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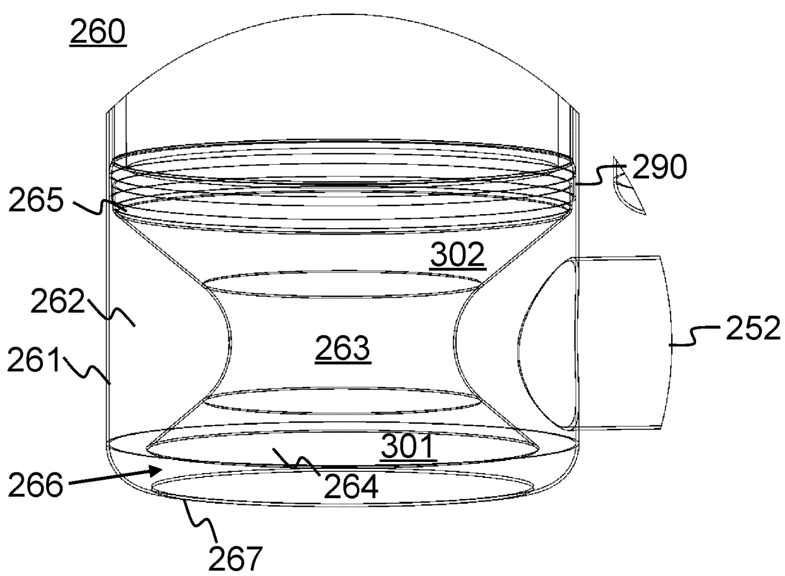
Other: **EPODOC, WPI, TXTE, TXTT**

(54) Title of the Invention: **Method, apparatus and device for improved aftertreatment of exhaust gas**
Abstract Title: **Exhaust gas mixer with double-funnel flow guide**

(57) A mixing device 260 for aftertreatment of an exhaust gas. The mixing device comprises a housing 261 defining an inner cavity 262, an exhaust inlet 252 into the inner cavity, an exhaust outlet 290 from the mixing device, and a double funnel-shaped tubular flow guide 263 in the inner cavity. The flow guide has first and second funnel-shaped portions 301, 302 connected at their smaller diameters, the first portion defining an inlet 264 of the flow guide, and the second portion defining an outlet 265 of the flow guide. The flow guide forms a swirling flow of exhaust gas around the flow guide within the inner cavity. A slot 266 between the inlet of the flow guide and a first end wall 267 of the inner cavity allows the swirling flow to enter the flow guide, and flow there through to the outlet thereof. The mixer unit may be provided downstream of a diesel particulate filter (DPF) and a mixer unit which dispenses a reducing agent (such as urea or ammonia), and upstream of a selective catalytic reduction (SCR) device in an exhaust system.

Fig. 3



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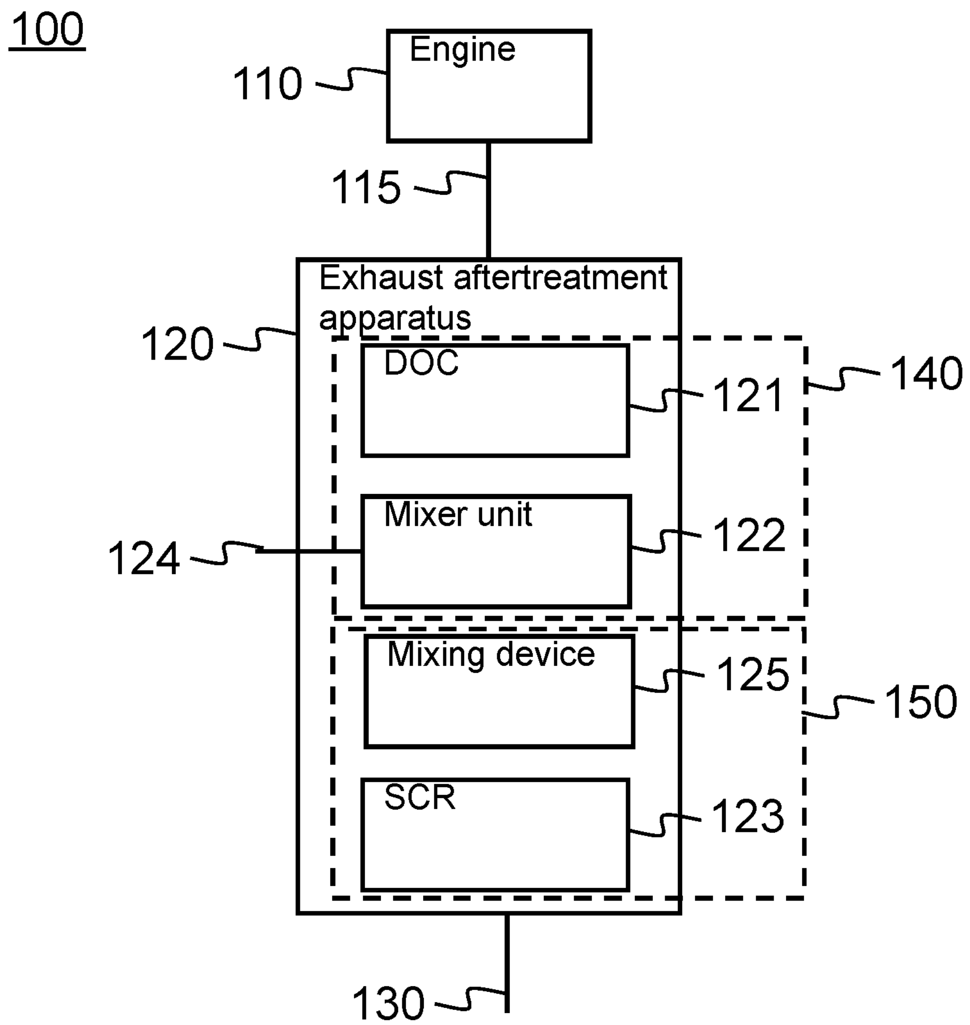
100
Engine
110
115
Exhaust aftertreatment apparatus
120
DOC
121
140
Mixer unit
122
124
Mixing device
125
150
SCR
123
130

Fig. 1

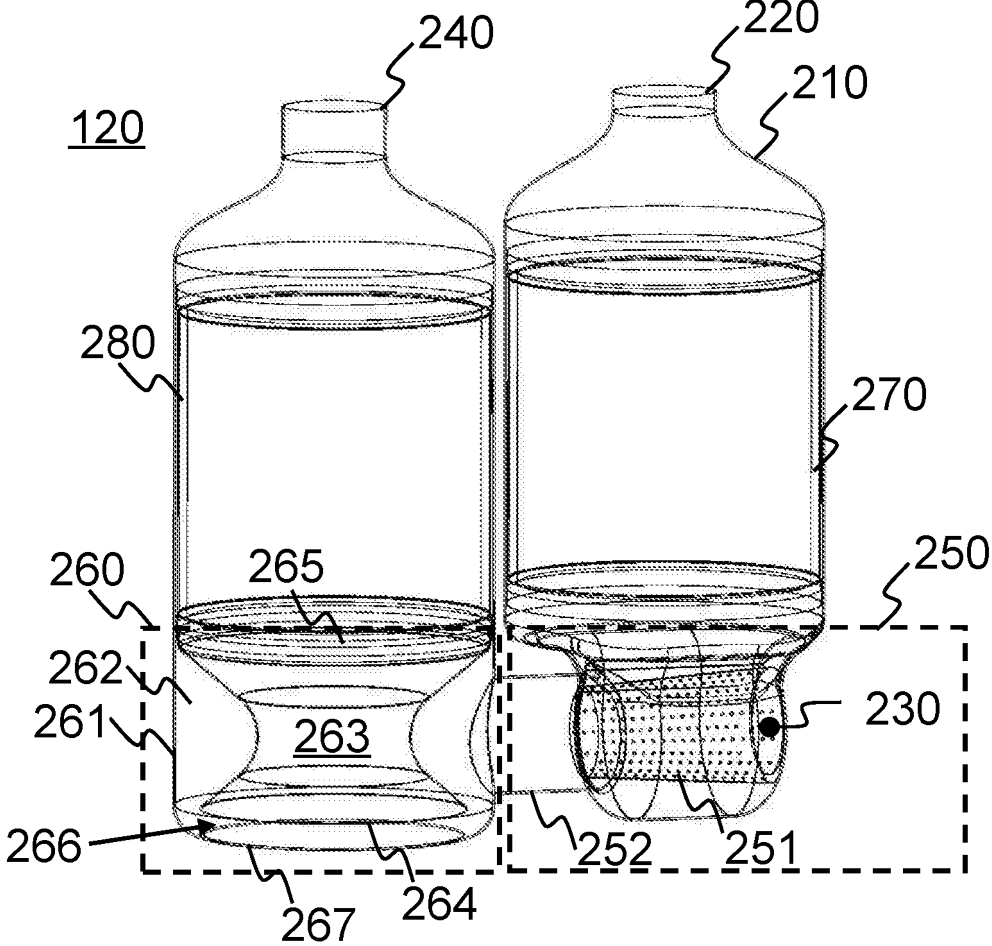
120
240
220
210
280
270
260
265
250
262
261
263
230
266
252
251
267
264

Fig. 2

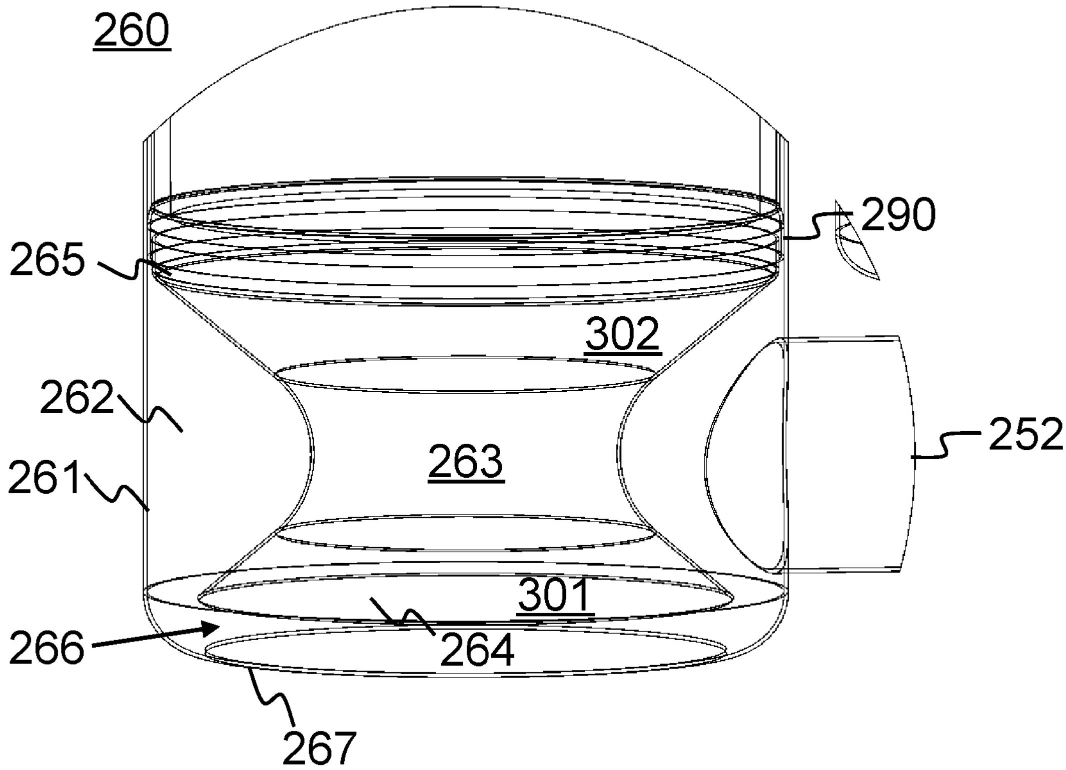
260
290
265
302
262
263
252
261
301
266
264
267

Fig. 3

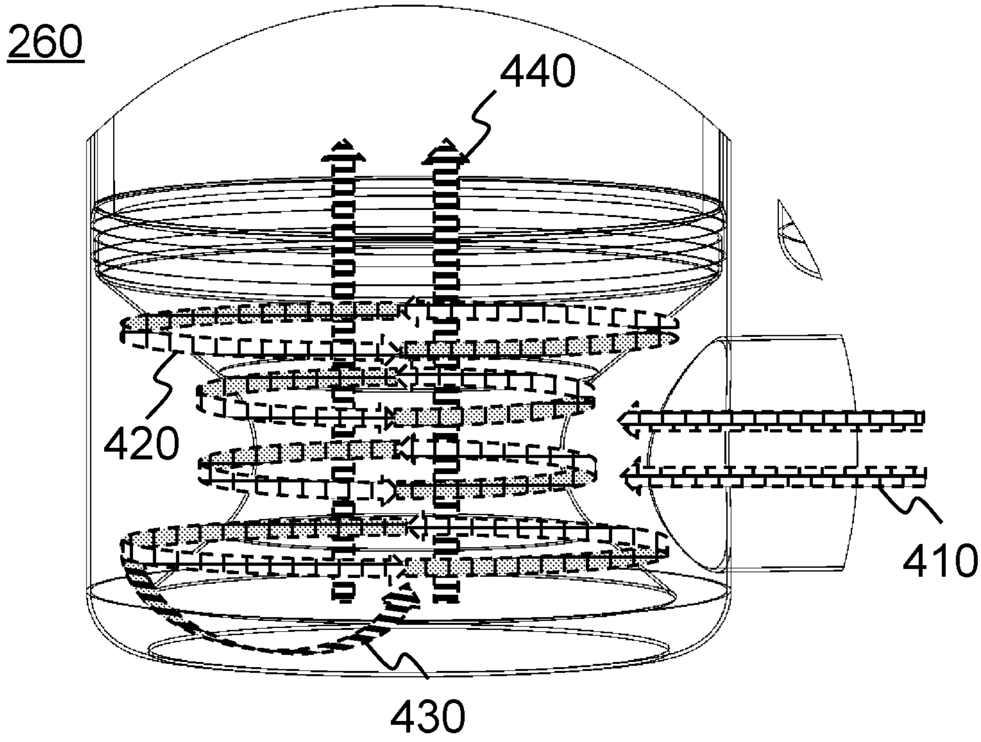

Fig. 4

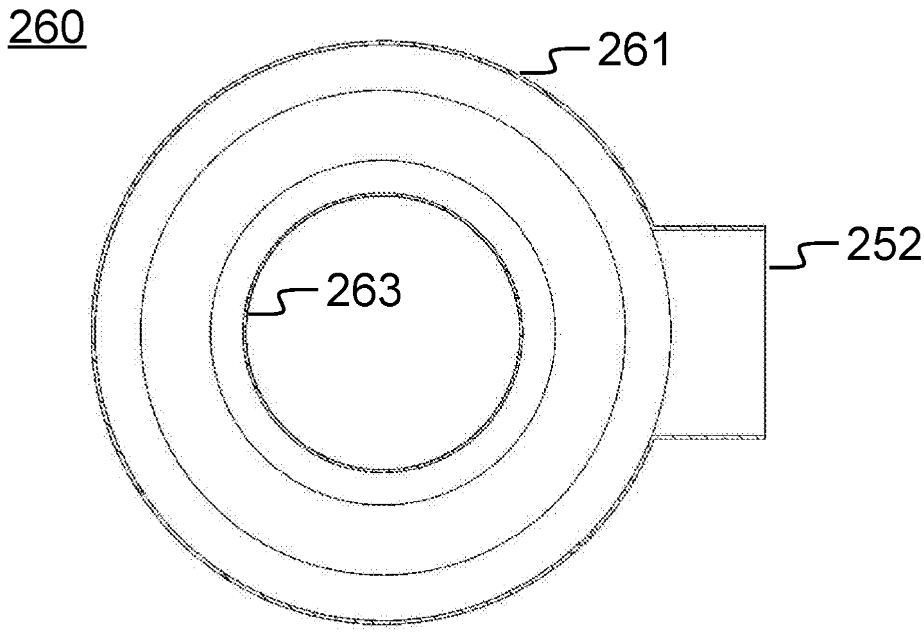

Fig. 5

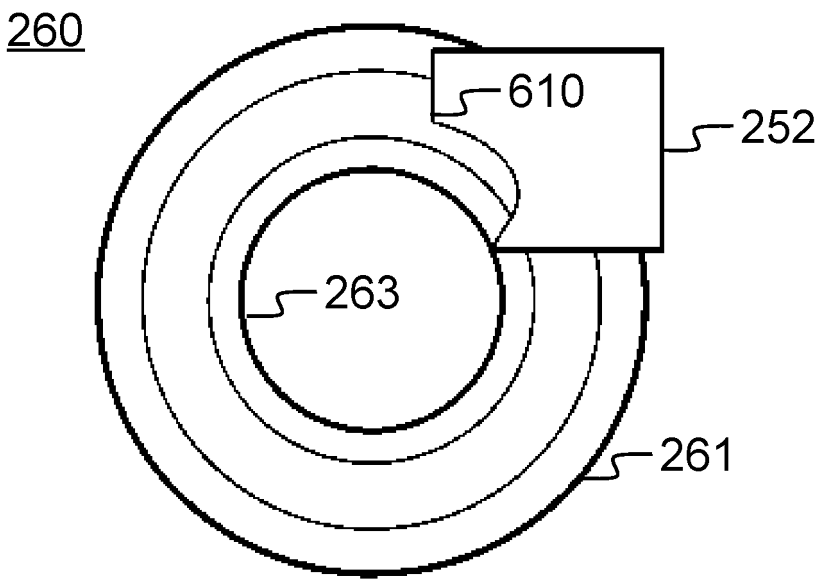

Fig. 6

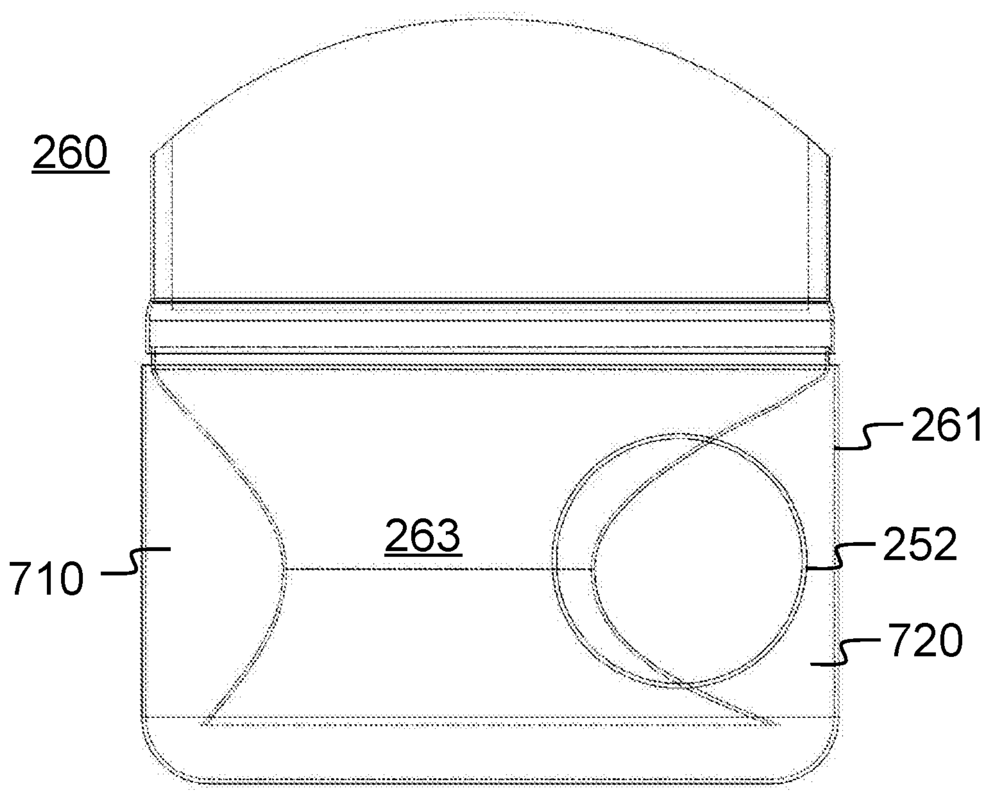

Fig. 7

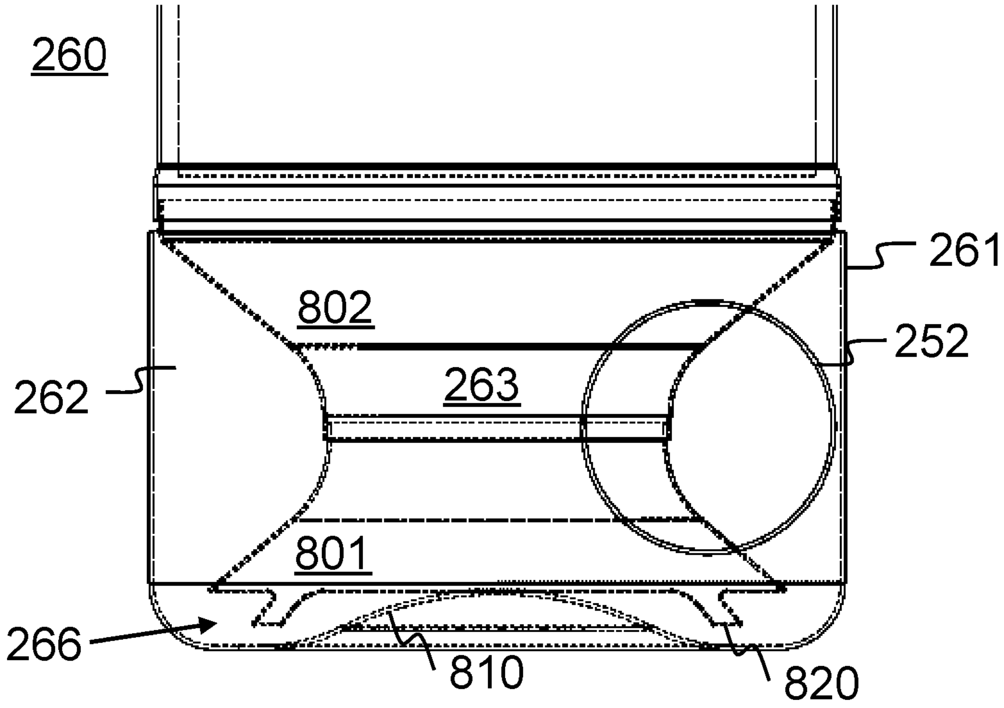
260
261
802
252
262
263
801
266
810
820

Fig. 8

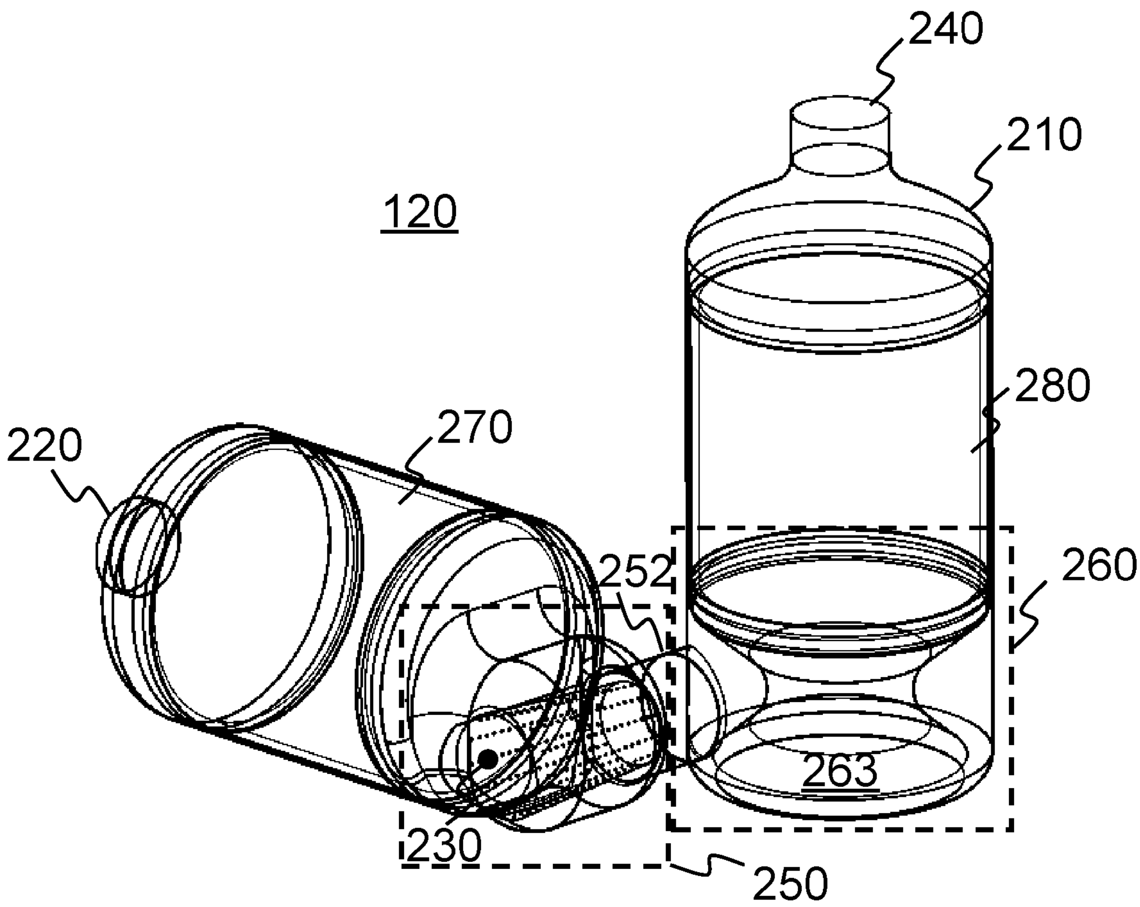
240
210
120
280
220
270
252
260
263
230
250

Fig. 9

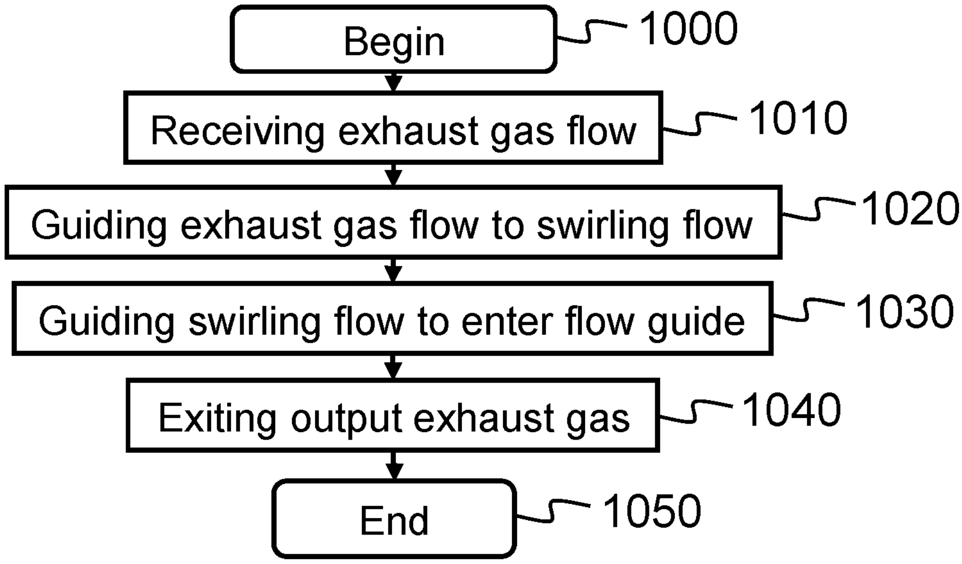
Begin
1000
Receiving exhaust gas flow
1010
Guiding exhaust gas flow to swirling flow
1020
Guiding swirling flow to enter flow guide
1030
Exiting output exhaust gas
1040
End
1050

Fig. 10

The following terms are registered trade marks and should be read as such wherever they occur in this document:

AdBlue

METHOD, APPARATUS AND DEVICE FOR IMPROVED AFTERTREATMENT OF EXHAUST GAS

TECHNICAL FIELD

The present application generally relates to a device, method and apparatus for aftertreatment of exhaust gas.

BACKGROUND ART

This section illustrates useful background information without admission of any technique described herein representative of the state of the art.

Emission regulations for internal combustion engines have tightened over recent years, and the trend is even tightening. For example, regulated emissions of NOx and particles from internal combustion engines are becoming so low that the target emissions levels are hard to be met. Therefore, aftertreatment systems are used in engines to reduce emissions. For reducing NOx emissions, NOx reduction catalysts, including selective catalytic reduction (SCR) systems, are utilized to convert NOx (NO and NO2) to N2 and other compounds. SCR systems utilize a reactant, such as ammonia, to reduce the NOx.

Simultaneously with the emission regulation demands, also power and efficiency demands for engines increase. On top of that the internal combustion engines should be designed and manufactured with smaller size and decreased weight, if possible.

A solution is needed for cost-efficiently providing an aftertreatment system of exhaust gas for internal combustion engine to reduce emissions capable of fulfilling the requirements for emission regulations without sacrificing too much power and efficiency of the engine. Furthermore, an improved solution is needed to reduce the size and the length of the exhaust gas ducts needed for the aftertreatment system.

SUMMARY

According to a first example aspect of the invention there is provided a mixing device for aftertreatment of exhaust gas comprising:

a housing configured to define an inner cavity;

an exhaust inlet arranged to the housing for entering exhaust gas flow to the inner cavity;

a double funnel-shaped tubular flow guide, in the inner cavity, whose first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide, the double funnel-shaped tubular flow guide forming, from the entering exhaust gas flow, a swirling flow around the double funnel-shaped tubular flow guide within the inner cavity;

a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity for allowing the swirling flow to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide; and

an exhaust outlet arranged to the housing for exiting exhaust gas flow from the mixing device.

In an embodiment, the double funnel-shaped tubular flow guide is arranged vertically within the inner cavity, and the exhaust inlet arranged to the housing for entering exhaust gas flow horizontally to the inner cavity.

In an embodiment, the exhaust inlet is arranged to the housing for entering exhaust gas flow horizontally to the inner cavity to a vertical position, where the first and the second funnel-shaped portions being combined at their smaller diameters.

In an embodiment, the exhaust inlet is arranged to the housing for entering exhaust gas flow horizontally to the inner cavity in a tangential direction in relation to a central axis of the double funnel-shaped tubular flow guide.

In an embodiment, the housing is configured to define the inner cavity of a cylindrical shape, whose central axis being parallel to a central axis of the double funnel-shaped tubular flow guide.

In an embodiment, the second funnel-shaped portion of the double funnel-shaped tubular flow guide is connected to a second end wall of the inner cavity, different to the first end wall, and the second end wall of the inner cavity between the second funnel-shaped portion of the double funnel-shaped tubular flow guide and a side wall of the cylindrical shape inner cavity being closed to exhaust gas flow.

In an embodiment, a largest diameter of the first portion of the double funnel-shaped tubular flow guide being smaller than a largest diameter of the second portion of the double funnel-shaped tubular flow guide.

In an embodiment, the outlet of the double funnel-shaped tubular flow guide forms the exhaust outlet of the mixing device.

In an embodiment, the mixing device further comprises an outlet duct extending from the exhaust outlet.

In an embodiment, the mixing device further comprises an inlet duct extending from the exhaust inlet to the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide.

In an embodiment, the inlet duct extending tangentially to a vertical axis of the double funnel-shaped tubular flow guide.

In an embodiment, the mixing device further comprises an elongated blade extending across the exhaust inlet in the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide.

In an embodiment, the double funnel-shaped tubular flow guide is asymmetric around a vertical axis of the double funnel-shaped tubular flow guide.

In an embodiment, the double funnel-shaped tubular flow guide is arranged vertically within the inner cavity in an eccentric manner.

In an embodiment, the first end wall of the inner cavity is bent inwards.

In an embodiment, the first end wall of the inner cavity is flat.

In an embodiment, the first end wall of the inner cavity is concave.

In an embodiment, an inner surface of the housing is configured to define the inner cavity.

According to a second example aspect of the invention there is provided an apparatus for aftertreatment of exhaust gas comprising:

a diesel particulate filter (DPF) for receiving exhaust gas;

a mixer unit, located downstream of the diesel particulate filter (DPF), to dispense a reactant to an exhaust gas flow from the diesel particulate filter (DPF);

a mixing device of the first example aspect, located downstream of the mixer unit, to evenly mix the reactant with the exhaust gas flow from the mixer unit; and

a selective catalytic reduction (SCR) substrate, located downstream of the mixing device.

According to a third example aspect of the invention there is provided a method for aftertreatment of exhaust gas comprising:

receiving exhaust gas flow to an inner cavity of a mixing device housing via an exhaust inlet;

guiding, from the received exhaust gas flow, a swirling flow around a double funnel-shaped tubular flow guide within the inner cavity, wherein the double funnel-shaped tubular flow guide having first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide;

guiding the swirling flow to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide via a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity; and

exiting exhaust gas flow from the mixing device via an exhaust outlet arranged to the housing.

Different non-binding example aspects and embodiments of the present invention have been illustrated in the foregoing. The above embodiments are used merely to explain selected aspects or steps that may be utilized in implementations of the present invention. Some embodiments may be presented only with reference to certain example aspects of the invention. It should be appreciated that corresponding embodiments may apply to other example aspects as well.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a schematic picture of a system according to an example embodiment of the invention;

Fig. 2 shows a schematic picture of an apparatus according to an example embodiment of the invention;

Fig. 3 shows a schematic picture of a mixing device according to an example embodiment of the invention;

Fig. 4 shows a schematic picture of exhaust gas flows in a mixing device according to an example embodiment of the invention;

Fig. 5 shows a schematic picture from above view of a mixing device according to an example embodiment of the invention;

Fig. 6 shows a schematic picture from above view of a mixing device according to another example embodiment of the invention;

Fig. 7 shows a schematic picture from side view of a mixing device according to another example embodiment of the invention;

Fig. 8 shows a schematic picture from side view of a mixing device according to another example embodiment of the invention;

Fig. 9 shows a schematic picture of an exhaust gas aftertreatment apparatus according to an alternative embodiment of the invention; and

Fig. 10 shows a flow diagram showing operations in accordance with an example embodiment of the invention.

DETAILED DESCRIPTION

In the following description, like reference signs denote like parts or steps.

Fig. 1 shows a schematic picture of a system according to an example embodiment of the invention. An engine system 100 is shown. The engine system 100 comprises an engine 110 and an exhaust aftertreatment apparatus 120. Furthermore, the system 100 may comprise other devices that are not shown in the Fig. 1. Such devices comprise, for example, fuel storage for the engine 110 (e.g. diesel), and an air intake device including an air filter.

Fig. 1 shows a connection 115 between the engine 110 and the exhaust aftertreatment apparatus 120. The connection 115 may comprise a pipe for guiding exhaust gas from the engine 110, for example.

The exhaust aftertreatment apparatus 120 receives the exhaust gas from the engine 110 over the connection 115. In an embodiment, the apparatus 120 comprises a catalytic converter, such as diesel oxidation catalyst (DOC) device 121, a mixer unit 122, a mixing device 125 and a selective catalytic reduction (SCR) device 123. The devices 121-125 are in an embodiment implemented within the same housing of the apparatus 120 but at least one of the devices 121-125 may also be placed outside the housing of the apparatus 120. In another embodiment, any of the devices 121-125 may be implemented within different housings. For example, the DOC 121 and the mixer unit 122 may be implemented within the same housing, and the mixing device 125 and the SCR 123 within another housing. In another embodiment, the mixer unit 122 and the mixing device 125 are implemented within the same housing. In still another embodiment, all devices 121-125 may be implemented within different housings. A connection 124 for receiving reactant for the mixer unit 122 is also disclosed. The apparatus 120 may further comprise devices not shown in Fig. 1, such as doser for the reactant, storage for the reactant (such as urea or ammonia), gas flow guides and connections within the apparatus 120 and within its devices 121-125.

Catalytic converters (diesel oxidation catalysts or DOC's) 121 are typically used in an exhaust system to convert undesirable gases such as carbon monoxide and hydrocarbons from engine's exhaust into carbon dioxide and water. DOC's may have different configurations. The substrates used in catalytic converters preferably include a catalyst.

A diesel particulate filter (DPF) may also be implemented together or alternatively to the DOC 121 in an exhaust system to remove particulate matter (e.g., carbon based particulate matter such as soot) from the exhaust. DPF's can have a variety of known configurations.

The selective catalytic reduction (SCR) catalyst device 123 is typically used in an exhaust system to remove undesirable gases such as nitrogen oxides (NOx) from the engine’s emissions. SCR's are capable of converting NOx to nitrogen and oxygen in an oxygen rich environment with the assistance of reactants such as urea or ammonia, which are injected into the exhaust gas upstream of the SCR device 123.

A mixer unit 122 is configured to receive exhaust gas from the engine 110 over connection 115, which gas is possibly run through a DOC 121 or DPF, as disclosed above. The mixer unit 122 receives also reactant, such as diesel exhaust fluid (DEF), over the connection 124, the reactant commonly referred to as AdBlue that is an aqueous urea solution made with 32.5% high-purity urea and 67.5% deionized water. DEF may be used as a consumable in selective catalytic reduction (SCR) in order to lower NOx concentration in the diesel exhaust emissions from diesel engines. The mixer unit 122 is configured to dispense the reactant to the exhaust gas and start mixing them.

The even mixing is carried on by the mixing device 125 and also targeting to reduce urea deposits in exhaust pipelines. When SCR process uses DEF, it can cause urea deposits in exhaust pipes, especially in off-road applications using airless DEF injectors. Larger DEF spray droplets might lead to wall wetting and film formation on exhaust pipe inner surfaces, causing deposits when the local temperatures are low. Urea deposit problems have become frequent and critical, and the mixer unit 122 together with the mixing device 125 are configured to keep pipelines clean by evenly distributing the reactant to the exhaust gas in the shortest possible pipe length and avoiding this way the wall wetting and film formation. The mixing device 125 is especially advantageous to reduce the pipe length needed fro mixing to achieve evenly enough mixing of the reactant and the exhaust gas before reaching the SCR. Thus not only the pipe length needed, but also the overall size of the aftertreatment system, is reduced.

The apparatus 120 may also help water evaporation from DEF and ensures optimal reactions with the reactant with no unwanted side effects. The apparatus 120 may be used with all reactant dosers (e.g. urea or ammonia) to achieve even NH3 distribution within the exhaust gas. Further benefit is experienced with airless injectors, which have rather large Sauter mean diameter (SMD) and when the injection must start at low temperatures. An exhaust gas outlet pipe 130 guides the aftertreated exhaust gas from the apparatus 120.

In an embodiment, the apparatus 120 is configured to inject small droplets of reactant, such as urea-water solution, to the exhaust gas flow and causing the reactant to vaporize in an exhaust gas flow channel defined by the mixer unit and the mixing device and to react with the nitric oxides of the exhaust gas and changing them to plain nitrogen. Such final change to nitrogen takes place in SCR catalysator 123.

In an embodiment, an exhaust gas cleaning unit is arrangeable to an exhaust gas channel, which unit comprises an inlet duct 115 for the inflow of exhaust gas to be cleaned and an outlet duct 130 for the outflow of exhaust gas. Between the inlet duct 115 and the outlet duct 130 is a first housing part 140 that comprises a DOC-substrate 121 (Diesel Oxidation Catalyst) and a second housing part 150 that comprises a SCR catalysator 123. The housing parts may also comprise other devices for cleaning exhaust gas, such as a particle filter, (Diesel Particulate Filter).

Inside the second housing part 150 there are the mixing device 125 that provides even mixing of the exhaust gas and the reactant with reduced size and length of the apparatus 120, and possibly a SCR 123.

Fig. 2 shows a schematic picture of an exhaust gas aftertreatment apparatus 120 according to an example embodiment of the invention. The apparatus 120 for aftertreatment of exhaust gas comprises a housing 210, an exhaust inlet 220, a reactant inlet 230, and an exhaust outlet 240.

In an embodiment, the reactant inlet 230 comprises a nozzle (not shown).

The exhaust inlet 220 is arranged to the housing 210 for entering input exhaust gas to the apparatus 120. The reactant inlet 230 is arranged to the housing 210 for dispensing reactant to the apparatus 120, and the reactant is configured to mix with the input exhaust gas to provide mixed exhaust gas. The exhaust outlet 240 is arranged to the housing 210 for exiting output exhaust gas from the apparatus 120. Furthermore, the apparatus 120 may comprise, for example, attachment elements for attaching the apparatus 120 to an engine system or a chassis of a vehicle. The exhaust outlet 240 may comprise an outlet duct.

In an embodiment, the apparatus 120 comprises a mixer unit 250 and a mixing device 260, as illustrated in Fig. 2 using dashed lines. The mixing device 260, located downstream to the mixer unit 250, receives the exhaust gas mixed with the reactant, and provides evenly mixing of those with reduced apparatus 120 size. A mixing tube 252 may be provided to connect the mixer unit 250 and the mixing device 260.

In an embodiment, a diesel oxidation catalyst (DOC) substrate 270 is placed downstream to the exhaust inlet 220, and upstream to the reactant inlet 230.

In an embodiment, a selective catalytic reduction (SCR) substrate 280 is placed downstream to the reactant inlet 230, the mixer unit 250, and the mixing device 260, and upstream to the exhaust gas outlet 240.

In an embodiment, the SCR substrate 280 may also comprise a diesel particulate filter (DPF) for particulate matter reduction.

In an embodiment, a housing 210 is configured to define at least one inner cavity, wherein the exhaust gas is aftertreated by the apparatus 120. An exhaust inlet 220 is arranged to the housing 210 for entering input exhaust gas for the inner cavity. The exhaust gas may travel through DOC substrate 270 within the inner cavity before reaching a mixer unit 250.

In an embodiment, the mixer unit 250 comprises at least one flow guide, for example an elongated blade extending across the inner cavity. The blade may also extend only partially across the inner cavity.

A reactant inlet 230 is arranged to the mixer unit 250 for dispensing reactant to the inner cavity, wherein the reactant is configured to mix with the input exhaust gas to provide mixed exhaust gas.

In an embodiment, the flow guide in the inner cavity is configured to assist the exhaust gas to circulating and advancing movement in a horizontal direction within the inner cavity of the mixer unit 250. The reactant is configured to mix with the exhaust gas when circulating and advancing.

In an embodiment, the apparatus further comprises a perforated tubular element 251, wherein at least part of the input exhaust is configured to enter an interior of the perforated tubular element through apertures. The perforated tubular element 251 is configured to assist the exhaust gas to circulating and advancing movement in a horizontal direction within the inner cavity of the mixer unit 250 towards the mixing device 260. The reactant is configured to mix with the input exhaust gas when circulating and advancing. The circulating and advancing movement of the mixed exhaust gas may take place both inside the perforated tubular element 251 and outside the perforated tubular element 251.

In an embodiment, the perforated tubular element may have different shapes, such as cylindrical or conical. As can be seen, the perforated tubular element of Fig. 2 is conical.

From the mixer unit 250, the mixed exhaust gas is guided to the mixing device 260, where more evenly mixed exhaust gas is achieved. A connecting pipe 252 between the mixer unit 250 and the mixing device 260 may be used. Alternatively, the devices 250, 260 may be connected directly with each other, for example.

In an embodiment, a mixing device 260 for aftertreatment of exhaust gas comprises a housing 261 configured to define an inner cavity 262, an exhaust inlet 252 arranged to the housing 261 for entering exhaust gas flow to the inner cavity 262. The device 260 further comprises a double funnel-shaped tubular flow guide 263, in the inner cavity 262, whose first (lower part in Fig. 2) and second (upper part in Fig. 2) funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet 264 of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet 265 of the double funnel-shaped tubular flow guide 263, the double funnel-shaped tubular flow guide 263 forming, from the entering exhaust gas flow, a swirling flow around the double funnel-shaped tubular flow guide 263 within the inner cavity 262.

Additionally, a slot 266 is provided between the inlet 264 of the of the double funnel-shaped tubular flow guide 263 and a first end wall 267 of the inner cavity 262 for allowing the swirling flow to enter inside the double funnel-shaped tubular flow guide 263 and to flow through the double funnel-shaped tubular flow guide to the outlet 265 of the double funnel-shaped tubular flow guide 263. The exhaust outlet 265 may be arranged to the housing 261 for exiting exhaust gas flow from the mixing device 260.

By guiding the circulating and advancing gas flow to swirl around the double funnel-shaped tubular flow guide 263 before entering the inlet 264 and passing through the guide 263 to the outlet 265, the time and channel length for the reactant to mix with the exhaust gas is increased. Furthermore the size of the apparatus 120 may be reduced and thus ease the attachment to an engine system. Since the time for the reactant to mix with the exhaust gas is increased, vaporization of the reactant is improved.

Fig. 3 shows a schematic picture of a mixing device 260 according to an example embodiment of the invention.

A housing 261 is configured to define an inner cavity 262 and an exhaust inlet 252 is arranged to the housing 261 for entering exhaust gas flow to the inner cavity 262. A double funnel-shaped tubular flow guide 263 is arranged in the inner cavity 262, comprising first 301 and second 302 funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion 301 having an inlet 264 of the double funnel-shaped tubular flow guide 263, and the second funnel-shaped portion 302 having an outlet 265 of the double funnel-shaped tubular flow guide 263, and the double funnel-shaped tubular flow guide 263 forming, from the entering exhaust gas flow, a swirling flow around the double funnel-shaped tubular flow guide 263 within the inner cavity 262.

A slot 266 between the inlet 264 of the of the double funnel-shaped tubular flow guide 263 and a first end wall 267 of the inner cavity 262 is provided for allowing the swirling flow to enter inside the double funnel-shaped tubular flow guide 263 and to flow through the double funnel-shaped tubular flow guide 263 to the outlet 265 of the double funnel-shaped tubular flow guide 263. A separate exhaust outlet may be arranged to the housing 261 for exiting exhaust gas flow from the mixing device 260 or the outlet 265 of the guide 263 may be used as such.

In an embodiment, an inner surface of the housing 261 is configured to define the inner cavity 262.

In an embodiment, the first end wall 267 of the inner cavity 262 is flat.

In an embodiment, the double funnel-shaped tubular flow guide 263 is arranged vertically within the inner cavity 262, and the exhaust inlet 252 is arranged to the housing 261 for entering exhaust gas flow horizontally to the inner cavity 262.

In an embodiment, the exhaust inlet 252 is arranged to the housing 261 for entering exhaust gas flow horizontally to the inner cavity 262 to a vertical position, where the first 301 and the second 302 funnel-shaped portions being combined at their smaller diameters.

In an embodiment, the exhaust inlet 252 is arranged to the housing for entering exhaust gas flow horizontally to the inner cavity 262 in a tangential direction in relation to a central axis of the double funnel-shaped tubular flow guide 263.

In an embodiment, the housing 261 is configured to define the inner cavity 262 of a cylindrical shape, whose central axis being parallel to a central axis of the double funnel-shaped tubular flow guide 263.

In an embodiment, the second funnel-shaped portion 302 of the double funnel-shaped tubular flow guide 263 is connected to the housing 261 in such a way that no exhaust gas flow is passed from the inner cavity 262 between the housing 261 side wall of the cylindrical shape and the second funnel-shaped portion 302 of the double funnel-shaped tubular flow guide directly to the outlet 265, without flowing first through the inlet 264.

In an embodiment, the slot 266 is not open for gas flow for the whole circumference of the first funnel-shaped portion 301 at an end of an inlet 264. Only part of the circumference of the first funnel-shaped portion 301 may be open and allow gas flow to enter through the inlet 264 inside the double funnel-shaped tubular flow guide 263. For example, one third of the circumference of the first funnel-shaped portion 301 may be providing the slot 266, and remaining portion of the circumference is closed by connecting circumference to the first end wall 267 of the inner cavity 262.

In an embodiment, the slot 266 comprises a plurality of slots arranged along the circumference of the first funnel-shaped portion 301.

The slot 266 may be of any shape.

In an embodiment, at least one flow guide, such as a blade, may be arranged between the first end wall 267 and the first funnel-shaped portion 301 to guide exhaust gas flow through the slot 266.

In an embodiment, a lower end of the first funnel-shaped portion 301 is arranged adjacent to the first end wall 267 of the inner cavity 262 in such a way that a first portion of the circumference of the first funnel-shaped portion 301 is connected to the first end wall 267 and not allowing the exhaust gas flow to enter inside the double funnel-shaped tubular flow guide 263. A second portion of the circumference of the first funnel-shaped portion 301 comprises an opening 266 that allows the exhaust gas flow from the inner cavity 262 to enter inside the double funnel-shaped tubular flow guide 263.

In an embodiment, a largest diameter of the first portion 301 of the double funnel-shaped tubular flow guide is smaller than a largest diameter of the second portion 302 of the double funnel-shaped tubular flow guide 263.

No matter the double funnel-shaped tubular flow guide 263 in Fig. 3 is illustrated as a solid tubular element, the double funnel-shaped tubular flow guide 263 may also comprise at least one aperture on a tubular surface of the flow guide 263 to provide a perforated double funnel-shaped tubular flow guide 263, wherein at least part of the exhaust gas flowing within the inner cavity 262 is configured to enter an interior of the perforated double funnel-shaped tubular flow guide 263 through the at least one aperture. The perforated double funnel-shaped tubular flow guide 263 is configured to assist the exhaust gas to circulating and advancing movement inside the perforated double funnel-shaped tubular flow guide 263 towards an outlet 265. A plurality of apertures may also be arranged.

Apertures may be arranged only to one of the first funnel-shaped portion 301 and the second funnel-shaped portion 302, or both of them. Sizes and shapes of the apertures may also vary, depending on the device design and engine destination for example.

In an embodiment, the outlet 265 of the double funnel-shaped tubular flow guide 263 forms the exhaust outlet of the device 260.

In an embodiment, the device 260 may further comprise an outlet duct 290 extending from the exhaust outlet 265.

Fig. 4 shows a schematic picture of exhaust gas flows in a mixing device 260 according to an example embodiment of the invention.

An input exhaust gas flow 410 (e.g. mixed exhaust gas flow with dispensed reactant) is received via an inlet. No matter horizontal flow 410 is shown, the input exhaust gas flow 410 may comprise circulating and advancing mixed exhaust gas flow. Within an inner cavity of the mixing device 260, the input exhaust gas flow 410 is guided to a swirling flow 420 around a double funnel-shaped tubular flow guide within the inner cavity. The double funnel-shaped tubular flow guide, in the inner cavity, has first and second funnel-shaped portions being combined at their smaller diameters. The swirling flow 420 around the double funnel-shaped tubular flow guide within the inner cavity is then guided to the end of the first funnel-shaped portion (lower portion in Fig. 4) having an inlet of the double funnel-shaped tubular flow guide.

Via a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity, a flow 430 from the swirling flow 420 is allowed to enter inside the double funnel-shaped tubular flow guide and to flow as a vertical flow 440 through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide. The second funnel-shaped portion comprises the outlet of the double funnel-shaped tubular flow guide. No matter a horizontally swirling flow 420, a rounding flow 430 and a vertical flow 440 is shown, all these flows 420-440 may comprise circulating and advancing mixed exhaust gas flow.

Fig. 5 shows a schematic picture from above view of a mixing device 260 according to an example embodiment of the invention.

In an embodiment, the inlet 252 is arranged in a centric manner to the cylindrical housing 261 and to the central axis of the double funnel-shaped tubular flow guide 263.

In an embodiment, the device 260 may further comprise an elongated blade (not shown) extending across the exhaust inlet 252 in the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide 263.

Fig. 6 shows a schematic picture from above view of a mixing device 260 according to another example embodiment of the invention.

In an embodiment, the inlet 252 is arranged in a tangential manner to the cylindrical housing 261 and to the vertical central axis of the double funnel-shaped tubular flow guide 263. Such placement of the inlet 252 improves the swirling effect around the double funnel-shaped tubular flow guide 263.

In an embodiment, the device 260 further comprises an inlet duct 610 extending from the exhaust inlet 252 to the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide 263.

Fig. 7 shows a schematic picture from side view of a mixing device 260 according to another example embodiment of the invention.

In an embodiment, the inlet 252 is arranged in a tangential manner to the cylindrical housing 261 and to the vertical central axis of the double funnel-shaped tubular flow guide 263.

The double funnel-shaped tubular flow guide 263 is asymmetric around a vertical axis of the double funnel-shaped tubular flow guide 263. Such asymmetry makes a first portion 710 of the inner cavity and a second portion 720 of the inner cavity different in shape and volume. By design of the asymmetry of the double funnel-shaped tubular flow guide 263, a further improvement of the performance to the mixing device 260 is achieved. Swirling effect is improved and counter pressure caused by the flow turning is reduced.

By designing the asymmetry of the double funnel-shaped tubular flow guide 263, the volume of the inner cavity, the placement and direction of the inlet 252, the largest and the smallest diameters of the first and the second parts of the double funnel-shaped tubular flow guide 263, and the size of the slot, the performance of the device 260 and the counter pressure created may be adjusted to an optimum.

In an embodiment, the double funnel-shaped tubular flow guide 263 is arranged vertically within the inner cavity in an eccentric manner.

No matter in Fig. 7 both asymmetric design of the double funnel-shaped tubular flow guide 263, as well as placing of the double funnel-shaped tubular flow guide 263 vertically within the inner cavity in an eccentric manner, these two features do not necessarily need to implemented simultaneously. Only one of them can be implemented according to an embodiment of the invention.

Fig. 8 shows a schematic picture from side view of a mixing device 260 according to another example embodiment of the invention.

In an embodiment, the inlet 252 is arranged to the cylindrical housing 261.

The housing 261 is configured to define an inner cavity 262 and the exhaust inlet 252 is arranged to the housing 261 for entering exhaust gas flow to the inner cavity 262. A double funnel-shaped tubular flow guide 263 is arranged in the inner cavity 262, comprising first 801 and second 802 funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion 801 having an inlet of the double funnel-shaped tubular flow guide 263, and the second funnel-shaped portion 802 having an outlet of the double funnel-shaped tubular flow guide 263, and the double funnel-shaped tubular flow guide 263 forming, from the entering exhaust gas flow, a swirling flow around the double funnel-shaped tubular flow guide 263 within the inner cavity 262.

A slot 266 between the inlet of the of the double funnel-shaped tubular flow guide 263 and a first end wall 810 of the inner cavity 262 is provided for allowing the swirling flow to enter inside the double funnel-shaped tubular flow guide 263 and to flow through the double funnel-shaped tubular flow guide 263 to the outlet of the double funnel-shaped tubular flow guide 263.

In an embodiment, the first end wall 810 of the inner cavity 262 is bent inwards or formed as concave. The concave shape of the end wall 810 ease the turning of the direction of the gas flow from the swirling flow to the vertical flow inside the double funnel-shaped tubular flow guide 263. Also the circulating component of the gas flow eases the turning of the flow. Thus the counter pressure caused by the turning is reduced.

In an embodiment, at least one support element 820 is arranged for the first portion 801 of the double funnel-shaped tubular flow guide 263. The support element may be attached to the end wall 810 or to the sidewall of the housing 261, for example. The support element 820 not only supports the double funnel-shaped tubular flow guide 263 with the inner cavity 262 but by changing the size of the support element 820 also the size of the slot 266 may be adjusted. By increasing the size of the support element 820, or a plurality of support elements 820, the size of the slot may be adjusted as a design option depending on the target engine for the mixing device 260, for example.

Fig. 9 shows a schematic picture of an exhaust gas aftertreatment apparatus 120 according to an alternative embodiment of the invention.

The apparatus 120 for aftertreatment of exhaust gas comprises a housing 210, an exhaust inlet 220, a reactant inlet 230, and an exhaust outlet 240.

In an embodiment, the reactant inlet 230 comprises a nozzle (not shown).

The exhaust inlet 220 is arranged to the housing 210 for entering input exhaust gas to the apparatus 120. The reactant inlet 230 is arranged to the housing 210 for dispensing reactant to the apparatus 120, and the reactant is configured to mix with the input exhaust gas to provide mixed exhaust gas. The exhaust outlet 240 is arranged to the housing 210 for exiting output exhaust gas from the apparatus 120. Furthermore, the apparatus 120 may comprise, for example, attachment elements for attaching the apparatus 120 to an engine system or a chassis of a vehicle. The exhaust outlet 240 may comprise an outlet duct (not shown).

In an embodiment, the apparatus 120 comprises a mixer unit 250 and a mixing device 260, as illustrated in Fig. 9 using dashed lines. The mixing device 260, located downstream to the mixer unit 250, receives the exhaust gas mixed with the reactant, and provides evenly mixing of those with reduced apparatus size. A connecting tube 252 may be provided to connect the mixer unit 250 and the mixing device 260.

In an embodiment, a diesel oxidation catalyst (DOC) substrate 270 is placed downstream to the exhaust inlet 220, and upstream to the reactant inlet 230.

In an embodiment, a selective catalytic reduction (SCR) substrate 280 is placed downstream to the reactant inlet 230, the mixer unit 250, and the mixing device 260, and upstream to the exhaust gas outlet 240.

In an embodiment, the SCR substrate 280 may also comprise a diesel particulate filter (DPF) for particulate matter reduction.

In an embodiment, a housing 210 is configured to define at least one inner cavity, wherein the exhaust gas is aftertreated by the apparatus 120. An exhaust inlet 220 is arranged to the housing 210 for entering input exhaust gas to the inner cavity. The exhaust gas may travel through DOC substrate 270 within the inner cavity before reaching a mixer unit 250.

In an embodiment, the mixer unit 250 and the mixing device 260 are arranged in different angle in relation to each other than in the embodiment of Fig. 2. In Fig. 9 the relation is substantially perpendicular. As can be seen from Fig. 9, an angled arrangement of the mixer unit 250 and the mixing device 260 is provided when the mixer unit 250 and the mixing device 260 are located in different housing parts and connected via a connecting tube 252. Thus any angle between the mixer unit 250 and the mixing device 260 may be arranged.

The angled arrangement as illustrated in Fig. 9 provides further advantages, such as more flexible installation of the exhaust gas aftertreatment apparatus 120 to an engine system and shorter connecting tube 252 because the mixer unit 250 and the mixing device 260 can be connected closer to each other.

In an embodiment, a solid connecting tube 252 is located downstream to the perforated tubular element of the mixer unit 250 and configured to guide the circulating and advancing mixed exhaust gas in the first direction towards the mixing device 260. A diameter of the solid tubular element 252 may be greater than a diameter of a downstream end of the perforated tubular element and may allow a part of the externally circulating and advancing mixed exhaust gas around the perforated tubular element to enter the solid connecting tube 252.

In an embodiment, an exhaust gas cleaning unit is arrangeable to an exhaust gas channel, which unit comprises an inlet duct 220 for the inflow of exhaust gas to be cleaned and an outlet duct for the outflow of exhaust gas. Between the inlet duct 115, 220 and the outlet duct 130, 240 is a first housing part 140 (see e.g. Fig. 1) that comprises a DOC-substrate 121, 270 (Diesel Oxidation Catalyst) and a second housing part 150 (see e.g. Fig. 1) that comprises a SCR catalysator 123, 280. The housing parts may also comprise other devices for cleaning exhaust gas, such as a particle filter, (Diesel Particulate Filter). The first and the second housing part may be connected by a connection pipe 252. Inside the first housing part there is a swirl structure comprising a tubular feeding element 251 (see e.g. Fig. 2) and possibly flow guides arranged around the tubular feeding element. In a wall of the first housing there is a nozzle hole for a nozzle 230 that is used for injecting urea-water solution to the exhaust gas flowing in the tubular feeding element. With the help of the swirl structure, the exhaust gas passed through the DOC-substrate is divided to a central flow flowing inside the tubular feeding element and an edge flow surrounding the tubular feeding element. These flows are guided out from a first housing part 140 to the connection pipe 252, wherein the flows are combined to an advancing exhaust gas flow that circulates around the central axis of the connection pipe 252 to the mixing device 260.

Inside the second housing part 150 (see e.g. Fig. 1) there are the mixing device 260 that provides even mixing of the exhaust gas and the reactant with reduced size and length of the apparatus 120, and a SCR 280, for example.

The size, especially length, of the exhaust gas aftertreatment apparatus may be decreased by utilizing the mixing device 260 according to different embodiments described and further advantages may be achieved by the design options of the mixing device and angled arrangement of the mixer unit 250 and the mixing device 260. Furthermore, the counter pressure caused by the mixing device 260 is minimal. Reactant is better mixed with the exhaust gas with the described apparatus and vaporized more quickly. Thus, the amount of deposit generated to the inner wall of the exhaust gas channel is reduced.

In an embodiment, a perforated tubular element 251 (see e.g. Fig. 2) reduces turbulence of an exhaust gas entering the interior of the perforated tubular element 251. The exhaust gas entering the interior of the perforated tubular element 251 forms a center flow, wherein the reactive substance is fed. Reducing the turbulence in the interior of the perforated tubular element 251 results in that the center flow and the edge flow remain apart from each other in the beginning of a mixing procedure, whereby the reactive substance fed into the center flow does not come into contact with a wall of the inner cavity before it is converted to ammonia, for example.

The perforated tubular element 251 reduces formation of solid deposit generated in the conversion process of urea (or some other reactant) in the inner cavity and thus reduces the service need of the apparatus and the engine system. Furthermore, the engine system retains its operational ability and efficiency better.

In an embodiment, not only the size of the mixing apparatus may be reduced but also the shape may be more freely designed. Since the deposit risk of the urea also in the bends of the housing 210 is reduced, the designing of the aftertreatment apparatus 120 becomes easier.

Some of the advantages provided by embodiments of the invention comprise at least one of the following. First, a length of a mixing flow channel is increased without increasing the size of the apparatus too much. Second, the mixing flow channel diameter may be increased. Third, there is no dedicated reactant (e.g. ammonia or urea) concentration point within the inner cavity or flow channel that would increase risk of urea deposits in exhaust pipelines.

Fig. 10 shows a flow diagram showing operations in accordance with an example embodiment of the invention. In step 1000, the method for aftertreatment of exhaust gas is started. In step 1010, exhaust gas flow is received to an inner cavity of a mixing device housing via an exhaust inlet. In step 1020, a swirling flow is guided from the received exhaust gas flow to swirl around a double funnel-shaped tubular flow guide within the inner cavity, wherein the double funnel-shaped tubular flow guide having first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide. In step 1030, the swirling flow is guided to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide via a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity. In step 1040, exhaust gas flow is exited from the mixing device via an exhaust outlet arranged to the housing. In step 1050, the method ends.

Various embodiments have been presented. It should be appreciated that in this document, words comprise, include and contain are each used as open-ended expressions with no intended exclusivity. If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined. Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

The foregoing description has provided by way of non-limiting examples of particular implementations and embodiments of the invention a full and informative description of the best mode presently contemplated by the inventors for carrying out the invention. It is however clear to a person skilled in the art that the invention is not restricted to details of the embodiments presented above, but that it can be implemented in other embodiments using equivalent means or in different combinations of embodiments without deviating from the characteristics of the invention.

Furthermore, some of the features of the above-disclosed embodiments of this invention may be used to advantage without the corresponding use of other features. As such, the foregoing description shall be considered as merely illustrative of the principles of the present invention, and not in limitation thereof. Hence, the scope of the invention is only restricted by the appended patent claims.

Claims:

1. A mixing device for aftertreatment of exhaust gas comprising:

a housing configured to define an inner cavity;

an exhaust inlet arranged to the housing for entering exhaust gas flow to the inner cavity;

characterized in that the device further comprising:

a double funnel-shaped tubular flow guide, in the inner cavity, whose first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide, the double funnel-shaped tubular flow guide forming, from the entering exhaust gas flow, a swirling flow around the double funnel-shaped tubular flow guide within the inner cavity;

a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity for allowing the swirling flow to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide; and

an exhaust outlet arranged to the housing for exiting exhaust gas flow from the mixing device.

2. The device of claim 1, wherein the double funnel-shaped tubular flow guide being arranged vertically within the inner cavity, and the exhaust inlet arranged to the housing for entering exhaust gas flow horizontally to the inner cavity.

3. The device of claim 2, wherein the exhaust inlet arranged to the housing for entering exhaust gas flow horizontally to the inner cavity to a vertical position, where the first and the second funnel-shaped portions being combined at their smaller diameters.

4. The device of claim 2, wherein the exhaust inlet arranged to the housing for

entering exhaust gas flow horizontally to the inner cavity in a tangential direction in relation to a central axis of the double funnel-shaped tubular flow guide.

5. The device of any of claims 1-4, wherein the housing being configured to define the inner cavity of a cylindrical shape, whose central axis being parallel to a central axis of the double funnel-shaped tubular flow guide.

6. The device of claim 5, wherein the second funnel-shaped portion of the double funnel-shaped tubular flow guide being connected to a second end wall of the inner cavity, different to the first end wall, and the second end wall of the inner cavity between the second funnel-shaped portion of the double funnel-shaped tubular flow guide and a side wall of the cylindrical shape inner cavity being closed to exhaust gas flow.

7. The device of any of claims 1-6, wherein a largest diameter of the first portion of the double funnel-shaped tubular flow guide being smaller than a largest diameter of the second portion of the double funnel-shaped tubular flow guide.

8. The device of any of claims 1-7, wherein the outlet of the double funnel-shaped tubular flow guide forms the exhaust outlet of the device.

9. The device of any of claims 1-8, further comprising an outlet duct extending from the exhaust outlet.

10. The device of any of claims 1-9, further comprising an inlet duct extending from the exhaust inlet to the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide.

11. The device of any of claims 1-10, wherein the inlet duct extending tangentially to a vertical axis of the double funnel-shaped tubular flow guide.

12. The device of any of claims 1-11, further comprising an elongated blade extending across the exhaust inlet in the inner cavity for steering the exhaust gas

flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide.

13. The device of any of claims 1-12, wherein the double funnel-shaped tubular flow guide being asymmetric around a vertical axis of the double funnel-shaped tubular flow guide.

14. The device of any of claims 1-13, wherein the double funnel-shaped tubular flow guide being arranged vertically within the inner cavity in an eccentric manner.

15. The device of any of claims 1-14, wherein the first end wall of the inner cavity being bent inwards.

16. The device of any of claims 1-14, wherein the first end wall of the inner cavity is flat.

17. The device of any of claims 1-14, wherein the first end wall of the inner cavity is concave.

18. The device of any of claims 1-17, wherein an inner surface of the housing configured to define the inner cavity.

19. An apparatus for aftertreatment of exhaust gas comprising:

a diesel particulate filter (DPF) for receiving exhaust gas;

a mixer unit, located downstream of the diesel particulate filter (DPF), to dispense a reactant to an exhaust gas flow from the diesel particulate filter (DPF);

a mixing device of any of the claims 1-18, located downstream of the mixer unit, to evenly mix the reactant with the exhaust gas flow from the mixer unit; and

a selective catalytic reduction (SCR) substrate, located downstream of the mixing device.

20. A method for aftertreatment of exhaust gas comprising:

receiving exhaust gas flow to an inner cavity of a mixing device housing via an exhaust inlet;

characterized in that the method further comprising:

guiding, from the received exhaust gas flow, a swirling flow around a double funnel-shaped tubular flow guide within the inner cavity, wherein the double funnel-shaped tubular flow guide having first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide;

guiding the swirling flow to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide via a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity; and

exiting exhaust gas flow from the mixing device via an exhaust outlet arranged to the housing.

Amendments to the claims have been made as follows:

Claims:

1. A mixing device for aftertreatment of exhaust gas comprising:

a housing configured to define an inner cavity;

an exhaust inlet arranged to the housing for entering exhaust gas flow to the inner cavity;

characterized in that the device further comprising:

a double funnel-shaped tubular flow guide, in the inner cavity, whose first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide, the double funnel-shaped tubular flow guide forming, from the entering exhaust gas flow comprising exhaust gas and a reactant, a swirling flow around the double funnel-shaped tubular flow guide within the inner cavity, wherein the reactant is configured to mix with the exhaust gas within the swirling flow;

a slot between the inlet of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity for allowing the swirling flow to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide; and

an exhaust outlet arranged to the housing for exiting exhaust gas flow from the mixing device.

2. The device of claim 1, wherein the double funnel-shaped tubular flow guide being arranged vertically within the inner cavity, and the exhaust inlet arranged to the housing for entering exhaust gas flow horizontally to the inner cavity.

3. The device of claim 2, wherein the exhaust inlet arranged to the housing for entering exhaust gas flow horizontally to the inner cavity to a vertical position, where the first and the second funnel-shaped portions being combined at their smaller diameters.

4. The device of claim 2, wherein the exhaust inlet arranged to the housing for entering exhaust gas flow horizontally to the inner cavity in a tangential direction in relation to a central axis of the double funnel-shaped tubular flow guide.

5. The device of any of claims 1-4, wherein the housing being configured to define the inner cavity of a cylindrical shape, whose central axis being parallel to a central axis of the double funnel-shaped tubular flow guide.

6. The device of claim 5, wherein the second funnel-shaped portion of the double funnel-shaped tubular flow guide being connected to a second end wall of the inner cavity, different to the first end wall, and the second end wall of the inner cavity between the second funnel-shaped portion of the double funnel-shaped tubular flow guide and a side wall of the cylindrical shape inner cavity being closed to exhaust gas flow.

7. The device of any of claims 1-6, wherein a largest diameter of the first portion of the double funnel-shaped tubular flow guide being smaller than a largest diameter of the second portion of the double funnel-shaped tubular flow guide.

8. The device of any of claims 1-7, wherein the outlet of the double funnel-shaped tubular flow guide forms the exhaust outlet of the device.

9. The device of any of claims 1-8, wherein the exhaust outlet comprising an outlet duct.

10. The device of any of claims 1-9, further comprising an inlet duct extending from the exhaust inlet to the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide.

11. The device of any of claims 1-10, wherein the inlet duct extending tangentially to a vertical axis of the double funnel-shaped tubular flow guide.

12. The device of any of claims 1-11, further comprising an elongated blade extending across the exhaust inlet in the inner cavity for steering the exhaust gas flow in the inner cavity into a motion circulating the double funnel-shaped tubular flow guide.

13. The device of any of claims 1-12, wherein the double funnel-shaped tubular flow guide being asymmetric around a vertical axis of the double funnel-shaped tubular flow guide.

14. The device of any of claims 1-13, wherein the double funnel-shaped tubular flow guide being arranged vertically within the inner cavity in an eccentric manner.

15. The device of any of claims 1-14, wherein the first end wall of the inner cavity being bent inwards.

16. The device of any of claims 1-14, wherein the first end wall of the inner cavity is flat.

17. The device of any of claims 1-14, wherein the first end wall of the inner cavity is concave.

18. The device of any of claims 1-17, wherein an inner surface of the housing configured to define the inner cavity.

19. An apparatus for aftertreatment of exhaust gas comprising:

a diesel particulate filter (DPF) for receiving exhaust gas;

a mixer unit, located downstream of the diesel particulate filter (DPF), to dispense a reactant to an exhaust gas flow from the diesel particulate filter (DPF);

a mixing device of any of the claims 1-18, located downstream of the mixer unit, to evenly mix the reactant with the exhaust gas flow from the mixer unit; and

a selective catalytic reduction (SCR) substrate, located downstream of the mixing device.

20. A method for aftertreatment of exhaust gas comprising:

receiving exhaust gas flow to an inner cavity of a mixing device housing via an exhaust inlet;

characterized in that the method further comprising:

guiding, from the received exhaust gas flow comprising exhaust gas and a reactant, a swirling flow around a double funnel-shaped tubular flow guide within the inner cavity, the reactant is configured to mix with the exhaust gas within the swirling flow, wherein the double funnel-shaped tubular flow guide having first and second funnel-shaped portions being combined at their smaller diameters, and the first funnel-shaped portion having an inlet of the double funnel-shaped tubular flow guide, and the second funnel-shaped portion having an outlet of the double funnel-shaped tubular flow guide;

guiding the swirling flow to enter inside the double funnel-shaped tubular flow guide and to flow through the double funnel-shaped tubular flow guide to the outlet of the double funnel-shaped tubular flow guide via a slot between the inlet of the of the double funnel-shaped tubular flow guide and a first end wall of the inner cavity; and

exiting exhaust gas flow from the mixing device via an exhaust outlet arranged to the housing.

Intellectual Property Office

Application No:	GB1423329.0	**Examiner:**	Alex Swaffer
Claims searched:	1-20	**Date of search:**	18 June 2015

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-3, 5-9, 15, 16, 18, 20	US2007/119433 A1 (Popik et al): See figure 2 in particular.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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B01F; F01N

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, TXTE, TXTT

International Classification:

Subclass	Subgroup	Valid From
F01N	0003/28	01/01/2006
F01N	0013/08	01/01/2010