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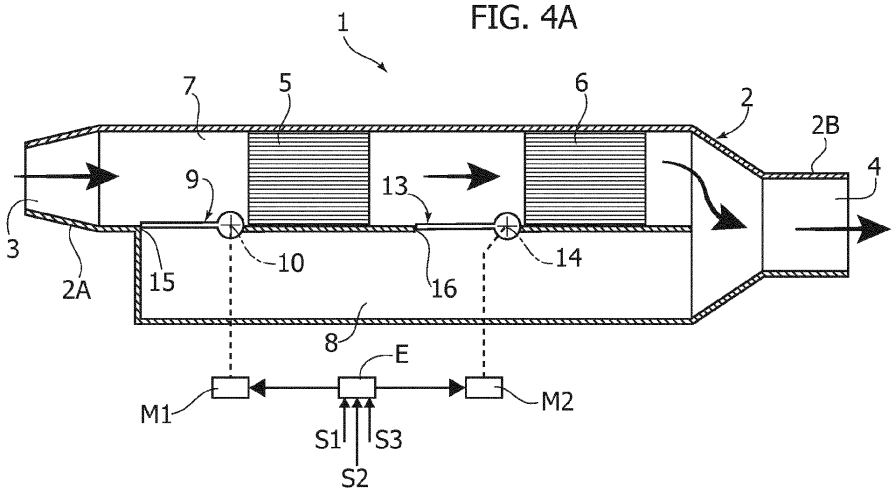
(54) DEVICE FOR COOLING AN EXAUST GAS RECIRCULATION (EGR) FLOW OF AN INTERNAL COMBUSTION ENGINE

(57) A device for cooling an exhaust gas recirculation (EGR) flow of an internal combustion engine comprises a body (2) with an inlet (3) and an outlet (4) for the EGR flow, defining a main duct (7) for the EGR flow and a secondary duct (8) in parallel with the main duct. The device also comprises a first heat exchanger module (5) in the main duct, and a second heat exchanger module (6) in either the main duct or the secondary duct, downstream of the first heat exchanger module (5), with reference to the direction of the EGR flow. The device comprises a first communication passage (15) between the main duct and the secondary duct, located upstream of the first heat exchanger module, and a second communication passage (16) between the main duct and the secondary duct, located downstream of the first heat exchanger module and upstream of the second heat exchanger module. The device also comprises valve means (9, 13) arranged in the body to control the EGR flow through the main duct and the secondary duct. These valve means comprise a first valve (9) arranged upstream of the first heat exchanger module and a second valve (13) arranged upstream of the second heat exchanger module. The device also comprises means for controlling the first valve and the second valve in order to direct the EGR flow either through both heat exchanger modules, or through only one of the two heat exchanger modules, or along a path that passes through neither the first heat exchanger module nor the second heat exchanger module.

FIG. 4A



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Description

Field of the invention

[0001] The present invention relates to devices for cooling an exhaust gas recirculation (EGR) flow of an internal combustion engine, of the type comprising:

- a body with an inlet and an outlet for the EGR flow, defining a main duct for the EGR flow from said inlet to said outlet, and a secondary duct in parallel with the main duct,
- at least one heat exchanger module for cooling the EGR flow, arranged in the main duct, and
- valve means arranged in said body for controlling the EGR flow through the main duct and the secondary duct.

Prior art

[0002] Devices of the type indicated above are known to the person skilled in the art. Such known devices usually include a single heat exchanger module and two valves, controllable according to the operating conditions of the engine, to vary the degree of cooling to which the EGR flow is subjected. In particular, such devices are able to operate in a "full cooling" condition, wherein the maximum cooling capacity of the heat exchanger module is exploited, in a condition of "partial cooling", wherein the cooling function is only partial, or in a "no cooling" condition wherein the cooling function is totally excluded.

[0003] In such known devices, the first of the two valves, being able to move between two different operating positions, can determine the exposure of the EGR flow to the cooling function, or the total exclusion of said cooling function. The second of the two valves, also being able to move between two different operating positions, instead determines a partialization of the cooling function, being able to force the EGR flow to flow only through a reduced section of the single heat exchanger module, in case the first valve is in the operating position that determines the exposure of the EGR flow to the cooling function.

[0004] The aforesaid known devices, however, have the drawback of an uneven distribution of heat inside the heat exchanger module in the "partial cooling" operating mode. In such known devices, the heat exchanger module can, therefore, be subjected to a non-uniform thermal field. This non-uniformity of the thermal field can cause deformations and/or thermal-mechanical stresses of the heat exchanger module, which can limit the resistance over time of the device for cooling the EGR flow.

Object of the invention

[0005] The object of the present invention is to provide a device of the type indicated at the beginning of the present description, which is characterized by a structure that allows limiting the generation of non-uniform thermal fields inside the heat exchanger modules during the "partial cooling" operating mode.

[0006] Another object of the invention is to provide more than one "partial cooling" operating mode, thus offering the possibility of varying more finely the degree of cooling to which the EGR flow can be subjected.

[0007] Still another object of the invention is to provide a system for actuating the valve means arranged in the body of the device comprising a limited number of actuators.

Summary of the invention

[0008] In view of achieving this object, the present invention relates to a device for cooling an exhaust gas recirculation (EGR) flow having all the characteristics indicated at the beginning of the present description and further characterized in that it comprises:

- a first heat exchanger module in the main duct,
- a second heat exchanger module in one of said main duct and secondary duct, downstream of the first heat exchanger module, with reference to the direction of the EGR flow,
- a first communication passage between the main duct and the secondary duct, located upstream of the first heat exchanger module, with reference to the direction of the EGR flow, and
- a second communication passage between the main duct and the secondary duct, located downstream of the first heat exchanger module and upstream of the second heat exchanger module, with reference to the direction of the EGR flow.

[0009] Furthermore, the device according to the invention is also characterized in that the valve means for controlling the EGR flow comprise:

- a first valve arranged upstream of the first heat exchanger module and having at least one first operating position in which said first valve closes said first communication passage, and a second operating position in which said first valve obstructs the inlet of the first heat exchanger module, and
- a second valve arranged upstream of the second heat exchanger module and having at least one first operating position in which said second valve closes said second communication passage, and a second operating position in which said second valve obstructs the inlet of the second heat exchanger module.

[0010] The device according to the invention is also characterized in that it comprises means for controlling the first valve and the second valve in order to direct the EGR flow either through both heat exchanger modules, or through only one of the two heat exchanger modules,

or along a path that passes through neither the first heat exchanger module nor the second heat exchanger module.

[0011] Thanks to the arrangement described above, the device according to the invention is able to control the degree of cooling of the EGR flow in a simple and efficient manner, avoiding the generation of non-uniform thermal fields inside the heat exchanger modules, since the partialization of the cooling function does not occur in the same way as in known devices, i.e. forcing the EGR flow to flow through a reduced section of a single heat exchanger, but instead forcing the EGR flow to flow through just one of the two heat exchanger modules included in the body of the device.

[0012] In a first embodiment, the device according to the invention is also characterized in that the second heat exchanger module is included in the main duct, in such a way that:

- in a first operating configuration of the valves, the first valve closes the first communication passage and the second valve closes the second communication passage, so that the EGR flow is directed through both heat exchanger modules,
- in a second operating configuration of the valves, the first valve closes the first communication passage and the second valve obstructs the inlet of the second heat exchanger module, so that the EGR flow is only directed through the first heat exchanger module, and
- in a third operating configuration of the valves, the first valve obstructs the inlet of the first heat exchanger module and the second valve closes the second communication passage, so that the EGR flow is directed through a path that passes through neither the first heat exchanger module nor the second heat exchanger module.

[0013] In a variant of the aforesaid first embodiment, the device according to the invention is further characterized in that the second valve has a third operating position in which it blocks the secondary duct downstream of the second communication passage, in such a way that in a fourth operating configuration of the valves, the first valve obstructs the inlet of the first heat exchanger module and the second valve obstructs the secondary duct downstream of the second communication passage, so that the EGR flow is only directed through the second heat exchanger module.

[0014] According to yet another embodiment, the device according to the invention is characterized in that the second heat exchanger module is included in the secondary duct, the first valve has a third operating position in which it obstructs the secondary duct downstream of the first communication passage, and the second valve has a third operating position in which it obstructs the primary duct downstream of the second communication passage, in such a way that:

- in a first operating configuration of the valves, the first valve closes the first communication passage and the second valve closes the second communication passage, so that the EGR flow is directed through the first heat exchanger module only,
- in a second operating configuration of the valves, the first valve obstructs the inlet of the first heat exchanger module and the second valve obstructs the inlet of the second heat exchanger module, so that the EGR flow is directed through a path that passes through neither the first heat exchanger module nor the second heat exchanger module, and
- in a third operating configuration of the valves, the first valve obstructs the second duct downstream of the first communication passage and the second valve obstructs the primary duct downstream of the second communication passage, so that the EGR flow is directed through both heat exchanger modules.

Detailed description of some embodiments

[0015] Further characteristics and advantages of the invention will become apparent from the description that follows, with reference to the attached drawings, provided purely by way of non-limiting example, wherein:

- Figure 1 is a schematic cross-sectional view that shows a device for cooling an exhaust gas recirculation (EGR) flow of an internal combustion engine, according to the prior art,
- Figure 2 is a schematic cross-sectional view of a further cooling device according to the prior art,
- Figures 3A and 3B are two schematic cross-sectional views, on an enlarged scale, of the heat exchanger module forming part of the known device of Figure 2, in two different operating conditions of this device,
- Figures 4A, 4B, and 4C are schematic cross-sectional views that show a first embodiment of the device according to the invention in three different operating conditions,
- Figure 5 is a schematic cross-sectional view of another embodiment of the device according to the invention in one of its operating conditions, and
- Figures 6A, 6B, and 6C are schematic cross-sectional views that show another embodiment of the device according to the invention in three different operating conditions.

[0016] In Figure 1, the reference number 1 indicates in its entirety a conventional cooling device for the exhaust gas recirculation (EGR) flow of an internal combustion engine. The device 1 comprises a body 2 with an inlet connector 2A and an outlet connector 2B. The connectors 2A, 2B define an inlet 3 and an outlet 4 of an in-line (or I-shaped) path inside the device. In the context of the present description, an in-line or "I-shaped" path means a path defined by a device having the inlet 3 and

the outlet 4 located at opposite ends of the body 2 (in contrast to a "U-shaped" path).

[0017] In Figure 1, the device 1 thus has an in-line configuration, with the inlet 3 and the outlet 4 at opposite ends of the body 2. The body includes a heat exchanger module located between the inlet 3 and the outlet 4 inside a main duct 7 defined by the body 2. The body also includes a secondary duct 8 in parallel with the main duct 7 and, therefore, in parallel with the single heat exchanger 5. The secondary duct 8 thus allows "by-passing" the heat exchanger 5.

[0018] Circulation of the EGR flow is controlled by a door valve 9, pivotally connected in 10 to the body of the device, adjacent to the inlet 3. The door valve 9 enables the EGR to selectively flow towards the main duct 7, and therefore towards the heat exchanger 5, or towards the secondary duct 8.

[0019] The door valve 9 of the device of Figure 1 has a first operating position, indicated with a continuous line in Figure 1, wherein it obstructs the access to the heat exchanger 5, so that the entire EGR flow passes from the inlet 3 to the outlet 4 through the secondary duct 8 and the cooling function is completely excluded. The door valve 9 of the device of Figure 1 also has a second operating position, indicated by a dashed line in Figure 1, wherein said door valve 9 completely obstructs the inlet of the secondary duct 8, so as to enable the cooling function, obtained through the passage of the entire EGR flow through the heat exchanger 5 located in the main duct 7.

[0020] In the known device described above, therefore, it is possible to obtain two different operating conditions: a first operating condition (corresponding to the operating position of the door valve 9 indicated with a continuous line in Figure 1) in which the EGR flow does not pass through the heat exchanger 5, so that the cooling function is totally excluded ("no cooling"), and a second operating condition (corresponding to the operating position of the door valve 9 indicated by the dashed line in Figure 1) in which the EGR flow passes through the heat exchanger 5, thus obtaining the cooling of the EGR flow ("full cooling").

[0021] Again, with reference to the known device of Figure 1, the heat exchanger 5 is usually constituted by a body including a bundle of tubes through which the EGR flow passes and that are arranged in a chamber, through which a coolant flows, typically the coolant of the internal combustion engine. To this end, the heat exchanger is inserted into the part of the engine cooling circuit that is external to the engine.

[0022] Still with reference to the known arrangement exemplified in Figure 1, the door valve 9 is controlled by an actuator, for example, an electrically-operated actuator, which is in turn controlled by an electronic controller on the basis of signals indicative of the operating conditions of the engine, so as to enable or disable the cooling function of the EGR flow according to these operating conditions.

[0023] Figure 2 illustrates a second device according to the prior art. In this Figure, the parts that are the same or corresponding to those of Figure 1 are indicated by the same reference numbers.

[0024] The main difference with respect to the solution of Figure 1 lies in the fact that, in this case, a first door valve 9 is provided, which directs the EGR flow entering the device selectively towards the main duct 7 (and, therefore, towards the heat exchanger 5) or towards the secondary duct 8, as well as a second door valve 11, pivotally connected in 12 to the body of the device inside the main duct 7, which is able to "obstruct" a part of the bundle of tubes of the heat exchanger 5 with respect to the incoming EGR flow.

[0025] Figures 3A and 3B schematically show the bundle of tubes 51 of the heat exchanger 5, immersed in a chamber 50 through which the engine coolant flows.

[0026] In the position of the door valve 11 that is shown with a continuous line in Figure 2, the two lower rows of the tubes 51 of the exchanger 5 (whose cross-sections are darkened in Figure 3B) are not accessible for the EGR flow entering the device, so that in this condition the cooling function is partialized ("partial cooling").

[0027] In the position of the door valve 11 that is shown with a dashed line in Figure 2, instead, all the rows of the tubes 51 of the heat exchanger 5 are accessible for the EGR flow entering the device, so that in this condition the maximum cooling capacity of the heat exchanger 5 ("full cooling") is exploited.

[0028] The door valve 9 instead, analogously to that of the solution in Figure 1, enables the arrival of the EGR flow to the heat exchanger 5, or completely excludes it, diverting the inlet flow entirely through the secondary duct 8, which represents the by-pass of the main duct 7 comprising the heat exchanger 5, so that in this condition the cooling function is totally excluded ("no cooling").

[0029] The solution illustrated in Figure 2 is, therefore, able to obtain some form of regulation (partialization) of the cooling of the EGR flow, but has the drawback of causing undesired thermal stresses of the structure of the device, due to the non-uniform thermal field to which the heat exchanger 5 is subjected. These thermo-mechanical stresses can cause, for example, deformation of the structure of the heat exchanger 5, and limit its resistance.

[0030] Figures 4A, 4B, and 4C are schematic cross-sectional views illustrating three different operating conditions of a first embodiment of the device according to the invention. In these figures as well, and in the subsequent figures referred to in the present description, the parts common or corresponding to the preceding figures are indicated by the same reference numbers.

[0031] As for the devices of Figures 1 and 2, the device according to the invention also has an in-line configuration with an inlet 3 and an outlet 4 at opposite ends of a body 2.

[0032] In the case of the invention, instead of a single heat exchanger module 5, a first and a second heat exchanger module 5, 6 are provided, arranged in series

between the inlet 3 and the outlet 4, with the second heat exchanger module 6 arranged downstream of the first heat exchanger module 5, with reference to the direction of the EGR flow.

[0033] In this first embodiment exemplified in Figures 4A, 4B and 4C, both the heat exchangers 5, 6 are included within a main duct 7 defined by the body 2 of the device in direct correspondence with the inlet 3. This body also defines a secondary duct 8, in parallel with the main duct 7 (and, therefore, in parallel with both heat exchanger modules), which allows "by-passing" at least one of the heat exchangers 5, 6.

[0034] The body 2 of the device exemplified in Figures 4A, 4B and 4C further defines a first communication passage 15 between the main duct 7 and the secondary duct 8, said first communication passage being located upstream of the first heat exchanger module 5, with reference to the direction of the EGR flow. Similarly, the body 2 of the device defines a second communication passage 16 between the main duct 7 and the secondary duct 8, this second communication passage being located downstream of the first heat exchanger module 5 and upstream of the second heat exchanger module 6, with reference to the direction of the EGR flow.

[0035] Furthermore, in the case of the invention, the inlet to each heat exchanger module can be enabled or disabled (opened or closed) by a respective door valve. The valve means of the device according to the invention exemplified in Figures 4A, 4B and 4C comprise the door valve 9, arranged upstream of the first heat exchanger module 5 and at the first communication passage 15, which directs the EGR flow towards the first heat exchanger module 5 arranged in the main duct 7, or towards the secondary duct 8 through the first communication passage 15, and a second door valve 13 pivotally connected at the axis 14 upstream of the second heat exchanger module 6 and at the second communication passage 16, which directs the EGR flow towards the second heat exchanger module 6 arranged in the main duct 7, or towards the secondary duct 8 through the second communication passage 16.

[0036] Figure 4A shows a first arrangement of the door valves 9, 13, corresponding to the "full cooling" operating condition of the device. In this arrangement, the door valve 9 closes the first communication passage 15 between the main duct 7 and the secondary duct 8, while the door valve 13 closes the second communication passage 16. In this condition, therefore, the EGR flow entering the device firstly flows entirely through the first upstream heat exchanger module 5, then through the second downstream heat exchanger module 6, and finally leaves the device through the outlet 4.

[0037] Figure 4B shows a second arrangement of the door valves 9, 13, corresponding to the "partial cooling" operating condition of the device. In this arrangement, the door valve 9 closes the first communication passage 15 between the main duct 7 and the secondary duct 8, while the door valve 13 obstructs the inlet of the second heat exchanger module 6 and opens the second communication passage 16. In this condition, therefore, the EGR flow entering the device firstly flows entirely through the first heat exchanger module 5 arranged in the main duct 7, and from there it flows then into the secondary duct 8 through the communication passage 16, then leaving the device through the outlet 4, by-passing the second heat exchanger module 6.

[0038] Figure 4C shows a third arrangement of the door valves 9, 13, corresponding to the "no cooling" operating condition of the device. In this arrangement, the door valve 9 blocks the inlet of the first heat exchanger module 5 and opens the first communication passage 15, while the door valve 13 closes the second communication passage 16. In this condition, therefore, the EGR flow entering the device is forced to flow from the inlet 3 to the outlet 4 entirely passing through the secondary duct 8, and bypassing both heat exchanger modules 5, 6. The cooling function is therefore completely excluded.

[0039] Still with reference to Figure 4A, in this figure are shown in a purely schematic way two actuators (for example, electric actuators) M1, M2 arranged to control the operating position of the valve elements 9, 13, and an electronic controller E, which controls the actuators M1, M2 according to signals S1, S2, S3, etc. indicative of parameters that define the operating conditions of the internal combustion engine. These parameters can include, for example, the temperature of the engine coolant, the temperature of the engine exhaust gases, the engine rotation speed, the engine load, etc.

[0040] The electronic controller E controls the actuators M1, M2 according to techniques well known to those skilled in the art, also on the basis of a signal indicative of the operating positions of the valve elements 9 and/or 13, or of the actuators M1 and/or M2, or any other element interposed in the transmission between the actuators M1, M2 and the respective valve elements 9, 13.

[0041] It is understood that these actuators M1, M2 and this electronic controller E, indicated in a purely schematic manner in Figure 4A, are not visible in Figures 4B and 4C for simplicity of illustration only. Since Figures 4B and 4C illustrate the same embodiment exemplified in Figure 4A in two additional operating conditions, it should be understood that these components M1, M2 and E are present, insofar as they are present in the embodiment exemplified in Figure 4A.

[0042] In the first embodiment of the device according to the invention exemplified in Figures 4A, 4B and 4C, therefore, each heat exchanger module 5, 6 is provided with a respective door valve 9, 13 located at the respective inlet. Each of the door valves 9, 13 can be actuated into two different positions, thus enabling the EGR to selectively flow towards the respective heat exchanger module, or towards the respective communication passage between the main duct 7 and the secondary duct 8, so as to be able to achieve three operating modes: "full cooling", "partial cooling" and "no cooling".

[0043] It should be noted that in all the embodiments

of the device according to the invention described in the present description, the two heat exchanger modules 5, 6 can be equal or different (e.g. in relation to their dimensions such as length, cross-section, diameter of the tubes 51, number of the tubes 51 etc.).

[0044] Likewise, in all the embodiments described herein, the two heat exchanger modules 5, 6 can be inserted into the same cooling circuit or into two separate cooling circuits, e.g. containing coolants with different characteristics and/or different temperatures.

[0045] Figure 5 illustrates a variant of the first embodiment of the device according to the invention. This variant is substantially similar to the solution of Figures 4A, 4B and 4C except that the door valve 13 can be moved into three different operating positions, instead of the two operating positions that characterize the operation of the valve 13 in the device illustrated in Figures 4A, 4B and 4C. This additional operating position of the door valve 13, illustrated in Figure 5, allows the "partial cooling" function to be carried out in a different manner from that illustrated in Figure 4B.

[0046] Figure 5 shows an arrangement of the door valves 9, 13, corresponding to a second "partial cooling" operating condition, different from the one illustrated in Figure 4B. In this arrangement of Figure 5, the door valve 9 obstructs the inlet of the first heat exchanger module 5 and opens the first communication passage 15, while the door valve 13 obstructs the secondary duct 8 downstream of the second communication passage 16. In this condition, therefore, the EGR flow entering the device flows from the inlet 3 towards the secondary duct 8 through the first communication passage 15, then passes through the second communication passage 16 to flow through the second heat exchanger module 6, and from this it finally leaves the device through the outlet 4.

[0047] Since the door valves 9, 13 of the solution exemplified in Figure 5 can also assume the positions already discussed in the case of the embodiment exemplified in Figures 4A, 4B and 4C, the solution of Figure 5 allows four different operating modes to be achieved: "full cooling", "partial cooling 1", "partial cooling 2" and "no cooling".

[0048] In the "partial cooling 1" operating mode, corresponding to the example in Figure 4B, the EGR flow passes through the upstream heat exchanger 5 only. Conversely, in the "partial cooling 2" operating mode, corresponding to the example in Figure 5, the EGR flow passes through the downstream heat exchanger 6 only.

[0049] Since, as discussed above, the two heat exchanger modules 5, 6 can be different, for example, in relation to some of their geometric and/or structural characteristics, it follows that they can be characterized by different cooling capacities. Therefore, the "partial cooling 1" and "partial cooling 2" operating modes obtainable by means of the embodiment exemplified in Figure 5 can correspond to different degrees of cooling of the EGR flow, thus allowing a greater possibility of control and flexibility of use of the embodiment shown in Figure 5 with respect to the embodiment shown in Figures 4A, 4B and 4C.

[0050] Two actuators (for example electric actuators) M1, M2 are also shown in a purely schematic way in Figure 5, arranged for controlling the operating position of the valve elements 9, 13, and an electronic controller E, which controls the electric actuators M1, M2 as a function of signals S1, S2, S3, etc. as discussed above.

[0051] Figures 6A, 6B and 6C illustrate another embodiment of the device according to the invention. In this embodiment, the first heat exchanger module 5 is located inside the main duct 7, and the second heat exchanger module 6 is located inside the secondary duct 8. Also in the case of this additional embodiment exemplified in Figures 6A, 6B and 6C, the body 2 of the device defines a first and a second communication passage 15, 16 between the main duct 7 and the secondary duct 8.

[0052] In a similar manner to that previously discussed for other embodiments, in the case of the present embodiment, the first communication passage 15 is also located upstream of the first heat exchanger module 5, with reference to the direction of the EGR flow, and the second communication passage 16 is located downstream of the first heat exchanger module 5 and upstream of the second heat exchanger module 6.

[0053] In the embodiment exemplified in Figures 6A, 6B and 6C, each of the two door valves 9, 13 can be moved into three different operating positions.

[0054] By a kinematic mechanism of any known type, exemplified by the block L interposed in the kinematic chain exemplified by the dashed line that connects the valves 9, 13 in Figure 6A, the two door valves are actuated by the same actuator M, in such a way that the respective movements are mutually linked. For example, the two valves 9, 13 can rotate by the same angle, but in opposite directions.

[0055] Figure 6A shows a first arrangement of the door valves 9, 13, corresponding to a "partial cooling" operating condition of the device. In this arrangement, the door valve 9 closes the first communication passage 15 between the main duct 7 and the secondary duct 8, while the door valve 13 closes the second communication passage 16. In this condition, therefore, the EGR flow entering the device firstly flows entirely through the first heat exchanger module 5, and from there it continues through the main duct 7 towards the outlet 4 of the device, by-passing the second heat exchanger module 6.

[0056] Figure 6B shows a second arrangement of the door valves 9, 13, corresponding to the "no cooling" operating condition of the device. In this arrangement, the door valve 9 obstructs the inlet of the first heat exchanger module 5 and opens the first communication passage 15, while the door valve 13 obstructs the inlet of the second heat exchanger module 6 and opens the second communication passage 16. In this condition, therefore, the EGR flow entering the device flows from the inlet 3 towards the secondary duct 8 through the first communication passage 15, thus by-passing the first heat ex-

changer module 5, then it passes through the second communication passage 16 to flow through the main duct 7, thus by-passing the second heat exchanger module 6, and it finally leaves the device through the outlet 4.

[0057] Figure 6C shows a third arrangement of the door valves 9, 13, corresponding to the "full cooling" operating condition of the device. In this arrangement, the door valve 9 obstructs the secondary duct 8 downstream of the first communication passage 15, while the door valve 13 obstructs the main duct 7 downstream of the second communication passage 16. In this condition, therefore, the EGR flow entering the device firstly flows entirely through the first heat exchanger module 5 arranged in the main duct 7, and from there it then flows into the secondary duct 8 through the communication passage 16, thus passing through the second heat exchanger module 6 arranged in the secondary duct 8, then leaving the device through the outlet 4.

[0058] With reference to Figure 6A, in this Figure, an actuator (e.g., an electric actuator) M is indicated in a purely schematic manner, arranged for controlling the operating position of the valve elements 9, 13, and an electronic controller E, which controls the actuator M as a function of signals S1, S2, S3, etc.

[0059] It should be noted that, unlike the embodiments exemplified in Figures 4A to 5, the embodiment exemplified in Figures 6A, 6B and 6C envisages the use of only one actuator M for actuating both the door valves 9, 13, as the respective actuation mechanisms are coupled by means of the kinematic mechanism L.

[0060] As in the case of Figures 4A, 4B and 4C, for Figures 6A, 6B and 6C it should be understood that this actuator M and this electronic controller E, indicated in a purely schematic manner in Figure 6A, are also not visible in Figures 6B and 6C for simplicity of illustration only, but they are still considered present.

[0061] It should be noted that a further advantage of this last embodiment discussed and exemplified in Figures 6A, 6B and 6C is given by the possibility of simplifying the actuation system of the door valves 9, 13, envisaging the use of just one actuator M and one simple kinematic mechanism L, thus reducing the number of components necessary for producing the three different operating modes ("full cooling", "partial cooling" and "no cooling") of the device for cooling the EGR flow.

[0062] As is evident from the above description, a fundamental concept common to all the embodiments of the present invention, and advantageous with respect to known devices, lies in the fact that the EGR flow never passes through the heat exchanger modules 5, 6 in a "partial" manner. The EGR flow passes through the heat exchanger modules 5, 6 throughout their entire section, or the heat exchanger modules 5, 6 are completely excluded from the recirculation circuit of the exhaust gases.

[0063] In this way, undesirable thermal stresses of the structure of the heat exchangers 5, 6 are avoided, since they are always subjected to (almost) uniform thermal fields. Accordingly, a device according to embodiments reduces the probability that the heat exchanger modules undergo deformations and/or breakages.

[0064] Of course, without prejudice to the principle of the invention, the details of construction and the embodiments may vary widely with respect to those described and illustrated here purely by way of example, without departing from the scope of the present invention, as defined by the attached claims.

Claims

1. A device (1) for cooling an exhaust gas recirculation (EGR) flow of an internal combustion engine, comprising:

- a body (2) with an inlet (3) and an outlet (4) for the EGR flow, defining a main duct (7) for the EGR flow from said inlet to said outlet, and a secondary duct (8) in parallel with the main duct,
- at least one heat exchanger module (5) for cooling the EGR flow, arranged in said main duct (7), and
- valve means (9, 13) arranged in said body (2) for controlling the EGR flow through the main duct (7) and the secondary duct (8),

characterized in that said device comprises:

- a first heat exchanger module (5) in the main duct (7),
- a second heat exchanger module (6) in one of said main duct (7) and secondary duct (8), downstream of the first heat exchanger module (5), with reference to the direction of the EGR flow,
- a first communication passage (15) between the main duct (7) and the secondary duct (8), located upstream of the first heat exchanger module (5), with reference to the direction of the EGR flow, and
- a second communication passage (16) between the main duct and the secondary duct, located downstream of the first heat exchanger module (5) and upstream of the second heat exchanger module (6), with reference to the direction of the EGR flow,
- said valve means comprising:

  - a first valve (9) arranged upstream of the first heat exchanger module (5) and having at least one first operating position wherein said first valve closes said first communication passage (15), and a second operating position wherein said first valve obstructs the inlet of the first heat exchanger module (5), and
  - a second valve (13) arranged upstream of the second heat exchanger module (6) and

having at least one first operating position wherein said second valve closes said second communication passage (16), and a second operating position wherein said second valve obstructs the inlet of the second heat exchanger module (6),

wherein said device also comprises means for controlling said first valve (9) and said second valve (13) in order to direct the EGR flow either through both the heat exchanger modules, or through only one of the two heat exchanger modules, or along a path that passes through neither the first heat exchanger module nor the second heat exchanger module.

2. A device according to claim 1, wherein said second heat exchanger module (6) is included in said main duct (7), in such a way that:

- in a first operating configuration of said valves (9, 13), the first valve (9) closes said first communication passage (15) and the second valve (13) closes said second communication passage (16), so that the EGR flow is directed through both heat exchanger modules (5, 6),
- in a second operating configuration of said valves (9, 13), the first valve (9) closes said first communication passage (15) and the second valve (13) obstructs the inlet of the second heat exchanger module (6), so that the EGR flow is directed through the first heat exchanger module (5) only, and
- in a third operating configuration of said valves (9, 13), the first valve (9) obstructs the inlet of the first heat exchanger module (5) and the second valve (13) closes said second communication passage (16), so that the EGR flow is directed through a path that passes through neither the first heat exchanger module (5) nor the second heat exchanger module (6).

3. A device according to claim 2, wherein said means for controlling said first valve (9) and said second valve (13) comprise a first actuator (M1) for controlling said first valve (9), a second actuator (M2) for controlling said second valve (13), and an electronic controller (E) for controlling said actuators (M1, M2).

4. A device according to claim 2 or claim 3, wherein said second valve (13) has a third operating position wherein it obstructs said secondary duct (8) downstream of said second communication passage (16), in such a way that in a fourth operating configuration of said valves (9, 13), the first valve (9) obstructs the inlet of the first heat exchanger module (5) and the second valve (13) obstructs said secondary duct (8) downstream of said second communication passage (16), so that the EGR flow is directed through the second heat exchanger module (6) only.

5. A device according to claim 1, wherein:

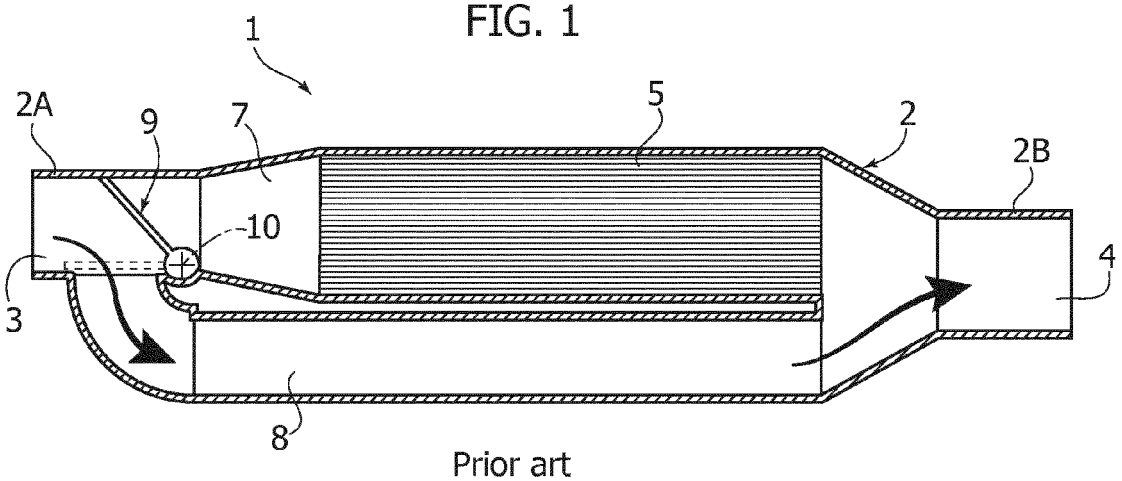
- said second heat exchanger module (6) is included in said secondary duct (8),
- said first valve (9) has a third operating position wherein it obstructs said secondary duct (8) downstream of said first communication passage (15), and
- said second valve (13) has a third operating position wherein it obstructs said primary duct (7) downstream of said second communication passage (16),

in such a way that:

- in a first operating configuration of said valves (9, 13), the first valve (9) closes said first communication passage (15) and the second valve (13) closes said second communication passage (16), so that the EGR flow is directed through the first heat exchanger module (5) only,
- in a second operating configuration of said valves (9, 13), the first valve (9) obstructs the inlet of the first heat exchanger module (5) and the second valve (13) obstructs the inlet of the second heat exchanger module (6), so that the EGR flow is directed through a path that passes through neither the first heat exchanger module (5) nor the second heat exchanger module (6), and
- in a third operating configuration of said valves (9, 13), the first valve (9) obstructs said second duct (8) downstream of the first communication passage (15) and the second valve (13) obstructs the primary duct (7) downstream of the second communication passage (16), so that the EGR flow is directed through both heat exchanger modules (5, 6).

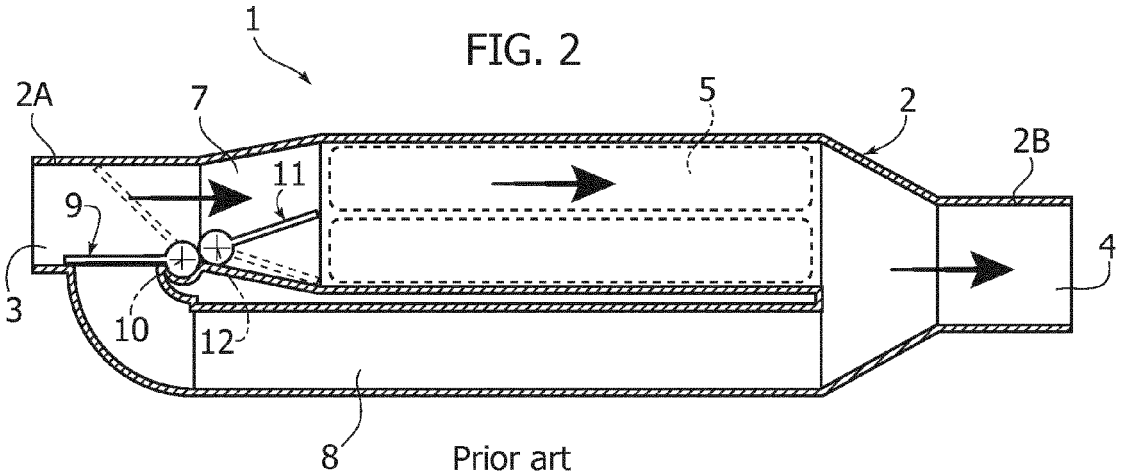
6. A device according to claim 5, wherein said means for controlling said first valve (9) and said second valve (13) comprise an actuator (M), an electronic controller (E) for controlling said actuator (M), and a kinematic mechanism (L), which mutually links the movements of the first valve (9) and of the second valve (13).

FIG. 1



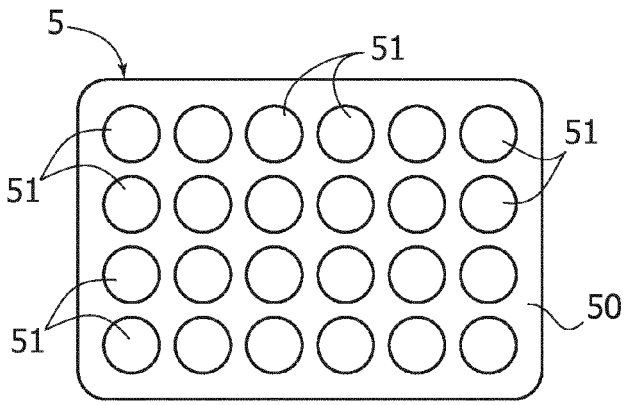
Prior art

FIG. 2



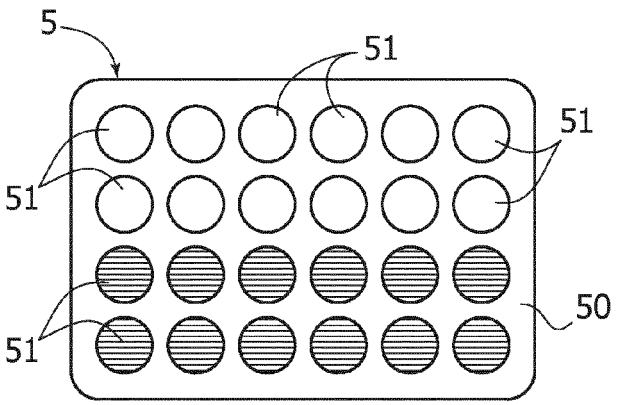
Prior art

FIG. 3A



Prior art

FIG. 3B



Prior art

FIG. 4A

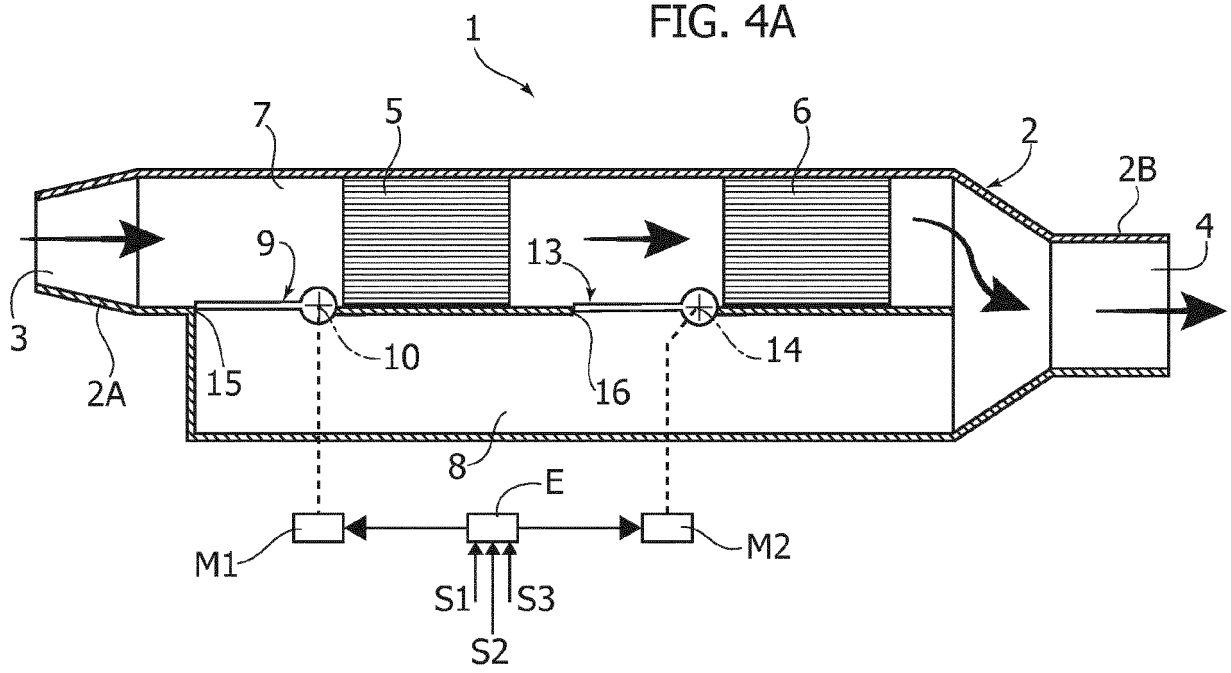


FIG. 4B

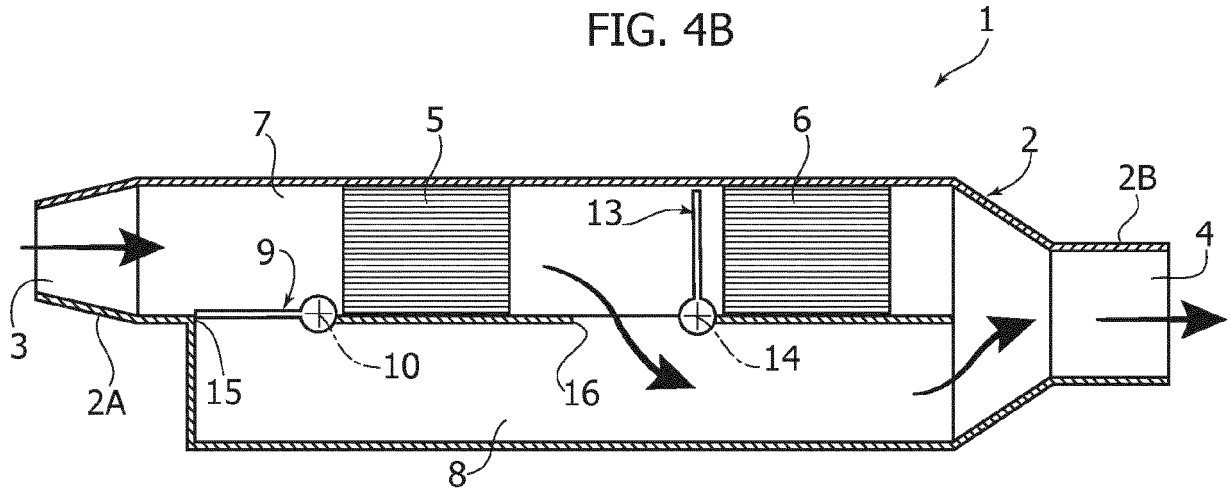


FIG. 4C

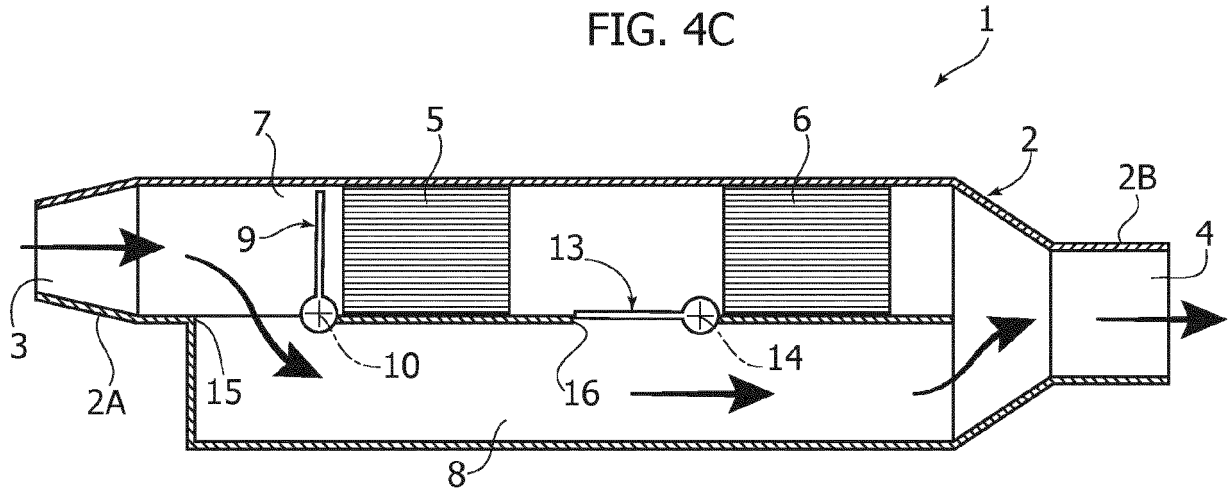


FIG. 5

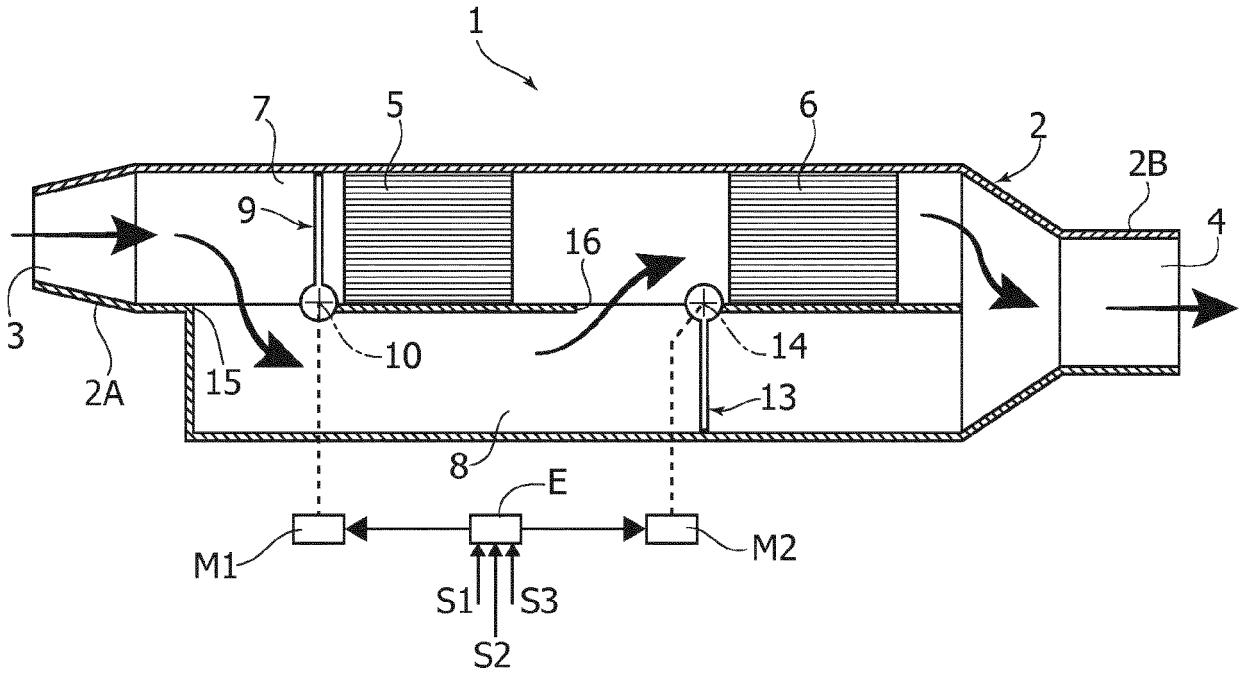
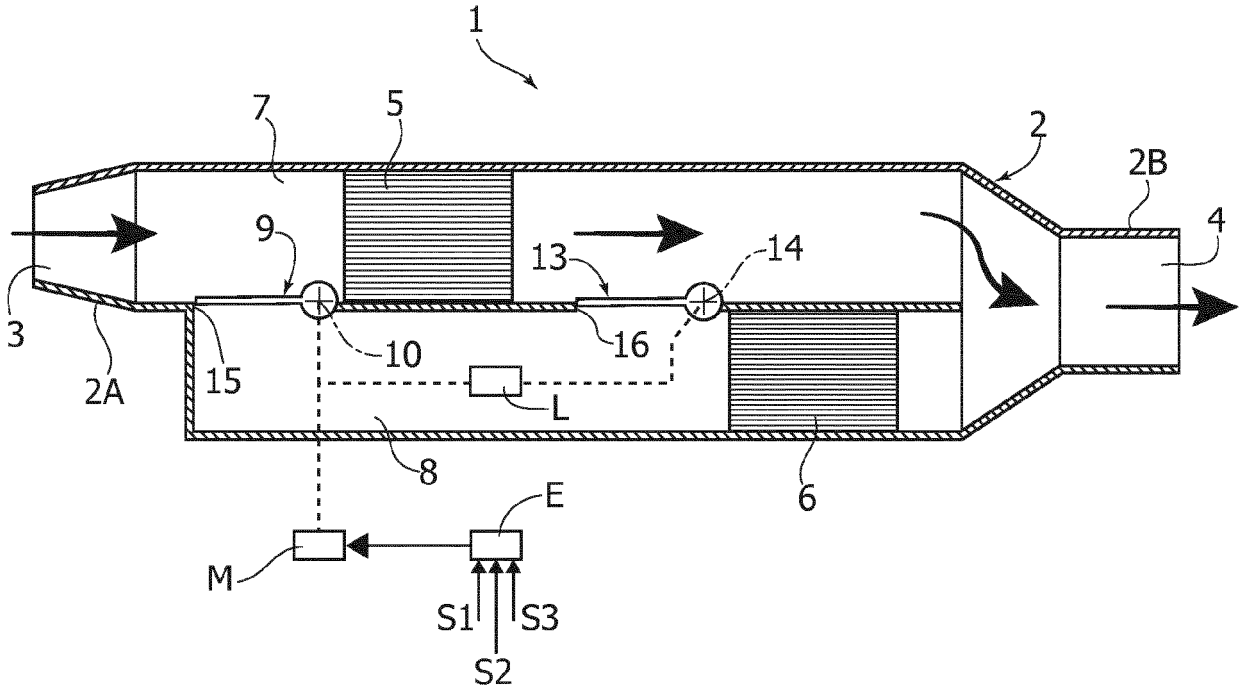

1
7
5
6
2
2B
4
9
16
3
10
14
2A
15
13
8
E
M1
M2
S1
S3
S2

FIG. 6A


1
7
5
2
2B
4
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13
14
3
16
10
2A
15
L
8
6
E
M
S1
S3
S2

FIG. 6B

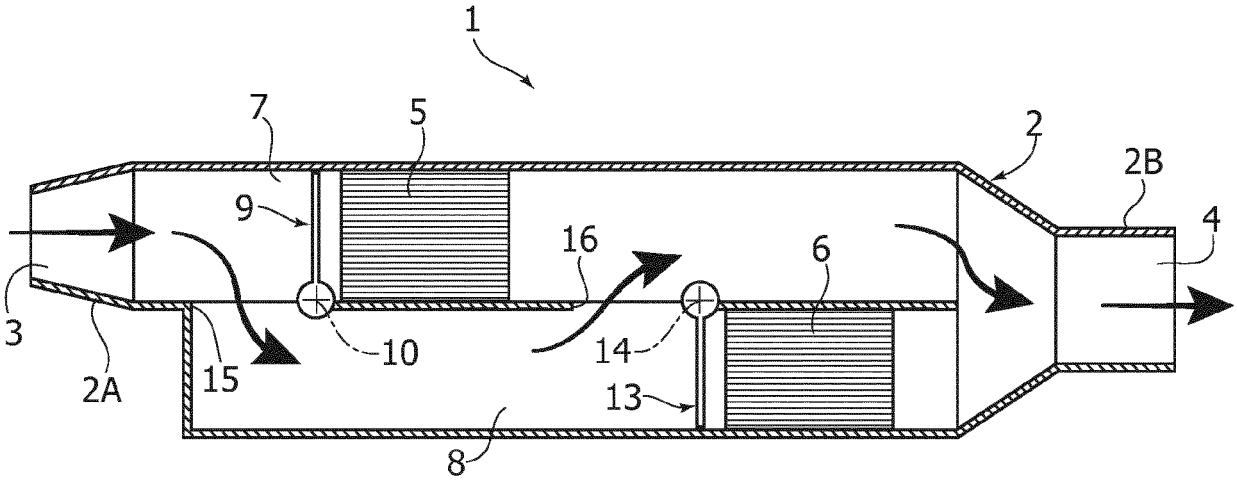
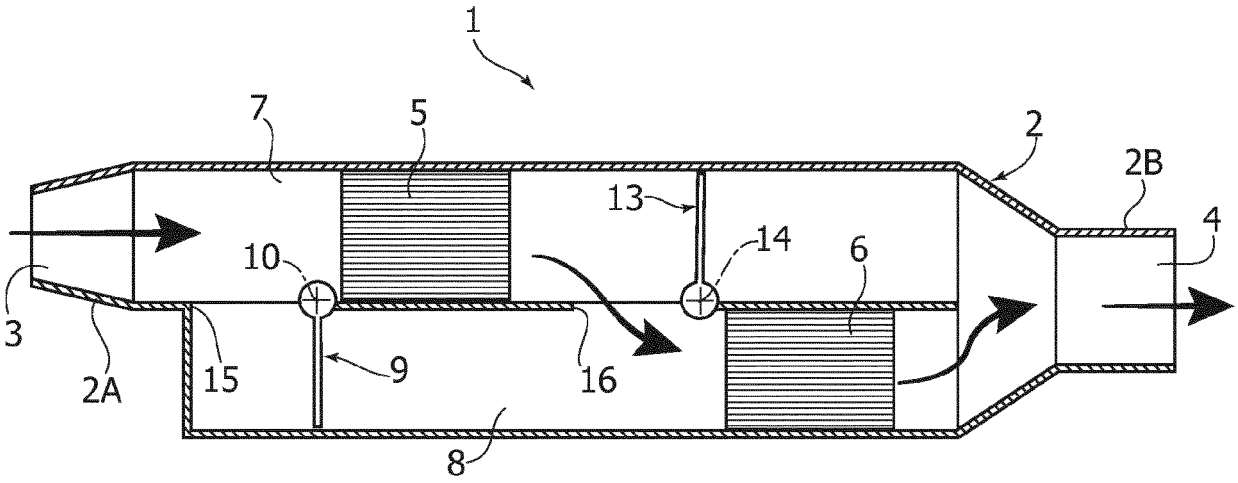


FIG. 6C



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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 6599

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X	US 2008/149080 A1 (REUSS THOMAS [DE] ET AL) 26 June 2008 (2008-06-26) * paragraph [0036] - paragraph [0048]; figures 1, 3 *	1,2,4	

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F02M
F28D
F02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 August 2018	Kolodziejczyk, Piotr

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