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(54) **EXHAUST GAS EVAPORATOR**

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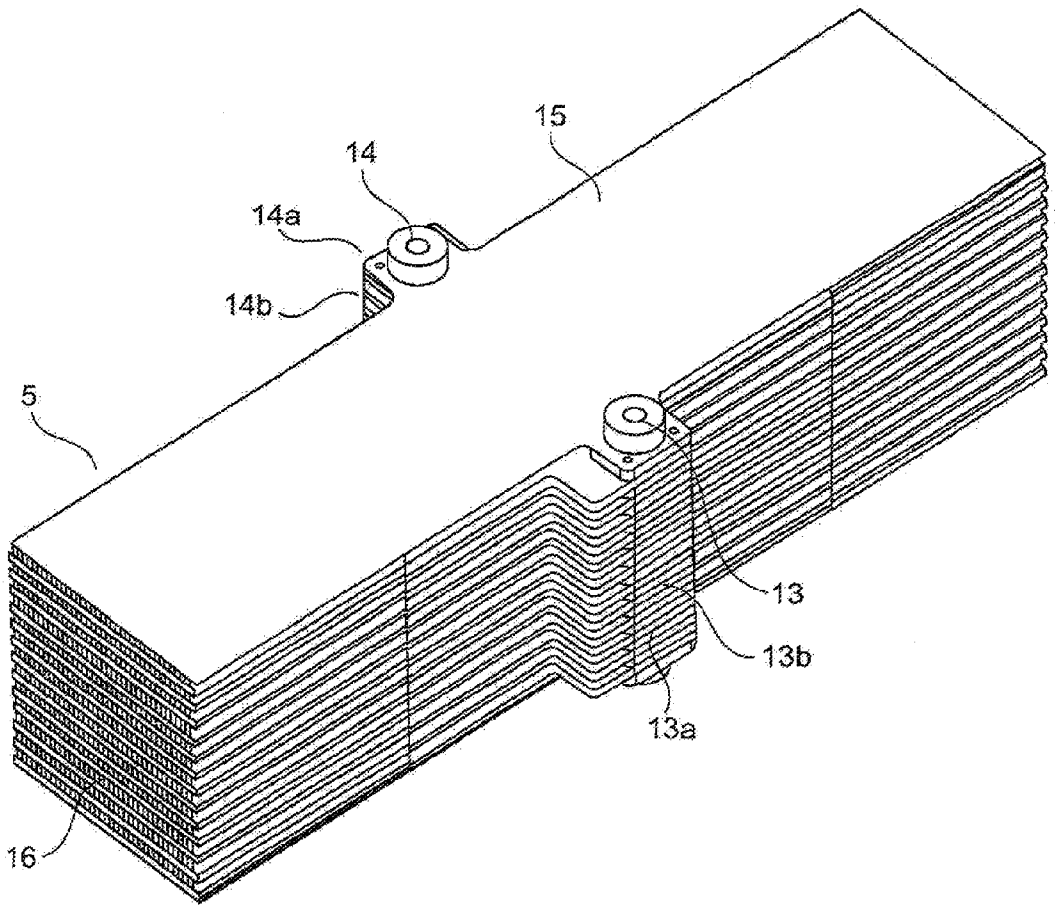
(57) **ABSTRACT**

An evaporator, in particular an exhaust gas evaporator for an exhaust gas system of a motor vehicle, is provided that includes a plate sandwich structure having a plurality of fluid-guiding plate elements stacked on top of one another for guiding a first fluid, wherein at least one rib, in particular a corrugated rib, is disposed between two plate elements for guiding a second fluid, wherein a plate element comprises at least one cover element covering a flow channel and a flow channel plate unit, wherein the flow channel plate unit comprises at least one flow channel plate having flow channels in order to guide the first fluid from an inlet to an outlet.



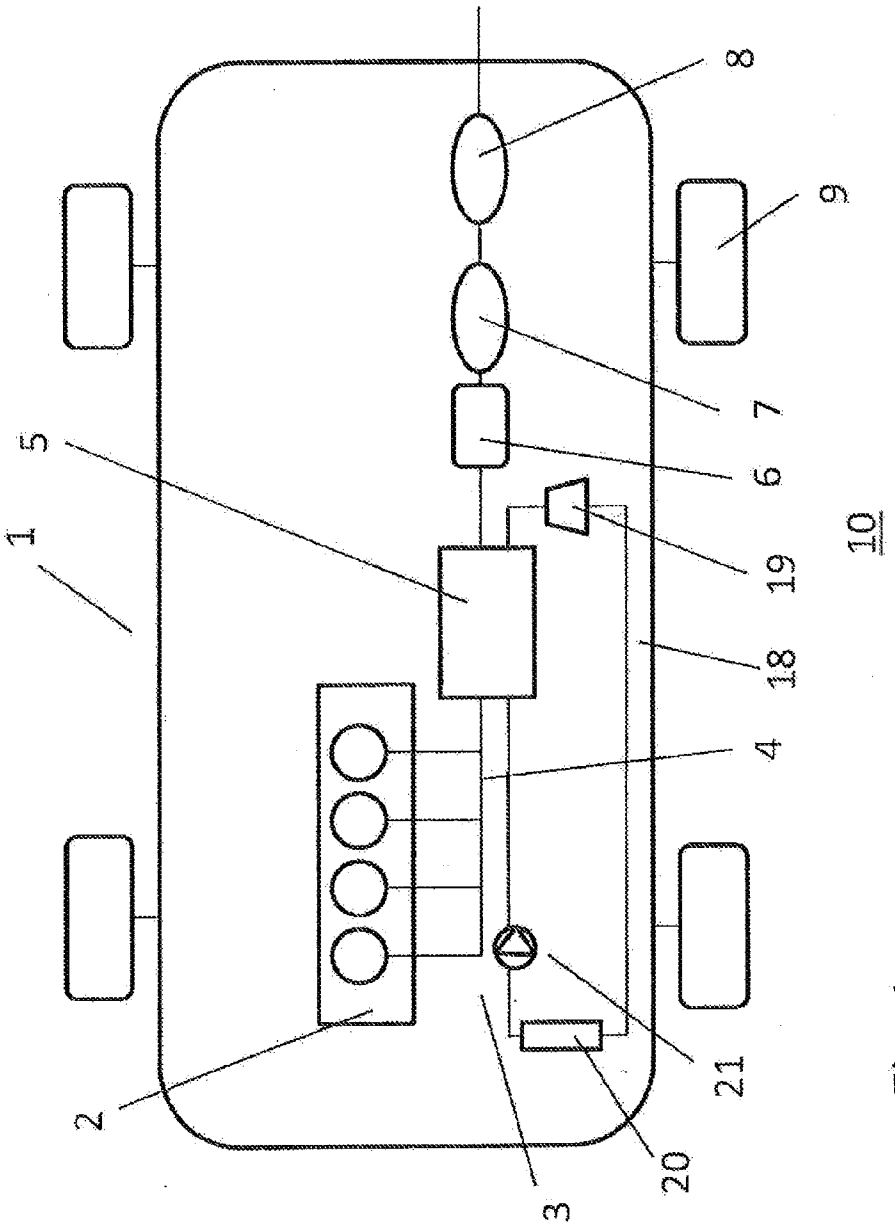


Fig. 1

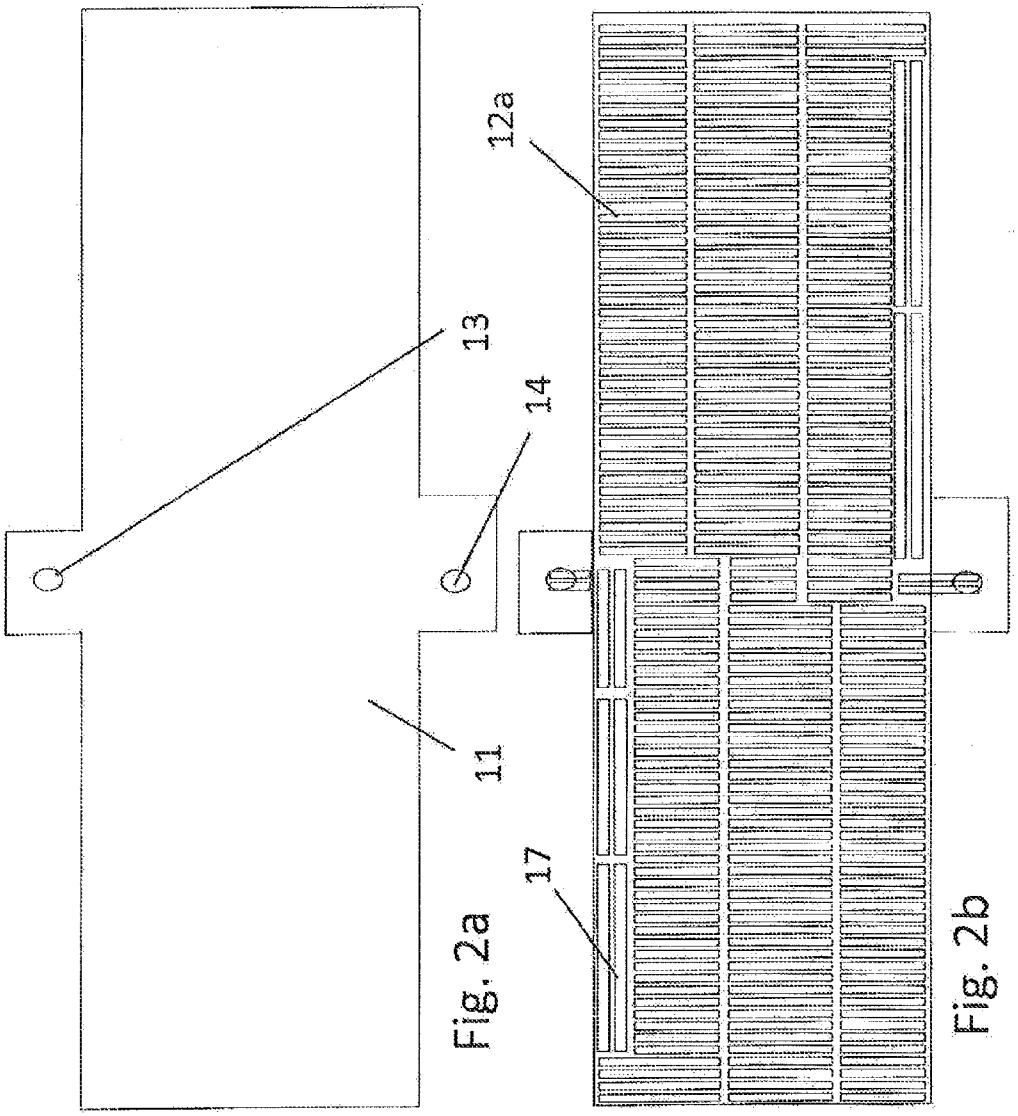


Fig. 2a

Fig. 2b

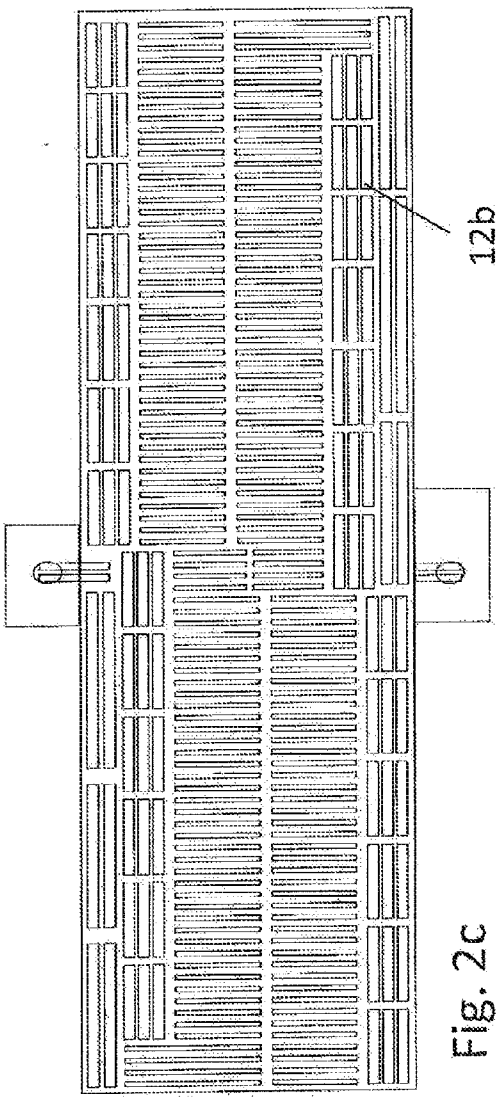


Fig. 2c

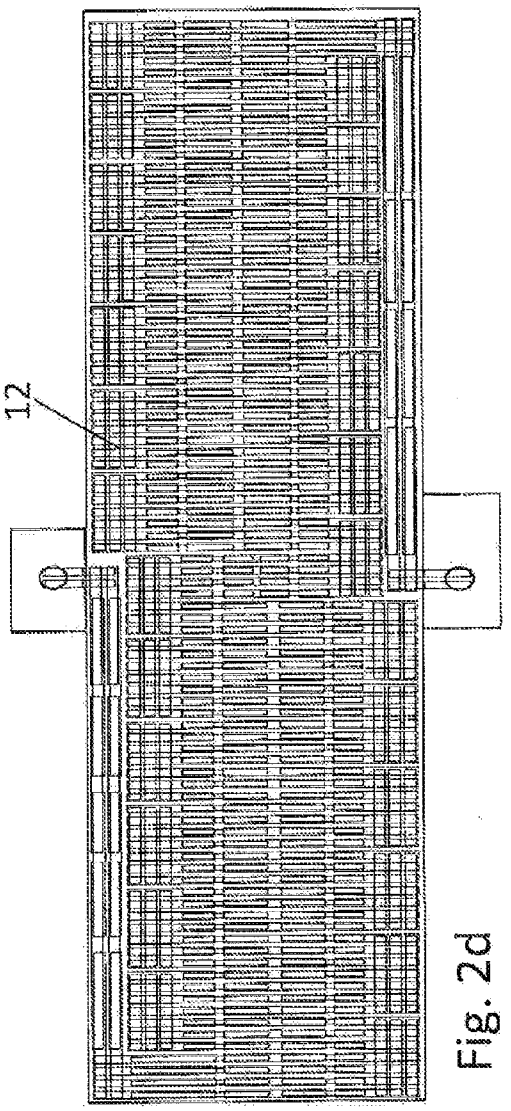


Fig. 2d

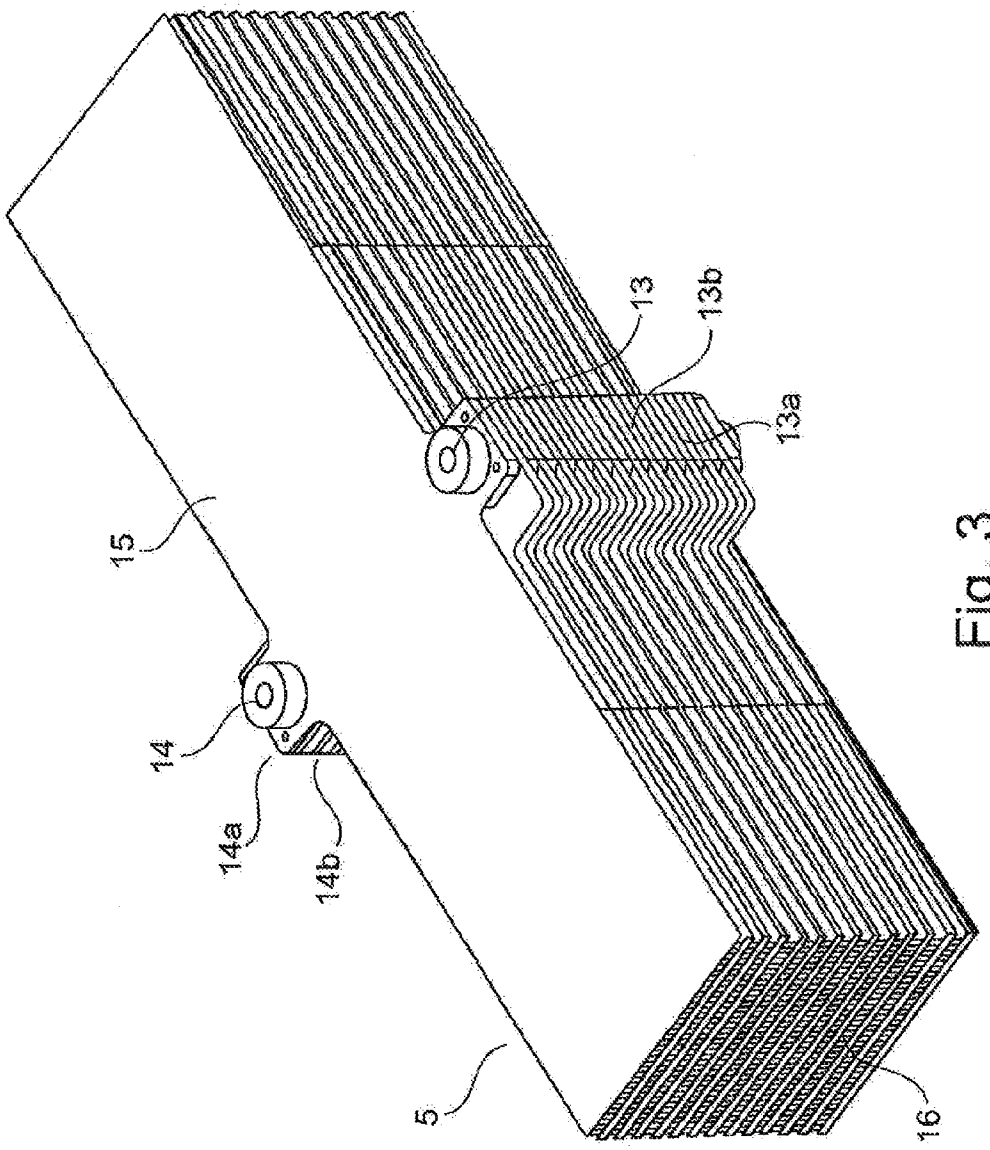


Fig. 3

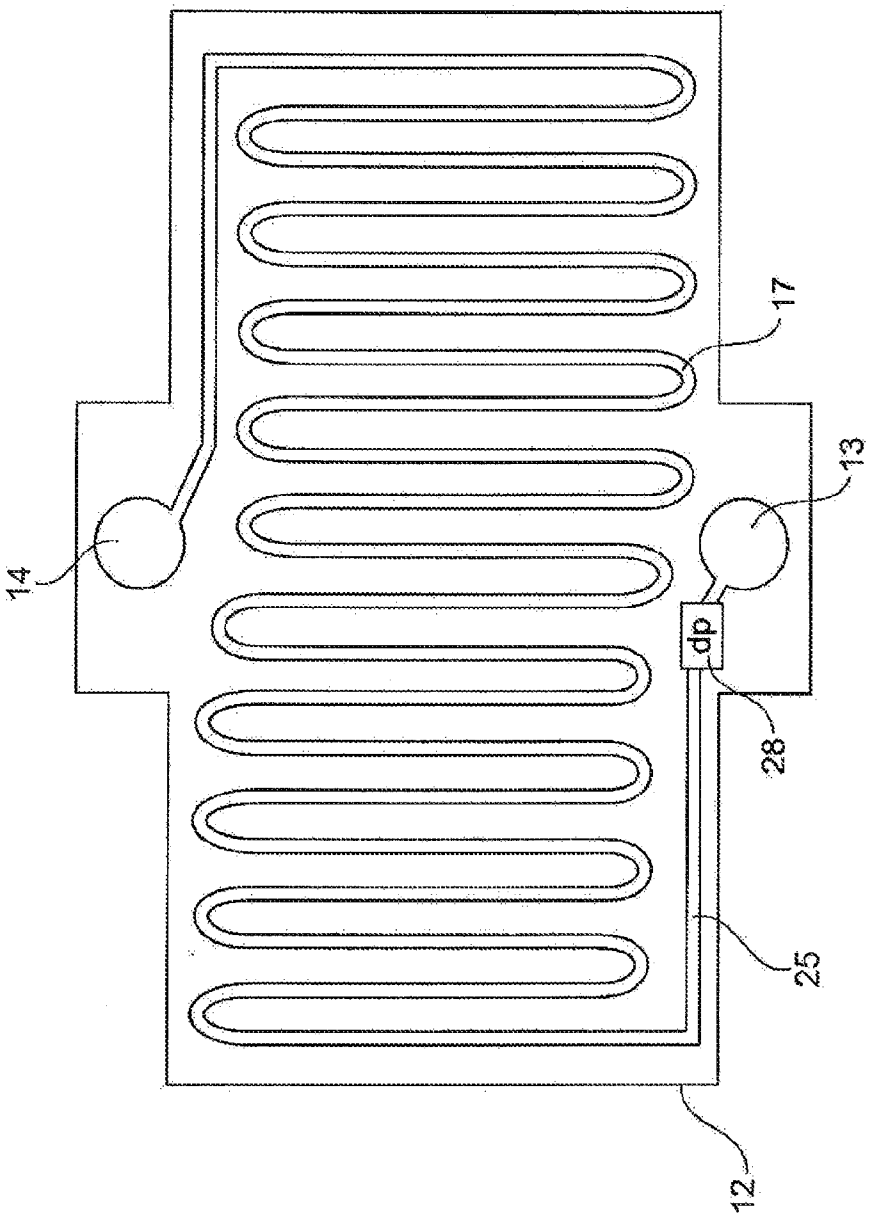


Fig. 4

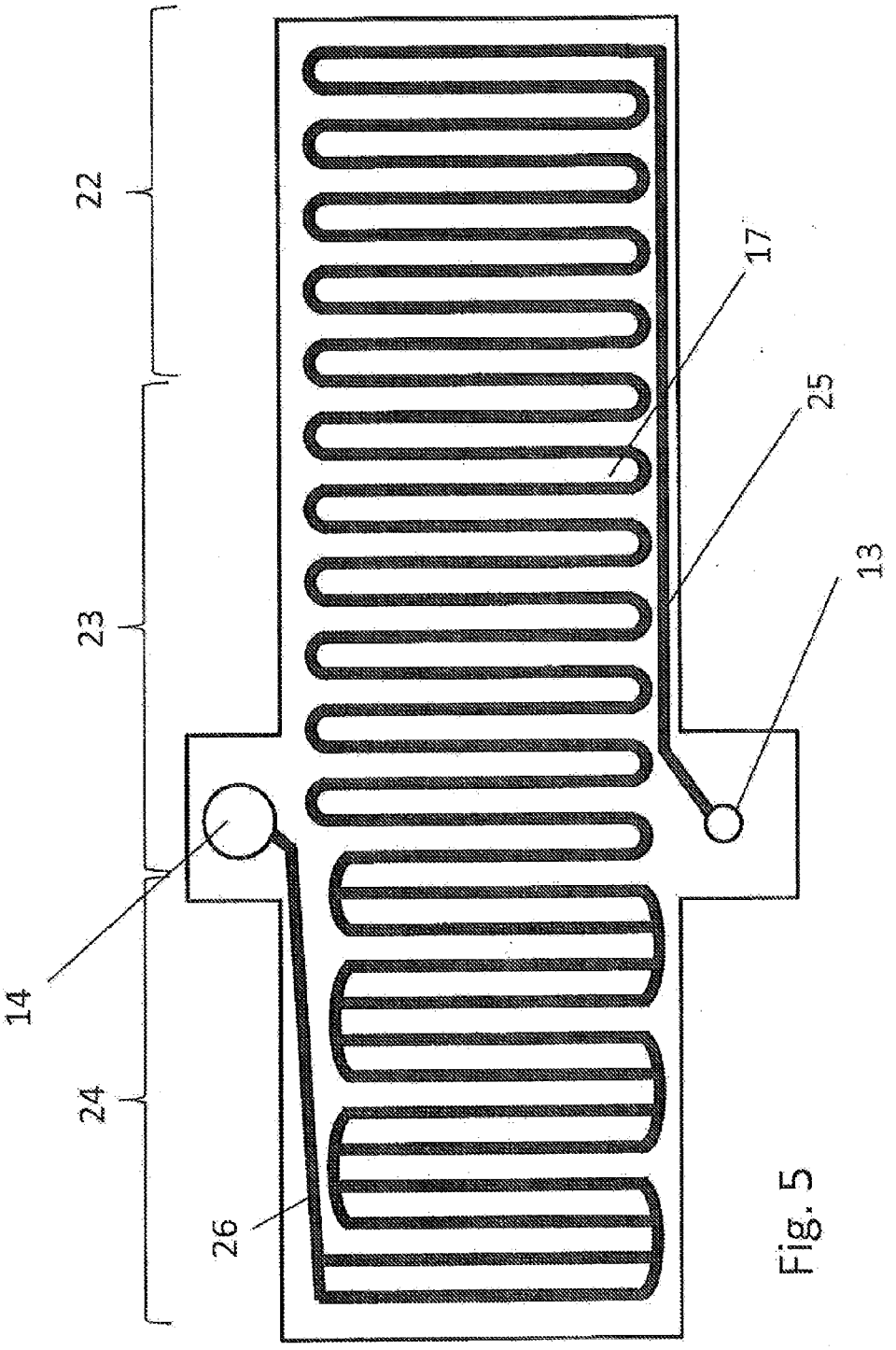


Fig. 5

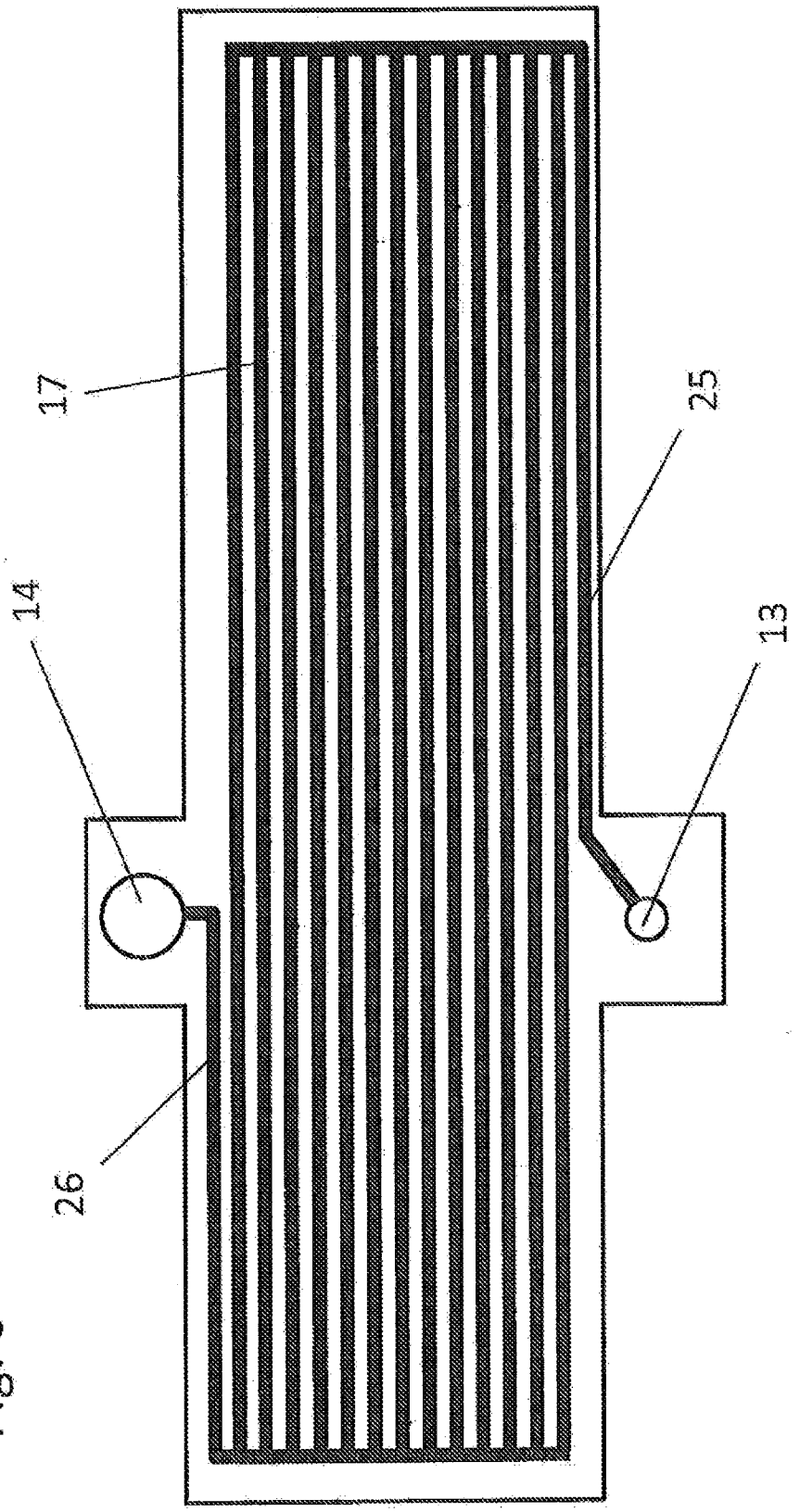


Fig. 6

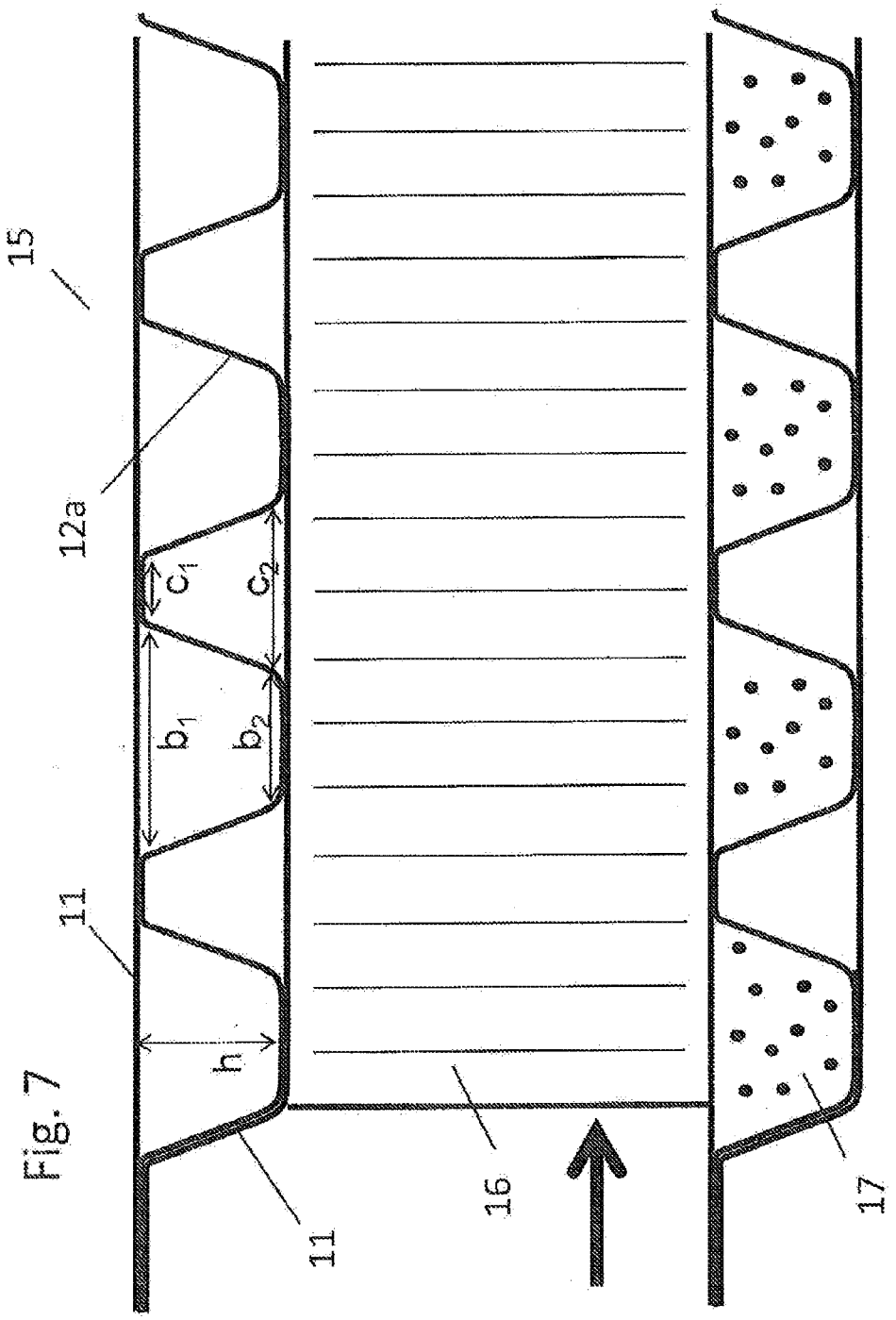


Fig. 7

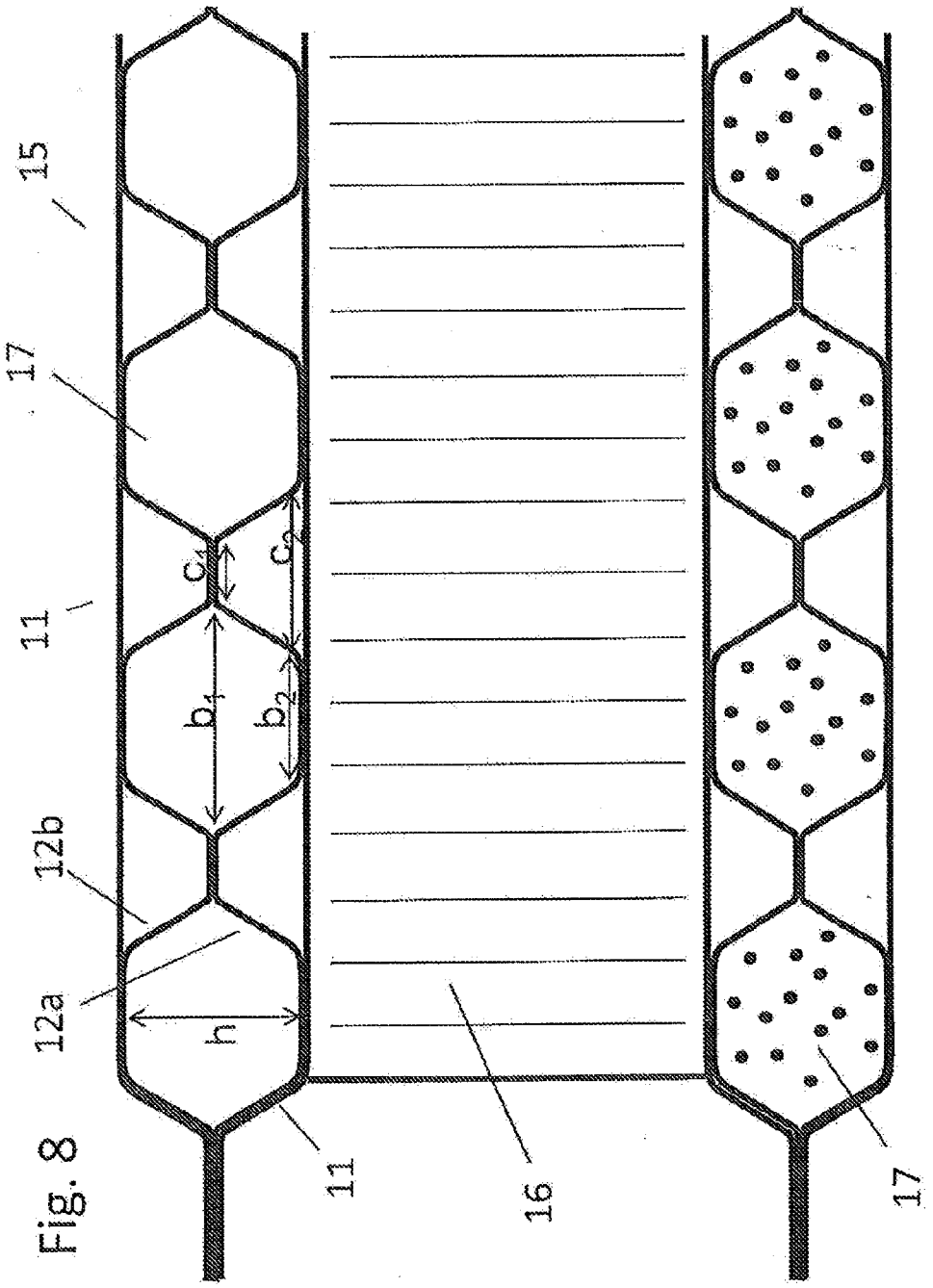


Fig. 8

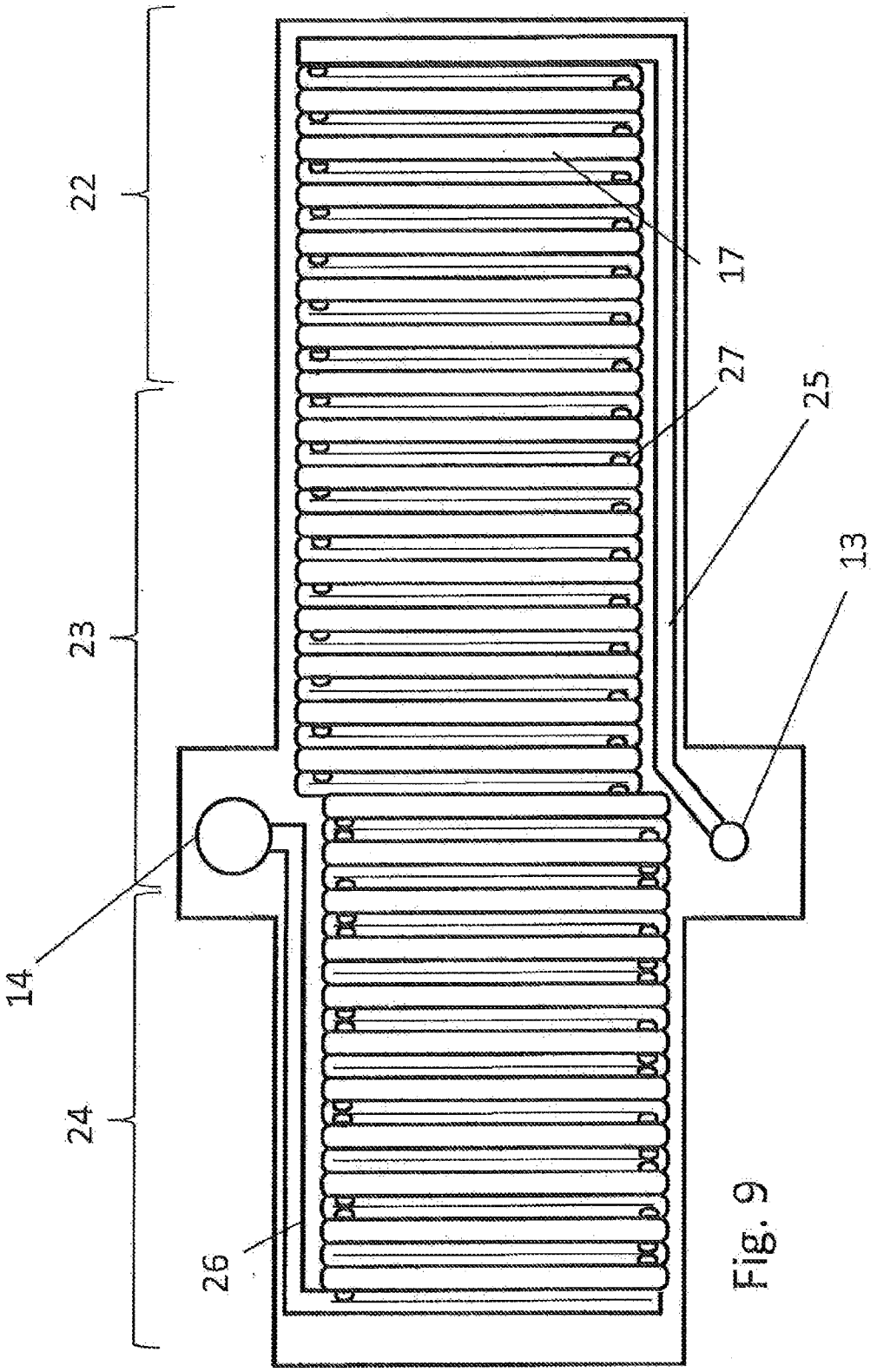


Fig. 9

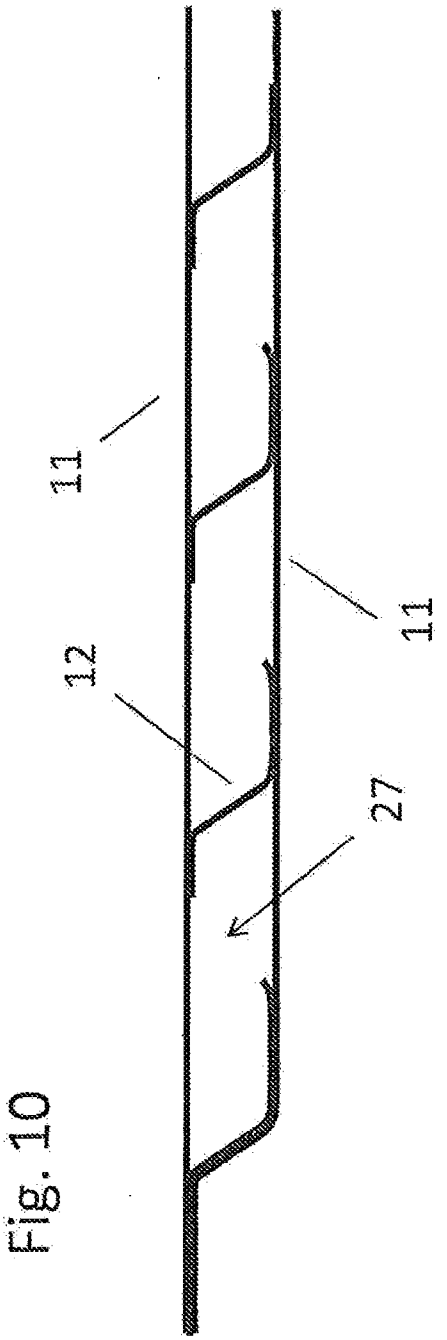


Fig. 10

EXHAUST GAS EVAPORATOR

[0001] This nonprovisional application is a continuation of International Application No. PCT/EP2010/065899, which was filed on Oct. 21, 2010, and which claims priority to German Patent Application No. DE 10 2009 050 889.9, which was filed in Germany on Oct. 27, 2009, and which are both herein incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an evaporator, in particular an exhaust gas evaporator, for an exhaust gas system of a motor vehicle.

[0004] 2. Description of the Background Art

[0005] The recovery of thermal energy from exhaust gases of an internal combustion engine is growing steadily in importance in the area of automotive engineering. In particular, the focus is increasingly on the recovery of thermal energy with the aid of exhaust gas evaporators in order to thereby increase efficiency with regard to the operation of the internal combustion engine. In an exhaust gas evaporator, heat is removed from the exhaust gas and supplied to a coolant or refrigerant, which is usually evaporated during this process. The thermal energy removed from the exhaust gas may be used for a downstream Clausius-Rankine process.

[0006] For example, DE 10 2007 060 523 A1, which corresponds to US 20100319887, and which is incorporated herein by reference, discloses an exhaust gas evaporator, the exhaust gas evaporator having a sandwich design in which exhaust gas planes and coolant planes are alternately disposed immediately next to each other.

SUMMARY OF THE INVENTION

[0007] It is therefore an object of the invention to provide an evaporator which is improved with regard to its pressure stability and which is also easy and cost-effective to manufacture.

[0008] According to an embodiment of the invention, the evaporator, which is suitable, in particular, for use as an exhaust gas evaporator for an exhaust gas system of a motor vehicle, has a plate sandwich structure including multiple fluid-guiding plate elements which are stacked on top of each other for guiding a first fluid, at least one rib, in particular a connecting rib or a corrugated rib, being disposed between two plate elements for guiding a second fluid, a plate element comprising at least one cover plate covering a flow channel and a flow channel plate unit, the flow channel plate having at least one flow channel plate provided with flow channels in order to guide the first fluid from an inlet to an outlet.

[0009] Representing the evaporator in a plate sandwich structure provides the evaporator with a particularly high pressure stability, and it may thus sufficiently withstand the working pressures of up to 100 bar, which occur, for example, in a Clausius-Rankine process.

[0010] In an embodiment, the flow channel plate unit comprises a single flow channel plate, the flow channel plate being closed by a cover plate covering the flow channel. A specific embodiment of this type represents the simplest and most cost-effective design of a flow channel plate unit.

[0011] In a further embodiment, another cover element is provided which is disposed between the single flow channel plate and the at least one rib, so that the flow channel plate is disposed between the two cover plates.

[0012] In other words, plate elements in the sequence of cover plate—flow channel plate—cover plate are disposed between two ribs, so that the two cover plates represent a good contact surface or a flat connection to the rib.

[0013] In a further embodiment, the flow channel plate unit comprises exactly two flow channel plates, which are disposed between two cover plates. Due to the integral connection of the two channel plates, a channel structure is provided which has an increased pressure resistance.

[0014] The flow channels of the flow channel plates are preferably provided by means of an embossing process or a deep-drawing process. Methods of this type are cost-effective and, in addition, this method makes it possible to introduce different channel structures into the flow channel plates. For example, a meander-shaped channel structure is conceivable, in which the first fluid, for example water or an alcohol mixture of a Clausius-Rankine cycle, may be guided from an inlet to an outlet.

[0015] In another embodiment, the flow channels are formed by parallel seams which are connected to each other by openings. Due to a specific embodiment of this type, a particularly easy-to-manufacture flow channel plate is provided, it being possible to introduce the in particular stamped channels at any point, depending on the application.

[0016] In another embodiment, the flow channels of the flow channel plates are designed as openings, the openings in the two flow channel plates overlapping to form one or multiple flow channels. The overlapping openings are preferably designed to have different widths, so that any burrs that may be present on the edges of the openings do not hinder the fluid interconnection of the flow channels.

[0017] The openings can be provided by means of a stamping process, by laser cutting or water jet cutting.

[0018] In another embodiment, the inlet and/or the outlet is/are disposed in a central area of the evaporator. A specific embodiment of this type achieves the fact that a thermal expansion, in particular in a longitudinal direction of the evaporator, is not hindered. According to the invention, a "central area" is understood to be an area which extends 0 to 20 percent, preferably 0 to 10 percent, of the entire length of the evaporator in both directions from the geometric center of the evaporator.

[0019] In another embodiment, the inlet and/or the outlet is/are disposed on the side of the evaporator so as not to hinder the flow of the second fluid, in particular an exhaust gas of a motor vehicle. The plate elements, which have an essentially rectangular design, have projections with openings on both longitudinal sides for this purpose. Stacking the individual plate elements forms an inlet having an inlet collecting channel, on the one hand, and a corresponding outlet having an outlet collecting channel, on the other hand.

[0020] In another embodiment, at least one, preferably each, flow channel plate unit has an element which is designed to generate an elevated pressure loss. The element is preferably designed as a nozzle, an aperture or a labyrinth. A specific embodiment of this type achieves the fact that the pressure loss difference between the individual flow channels of different flow channel plate units is lower in terms of percentage by selectively introducing a "preliminary pressure loss." This ensures uniform medium distribution of the first fluid to the respective flow channel plate units.

[0021] An evaporator of this type can be used as an exhaust gas evaporator in an exhaust gas system of a motor vehicle, it being possible to couple an exhaust gas evaporator of this type to a Clausius-Rankine cycle.

[0022] It is understood that the aforementioned features and the features still to be explained below may be used not only in the combinations indicated but also in other combinations or alone without going beyond the scope of the present invention.

[0023] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitive of the present invention, and wherein:

[0025] FIG. **1** shows a schematic representation of a view of a motor vehicle having an internal combustion engine and an exhaust gas system having an exhaust gas evaporator;

[0026] FIGS. **2***a* to **2***d* show schematic representations of a view of different flow channel plates;

[0027] FIG. **3** shows a schematic representation of a view of an exhaust gas evaporator according to the invention;

[0028] FIGS. **4** to **6** show schematic representations of a view of three additional exemplary embodiments of a flow channel plate according to the invention;

[0029] FIGS. **7** and **8** show schematic representations of two exemplary embodiments of a plate element according to the invention, a corrugated rib disposed between them; and

[0030] FIGS. **9** and **10** show schematic representations of a view of another exemplary embodiment of a flow channel plate according to the invention and the flow channel plate in a detailed view.

DETAILED DESCRIPTION

[0031] Motor vehicle **1** shown in FIG. **1** comprises an internal combustion engine **2** which includes a downstream exhaust gas system **3** in which, in this exemplary embodiment, an exhaust gas evaporator **5**, a catalytic converter **6**, a central muffler **7** and a rear muffler **8** are disposed in an exhaust gas branch **4**. Motor vehicle **1** stands on four wheels **9** (identified by reference numerals only by way of example) on a road surface **10** which, according to the representation in FIG. **1**, lies on the paper plane.

[0032] As furthermore shown in FIG. **1**, an exhaust gas evaporator **5** of this type is thermally coupled to a so-called Rankine cycle **18**. Rankine cycle **18** has at least one evaporator **5**, an expander **19**, a Rankine condenser **20** and a pump **21**. The working medium of the Rankine cycle, for example water, is increased to an elevated pressure level by pump **21**. Afterwards, the medium flows into evaporator **5**. The working medium flows out of the evaporator into expander **19**, in which it performs mechanical work and expands to a lower temperature and pressure level. From there it flows into a Rankine condenser **20**, in which the working medium is liquefied. Pump **21** subsequently draws the working medium in again.

[0033] FIG. **2***a* through FIG. **2***d* show a first exemplary embodiment of flow channel plates **12***a* and **12***b* according to the invention, which, when assembled, form a flow channel plate unit **12**; the figures also show a cover plate **11**. Flow channel plates **12***a* and **12***b* have a plurality of openings **17**, the widths of the individual openings in the two plates being different, so that when the plates are stacked (as shown in FIG. **2***d*), any burrs that may exist do not unnecessarily hinder the connection of the plates to each other. The two flow channel plates are covered by a cover plate **11** on the top and bottom. According to the invention, a unit comprising flow channel plate unit **12** an cover plate **11** is referred to as plate element **15**.

[0034] If a stack of plate elements **15** of this type is then constructed by alternately placing one plate element **15** and one rib **16** on top of each other and subsequently soldering them to each other, this results in an exhaust gas evaporator, as shown in FIG. **3**.

[0035] The exhaust gas evaporator has an inlet **13** and an outlet **14** which are disposed approximately in the center, viewed in the longitudinal direction. The fluid, for example water from a Clausius-Rankine cycle, flows from inlet **13** into a collecting channel **13***a*, which is formed by plate elements **15** and intermediate elements **13***b* inserted between them.

[0036] From there, the fluid is distributed to the respective plate elements and, once it has been collected in a second collecting channel **14***a*, flows out of the evaporator through outlet **14**. Second collecting channel **14***a* is also formed from respective plate elements **15** and intermediate elements **14***b* inserted inbetween. The two collecting channels **13***a* and **14***a* are disposed on the side of the evaporator so that the flow of the second fluid, in particular an exhaust gas of a motor vehicle, is not hindered along ribs **16**.

[0037] FIG. **4** through FIG. **6** show schematic representations of additional exemplary embodiments of a flow channel plate unit **12** according to the invention, unit **12** being able to comprise either two flow channel plates **12***a* and **12***b*, in that individual flow channels **17** are provided by means of a stamping process (as shown in FIG. **2***a* through FIG. **2***d*) or provided from a single flow channel plate **12***a*, in that the flow channels are provided by means of a deep drawing process.

[0038] As demonstrated by the exemplary embodiment according to FIG. **4**, a pressure loss element **28**, which is identified by "dp," is disposed in a supply line **25** to channels **17**. Due to a pressure loss element **28** of this type, which is designed, for example, as a nozzle or aperture, a pressure loss is selectively set which subsequently results in a more uniform distribution of medium, as described in greater detail below.

[0039] As shown in FIG. **5**, an exhaust gas evaporator has three zones which differ from each other, in particular, by the fact that the working fluid has different phase states in the respective zones. While the working fluid is largely present in liquid form in a supercooling area **22** and largely in a two-phase form in an evaporation area **23**, the working fluid is completely evaporated in an overheating area **24**. Pressure losses of different amounts form as a result of the different flow velocities produced thereby, the pressure loss increasing, starting from a supercooling area.

[0040] Due to the provision of a pressure loss "dp," the pressure loss difference through different zones **22** through

24 is lower in terms of percentage. This measure ensures a more uniform distribution of medium. The ratio between the preliminary pressure loss and the pressure loss in the rest of flow channel **17** should thus be between 0.25 and 1.

[0041] The additional pressure loss does not produce any major losses in the overall efficiency of the Clausius-Rankine cycle, since the power of pump **21** increases only minimally due to the low mass flows caused by the additional overall pressure loss via evaporator **5**.

[0042] In another exemplary embodiment according to FIG. **5**, multiple flow channels **17** may be connected in parallel in overheating area **24**. The rising pressure loss may also be counteracted by an associated increase in the flow cross section.

[0043] The level of the mass flows varies, depending on the working fluid selected. For example, a parallel disposition of flow channels **17** is suitable for alcohols, as shown in FIG. **6**.

[0044] FIG. **7** and FIG. **8** show two particularly preferred exemplary embodiments of an exhaust gas evaporator according to the invention. In the specific embodiment according to FIG. **7**, flow channels **17** are pressed into flow channel plate **12***a* with the aid of a deep-drawing process. Channels **17** are closed to the top by a first cover plate **11**. This plate also represents a flat connection to a rib, which is not illustrated. To provide a flat surface for rib **16** toward the bottom as well, flow channel plate **12***a* is inserted into another deep-drawn, second cover plate **11** on the edge.

[0045] Under certain circumstances, this second cover plate **11** may be eliminated so that flow channel plate **12***a* directly adjoins rib **16**.

[0046] The specific embodiment according to FIG. **8** essentially differs from the specific embodiment according to FIG. **7** by the fact that flow channel plate unit **12** now comprises exactly two flow channel plates **12***a* and **12***b*. Cavities, which are used as flow channels **17**, are formed by stacking the two flow channel plates.

[0047] If necessary, lower second cover plate **11** may also be omitted in this specific embodiment.

[0048] Based on a plurality of tests, the following geometric parameters have proven to be particularly favorable:

[0049] 0.5 mm≦h≦3 mm, preferably: 0.8 mm≦h≦2 mm;

[0050] mm≦b**1**≦8 mm, preferably: 3.0 mm≦b**1**≦5 mm;

[0051] mm≦b**2**≦8 mm, preferably: 3.0 mm≦b**2**≦5 mm;

[0052] where: b**2**<b**1**;

[0053] 0.5 mm≦c**1**≦3 mm, 0.5 mm≦c**2**≦3 mm, where: c**1**<c**2**;

[0054] The thicknesses of cover plates **11** are preferably 0.5 mm to 0.8 mm. The thickness of the at least one flow channel plate is preferably between 0.3 mm and 0.7 mm; this means that the at least one flow channel plate may be of a thinner design than the at least one cover plate.

[0055] FIG. **9** and FIG. **10** (FIG. **10** representing a detailed view) show another exemplary embodiment of an exhaust gas evaporator according to the present invention. In this specific embodiment, flow channels **17** are formed by parallel seams which are communicatively connected to each other by openings **27**. These openings are preferably provided by a stamping process. Deflections of the flow channels may be ideally set by means of the stamped openings or through-openings. Similarly to the specific embodiment according to FIG. **5**, two or more flow channels may be connected in parallel in overheating area **24** in order to reduce the elevated pressure loss.

[0056] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are to be included within the scope of the following claims.

What is claimed is:

1. An evaporator for an exhaust gas system of a motor vehicle, the evaporator comprising:

a plate sandwich structure that has multiple fluid-guiding plate elements stacked on top of each other for guiding a first fluid;

at least one rib arranged between two plate elements and configured to guide a second fluid; and

a plate element having at least one cover plate covering a flow channel and a flow channel plate unit, the flow channel plate unit having at least one flow channel plate provided with flow channels in order to guide the first fluid from an inlet to an outlet.

2. The evaporator according to claim **1**, wherein the flow channel plate unit includes a single flow channel plate, and wherein the flow channel plate is closed by a cover plate covering a flow channel.

3. The evaporator according to claim **2**, wherein another cover plate is arranged between the single flow channel plate and the at least one rib so that the flow channel plate is arranged between the two cover plates (**11**).

4. The evaporator according to claim **3**, wherein the flow channel plate unit includes exactly two flow channel plates that are arranged between two cover plates.

5. The evaporator according to claim **1**, wherein the flow channels are provided viaan embossing process or a deep drawing process.

6. The evaporator according to claim **4**, wherein the flow channels of the flow channel plates are designed as openings, the openings in the two flow channel plates overlapping to form one or multiple flow channels.

7. The evaporator according to claim **6**, wherein the widths of the overlapping openings are different.

8. The evaporator according to claim **6**, wherein the openings are provided by a stamping process, laser cutting or water jet cutting.

9. The evaporator according to claim **1**, wherein the inlet and/or the outlet is/are situated in a central area of the evaporator.

10. The evaporator according to claim **1**, wherein the inlet and/or the outlet is/are situated on a side of the evaporator.

11. The evaporator according to claim **1**, wherein at least one flow channel plate unit has an element that is designed to generate an elevated pressure loss, the element being designed as a nozzle, aperture or labyrinth.

12. The evaporator according to claim **1**, wherein the flow channels have a meander-shaped structure.

13. The evaporator according to claim **1**, wherein the flow channels are formed by parallel seams which are connected to each other by openings.

14. An exhaust gas system for a motor vehicle comprising an exhaust gas evaporator according to claim **1**.

15. The exhaust gas system according to claim **14**, wherein the exhaust gas evaporator is configured to be thermally coupled to a Rankine cycle.

16. The evaporator according to claim **1**, wherein the at least one rib is a connecting rib or a corrugated rib.

* * * * *