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(54) METHOD AND APPARATUS FOR GASEOUS MIXING IN A DIESEL EXHAUST SYSTEM

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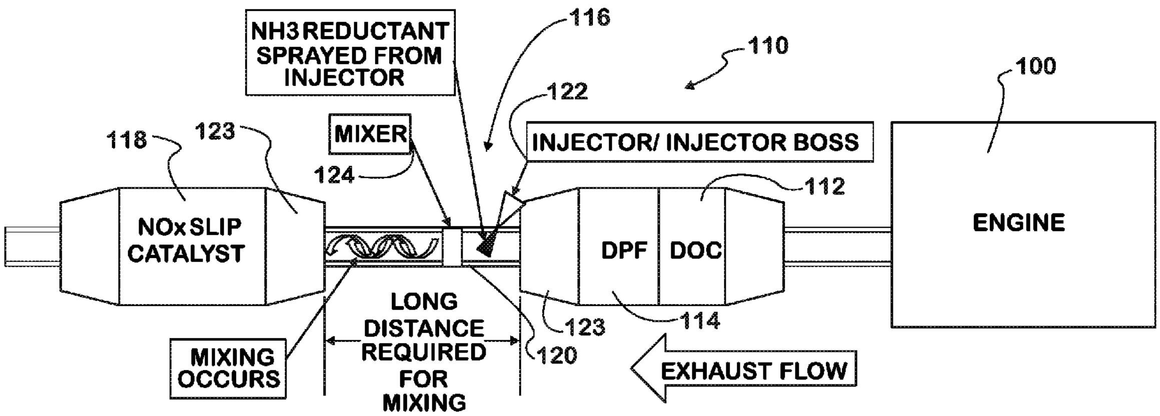
(57) **ABSTRACT**

A mixing device and method for a diesel exhaust system is disclosed having a chamber, a mixer within the chamber, and an injection tube supported on the mixer within the chamber. The mixer is positioned within the chamber adjacent an inlet and includes a plurality of angled blades to effect turbulent flow in a diesel exhaust stream entering the chamber through the inlet. The injection tube includes a plurality of injection points (e.g., openings) for discharging a reagent, such as gaseous ammonia (NH_3), into the exhaust stream. The injection tube is curved, and more specifically it is coiled with the injection points spread along the length of the tube in order to deliver reagent across a section of the chamber perpendicular to the exhaust stream flow.



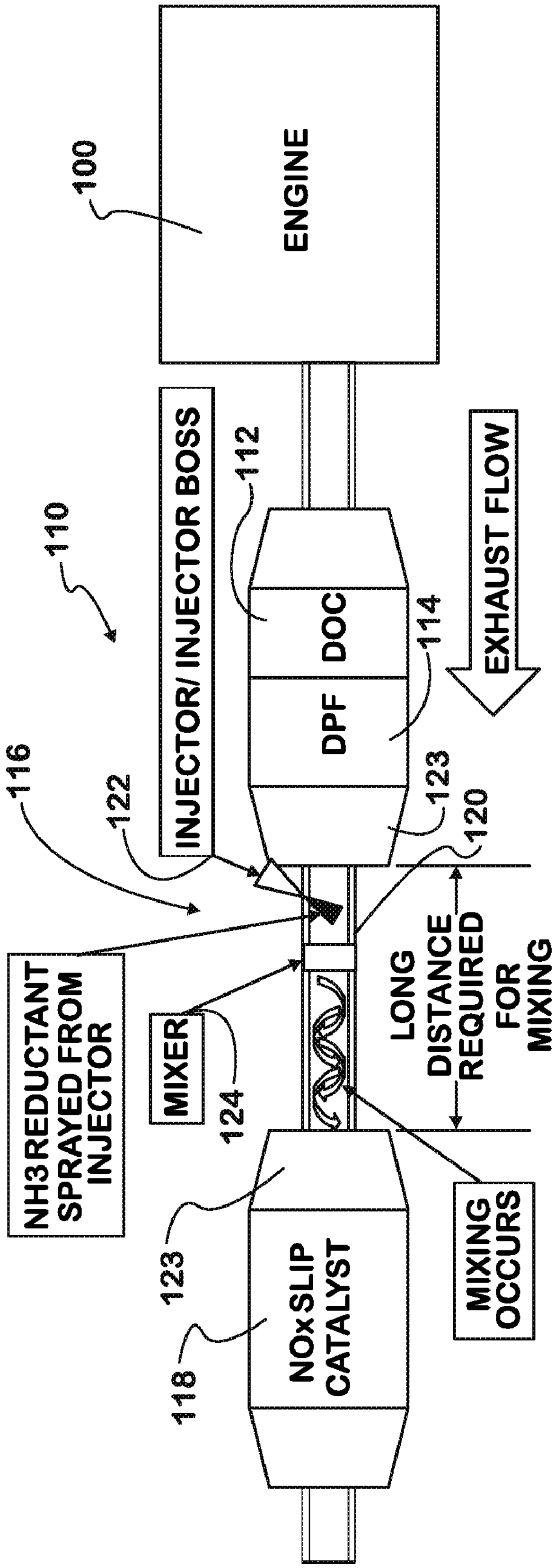

100
ENGINE
110
INJECTOR/ INJECTOR BOSS
112
DOC
114
DPF
EXHAUST FLOW
116
122
123
120
NH3 REDUCTANT SPRAYED FROM INJECTOR
MIXER
124
LONG DISTANCE REQUIRED FOR MIXING
MIXING OCCURS
123
118
NOx SLIP CATALYST

FIG. 1

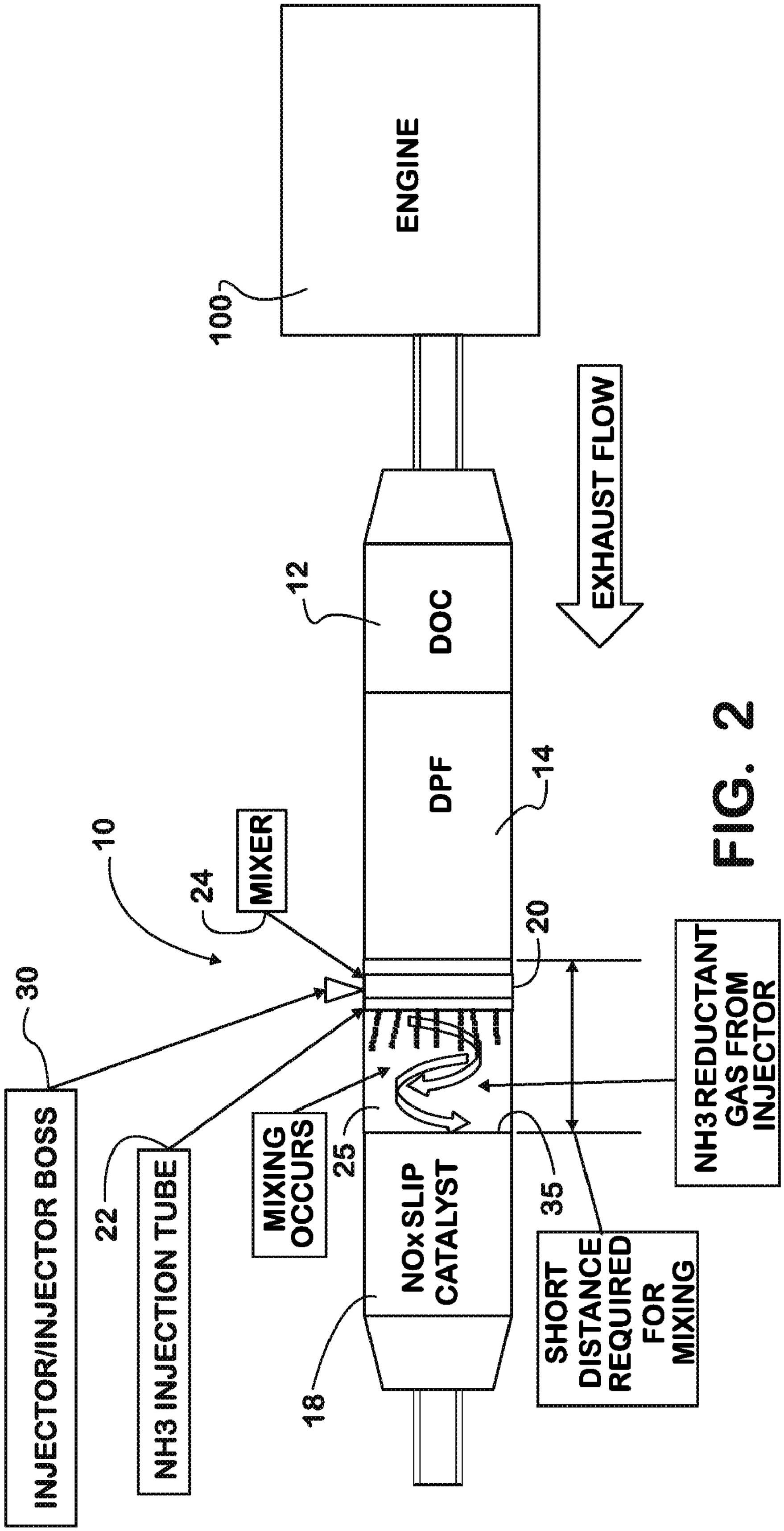

ENGINE
100
EXHAUST FLOW
12
DOC
DPF
14
10
MIXER
24
20
30
INJECTOR/INJECTOR BOSS
22
NH3 INJECTION TUBE
MIXING OCCURS
25
NOx SLIP CATALYST
35
18
SHORT DISTANCE REQUIRED FOR MIXING
NH3 REDUCTANT GAS FROM INJECTOR

FIG. 2

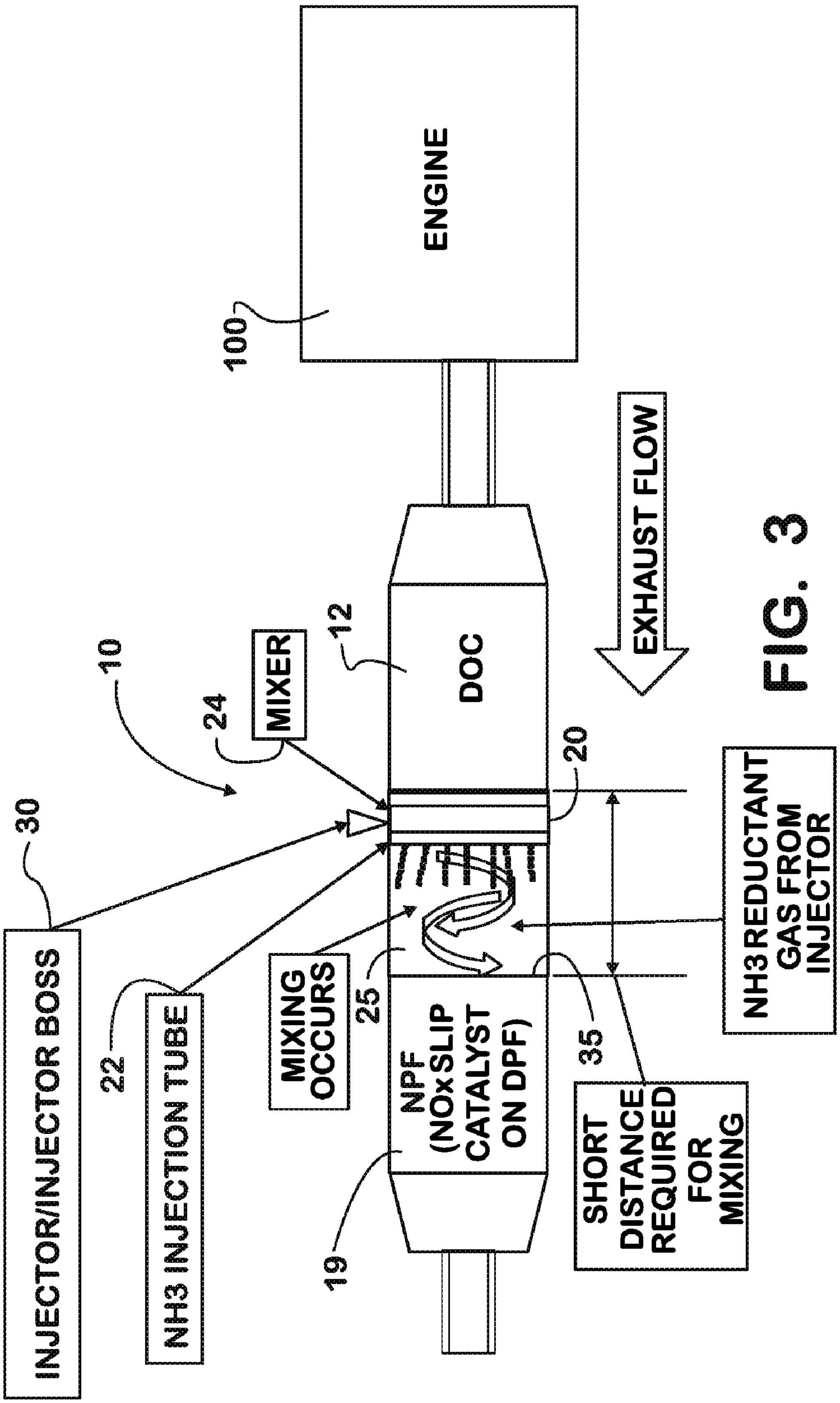

ENGINE
100
EXHAUST FLOW
DOC
12
10
MIXER
24
20
30
INJECTOR/INJECTOR BOSS
22
NH3 INJECTION TUBE
MIXING OCCURS
25
NPF (NOx SLIP CATALYST ON DPF)
19
35
SHORT DISTANCE REQUIRED FOR MIXING
NH3 REDUCTANT GAS FROM INJECTOR

FIG. 3

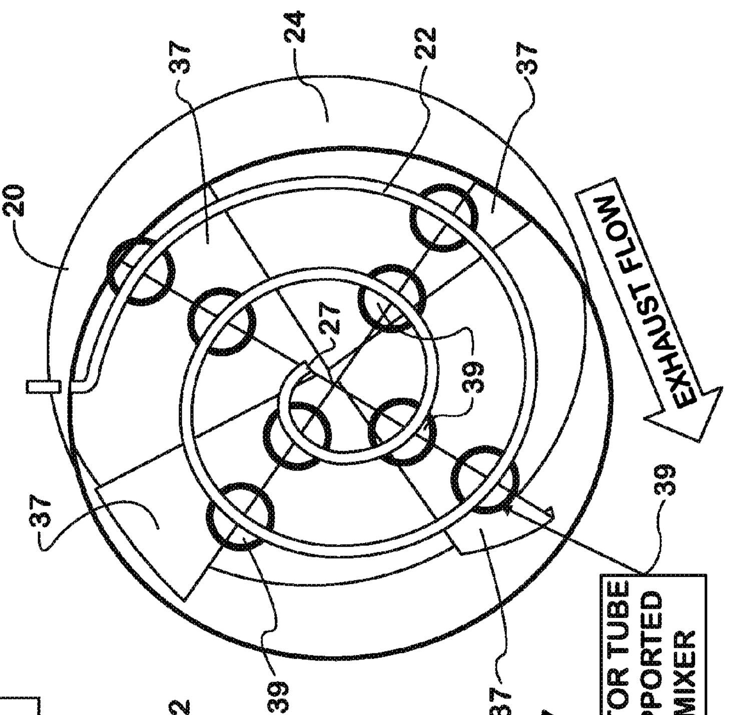

20
24
22
37
37
37
37
27
39
39
39
39
EXHAUST FLOW
INJECTOR TUBE IS SUPPORTED BY MIXER

FIG. 5

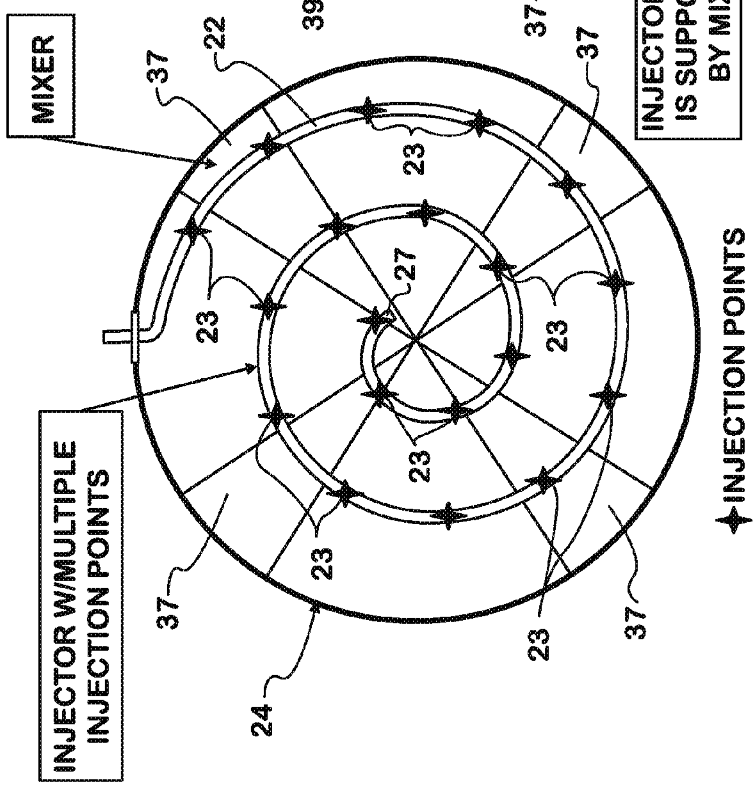

MIXER
INJECTOR W/MULTIPLE INJECTION POINTS
22
37
37
37
37
23
23
23
23
23
23
23
27
24
INJECTION POINTS

FIG. 4

METHOD AND APPARATUS FOR GASEOUS MIXING IN A DIESEL EXHAUST SYSTEM

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to an apparatus and method for treating and mixing diesel exhaust in a diesel exhaust system. Particularly, the present invention provides methods and apparatus for injecting reagent into a diesel exhaust stream to reduce nitrogen oxides (NO_x) without increasing the packing space of the exhaust system.

BACKGROUND OF THE INVENTION

[0002] Diesel engines are efficient, durable and economical. Diesel exhaust, however, can harm both the environment and people. To reduce this harm, governments, such as the United States and the European Union, have proposed stricter diesel exhaust emission regulations. These environmental regulations require diesel engines to meet the same pollution emission standards as gasoline engines.

[0003] Typically, to meet such regulations and standards, systems require equipment additions and modifications. Additional equipment can often lead to additional weight and/or additional packaging length.

[0004] For example, a lean burning engine provides improved fuel efficiency by operating with an amount of oxygen in excess of the amount necessary for complete combustion of the fuel. Such engines are said to run "lean" or on a "lean mixture." However, the increase in fuel efficiency is offset by the creation of undesirable pollution emissions in the form of nitrogen oxides (NO_x). One method used to reduce NO_x emissions from lean burn internal combustion engines is known as selective catalytic reduction. When used to reduce NO_x emissions from a diesel engine, selective catalytic reduction involves injecting atomized urea into the exhaust stream of the engine in relation to one or more selected engine operational parameters and running the stream through a reactor containing a catalyst. However, selective catalytic reduction and the use of aqueous urea involve many disadvantages, including added packaging weight and added packaging length to the exhaust system, as well as the highly corrosiveness and poor lubricity of aqueous urea.

[0005] It would be advantageous to provide methods and apparatus for addressing the regulations and standards without adding weight or length to an already complex diesel exhaust system. Accordingly, it would be advantageous to provide methods and apparatus for injecting a NO_x reducing reagent into the diesel exhaust stream of a lean burn engine where little or no added weight or packaging length is required. Further, it would be advantageous to provide a mixing system which creates a more homogenous mixture in a limited length. It would also be advantageous to provide an injector which is capable of distributing the reagent more uniformly throughout a cross-section of the treatment area. Accordingly, it would be advantageous to provide multiple injection points within a diesel exhaust stream.

[0006] The methods and apparatus of the present invention provide the foregoing and other advantages.

SUMMARY OF THE INVENTION

[0007] There is disclosed herein an improved diesel exhaust treatment system and method which avoid disadvantages of prior devices and methods, while affording additional structural and operating advantages.

[0008] Generally speaking, a mixing device for a diesel exhaust system is disclosed having a chamber, a mixer within the chamber, and an injection tube supported on the mixer within the chamber. The mixer is positioned within the chamber adjacent an inlet and includes a plurality of angled blades to effect turbulent flow in a diesel exhaust stream entering the chamber through the inlet.

[0009] In specific embodiments of the system, the injection tube includes a plurality of injection points (e.g., openings) for discharging a reagent into the exhaust stream. The injection tube is curved, and more specifically it is coiled with the injection points spread along the length of the tube in order to deliver reagent across a section of the chamber perpendicular to the exhaust stream flow.

[0010] The disclosed method for mixing gaseous ammonia in a diesel exhaust system begins with a diesel exhaust stream from a diesel engine passing from the engine through a conduit in fluid communication with the engine. The exhaust stream is directed to flow through the conduit into a housing having a mixer, an injection tube and an exit disposed therein. Turbulent flow in the diesel exhaust stream is created within the housing as the stream passes through the mixer. A continuous injection of gaseous NH_3 from the injection tube into the diesel exhaust stream is made as the stream moves from the mixer toward the housing exit to create a treated homogenous exhaust stream. Finally, the treated exhaust stream is discharged through the housing exit.

[0011] These and other aspects of the invention may be understood more readily from the following description and the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For the purpose of facilitating an understanding of the subject matter sought to be protected, there are illustrated in the accompanying drawings embodiments thereof, from an inspection of which, when considered in connection with the following description, the subject matter sought to be protected, its construction and operation, and many of its advantages should be readily understood and appreciated.

[0013] FIG. **1** is a schematic illustrating a typical mixer/injector device in a diesel exhaust system;

[0014] FIG. **2** is a schematic illustrating an embodiment of a mixer/NH_3 injection device of the present invention in a diesel exhaust system;

[0015] FIG. **3** is a schematic illustrating another embodiment of a mixer/NH_3 injection device of the present invention in a diesel exhaust system;

[0016] FIG. **4** is a front view of an embodiment of a mixer/NH_3 injection device; and

[0017] FIG. **5** is a perspective view of the mixer/NH_3 injection device of FIG. **4**.

DETAILED DESCRIPTION OF THE INVENTION

[0018] While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail a preferred embodiment of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to embodiments illustrated.

[0019] Referring to FIG. **1**, there is illustrated a typical mixer/injector device. Exhaust is discharged from the diesel engine **100**, through conduit such as exhaust piping to an exhaust treatment system **110**. The exhaust treatment system **110** typically consists of, in downstream order, a diesel oxidation catalyst (DOC) **112**, a diesel particulate filter (DPF) **114**, a mixer/NH_3 treatment canister **116**, and a NO_x slip catalyst (NSC) **118**. The DOC **112**, DPF **114** and NSC **118** are additional exhaust treatment structures present in most diesel exhaust treatment systems and which form no part of the present system **10**. Such structures will be generally referenced herein and identified in the drawing figures but, as each of these additional exhaust treatment structures is commonly understood by those skilled in the art, a detailed discussion of each is avoided for the purpose of focusing discussion on the system **10** as set forth in the appended claims.

[0020] The mixer/treatment canister **116** is shown to include a connection pipe **120** with an injector **122** at the upstream end where NH_3—or an NH_3 containing reagent—is injected into a laminar diesel exhaust flow as it is discharged from the DOC **112** and DPF **114**. The ammonia/exhaust stream then passes through a mixer **124** to effect mixing of the NH_3 and the diesel exhaust. A substantial length of pipe **120** is needed to allow for adequate mixing of the two components before the flow enters the NSC **118**. As such, the mixer/injector system adds packaging length and weight to the diesel exhaust system **100** which might otherwise be used for other after-treatment substrates.

[0021] Referring to FIGS. **2-5**, there is illustrated a mixer/NH_3 injection system, generally designated by the numeral **10**. The system **10** is shown in two distinct exhaust treatment configurations. FIG. **2** illustrates a configuration similar to that of FIG. **1** where the downstream order of components is DOC **12**, then DPF **14** and NSC **18** sandwiched about system **10**. Alternatively, FIG. **3** illustrates a configuration where the NSC **18** is on the DPF **14**—i.e., NO_x slip catalyst on diesel particulate filter (NPF) **19**—sandwiching the system **10** with the DOC **12**. Other configurations may exist in which the system **10** is moved up or downstream in the exhaust flow.

[0022] Regardless of the specific configuration, it is clear from examination of FIGS. **2** and **3** that the packaging space required for system **10** is substantially reduced from that required for a typical mixer/injector device **110** illustrated in FIG. **1**.

[0023] Generally speaking, system **10** is comprised of a housing **20** defining a mixing chamber **25**, an injection tube **22** fed by an exterior injector boss **30** coupled to a supply (not shown), and a mixer **24**. FIGS. **2** and **3** illustrate the diameter of the housing **20** (approx. 12 inches (30.5 cm)) is substantially equal to that of the surrounding structures—e.g., DPF **14** and NSC **18**. By providing the larger diameter system housing **20** (vs. narrow connecting pipe **120**), the need for reducers **123** (FIG. **1**) is eliminated, further reducing the packaging size of the entire diesel exhaust treatment system.

[0024] FIGS. **4** and **5** illustrate a specific embodiment of a single-plane, coiled injection tube **22**. Injection tube **22** enters through the housing sidewall and begins a tortuous path to a center of the chamber **25**. The tube **22** includes a series of injection points **23** where reagent can be emitted into the chamber **25**. The injection points **23** are spaced along the tube **22** and, therefore, throughout a cross-section of the chamber **25** to provide a more uniform distribution of reagent throughout that cross-section of the mixing chamber **25**. The uniform distribution into the exhaust stream results in a more homogenous mixture of reagent and exhaust in a shorter mixing period.

[0025] The tube **22** may be configured in several alternative shapes, including circular and serpentine, so long as a distribution of the injection points **23** throughout a cross-section of the chamber is provided. Further, the injection points **23** comprise small openings in the tube **22** to allow discharge of the reagent from the tube **22**. To effect a uniform or even discharge from all the injection points **23**, the first opening has a very small diameter and successive opening diameters increase toward the tube end **27**—i.e., the smallest diameter openings are positioned at the beginning of the tube where the fluid pressure is the greatest. The purpose, again, is to achieve even distribution of reagent across the entire cross-section of the mixing chamber **25**.

[0026] Also shown in FIGS. **4** and **5**, is exhaust flow mixer **24**. The mixer **24** is comprised of a plurality of fixed blades **37**, four are shown, secured to one another at a midpoint and outwardly to and within a short section (approx. six inches (15.2 cm)) of the housing **20**. The blades **37** are angled from back to front as a way of imparting a turbulent flow to the substantially laminar exhaust flow entering system **10**. Though not shown, additional blade configurations are possible to achieve the desired turbulent exhaust flow for mixing.

[0027] Another feature of the mixer **24** is that it supports the injection tube **22**. That is, the tube **22**, which is positioned on the downstream side of the mixer **24**, attaches to, by way of welds or any other suitable attachment means, each of the mixer blades **37** for simple structural support. Attachment may be achieved, for example, at the areas **39** where the tube **22** crosses each blade **37**. The securing of the coiled tube **22** alleviates damage which might otherwise be caused by the more violent vibration of the tube **22** during operation of the vehicle. Reagent (e.g., gaseous NH_3) discharged from injection points **23** immediately enters the turbulent diesel exhaust stream as it moves toward the chamber exit **35** (FIGS. **2** and **3**). A relatively short distance is needed to provide the necessary mixing time to create a homogonous reagent/diesel exhaust.

[0028] The homogenous mixture is then exited from the mixing chamber **25** into one of either the NSC **18** (FIG. **2**) or the NPF **19** (FIG. **3**) for further treatment.

[0029] The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only and not as a limitation. While particular embodiments have been shown and described, it will be apparent to those skilled in the art that changes and modifications may be made without departing from the broader aspects of applicants' contribution. The actual scope of the protection sought is intended to be defined in the following claims when viewed in their proper perspective based on the prior art.

What is claimed is:

1. A mixing device for a diesel exhaust system comprising:

a chamber having an inlet at one end for permitting entrance of an exhaust stream from a diesel engine and an outlet at an opposing end;

a mixer within the chamber adjacent the inlet and positioned to effect turbulent flow in an exhaust stream entering the chamber through the inlet; and

an injection tube supported within the chamber by the mixer.

2. The mixing device of claim **1**, wherein the injection tube comprises a plurality of injection points therein for discharging a reagent into the exhaust stream, and extends within a plane of the chamber.

3. The mixing device of claim **2**, wherein the injection tube is curved.

4. The mixing device of claim **2**, wherein the injection tube is coiled.

5. The mixing device of claim **1**, wherein the mixer comprises a plurality of fixed blades angled to deflect the exhaust stream.

6. The mixing device of claim **2**, wherein the mixer comprises a plurality of blades angled to impart mixing to the exhaust stream and the injection tube extends across each blade within the chamber.

7. The mixing device of claim **1**, wherein the injection tube is connected to the mixer.

8. The mixing device of claim **1**, wherein the chamber is positioned between a diesel particulate filter (DPF) and a NO_x slip catalyst canister.

9. The mixing device of claim **1**, wherein the chamber is positioned between a diesel oxidation catalyst (DOC) canister and a NO_x particulate filter (NPF) canister.

10. A mixing device for a diesel exhaust system comprising:

a chamber having an inlet at one end for permitting entrance of an exhaust stream from a diesel engine and an outlet at an opposing end;

a mixer within the chamber adjacent the inlet; and

an injection tube having a plurality of injection points and extending into the chamber.

11. The mixing device of claim **10**, wherein the injection tube is supported by the mixer within the chamber.

12. The mixing device of claim **10**, wherein the injection tube is curved.

13. The mixing device of claim **12**, wherein the injection tube is coiled.

14. The mixing device of claim **10**, wherein the mixer comprises a plurality of fixed blades angled to effect turbulent flow in the exhaust stream.

15. The mixing device of claim **11**, wherein the mixer comprises a plurality of blades angled to impart mixing to the exhaust stream and the injection tube extends across each blade within the chamber.

16. The mixing device of claim **10**, wherein the injection tube is connected to the mixer.

17. The mixing device of claim **10**, wherein the chamber is positioned between a diesel particulate filter (DPF) and a NO_x slip catalyst canister.

18. The mixing device of claim **10**, wherein the chamber is positioned between a diesel oxidation catalyst (DOC) canister and a NO_x particulate filter (NPF) canister.

19. A method for mixing gaseous ammonia in a diesel exhaust system comprising the steps of:

a. exhausting a diesel exhaust stream from an engine through a conduit in fluid communication with the engine;

b. directing the diesel exhaust stream to flow through the conduit into a housing having a mixer, an injection tube and an exit disposed therein;

c. creating a turbulent flow in the diesel exhaust stream within the housing as the stream passes through the mixer;

d. injecting gaseous NH_3 from the injection tube into the diesel exhaust stream as the stream moves from the mixer toward the housing exit to create a treated exhaust stream; and

e. discharging the treated exhaust stream through the housing exit.

20. The method of claim **19**, wherein the mixer comprises a plurality of fixed blades angled to deflect the diesel exhaust stream.

21. The method of claim **19**, wherein the injection tube comprises a plurality of injection points for introducing NH_3 gas into the diesel exhaust stream.

22. The method of claim **21**, wherein the injection tube is supported in the housing by the mixer.

23. The method of claim **21**, wherein the injection tube comprises a coil.

24. The method of claim **19**, further comprising the step of creating a homogenous mixture of diesel exhaust and gaseous NH_3.

25. The method of claim **24**, wherein the step of creating a homogenous mixture comprises the step of injecting gaseous NH_3 into the diesel exhaust stream at a plurality of points.

26. The method of claim **25**, wherein the injection tube comprises a plurality of injection points spaced throughout a cross-section of the housing.

27. A method of treating diesel exhaust from an engine in a motor vehicle, the method comprising the steps of:

a. exhausting a diesel exhaust stream from an engine through a conduit in fluid communication with the engine;

b. directing the diesel exhaust stream to flow through the conduit into a housing having a mixer, an injection tube and an exit disposed therein, wherein the injection tube is in fluid communication with a reagent supply;

c. creating a turbulent flow in the diesel exhaust stream within the housing as the stream passes through the mixer;

d. injecting a gaseous reagent from the reagent supply through the injection tube into the diesel exhaust stream as the stream moves from the mixer toward the housing exit to create a treated exhaust stream; and

e. discharging the treated exhaust stream through the housing exit.

* * * * *