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(54) Title: COOLANT HEATING METHOD FOR RELEASING REDUCTANT

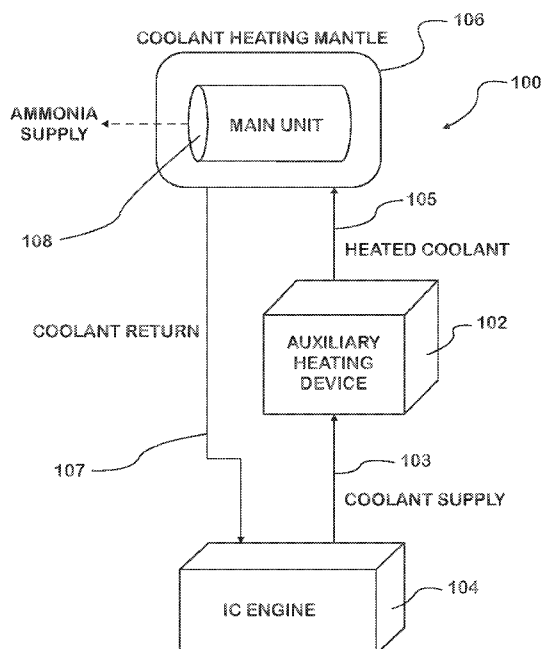


FIG. 1

(57) Abstract: A system and method for heating main unit containing host salt having ammonia that is used as reductant in an engine exhaust gas after-treatment system. Engine coolant is delivered from internal combustion engine to auxiliary heating device. When necessary, the auxiliary heating device heats the engine coolant to temperatures that will aid in releasing ammonia from the host salt. The auxiliary heating device may employ an electric heating element, a combustion element, or be an exhaust gas heat exchanger, among other heating methods. The heated engine coolant is delivered to a coolant heating manifold, where heat from the heated coolant is transferred to the main unit. The transferred heat may aid in elevating the temperature in/of the main unit to facilitate the release of stored ammonia from the host salt as a gaseous reductant. The gaseous ammonia may then flow from the main unit.



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COOLANT HEATING METHOD FOR RELEASING REDUCTANT

BACKGROUND

[0001] Combustion engines may employ emission controls or systems that are configured to reduce the amount of nitrogen oxides (NOx) present in the engine's exhaust gas. One aspect of controlling such emissions may include the use of a NOx particulate filter (NPF) that has a Selective Catalytic Reduction (SCR) system and particulate filter capabilities. For example, for diesel engines, the NPF may include an SCR and a diesel particulate filter. The particulate filter is configured to remove particulate matter, such as soot, from the exhaust gas. The SCR typically uses a catalyst, which, in some designs, may be coated on the particulate filter, and a reductant to convert NOx in the exhaust gas into nitrogen gas and water. Typically, the reductant is injected into the exhaust gas before the exhaust gas enters the NPF. The reductant may be a liquid or gas, such as, for example, urea, anhydrous ammonia, or aqueous ammonia, among others. The reductant may provide, or provide for the formation of, ammonia in dosing amounts or rates for the conversion of NOx in the SCR.

[0002] In some systems, the ammonia reductant is molecularly bounded to a solid host salt that is placed inside a metallic vessel, which may be referred to as a main unit. Through an exothermic reaction, the ammonia reductant is released from the host salt in a gaseous state. Initiation of such an exothermic reaction may be provided by the flow of hot engine coolant, which may circulate through a heating mantle surrounding the main unit. Moreover, in such systems, engine heat rejected to coolant through conduction may provide heat that aids the exothermic reaction that releases the ammonia reductant from the solid host salt.

[0003] However, with such systems, there may be a delay before the engine coolant reaches temperatures needed for the engine coolant to aid in the above-discussed exothermic reaction. For example, a cold internal combustion engine may require sufficient operation time following start-up before the engine coolant is

elevated to sufficient temperatures to aid in this exothermic reaction. This delay in time may be further extended due to the temperature of the surrounding environment, such as, for example, during extreme cold weather conditions.

[0004] In order to reduce the time before the exothermic reaction occurs, some systems include an additional, smaller start-up vessel that also has host salt containing ammonia, and wherein the smaller vessel has an embedded electrical heat pad. The electrical heat pad may be powered by a battery that is operably connected to a large alternator that is driven by the internal combustion engine. During operation, the battery provides power that is used to generate heat from the heat pad. Such heat at least assists in elevating the temperature of the start-up vessel so as to aid in the occurrence of the exothermic reaction that releases the ammonia reductant from the salt. Ammonia gas is then provided from the start-up vessel for the after-treatment of exhaust gas until the main unit reaches operating temperatures needed for ammonia gas to be released from the host salt in the main unit.

[0005] However, during extreme cold weather conditions, the main unit may take a relatively long period of time to reach operating temperatures, or, in some applications, may not reach operating temperatures. In such situations, the start-up vessel may be relied on for extended periods of time. Such extended reliance on the start-up vessel may result in excessive use, and eventual depletion, of the ammonia from the host salt in the start-up vessel. Additionally, extended use of the start-up vessel may also drain the battery used to supply power to the electric heating pad and/or cause consistent re-charging of its battery, which may compromise the life of the battery. Further, a constant need to sufficiently re-charge the battery may require the use of a relatively large alternator, which may reduce engine compartment space and increase the overall cost of the engine system. Additionally, such systems require the generation of auxiliary heat, rather than using heat already being created by the operation of the engine.

BRIEF SUMMARY

[0006] According to an embodiment, a method is provided for heating a main unit containing a host salt having ammonia. The method includes delivering an engine coolant to an auxiliary heating device. The method further includes heating the delivered engine coolant in the auxiliary heating device. A number of different heating methods may be employed to heat the coolant, including using an electric coolant heater, a fuel fired heater, or an exhaust gas heat exchanger, among others. Additionally, heat from the heated engine coolant is transferred to the main unit to aid in the release of an ammonia gas from the host salt.

[0007] According to another embodiment, an engine coolant is delivered from an engine to an auxiliary heating device. The engine coolant may be delivered to the auxiliary heating device through a coolant supply line. The delivered engine coolant may be heated in the auxiliary heating device. Again, a number of different heating methods may be employed to heat the coolant, including using an electric coolant heater, a fuel fired heater, or an exhaust gas heat exchanger, among others. The heated engine coolant from the auxiliary heating device is supplied to a coolant heating manifold. The heated coolant may be supplied to the coolant heating manifold via a heated coolant supply line. Further, heat from the heated engine coolant in the coolant heating mantle is transferred to the main unit to aid in the release of an ammonia gas from the host salt.

[0008] According to another embodiment, a system is provided for heating coolant from an engine. The heated coolant provides heat to assist in the release an ammonia reductant from a host salt. The system includes an auxiliary heating device having a coolant inlet, a coolant outlet, and a passageway. The auxiliary heating device is configured to receive engine coolant from the engine. The auxiliary heating device is also configured to heat engine coolant as the coolant flows through the passageway. For example, the auxiliary heating device may be an electric coolant heater, a fuel fired heater, or an exhaust gas heat exchanger, among others. The system also includes a coolant heating mantle that is configured to receive heated coolant from the auxiliary heating device. The system further

includes a main unit that is configured to contain the host salt. At least a portion of the main unit is surrounded by the coolant heating mantle. The coolant heating mantle is configured to transmit heat from heated coolant flowing through the coolant heating mantle to the main unit. This transferred heat may be used to increase the temperature of the main unit to a temperature that promotes the release of the gaseous ammonia reductant from the host salt.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0009] FIG. 1 is a function block diagram of a hybrid heating system for an emissions control device.

[0010] FIG. 2 illustrates an electric coolant heater having a heating element in the coolant flow passageway.

[0011] FIG. 3 illustrates an electric coolant heater having a heating element positioned about a wall of the coolant passage.

[0012] FIG. 4 illustrates a fuel fired coolant heater being used as the auxiliary heating device.

[0013] FIG. 5 illustrates an exhaust gas heat exchanger being used as the auxiliary heating device.

DETAILED DESCRIPTION

[0014] FIG. 1 is a function block diagram of a hybrid heating system 100 for an emissions control device. As illustrated, the hybrid heating system 100 may include an engine 104, an auxiliary heating device 102, a coolant heating mantle 106, and a main unit 108. According to the illustrated embodiment, the engine 104 is an internal combustion engine, such as an engine 104 that is powered at least in part by the internal combustion of a fossil fuel, including diesel fuel, gasoline, and petroleum gas. Further, the main unit 108 is configured to contain a solid host salt to which an ammonia reductant is molecularly bound.

[0015] As illustrated, a coolant, such as engine coolant, is supplied from the engine 104 to the auxiliary heating device 102 via a coolant supply line or hose 103.

The engine 104 may include components typically used to cool an internal combustion engine, such as, for example a radiator, a coolant pump, a coolant reservoir, and associated lines or hoses. As is often typical for engine coolant systems, the coolant is heated by the operation of the engine 104, such as by the internal combustion of the fossil fuels, and cooled at least in the radiator or by another heat transfer component in the engine coolant system. As shown in Figure 1, at least a portion of the coolant from the engine 104 is directed or diverted into the coolant supply line 103 of the hybrid heating system 100. For example, according to an embodiment, coolant that has been heated by the operation of the engine 104 may be directed to the hybrid heating system 100 before the heated engine coolant passes into the radiator.

[0016] According to certain embodiments, the coolant may be pumped into the hybrid heating system 100 through the use of the coolant pump used for circulating coolant about the engine 104 and/or by one or more coolant pumps positioned along or incorporated into the hybrid heating system 100. For example, according to certain embodiments, one or more coolant pumps may be placed along the coolant supply line 103, or may be incorporated into components of the system, such as for example, within the auxiliary heating device 102 or the engine 104.

[0017] The temperature at which coolant is supplied from the engine 104 to the auxiliary heating device 102 may vary. For example, upon start-up of a cold engine, the coolant may be at least initially at or around ambient temperatures. Therefore, at start-up, when whether conditions are relatively cold, the coolant supply may also be relatively cold. Further, the surrounding environmental temperatures may impact the rate at, or degree, which cold coolant increases in temperature. Other operational conditions may also impact the rate or degree to which the temperature of the coolant from the engine 104 is increased, such as, for example, the length of time that the engine 104 is operated and the amount of coolant in the engine 104 or in the hybrid heating system 100, among other factors. Thus, such environmental and/or operational conditions may result in the coolant supplied to the auxiliary heating device 102 remaining at relatively low temperatures.

[0018] The auxiliary heating device 102 may, when necessary, heat the coolant so that coolant is delivered to the heating mantle 106 at or above operational temperatures, such as temperatures needed for the occurrence of an exothermic reaction in the main unit 108 that releases ammonia gas from the solid host salt. Moreover, the auxiliary heating device 102 may be configured to elevate the temperature of the coolant to a temperature sufficient for the heated coolant to aid in the occurrence of an exothermic reaction in the main unit 108 that releases ammonia from the salt host contained therein. For example, the auxiliary heating device 102 may be configured to increase the temperature of the supplied coolant by approximately 10° to approximately 20° degrees Celsius.

[0019] The auxiliary heating device 102 may employ a number of different methods for heating coolant. For example, as shown in FIG. 2, according to one embodiment, the auxiliary heating device 102 may be an electrical coolant heater 200 that includes a housing 202 having a coolant inlet 204 that is in fluid communication with a coolant outlet 206 by a passageway 208. As shown, the coolant inlet 204 may be operably connected to the coolant supply line 103, such as, for example, through the use of a threaded connection, clips, or compression fittings, among others. Similarly, the coolant outlet 206 may be operably connected to the heated coolant supply line 105.

[0020] The electrical coolant heater 200 may include a heating element 210 that is configured to provide heat that is to be transferred to coolant as coolant flows through the passageway 208 of the electrical coolant heater 200. Moreover, the heating element 210 may be configured to use resistance to electrical current running through the heating element 210 to generate the heat used to heat coolant passing by or around the heat element 210 in the passageway 208. Further, the heating element 210 may be configured to be subjected to liquid, such as the coolant. As shown in FIG. 2, according to certain embodiments, at least a portion of the heating element 210 may be positioned inside of and/or spliced into the passageway 206. According to another embodiment, rather than employing a

separate housing 202, the auxiliary heating device 102 may include a heating element 210 that is inserted into a portion of the coolant supply line 103

[0021] According to certain embodiments, the heating element 210 may be operably connected to a controller 212, such as, for example, through wires 214 and/or electrical terminals. The controller 212 and/or heating element 210 may be supplied with power from an auxiliary power source, such as having a dedicated battery 216. According to another embodiment, the electrical coolant heater 200 may be tied into the overall electrical system used by the engine 104. Due to the size of the heating element 210, according to certain embodiments, during operation, the electrical coolant heater may be powered by less than 12 or 24 volts of electricity.

[0022] The controller 212 may control the delivery of electricity to the heating element 210. For example, according to certain embodiments, the controller 212 may be operably connected to a sensor 218, such as by a cable 220, that may provide the controller 212 with a signal that is used to indicate the temperature of coolant upstream, at, or downstream of the heating element 210. The controller 212 may be set or programmed to allow electrical current to flow to the heating element 210 when the temperature sensed by the sensor 218 is at or below a preset value or range. According to such an embodiment, the heating element 210 may be operated only when an increase in the temperature of the coolant being delivered to the cooling mantle 106 is desired. However, according to other embodiments, a controller 212 may not be used, in which case the heating element 210 may be directly connected to the electrical system of the vehicle in which the engine 104 is located or an auxiliary power source.

[0023] As illustrated by Figure 3, according to another embodiment, the electrical coolant heater 300 may include a heating element 302 that may be embedded in, abut against, or form, at least a portion of the outer wall 304 of the passageway 208 through which coolant flows or coolant supply line 103. For example, according to certain embodiments, a heating element 302 may abut against at least a portion of the coolant supply line 103. The heating element 302

may again be operably connected to a controller 212 that is operably connected to a sensor 218. According to such an embodiment, heat from the heating element 302 may be delivered through the wall 304 of the coolant supply line 103 and to the coolant flowing therein. Alternatively, the heating element 302 may be heating pad that is embedded in or attached to a sleeve or tube that is operably connected to the coolant supply line 103.

[0024] Examples of electrical coolant heaters 200, 300 that may be used or adapted for use in the hybrid heating system 100 include electrical coolant heaters 200, 300 that are employed in engine coolant systems, such as those used to heat coolant before or during cold start-up of engines in extreme low temperature weather conditions. However, as the quantity of coolant typically being circulated in the hybrid heating system 100 is smaller than the quantity of coolant being circulated for cooling the engine 104 during operation, the electrical coolant heater used by the hybrid heating system 100 may be a substantially smaller unit than that used for heating cooling for the operation of the engine 104.

[0025] According to another embodiment, the auxiliary heating device 102 may be a fuel fired heater 400. As illustrated in FIG. 4, the fuel fired heater 400 may include a housing 402 having a coolant inlet 404 that is in fluid communication with a coolant outlet 406 by a passageway 408. The coolant inlet 404 may be operably connected to the coolant supply line 103, such as, for example, through the use of a threaded connection, clips, or compression fittings, among others. Similarly, the coolant outlet 406 may be operably connected to the heated coolant supply line 105. Examples of fuel fired heaters that may be used or adapted for use in the hybrid heating system 100 include fuel fired heaters that are used to pre-heat a vehicle's passenger compartment.

[0026] The fuel fired heater 400 may receive, via a fuel line 410, a supply of fuel, such as a portion of the fossil fuel stored in a fuel tank in the vehicle in which the engine 104 operates. The fuel fired heater 400 may also include a combustion element 412 and an inner area 414 through which at least a portion of a wall 409 houses the passageway 408 may be positioned or pass. The fuel received by the

fuel fired heater 400 may be converted to heat by the combustion element 412, such as through the combustion of the delivered fuel. Heat from the combustion of fuel by the fuel fired heater 400 and/or from the resulting heated exhaust gas may be transferred to at least a portion of the wall 409 surrounding the passageway 408, and thereby to the coolant therein. According to such a system, the fuel fired heater 400 may also include an auxiliary exhaust line 416 for the removal of exhaust gas created by the operation of the fuel fired heater 400. Further, the fuel fired heater 400 may also include a heater cooling system to prevent the fuel fired heater 400 from reaching undesirable temperatures. The heater cooling system may be an air cool system, or, alternatively, may be a liquid cooled system.

[0027] The fuel fired heater 400 may also include a controller 418 that controls the delivery of fuel to the combustion element 412. For example, according to certain embodiments, the controller 418 may be operably connected to a sensor 420, such as by a cable 422 that may provide the controller 418 with a signal that is used to indicate the temperature of coolant upstream, at, or downstream of the fuel fired heater 400. The controller 418 may be set or programmed to allow fuel to flow to the combustion element 412 when the temperature sensed by the sensor 420 is at or below a preset value or range. According to such an embodiment, the fuel fired heater 400 may be operated only when an increase in the temperature of the coolant being delivered to the cooling mantle 106 is desired.

[0028] As illustrated in FIG. 5, according to another embodiment, the auxiliary heating device 102 may be an exhaust gas heat exchanger 500. According to such an embodiment, the exhaust gas heat exchanger 500 may include a housing 502 that includes a coolant inlet 504 that is in fluid communication with a coolant outlet 506 through a connecting passageway 508. The coolant inlet 504 may be operably connected to the coolant supply line 103, such as, for example, through the use of a threaded connection, clips, or compression fits, among others. Similarly, the coolant outlet 506 may be operably connected to the heated coolant supply line 105. Thus, coolant may flow into the exhaust gas heat exchanger 500 through the coolant inlet 504, flow through the passageway 508, and exit through the coolant outlet 506.

[0029] The housing 502 of the exhaust gas heat exchanger 500 may also include an exhaust gas inlet 510 that is in fluid communication with an exhaust gas outlet 512 by an exhaust gas line 514. At least a portion of the exhaust gas line 514 is positioned along the passageway 508 such that coolant flowing through the passageway 508 flows about or around the exhaust gas line 514. Moreover, as hot exhaust gas flows through the gas line 514, heat maybe transferred from the hot exhaust gas, through the wall of the gas line 514, and to the cooler coolant that is flowing through the passageway 508.

[0030] The exhaust gas line 514 in the passageway 508 may have a variety of different configurations that may facilitate the transfer of heat from the exhaust gas to the coolant. For example, as illustrated in FIG. 5, the gas line 514 may be configured to increase and/or enhance the surface area of the gas line 514 that is exposed to the coolant flowing though the passageway 508, such as having a winding or spiral configuration along the passageway 508. Although FIG. 5 illustrates the exhaust gas contained in a spiral gas line 514 and coolant flowing through the passageway 508, according to other embodiments, the exhaust gas may travel through the passageway 508 while the coolant flows through a coolant line positioned along the passageway 508.

[0031] Referring to FIG. 1, heated coolant flows past or from the auxiliary heating device 102, such as out of a coolant outlet 306, 406, through a coolant supply line 105, and to an inlet of a coolant heating mantle 106. The coolant heating mantle 106 may be a heat transfer device that is positioned and configured to transfer heat from the coolant to the main unit 108. For example, the heating mantle 106 may be a series of tubes of fluid flow pathways that may allow heat to be dissipated from the coolant and to the main unit 108. Further, the heating mantle 106 may be a separated component, or integrated into the main unit 108. For example, according to certain embodiments, the coolant heating mantle 106 may surround at least a portion of the main unit 108. Further, the heating mantle 106 may be positioned to heat an area containing the host salt within the main unit 108, such as through convection. Alternatively, the coolant heating mantle 106 may be

configured to heat a housing of the main unit 108, and thereby provide heat needed for the exothermic reaction that releases the ammonia from the host salt.

[0032] Ammonia released from the host salt may then travel out of the main unit 108 and be used by an exhaust gas after-treatment system. For example, ammonia released from the main unit 108 may be used for in converting NO_x in the exhaust gas of the engine 104 into nitrogen gas and water. Engine coolant may then return from the coolant heating mantle 106 to the engine 104 via a coolant return line 107, such as, for example, returning to a coolant reservoir in the coolant system of the engine 104.

CLAIMS

1. A method for heating a main unit containing a host salt having ammonia comprising:

delivering an engine coolant to an auxiliary heating device;

heating the delivered engine coolant in the auxiliary heating device when the delivered engine coolant is below a predetermined temperature; and

transferring heat from the heated engine coolant to the main unit to aid in the release of an ammonia gas from the host salt.

2. The method of claim 1, wherein the step of heating the delivered engine coolant includes supplying an electrical current to an electric heating element of the auxiliary heating device.

3. The method of claim 2, wherein at least a portion of the electric heating element is submersed in at least a portion of the engine coolant being delivered to the auxiliary heating device.

4. The method of claim 2, further including the step of controlling when electrical current is to be supplied to the electric heating element.

5. The method of claim 4, further including the step of sensing the temperature of the delivered engine coolant.

6. The method of claim 1, wherein the step of heating the engine coolant includes combusting a fuel supplied to the auxiliary heating device, the combustion of the fuel being used to heat the engine coolant delivered to the auxiliary device.

7. The method of claim 1, further including the step of transferring heat from a heated engine exhaust gas to the engine coolant in the auxiliary heating device.

8. A method for heating a main unit containing a host salt having ammonia comprising:

delivering an engine coolant from an engine to an auxiliary heating device through a coolant supply line;

heating the delivered engine coolant in the auxiliary heating device when the delivered engine coolant is below a predetermined temperature;

supplying the heated engine coolant from the auxiliary heating device to a coolant heating manifold through a heated coolant supply line; and

transferring heat from the heated engine coolant in the coolant heating mantle to the main unit to aid in the release of an ammonia gas from the host salt.

9. The method of claim 8, wherein the step of heating the engine coolant includes supplying an electrical current to an electric heating element of the auxiliary heating device.

10. The method of claim 8, wherein the step of heating the delivered engine coolant includes combusting a fuel supplied to the auxiliary heating device, the combustion of the fuel being used to heat the engine coolant delivered to the auxiliary device.

11. The method of claim 8, further including the step of sensing the temperature of the engine coolant.

12. A system for heating coolant from an engine to provide heat to assist in the release a gaseous ammonia reductant from a host salt, the system comprising:

an auxiliary heating device having a coolant inlet, a coolant outlet, and a passageway, the auxiliary heating device configured to receive engine coolant from the engine, the auxiliary heating device configured to heat engine coolant that flows through the passageway;

a coolant heating mantle configured to receive heated coolant from the auxiliary heating device; and

a main unit, the main unit configured to contain the host salt, at least a portion of the main unit being surrounded by the coolant heating mantle, the coolant heating mantle configured to transmit heat from heated coolant flowing through the coolant heating mantle to the main unit to increase the temperature of the main unit to a temperature that promotes the release of the gaseous ammonia reductant from the host salt.

13. The system of claim 12, wherein the auxiliary heating device is an electric coolant heater, the electric coolant heater having a heating element that is configured to heat the received engine coolant.

14. The system of claim 12, wherein the auxiliary heating device is a fuel fired heater having a combustion element that is configured to combust fuel that is delivered to the fuel fired heater, the combusted fuel providing heat that is used to heat the engine coolant.

15. The system of claim 12, wherein the auxiliary heating device is an exhaust gas heat exchanger having an exhaust gas inlet in fluid communication with an exhaust gas outlet by an exhaust gas line, at least a portion of the exhaust gas line positioned within the passageway, the auxiliary heating device being configured for exhaust gas from the engine to flow through the exhaust gas line.

AMENDED CLAIMS

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CLAIMS

1. A method for heating a main unit containing a host salt having ammonia comprising:

delivering an engine coolant to an auxiliary heating device;

heating the delivered engine coolant in the auxiliary heating device when the delivered engine coolant is below a predetermined temperature; and

transferring heat from the heated engine coolant to the main unit to aid in the release of an ammonia gas from the host salt, wherein the step of heating the delivered engine coolant includes supplying an electrical current to an electric heating element of the auxiliary heating device.

2. The method of claim 1, wherein at least a portion of the electric heating element is submersed in at least a portion of the engine coolant being delivered to the auxiliary heating device.

3. The method of claim 1, further including the step of controlling when electrical current is to be supplied to the electric heating element.

4. The method of claim 3, further including the step of sensing the temperature of the delivered engine coolant.

5. The method of claim 1, wherein the step of heating the engine coolant includes combusting a fuel supplied to the auxiliary heating device, the combustion of the fuel being used to heat the engine coolant delivered to the auxiliary device.

6. The method of claim 1, further including the step of transferring heat from a heated engine exhaust gas to the engine coolant in the auxiliary heating device.

7. A method for heating a main unit containing a host salt having ammonia comprising:

delivering an engine coolant from an engine to an auxiliary heating device through a coolant supply line;

heating the delivered engine coolant in the auxiliary heating device when the delivered engine coolant is below a predetermined temperature;

supplying the heated engine coolant from the auxiliary heating device to a coolant heating manifold through a heated coolant supply line; and

transferring heat from the heated engine coolant in the coolant heating mantle to the main unit to aid in the release of an ammonia gas from the host salt, wherein the step of heating the engine coolant includes supplying an electrical current to an electric heating element of the auxiliary heating device.

8. The method of claim 7, wherein the step of heating the delivered engine coolant includes combusting a fuel supplied to the auxiliary heating device, the combustion of the fuel being used to heat the engine coolant delivered to the auxiliary device.

9. The method of claim 7, further including the step of sensing the temperature of the engine coolant.

10. A system for heating coolant from an engine to provide heat to assist in the release a gaseous ammonia reductant from a host salt, the system comprising:

an auxiliary heating device having a coolant inlet, a coolant outlet, and a passageway, the auxiliary heating device configured to receive engine coolant from the engine, the auxiliary heating device configured to heat engine coolant that flows through the passageway;

a coolant heating mantle configured to receive heated coolant from the auxiliary heating device; and

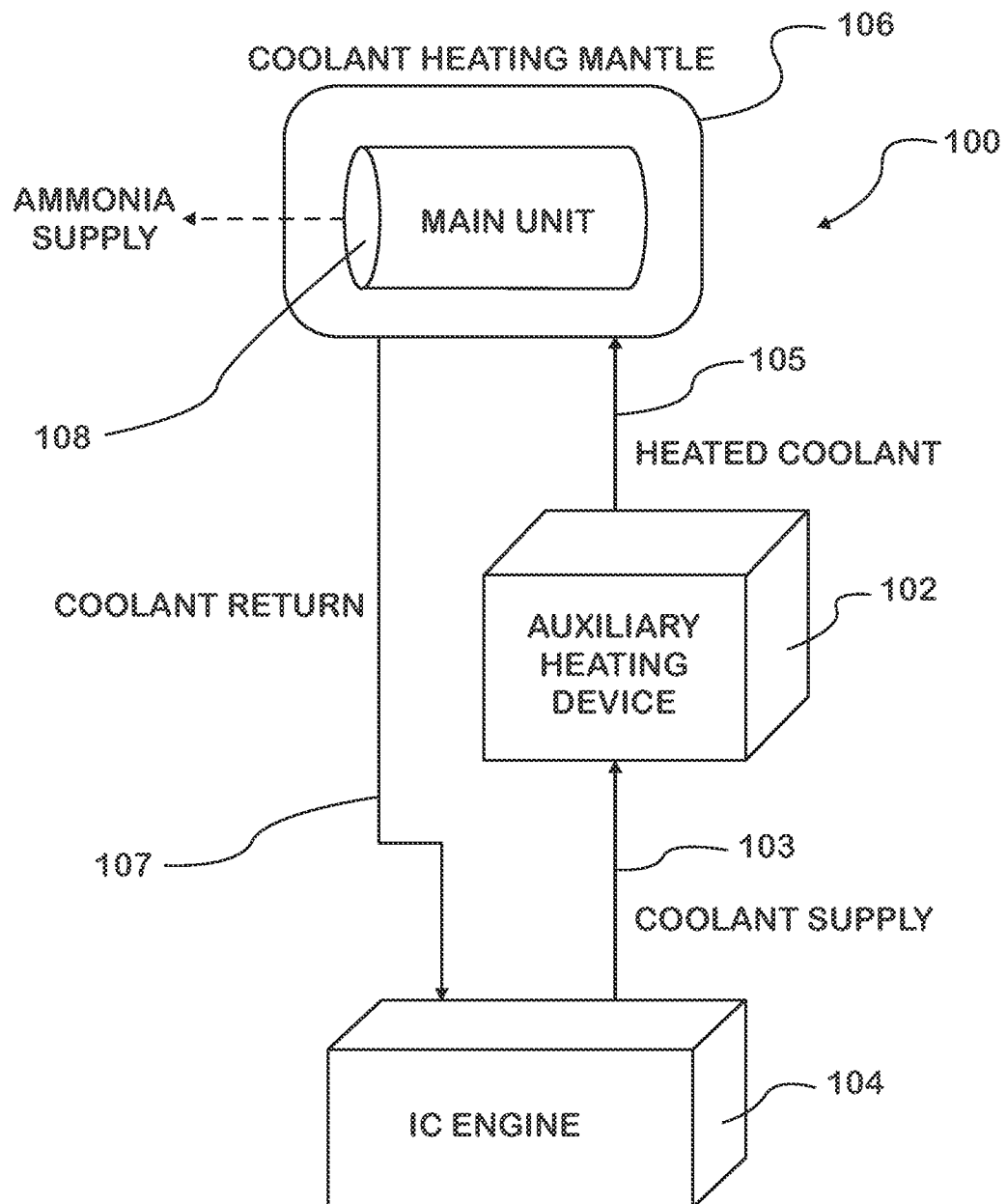
a main unit, the main unit configured to contain the host salt, at least a portion of the main unit being surrounded by the coolant heating mantle, the coolant heating mantle configured to transmit heat from heated coolant flowing through the coolant heating mantle to the main unit to increase the temperature of the main unit to a temperature that promotes the release of the gaseous ammonia reductant from the host salt.

11. The system of claim 10, wherein the auxiliary heating device is an electric coolant heater, the electric coolant heater having a heating element that is configured to heat the received engine coolant.

12. The system of claim 11, wherein the auxiliary heating device is a fuel fired heater having a combustion element that is configured to combust fuel that is delivered to the fuel fired heater, the combusted fuel providing heat that is used to heat the engine coolant.

13. The system of claim 11, wherein the auxiliary heating device is an exhaust gas heat exchanger having an exhaust gas inlet in fluid communication with an exhaust gas outlet by an exhaust gas line, at least a portion of the exhaust gas line positioned within the passageway, the auxiliary heating device being configured for exhaust gas from the engine to flow through the exhaust gas line.

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**FIG. 1**

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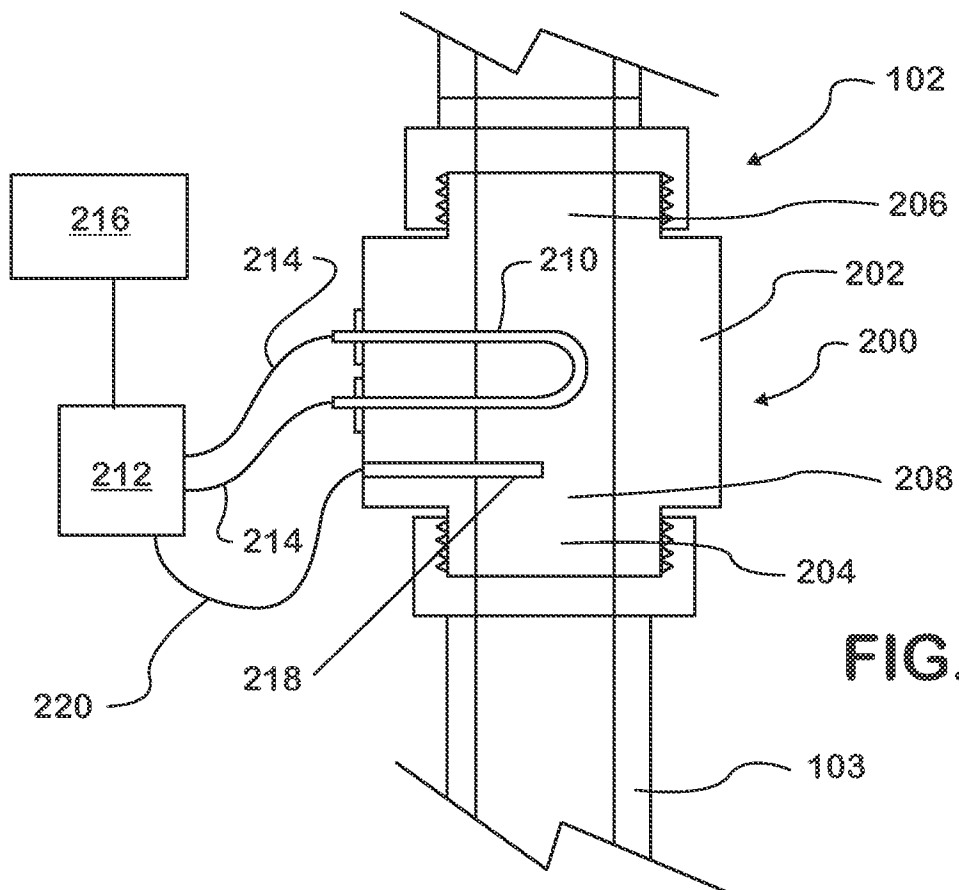


FIG. 2

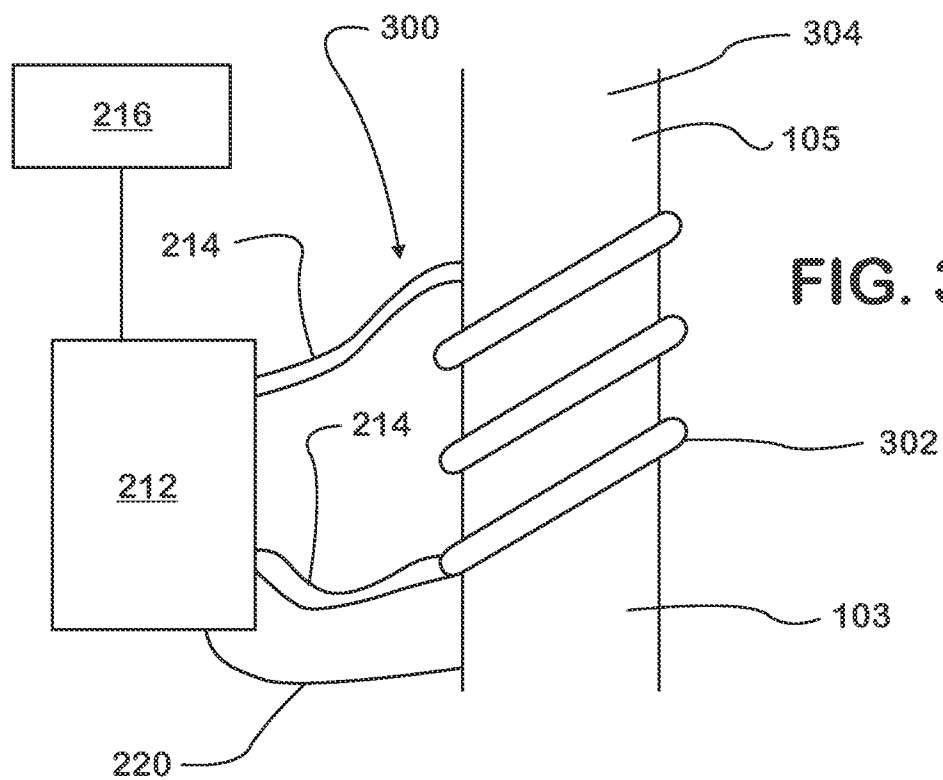
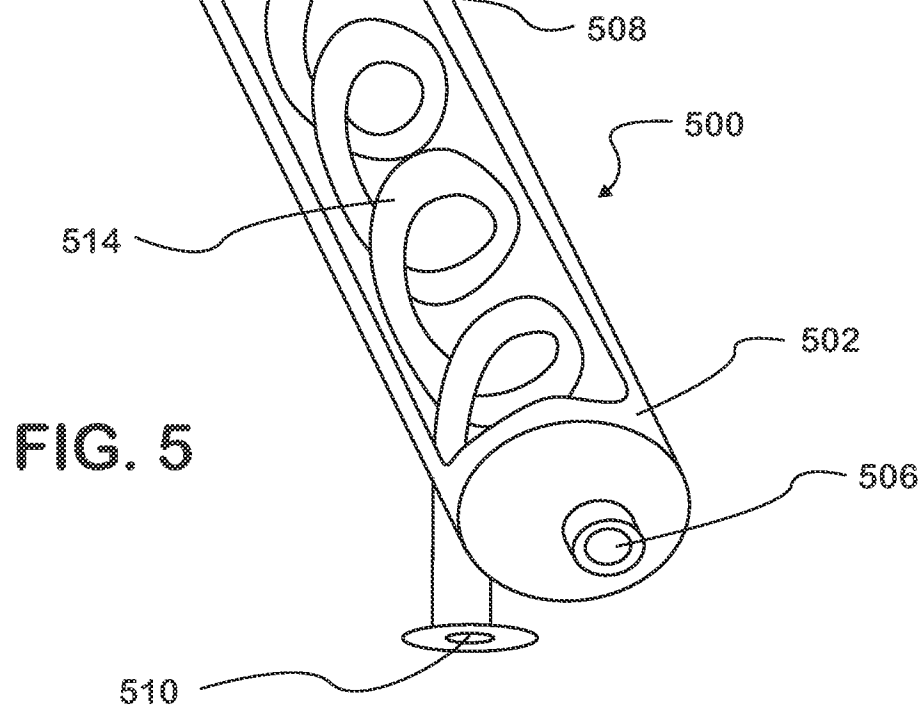
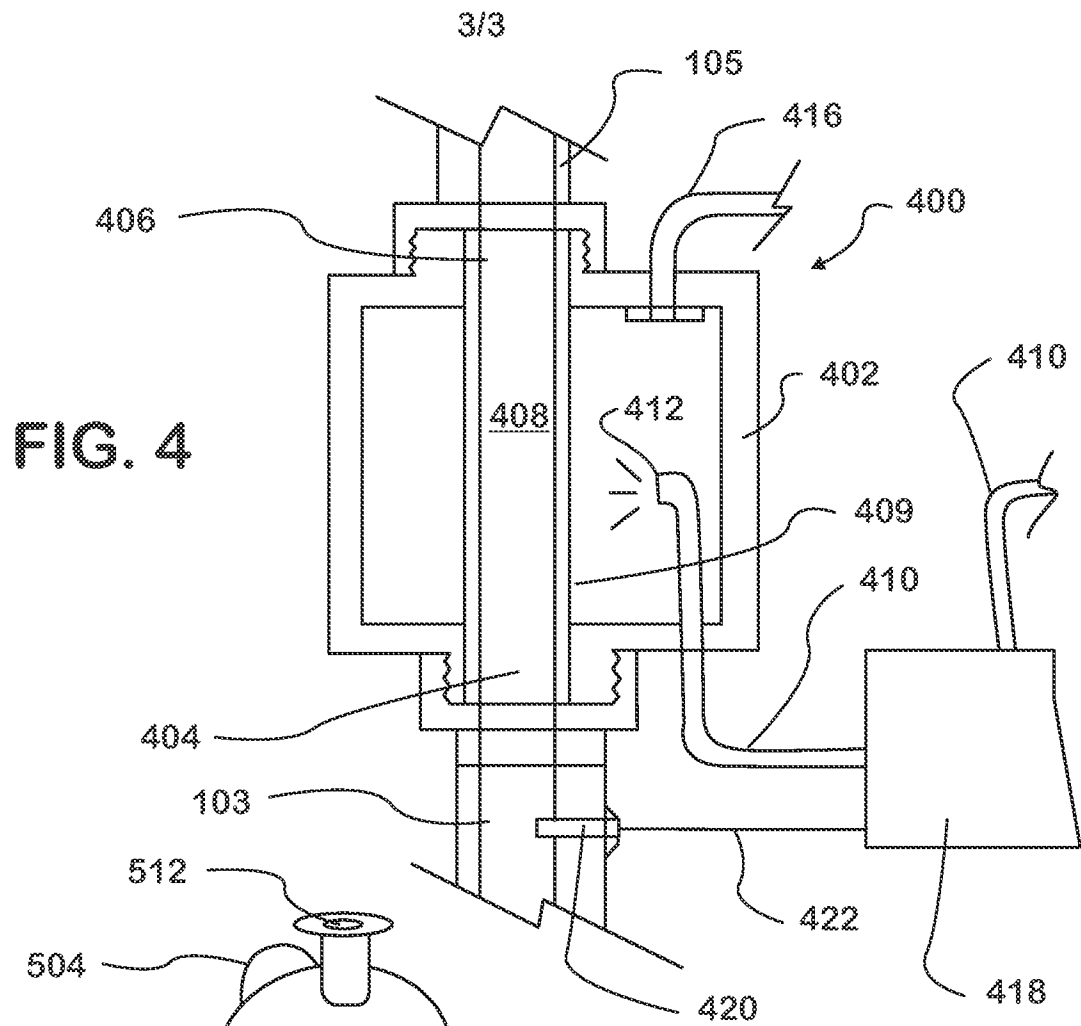


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/37954

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C01C 1/08; F01N 3/10 (2013.01)

USPC - 165/43, 104.11

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) Classification(s): B01D 53/94; B01J 19/00; C01C 1/08; F01N 3/10 (2013.01)

USPC Classification(s): 165/41, 43, 104.11, 902, 911

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

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

MicroPatent (US Granted, US Applications, EP-A, EP-B, WO, JP, DE-G, DE-A, DE-T, DE-U, GB-A, FR-A); DialogPro (Derwent, INSPEC, NTIS, PASCAL, Current Contents Search, Dissertation Abstracts Online, Inside Conferences); Google.com; Google.com/Scholar; ammonia, coolant, gas, engine, heat*, exhaust, electric*, salt, combust*

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 8,318,115 B2 (HAROLD, JR et al.) November 27, 2012; figure 1; column 8, lines 10-15; column 9, lines 1-25; column 11, lines 15-30	1, 6, 8, 10 — 2-5, 7, 9, 11-15
Y	US 5,834,742 A (YOSHIDA, N) November 10, 1998; figure 1; column 1, lines 5-10; column 2, lines 30-40; column 3, lines 50-65	2-5, 9, 11, 13
Y	US 8,361,422 B2 (SOUKHOJAK, A et al.) January 29, 2013; abstract; column 4, lines 1-10	7, 15
Y	US 2011/0283677 A1 (KAEFER, S) November 24, 2011; paragraph [0010]	12-15

☐ 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 date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 July 2013 (23.07.2013)

Date of mailing of the international search report

01 AUG 2013

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