates the threaded nut producing axial movement of the threaded piston; and

wherein axial movement of the threaded piston in a first direction increases pressure of a first fluid in the first pressurizing chamber and creates a vacuum in the second pressurizing chamber, and wherein axial movement of the threaded piston in a second direction increases pressure of a second fluid in the second pressurizing chamber and creates a vacuum in the first pressurizing chamber.

18. The reductant system of claim 17, further comprising:

a reductant reservoir in fluid communication with the first pressurizing chamber and the second pressurizing chamber;

an accumulator in fluid communication with the first pressurizing chamber and the second pressurizing chamber; and

an atomizer in fluid communication the accumulator.

19. The reductant system of claim 17, further comprising a reductant heater in thermal communication with the reductant reservoir.

20. The reductant system of claim 17, wherein the reductant reservoir comprises an expansion bladder.

21. The reductant system of claim 17, wherein the reductant pump further comprises:

a worm gear disposed on an outer surface of the rotatable shaft;

a first bevel gear in operable communication with the worm gear; and

a second bevel gear in operable communication with the first bevel gear, and annularly affixed to an outer surface of the threaded nut.

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