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(54) EFFICIENT MIXING OF GASES IN AN EXHAUST AFTERTREATMENT SYSTEM

EFFIZIENTES MISCHEN VON GASEN IN EINEM ABGASNACHBEHANDLUNGSSYSTEM

MÉLANGE EFFICACE DE GAZ DANS UN SYSTÈME POST-TRAITEMENT D'ÉCHAPPEMENT

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to exhaust systems for internal combustion engines, and more particularly to a system for decomposing reductant and mixing together reductant and exhaust gas in a selective catalytic reduction (SCR) catalyst device of an exhaust after-treatment system.

[0002] Exhaust aftertreatment systems receive and treat exhaust gas generated from an internal combustion engine such as a diesel engine. Typical exhaust after-treatment systems include any of various devices configured to reduce the level of harmful exhaust emissions present in the exhaust gas. Some exhaust aftertreatment systems for diesel powered internal combustion engines include various devices, such as a diesel oxidation catalyst (DOC), particulate matter filter or diesel particulate filter (DPF), and a selective catalytic reduction (SCR) catalyst device. In some exhaust aftertreatment systems, exhaust gas first passes through the diesel oxidation catalyst, then passes through the diesel particulate filter, and subsequently passes through the SCR catalyst.

[0003] Each of the DOC, DPF, and SCR catalyst devices is configured to perform a particular exhaust emissions treatment operation on the exhaust gas passing through the devices. Generally, the DOC reduces the amount of carbon monoxide and hydrocarbons present in the exhaust gas via oxidation techniques. The DPF filters harmful diesel particulate matter and soot present in the exhaust gas. Finally, the SCR catalyst device reduces the amount of nitrogen oxides (NOx) present in the exhaust gas.

[0004] The SCR catalyst device is configured to reduce NOx into less harmful emissions, such as N₂ and H₂O, in the presence of ammonia (NH₃). Because ammonia is not a natural byproduct of the combustion process, it must be artificially introduced into the exhaust gas prior to the exhaust gas entering the SCR catalyst device. Typically, ammonia is not directly injected into the exhaust gas due to safety considerations associated with the storage of liquid ammonia. Accordingly, conventional systems are designed to inject a urea-water solution, or diesel exhaust fluid (DEF) into the exhaust gas, which is capable of decomposing into ammonia in the presence of the exhaust gas. SCR systems typically include a urea source and a urea injector or doser coupled to the source and positioned upstream of the SCR catalyst device.

[0005] Generally, the decomposition of the urea-water solution into gaseous ammonia occupies three stages. First, urea evaporates or mixes with exhaust gas. Second, the temperature of the exhaust causes a phase change in the urea and decomposition of the urea into isocyanic acid (HNCO) and water. Third, the isocyanic acid reacts with water in a hydrolysis process under specific pressure and temperature concentrations to decompose into ammonia and carbon dioxide (CO₂). The am-

monia is then introduced at or near the inlet face of the SCR catalyst device, flows through the catalyst, and is consumed in the NOx reduction process. Any unconsumed ammonia exiting the SCR system can be reduced to N₂ and other less harmful or less noxious components using an ammonia oxidation catalyst.

[0006] To sufficiently decompose into ammonia, the injected urea must be given adequate time to complete the three stages. The time given to complete the three stages and decompose urea into ammonia before entering the SCR catalyst device is conventionally termed residence time. Some prior art exhaust aftertreatment systems utilize a long tube of a fixed linear decomposition length that extends between the urea injector and SCR catalyst device inlet face. The fixed linear decomposition length of prior art systems must be quite long in order to provide the necessary residence time. Long tubing for urea decomposition often takes up valuable space that could be occupied by other vehicle components and influences the design of the exhaust aftertreatment system. However, shorter decomposition tubes associated with some prior art end-in, end-out and end-in, side-out SCR systems may not provide a sufficiently long residence time to properly evaporate the injected urea.

[0007] Additionally, some prior art exhaust aftertreatment systems, particularly those systems that utilize or require in-line or end-to-end or end-to-side devices, do not provide adequate mixing of the urea/ammonia with the exhaust gas. Inadequate mixing results in a low ammonia vapor uniformity index, which can lead to crystallization/polymerization buildup inside the SCR catalyst device or other SCR system devices, localized aggregation of ammonia, inadequate distribution of the ammonia across the SCR catalyst surface, lower NO conversion efficiency, and other shortcomings.

[0008] Further, many exhaust aftertreatment systems with end-to-end or end-to-side SCR systems fail to adequately distribute exhaust gas across the inlet face of the SCR catalyst device. An uneven distribution of exhaust gas at the SCR catalyst device inlet can result in excessive ammonia slip and less than optimal NOx conversion efficiency. For example, a low exhaust flow distribution index at the SCR catalyst device inlet results in a lower amount of SCR catalyst surface area in contact with the exhaust gases. The lesser the catalyst surface area in contact with the exhaust gases, the lower the NOx reduction efficiency of the SCR catalyst device.

[0009] What is needed in the art is a more efficient mixing of the exhaust gases prior to or at the inlet of the SCR device.

[0010] Patent publication document DE102012008556 is related to a device comprising an injector which is arranged in an exhaust gas line for supplying a reducing agent in an exhaust gas mass flow, where a cylindrical exhaust gas line segment has a tangential inlet. A mixer is arranged downstream the tangential inlet for reversing the rotational direction of the exhaust gas mass flow.

[0011] Patent publication document US2014/0318112 is related to an exhaust treatment system for an internal combustion engine, with a fluid injection system and a swirl can plenum mixer for mixing injected fluid with exhaust gas exhausted from the engine. The mixer comprises a canister having an inner plenum. A bulkhead separates the inner plenum into an exhaust gas collector and a diffuser chamber. A flow port opens through the bulkhead to a tangential flow director on the downstream side of the bulkhead to collect the exhaust gas. A tangential flow director nozzle is configured to dispense the exhaust gas and fluid into the downstream plenum in a tangential flow trajectory, wherein mixing and vaporization of the exhaust gas and fluid mixture with the exhaust gas is accomplished.

[0012] Patent publication document EP2607641 is related to a mixing device having an inner tube having openings, through which the exhaust gas stream of an annular chamber flows into the interior of inner tube. An injection unit injects the reducing agent in the interior of inner tube.

SUMMARY OF THE INVENTION

[0013] The present invention seeks to provide apparatus more completely and uniformly mixing exhaust gas components in an exhaust aftertreatment system.

[0014] The invention is related to an exhaust aftertreatment system in accordance with the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a perspective view of an exhaust aftertreatment system incorporating a mixer according to the present invention; and

Fig. 2 is an expanded fragmentary perspective view of a portion of the exhaust aftertreatment system of Fig. 1 showing a mixer according to the present invention.

[0016] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Referring now to the drawings, and more particularly to Fig. 1, there is shown an exhaust aftertreatment system 110 for an agricultural vehicle, such as a combine harvester shown schematically as dashed line 111.

The aftertreatment system 110 generally includes exhaust pipe sections 112A, 112B, 112C, a first exhaust aftertreatment device 114 coupled to the exhaust pipe section 112 at a connection point 118, and a second exhaust aftertreatment device 120. Typically, the agricultural vehicle 111 will include additional internal systems for the separation and handling of collected crop material, but these additional systems are omitted from view for brevity of description. It should be appreciated that the aftertreatment system 110 described and illustrated herein does not necessarily need to be included on combine harvesters, but can be incorporated in other industrial vehicles or agricultural vehicles such as windrowers, tractors, etc.

[0018] The exhaust pipe 112A may link the exhaust of an engine, shown schematically as 116, to the first aftertreatment device 114, or the exhaust pipe 112 may link multiple aftertreatment devices 114 together. The exhaust pipe section 112B may have an insulation 122 surrounding it. The insulation 122 may extend along a portion or up to the entire length of the exhaust pipe section 112B. As shown, the insulation 122 spans the length of the exhaust pipe 112B and extends approximately up to the connection point 118. The insulation 122 may be in the form of any known insulation that desirably insulates the exhaust pipe section 112B.

[0019] The aftertreatment device 114 may be coupled to the exhaust pipe 112A in order to reduce nitrous oxides (NO_x) and/or diesel particulate matter (DPM). The aftertreatment device 114 may be in the form of an exhaust gas recirculation (EGR) device, a diesel particulate filter (DPF), a selective catalytic reduction (SCR) device, or a catalytic converter such as a diesel oxidation catalyst (DOC).

[0020] The aftertreatment device 114 includes at its outlet section a DEF injection device 124 for injecting diesel exhaust fluid into the exhaust for mixing and reaction with the exhaust stream flowing through exhaust pipe 112B. The resulting gas enters the second exhaust aftertreatment device 120 through the inlet end wall 128 of an outer housing 126 which leads to an outlet end wall 130 connecting with exhaust pipe 112C through connector 118. Exhaust aftertreatment device 120 is an SCR device and it includes a forward SCR catalyst 132 and an aft SCR catalyst 134 oriented in tandem and configured so that parallel exhaust flows pass separately through each of the SCR catalysts 132 and 134. It is important to obtain uniform and complete mixing of DEF with the exhaust gases so that it may allow the systems to properly reduce the oxides of nitrogen. In the event of inadequate mixing or mal-distribution between catalysts 132 and 134, the amount of DEF consumed is increased thereby taking away from the efficiency of the aftertreatment system 110.

[0021] Referring to Figs. 1 and 2, an inlet 136 is provided for the aftertreatment device 120 to provide efficient

and effective mixing in accordance with an aspect of the present invention..

[0022] Fig. 2 shows a perspective view of the inlet 136 with adjacent and interacting components in dashed lines. Inlet 136 may include a tubular upstream inlet 138 having a central axis B offset from the central axis A of housing 126. Housing 126 may have a circular or oval cross section configuration. Tube 138 extends to a bulkhead 140 separating the interior of housing 126 into a section 139 adjacent the inlet 136 and a section 141 containing SCR catalyst 132 and 134. Bulkhead 140 is perforated by a series of circular openings 142 providing a multiplicity of flows to the SCR catalysts 132 and 134. The relative porosity of the bulkhead 140 may be selected for particular operating conditions and may be up to approximately 45 % of the surface area of the bulkhead 140. The openings are circular, as shown, providing a plurality of flow paths from section 139 to section 141.

[0023] Tube 138 terminates in an end wall 144, shown as integral with bulkhead 140. A curved scroll section 146 begins at the circumference of tube 138 and extends outward to a point at or adjacent the circumference 143 of the bulkhead 140. The scroll section 146 imparts a tangential direction to a single stream through downstream outlet 148. Although the scroll section 146 is shown as integral with the tube 138, it may be provided as a separate element. The scroll section may be any one of a number of forms that direct exhaust flow to a tangential direction from the upstream end of tube 138.

[0024] In operation, the tangentially directed exhaust flow through inlet 136 creates a vortex inside the housing 126 resulting in strong shear driven mixing of DEF with the exhaust gas. As a result, the DEF is well mixed with the exhaust gas and results less wastage or slippage of the DEF. A benefit resulting from this flow is a uniform distribution and split between the separate exhaust flows directed toward the catalysts 132 and 134. One advantage of the present invention is a more efficient mixing of exhaust gases at the inlet of an SCR device. Another advantage is that the inlet is simplified, compact and has fixed geometry.

Claims

1. An exhaust aftertreatment system including a selective catalytic reduction (SCR) device (120) having a generally cylindrical or oval cross section shape with a central longitudinal axis (A), and an inlet (136), installed inside a first section (139) of the SCR device (120), the first section extending between an inlet end wall (128) of the SCR device and a perforated bulkhead (140) of the SCR device, the bulkhead forming a separation between the first section (139) and a second section (141) of the SCR device, **characterized in that:**

- the second section (141) comprises a plurality

of catalysts (132,134),

- the bulkhead (140) is perforated by a series of generally circular openings (142) providing a multiplicity of flows to the plurality of catalysts (132,134),

- said inlet (136) is radially offset from said central axis (A) and comprises a tube (138) mounted inside the first section (139) of the SCR device, said tube (138) including an axially directed upstream inlet, configured to be coupled to an exhaust pipe (112B), and a downstream outlet (148) configured to direct exhaust gases in a tangential direction relative to the central longitudinal axis A of said SCR device (120),

- said tube (138) terminates in an end wall (144) that is integral with the bulkhead (140),

- the inlet (136) further comprises a curved scroll section (146) adjacent said downstream outlet (148), extending from the circumference of said tube (138) for imparting said tangential direction to the exhaust gases.

2. The exhaust aftertreatment system according to claim 1, wherein the total area of said generally circular openings (142) is approximately 45 % of the circumferential cross sectional area of the bulkhead (140).

3. The exhaust aftertreatment system according to any one of the preceding claims, wherein each catalyst (132, 134) has a separate flow path from said inlet (136).

Patentansprüche

1. Abgasnachbehandlungssystem aufweisend eine selektive katalytische Reduktions- (SCR) Einrichtung (120) mit einer allgemein zylindrischen oder ovalen Querschnittsform mit einer zentralen Längsachse (A), und einen Einlass (136), welcher innerhalb eines ersten Abschnitts (139) der SCR-Einrichtung (120) installiert ist, wobei sich der erste Abschnitt (139) zwischen einer Einlass-Endwand (128) der SCR-Einrichtung (120) und einer perforierten Trennwand (140) der SCR-Einrichtung (120) erstreckt, wobei die Trennwand (140) eine Abgrenzung zwischen dem ersten Abschnitt (139) und einem zweiten Abschnitt (141) der SCR-Einrichtung (120) bildet,

dadurch gekennzeichnet, dass:

- der zweite Abschnitt (141) eine Mehrzahl von Katalysatoren (132, 134) aufweist,

- die Trennwand (140) durch eine Reihe von allgemein kreisförmigen Öffnungen (142) perforiert ist, die eine Vielzahl von Strömungen zu der Mehrzahl von Katalysatoren (132, 134) bereit-

- stellen,
- der Einlass (136) radial von der zentralen Achse (A) versetzt ist und ein Rohr (138) aufweist, das innerhalb des ersten Abschnitts (139) der SCR-Einrichtung angebracht ist, wobei das Rohr (138) einen axial ausgerichteten stromaufwärtigen Einlass aufweist, der dazu eingerichtet ist, mit einem Abgasrohr (112B) gekoppelt zu werden, und einen stromabwärtigen Auslass (148) aufweist, der dazu eingerichtet ist, Abgase in eine tangentielle Richtung relativ zur zentralen Längsachse (A) der SCR-Einrichtung (120) zu leiten,
 - das Rohr (138) in einer Endwand (144) endet, die integral mit der Trennwand (140) ist,
 - der Einlass (136) ferner einen gekrümmten Abschnitt (146) angrenzend an den stromabwärts gelegenen Auslass (148) aufweist, der sich vom Umfang des Rohrs (138) aus erstreckt, um den Abgasen die tangentielle Richtung zu verleihen.
2. Abgasnachbehandlungssystem nach Anspruch 1, wobei die Gesamtfläche der allgemein kreisförmigen Öffnungen (142) etwa 45 % der Umfangsquerchnittsfläche der Trennwand (140) beträgt.
3. Abgasnachbehandlungssystem nach einem der vorhergehenden Ansprüche, wobei jeder Katalysator (132, 134) einen eigenen Strömungsweg von dem Einlass (136) hat.
2. Système de post-traitement de gaz d'échappement selon la revendication 1, dans lequel la zone totale desdites ouvertures généralement circulaires (142) est d'environ 45 % de la zone de section transversale circonférentielle de la cloison (140).
3. Système de post-traitement de gaz d'échappement selon l'une quelconque des revendications précédentes, dans lequel chaque catalyseur (132, 134) a un chemin d'écoulement séparé de ladite entrée (136).

Revendications

1. Système de post-traitement de gaz d'échappement comprenant un dispositif de réduction catalytique sélective (SCR) (120) ayant une forme de section transversale généralement cylindrique ou ovale avec un axe longitudinal central (A), et une entrée (136),
installé à l'intérieur d'une première section (139) du dispositif SCR (120), la première section s'étendant entre une paroi d'extrémité d'entrée (128) du dispositif SCR et une cloison perforée (140) du dispositif SCR, la cloison formant une séparation entre la première section (139) et une seconde section (141) du dispositif SCR, **caractérisé en ce que** :
- la seconde section (141) comprend une pluralité de catalyseurs (132, 134),
 - la cloison (140) est perforée par une série d'ouvertures généralement circulaires (142) offrant une multiplicité de flux à la pluralité de catalyseurs (123, 134),
 - ladite entrée (136) est radialement déportée par rapport audit axe central (A) et comprend un tube (138) monté à l'intérieur de la première section (139) du dispositif SCR, ledit tube (138)

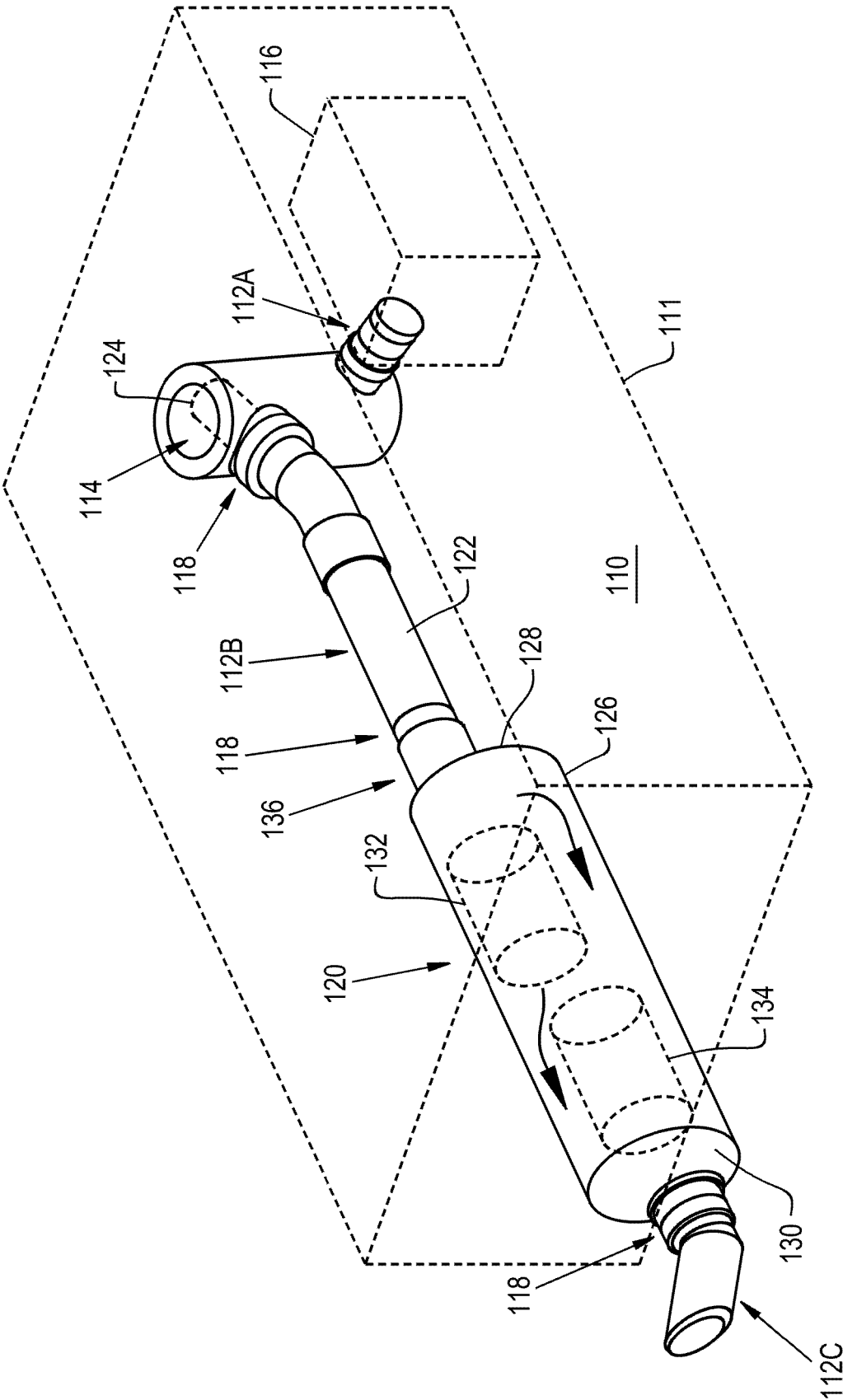


FIG. 1

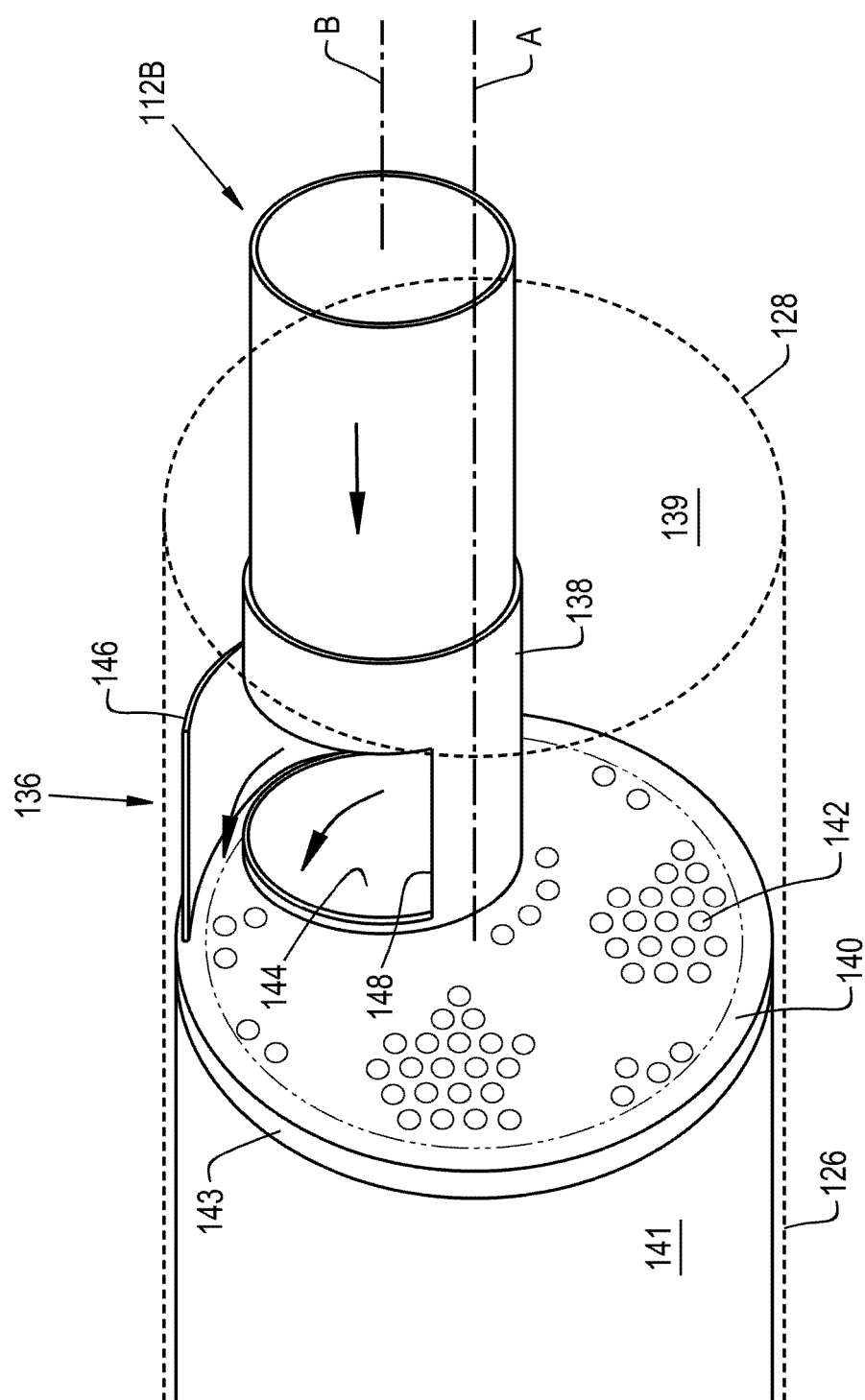


FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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