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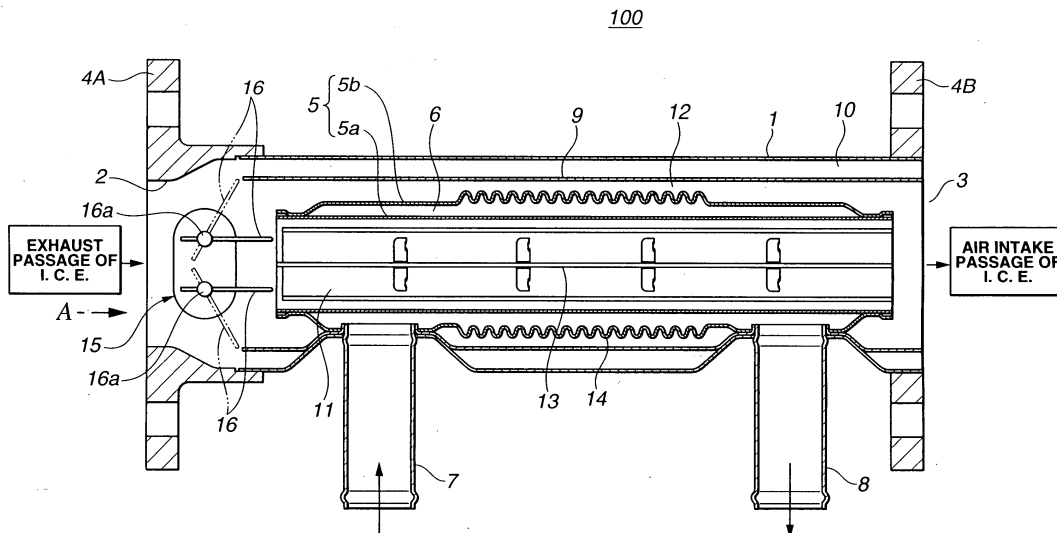
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(54) **Exhaust gas recirculation device of internal combustion engine**

(57) A first elongate casing (1) has gas inlet (2) and outlet ports (3) at axially opposed ends. A second elongate casing (5) is received in the first elongate casing (1) to define therebetween an axially extending space. The second elongate casing (5) includes a first gas flow passage (11) and a water flow passage (6) that surrounds the first gas flow passage (11). The first gas flow passage has an inlet part (2) exposed to the gas inlet port and an outlet part (3) exposed to the gas outlet port. A third elongate casing (9) is received in the axially extending space to define between the first elongate casing

and the third elongate casing a bypass passage (10) and between the third elongate casing and the second elongate casing a second gas flow passage (12). The bypass passage (10) and the second gas flow passage (12) have each an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port. A gas flow rate controller (15) is installed in either one of the gas inlet (2) and outlet (3) ports of the first elongate casing (1) to control a gas flow rate among the bypass passage (10), the first gas flow passage (11) and the second gas flow passage (12).

FIG.1



DescriptionBACKGROUND OF THE INVENTION1. Field of the Invention

[0001] The present invention relates in general to exhaust gas recirculation (viz., EGR) devices of an internal combustion engine, which feed part of the exhaust gas of the engine back to an intake side of the engine to reduce nitrogen oxides (NOx) in the exhaust gas, and more particularly to the EGR devices of a type that has a gas cooling means for cooling EGR gas.

2. Description of the Rotated Art

[0002] Hitherto, various EGR devices of an internal combustion engine have been proposed and put into practical use particularly in the field of wheeled motor vehicles. Some of them are of a gas cooling type that has a means for cooling EGR gas to achieve an efficient feeding of the EGR gas, which has been thermally expanded, to an intake side of the engine. However, in case just after engine starting wherein the engine temperature is low and/or under a low load operation of the engine, such cooling of EGR gas is not preferable. Actually, in such cases of the engine, the cooling of EGR gas tends to cause increase of particulates as well as nitrogen oxides (NOx) in the exhaust gas discharged from the engine.

[0003] For solving such drawbacks, measures are proposed by two Japanese Laid-open Patent Applications which are Tokuhyohei-9-508691 and Tokkai-2003-328864. In the former measure, a bypass passage is provided outside of a gas cooling passage. In the latter measure, a bypass passage is provided inside of a gas cooling passage like a nest. In both measures, when the gas cooling is not necessary, the EGR gas is fed back to the intake side of the engine through the bypass passage.

SUMMARY OF THE INVENTION

[0004] However, even the measures of the published applications have the following new drawbacks due to their inherent constructions. That is, in the former measure, the EGR device has a bulky construction causing a difficulty with which the EGR device is mounted to the engine, and in the latter measure, the EGR device fails to exhibit a satisfied ability for cooling EGR gas fed back to the engine.

[0005] It is therefore an object of the present invention to provide an exhaust gas recirculation device of an internal combustion engine, which is free of the above-mentioned drawbacks.

[0006] That is, according to the present invention, there is provided an exhaust gas recirculation device of an internal combustion engine, which can suitably con-

trol the temperature of EGR gas without enlarging the size of the device and sacrificing the gas cooling ability.

[0007] More specifically, according to the present invention, there is provided an exhaust gas recirculation device of an internal combustion engine, which can control the temperature of EGR gas in accordance with an operation condition of the engine.

[0008] In accordance with a first aspect of the present invention, there is provided an exhaust gas recirculation device of an internal combustion engine, which comprises a first elongate casing having gas inlet and outlet ports at axially opposed ends; a second elongate casing received in the first elongate casing to define therebetween an axially extending space, the second elongate casing including a first gas flow passage and a water flow passage that surrounds the first gas flow passage, the first gas flow passage having an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port; a third elongate casing received in the axially extending space to define between the first elongate casing and the third elongate casing a bypass passage and between the third elongate casing and the second elongate casing a second gas flow passage, the bypass passage and the second gas flow passage having each an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port; and a gas flow rate controller installed in either one of the gas inlet and outlet ports of the first elongate casing to control a gas flow rate among the bypass passage, the first gas flow passage and the second gas flow passage.

[0009] In accordance with a second aspect of the present invention, there is provided an exhaust gas recirculation device of an internal combustion engine, comprising a first elongate casing having gas inlet and outlet ports at axially opposed ends; a second elongate casing received in the first elongate casing to define therebetween an axially extending space, the second elongate casing including a first gas flow passage and a water flow passage that surrounds the first gas flow passage, the first gas flow passage having an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port; a third elongate casing received in the axially extending space to define between the first elongate casing and the third elongate casing a bypass passage and between the third elongate casing and the second elongate casing a second gas flow passage, the bypass passage and the second gas flow passage having each an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port; and a gas flow rate controller installed in the gas inlet port of the first elongate casing to control a rate between the amount of gas flowing in both the first and second gas flow passages and the amount of gas flowing in the bypass passage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Other objects and advantages of the present

invention will become apparent from the following description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a sectional view of an exhaust gas recirculation device which is a first embodiment of the present invention;

Fig. 2 is a view taken from the direction of the arrow "A" of Fig. 1;

Fig. 3 is a side view of the exhaust gas recirculation device of the first embodiment;

Fig. 4 is a view similar to Fig. 1, but showing an exhaust gas recirculation device of a second embodiment of the present invention;

Fig. 5 is a view taken from the direction of the arrow "B" of Fig. 4; and

Fig. 6 is a view similar to Fig. 1, but showing an exhaust gas recirculation device of a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0011] In the following, three embodiments 100, 200 and 300 of the present invention will be described in detail with reference to the accompanying drawings.

[0012] For ease of understanding, various directional terms, such as, right, left, upper, lower, rightward and the like are used in the following description. However, such terms are to be understood with respect to only a drawing or drawings on which a corresponding part or portion is shown.

[0013] Referring to Figs. 1 to 3 of the drawings, there is shown an exhaust gas recirculation (EGR) device 100 which is a first embodiment of the present invention.

[0014] Although not shown in the drawings, the EGR device 100 is arranged in an EGR piping that has an EGR gas inlet exposed to an interior of an exhaust passage of an associated internal combustion engine and an EGR gas outlet exposed to an interior of an air intake passage of the engine.

[0015] As is well seen from Fig. 1, the EGR device 100 comprises a cylindrical housing (or first elongate casing) 1 that has inlet and outlet ports 2 and 3 at axially opposed ends thereof. To the inlet and outlet ports 2 and 3 of the housing 1, there are connected respective flanges 4A and 4B. Upon assembly in the EGR piping, the flanges 4A and 4B are connected through bolts (not shown) to their counterparts (viz., flanges) of the piping. Of course, in place of the bolts, soldering, welding, brazing and the like may be used for connecting the device 100 to the piping.

[0016] Within the cylindrical housing 1, there is coaxially disposed a cylindrical casing (or second elongate casing) 5. As will become apparent hereinafter, the cylindrical casing 5 serves as a means for cooling EGR gas directed to the air intake passage of the engine.

[0017] The cylindrical casing 5 is of a double tube type including coaxially arranged inner and outer tubes 5a

and 5b which have respective axial ends hermetically soldered to form therebetween a cylindrical water passage 6. Preferably, the inner and outer tubes 5a and 5b are constructed of a thin metal plate such as a stainless steel or the like.

[0018] As shown in Fig. 1, the outer tube 5b has at axially opposed portions thereof respective openings (no numerals) to which water inlet and outlet pipes 7 and 8 are connected through soldering or the like. These water inlet and outlet pipes 7 and 8 are connected through respective tubes (not shown) to outlet and inlet portions of a source of a cooling water, such as a source of engine cooling water. As shown, the cylindrical housing 1 has depressed apertures (no numerals) through which the water inlet and outlet pipes 7 and 8 extend radially outward. Under operation of the associated engine, the cooling water is led into the cylindrical water passage 6 through the water inlet pipe 7 and returned back to the source of the cooling water through the water outlet pipe 8. As will be described in detail hereinafter, during flowing of the cooling water in the cylindrical water passage 6, a heat exchanging is carried out between the cooling water and EGR gas flowing in and outside of the cylindrical casing 5.

[0019] As shown, between the cylindrical housing 1 and the cylindrical casing 5, there is coaxially arranged a cylindrical partition tube (or third elongate casing) 9. The partition tube 9 has portions (no numerals) secured to the water inlet and outlet pipes 7 and 8, so that the tube 9 is stably held in the housing 1. Due to provision of the cylindrical partition tube 9, there is defined a cylindrical bypass passage 10 between an inner surface of the cylindrical housing 1 and an outer surface of the cylindrical partition tube 9.

[0020] In the cylindrical casing 5, there is defined a first gas cooling passage 11 that is cylindrical in shape, and between an inner surface of the cylindrical partition tube 9 and an outer surface of the cylindrical casing 5 (more specifically, the outer tube 5b), there is defined a second gas cooling passage 12 that is cylindrical in shape.

[0021] As shown in Fig. 1, the bypass passage 10, the first gas cooling passage 11 and the second gas cooling passage 12 have respective inlet portions exposed to the inlet port 2 of the cylindrical housing 1 and respective outlet portions exposed to the outlet port 3 of the cylindrical housing 1. Thus, each of the passages 10, 11 and 12 permits EGR gas to flow therein from the inlet port 2 toward the outlet port 3.

[0022] As is understood from the drawing, only EGR gas flowing in the first and second gas cooling passages 11 and 12 is permitted to carry out a heat exchanging with the cooling water flowing in the water passage 6 of the cylindrical casing 5. That is, the EGR gas flowing in the bypass passage 10 is not permitted to carry out such heat exchanging with the cooling water in the water passage 6.

[0023] For improving the heat exchanging between

EGR gas in the first gas cooling passage 11 and the cooling water in the water passage 6, the inner tube 5a of the cylindrical case 5 has at its inner surface a plurality of heat exchanging fins 13 soldered thereto, and for the same reason between EGR gas in the second gas cooling passage 12 and the cooling water in the water passage 6, the outer tube 5b of the cylindrical case 5 is formed with a bellows or corrugated portion 14.

[0024] As shown, the respective apertured portions of the cylindrical housing 1, the cylindrical partition tube 9 and the outer tube 5b to which the water inlet or outlet pipe 7 or 8 is secured are intimately pressed and coupled to one another, so that the cylindrical casing 5 and the cylindrical partition tube 9 are tightly and stably held in the cylindrical housing 1.

[0025] In the cylindrical housing 1 near the inlet port 2, there is arranged a gas flow rate controller 15 that adjusts a gas flow rate among the bypass passage 10, the first gas cooling passage 11 and the second gas cooling passage 12.

[0026] As is understood from Figs. 1, 2 and 3, the gas flow rate controller 15 is installed in the flange 4A connected to the inlet port 2 of the cylindrical housing 1.

[0027] As is seen from Figs. 1 and 2, the gas flow rate controller 15 comprises a pair of butterfly valves which are arranged in a parallel manner. Each butterfly valve includes a pivot shaft 16a that extends perpendicular to an axis of the cylindrical housing 1, and a valve plate 16 that is secured to the pivot shaft 16a to pivot therewith. As is seen from the drawings, the two pivot shafts 16a and 16a are symmetrically arranged with respect to the axis of the first gas cooling passage 11.

[0028] As is understood from Figs. 1 and 2, each valve plate 16 has a semicircular shape whose rounded outer periphery becomes in coincidence with the cylindrical inner surface of an inlet of the second gas cooling passage 12 when the valve plate 16 takes an inclined position (viz., the position shown by the dot-dash line) that will be described in the following.

[0029] As is seen from Fig. 1, when the valve plates 16 and 16 are in their flat positions as shown by the solid line, the EGR gas is led into all the bypass passage 10 and the first and second gas cooling passages 11 and 12 freely, more specifically, without being obstructed by the valve plates 16 and 16, while, when the valve plates 16 and 16 are in their inclined positions as shown by the dot-dash line, the amount of EGR gas led to the first and second gas cooling passages 11 and 12 is greatly reduced as compared with the amount of EGR gas led to the bypass passage 10. As is seen from the drawing, when the valve plates 16 and 16 take the inclined positions, shorter base parts of the valve plates 16 and 16 become close to each other thereby limiting the passage defined between the valve plates 16 and 16.

[0030] Referring to Figs. 2 and 3, there is shown an actuating mechanism for the gas flow rate controller 15. That is, the angular position of the valve plates 16 and 16 of the gas flow rate controller 15 is controlled by the

actuating mechanism that is powered by a negative pressure produced in the intake passage of the engine.

[0031] As is seen from Fig. 2, the two pivot shafts 16a have extending portions that are exposed to the outside of the cylindrical housing 1.

[0032] As is seen from Fig. 3, the exposed extending portions of the pivot shafts 16a are actuated by a diaphragm type actuator 17 through respective link mechanisms 19 and 19.

[0033] That is, each link mechanism 19 comprises a first link 19a having one end fixed to the pivot shaft 16a, and a second link 19b having one end pivotally connected to the other end of first link 19a through a pivot pin 19c. The other ends of the second links 19b and 19b of the two link mechanisms 19 and 19 are pivotally connected through a pivot pin 19d to a plunger 18 of the actuator 17. The actuator 17 is mounted to the outer surface of the cylindrical housing 1 and powered by a negative pressure produced in a throttle zone of the intake passage of the associated internal combustion engine.

[0034] Although not well shown in the drawings, the diaphragm type actuator 17 comprises generally a casing and a diaphragm installed in the casing to define therein a work chamber. The diaphragm has the other end of the plunger 18 fixed thereto, and the work chamber is connected through a tube to the throttle zone of the intake passage of the engine. Although not shown in the drawing, a pressure controller is arranged in the tube so that the negative pressure applied to the actuator 17 is controlled in accordance with an operation condition of the engine.

[0035] In place of the diaphragm type actuator 17, an electric type actuator or a hydraulic type actuator may be used.

[0036] Referring back to Fig. 1, the actual inlet of the bypass passage 10 is positioned much closer to the inlet port 2 of the cylindrical housing 1 than that of the cylindrical casing 5 is positioned. As is seen from this drawing, each valve plate 16 of the gas flow rate controller 15 is positioned and arranged to pivotally move the rounded outer periphery thereof in a limited zone that is defined in the inlet portion of the cylindrical housing 1 between the actual inlet of the bypass passage 10 and that of the cylindrical casing 5.

[0037] When the associated engine is in operation keeping its temperature relatively high, the pressure controller controls the negative pressure applied to the actuator 17 in such a manner that the valve plates 16 and 16 take their flat positions as shown by the solid line. In this condition, the EGR gas is led freely to all the bypass passage 10 and the first and second gas cooling passages 11 and 12. During the flow of EGR gas in the first and second gas cooling passages 11 and 12, heat exchanging is carried out between EGR gas and the cooling water in the water passage 6, and thus, the EGR gas directed to the air intake passage of the engine is suitably cooled. As is described hereinabove, this is advantageous for reducing nitrogen oxides (NOx) and par-

ticulates in the exhaust gas discharged from the engine.

[0038] While, when, like in case just after engine starting, the engine temperature is relatively low, the pressure controller controls the negative pressure applied to the actuator 17 in such a manner that the valve plates 16 and 16 take their inclined positions as shown by the dot-dash line. Under this condition, almost all EGR gas is led to the bypass passage 10 bypassing the first and second gas cooling passages 11 and 12. Thus, the EGR gas directed to the air intake passage of the engine is not cooled. It is to be noted that under this condition, the gas left in the second gas cooling passage 12 serves as a heat insulating layer and thus the EGR gas flowing in the bypass passage 10 is not affected or cooled by the cooling water in the water passage 6. Thus, ironical increase of nitrogen oxides (NOx) and particulates in the exhaust gas, which would occur when the engine temperature is low, is suppressed or at least minimized.

[0039] As is described hereinabove, the pressure controller arranged between the actuator 17 and the throttle zone of the intake passage of the engine is so constructed that the negative pressure applied to the actuator 17 is controlled in accordance with the operation condition of the engine. This means that the angular position of the two valve plates 16 and 16, that is, the rate between the amount of EGR gas flowing in both the first and second gas cooling passages 11 and 12 and the amount of EGR gas flowing in the bypass passage 10 is continuously controlled in accordance with the operation condition of the engine. Thus, the temperature of EGR gas fed back to the intake passage of the engine can be suitably controlled in accordance with the engine operation condition.

[0040] As is mentioned hereinabove, by operating the gas flow rate controller 15 of the EGR device 100 in accordance with the engine operation condition, the flow rate between the amount of EGR gas flowing in both the first and second gas cooling passages 11 and 12 and the amount of EGR gas flowing in the bypass passage 10 is optimally controlled.

[0041] In the EGR device 100, the three gas flow passages 10, 11 and 12 and the cooling water passage 6 are defined by the three cylindrical members 1, 9 and 5 which are coaxially assembled. Thus, the EGR device 100 can have a compact size, which is quite advantageous when mounting the device 100 to a limited space such as an engine room of current wheeled motor vehicles.

[0042] In the EGR device 100, in case of reducing EGR gas flow in the first and second gas cooling passages 11 and 12 (that is, in case of increasing EGR gas flow in the bypass passage 10), the valve plates 16 and 16 of the gas flow rate controller 15 are pivoted outward with respect to the axis of the cylindrical housing 1. In this case, the valve plates 16 and 16 can serve as a guide means through which the EGR gas flow is smoothly guided toward the bypass passage 10. While, in case of increasing EGR gas flow in the first and sec-

ond gas cooling passages 11 and 12 (that is, in case of reducing EGR gas flow in the bypass passage 10), the valve plates 16 and 16 are pivoted inward to take the flat positions that are in parallel with the axis of the cylindrical housing 1. In this case, the valve plates 16 and 16 have substantially no effect on the flowing of EGR gas in the first and second gas cooling passages 11 and 12.

[0043] In the foregoing description, the gas flow rate controller 15 is described to be arranged in the inlet port 2 of EGR device 100. However, if desired, such controller 15 may be arranged in the outlet port 3 of the device 100.

[0044] In the foregoing description, the gas flow rate controller 15 is described to be constructed to have the two valve plates 16 and 16. However, if desired, the gas flow rate controller 15 may have only one valve plate or more than two valve plates.

[0045] Referring to Figs. 4 and 5, there is shown an exhaust gas recirculation (EGR) device 200 which is a second embodiment of the present invention.

[0046] Since the EGR device 200 of this second embodiment is similar in construction to the EGR device 100 of the above-mentioned first embodiment, the following description on the second embodiment 200 will be directed to only parts or portions that are different from those of the first embodiment 100.

[0047] As shown in Fig. 4, in this second embodiment 200, the water inlet and outlet pipes 7 and 8 are arranged to project radially outward from axially and diametrically opposite portions of the cylindrical housing 1. As shown, the measures with which the water inlet or outlet pipe 7 or 8 is integrally connected to the depressed apertures of the cylindrical housing 1, the cylindrical partition tube 9 and the outer tube 5b of the cylindrical casing 5 are substantially the same as the measures mentioned in the first embodiment 100.

[0048] As is seen from Fig. 4, in this second embodiment 200, a slide-rotary type gas flow rate controller 115 is employed.

[0049] That is, the flow rate controller 115 comprises a conical guide member 20 that is connected at its larger peripheral edge to an inlet edge of the cylindrical partition tube 9. Due to provision of a conical wall of the guide member 20, the EGR gas flow in the inlet port 2 toward the inlet of the bypass passage 10 is smoothly carried out.

[0050] As is seen from Figs. 4 and 5, particularly Fig. 5, the conical wall of the conical guide member 20 is formed with four identical sector openings 21 that are circumferentially arranged at evenly spaced intervals. Thus, when, as is seen from Fig. 4, these openings 21 are kept open, the EGR gas in the inlet port 2 is permitted to flow toward the first and second gas cooling passages 11 and 12 through the openings 21.

[0051] Referring back to Fig. 4, a conical valve member 22 is coaxially and rotatably received in the conical guide member 20.

[0052] As is seen from Figs. 4 and 5, particularly Fig. 5, a conical wall of the conical valve member 22 is formed with four identical sector openings 23 that are circumferentially arranged at evenly spaced intervals and identical in shape and size to the four openings 21 of the above-mentioned conical guide member 20.

[0053] As is seen from Fig. 4, the conical valve member 22 has a center portion from which a control rod 24 extends axially outward (viz., leftward in the drawing) through a center opening (no numeral) of the conical guide member 20. Although not shown in the drawing, a leading end of the control rod 24 is connected to an actuator so that the control rod 24 is rotated about its axis in accordance with an operation condition of the associated internal combustion engine.

[0054] When, due to turning of the conical valve member 22 to a first given angular position, the sector openings 23 of the conical valve member 22 become in coincidence with the sector openings 21 of the conical guide member 20, the gas flow rate controller 115 assumes a full-open position. While, when, due to turning of the conical valve member 22 to a second given angular position, the sector openings 23 of the conical valve member 22 are fully closed by a solid portion of the conical wall of the conical guide member 20, the gas flow rate controller 115 assumes a full-close position. Thus, when, due to turning of the control rod 24, the conical valve member 22 is turned between the first and second given angular positions, an open degree of the sector openings 21 of the conical guide member 20 is varied.

[0055] In the EGR device 200 of this second embodiment, due to provision of the conical guide member 20, the EGR gas in the inlet port 2 can be smoothly led to the inlet of the bypass passage 10. When the flow rate controller 115 takes the full-close position, the sector openings 23 of the conical valve member 22 are fully and intimately closed by the solid part of the conical guide member 20. Thus, in this condition, almost all of EGR gas in the inlet port 2 can be led to the bypass passage 10. Due to the nature of the flow rate controller 115 of this slide - rotary type, undesired play, which would cause a noise in operation, is suppressed or at least minimized.

[0056] Referring to Fig. 6, there is shown an exhaust gas circulation (EGR) device 300 which is a third embodiment of the present invention.

[0057] Since, like the above-mentioned second embodiment 200, the EGR device 300 of this third embodiment is similar in construction to the EGR device 100 of the first embodiment, the following description on the third embodiment 300 will be directed to only parts or portions that are different from those of the first embodiment 100.

[0058] As is seen from Fig. 6, in this third embodiment 300, the water inlet and outlet pipes 7 and 8 are arranged to project radially outward from axially opposite and diametrically opposite portions of the cylindrical

housing 1, like the above-mentioned second embodiment 200. Furthermore, the measures with which the water inlet or outlet pipe 7 or 8 is integrally connected to the depressed apertures of the cylindrical housing 1, the cylindrical partition tube 9 and the outer tube 5b of the cylindrical casing 5 are substantially the same as the measures mentioned in the first embodiment 100.

[0059] As is understood from the drawing, in the EGR device 300 of the third embodiment, the inner tube 5a of the cylindrical case 5 is entirely formed with a bellows or corrugated portion 25 in place of the heat exchanging fins (13, see Fig. 1) of the first embodiment 100. The outer tube 5b of the cylindrical case 5 is formed with the bellows or corrugated portion 14, like in the first and second embodiments 100 and 200.

[0060] As is seen from the drawing, in this third embodiment 300, a bimetal type gas flow rate controller 215 is used.

[0061] That is, the flow rate controller 215 comprises a circular frame 31 that is fitted in the inlet port 2 of the cylindrical housing 1, and a pair of temperature sensitive valve plates 30 and 30 that are made of a bimetal material and have base ends held by the circular frame 31. Preferably, the valve plates 30 and 30 are made of a shape memory alloy.

[0062] Each valve plate 30 has a semicircular shape whose rounded outer periphery becomes in coincidence with the cylindrical inner surface of the inlet of the second gas cooling passage 12 when the valve plate 30 takes a largely bent position. Denoted by numeral 32 is a conical gas inlet member that is fixed to the inlet port 2 of the cylindrical housing 1 for smoothing the flow of EGR gas toward the inlet port 2.

[0063] As is seen from the drawing, when the valve plates 30 and 30 are in their generally flat positions as shown by the broken line, the EGR gas is led into all the bypass passage 10 and the first and second gas cooling passages 11 and 12 freely, more specifically, without being obstructed by the valve plates 30 and 30, while, when the valve plates 30 and 30 are in their largely bent positions as shown by the solid line, the amount of EGR gas led to the first and second gas cooling passages 11 and 12 is greatly reduced as compared with the amount of EGR gas led to the bypass passage 10.

[0064] When the associated engine is in operation keeping its temperature relatively high, the temperature of the exhaust gas discharged from the engine is relatively high, and thus, the temperature of EGR gas directed toward the EGR device 300 is relatively high. Under this condition, the temperature sensitive valve plates 30 and 30 take the generally flat positions as shown by the broken line. In this condition, the EGR gas is led to all the bypass passage 10 and the first and second gas cooling passages 11 and 12 as is described hereinabove. During the flow of EGR gas in the first and second gas cooling passages 11 and 12, heat exchanging is carried out between EGR gas and the cooling water in the water passage 6, and thus, the EGR gas directed

to the air intake passage of the engine is suitable cooled.

[0065] While, when, like in case just after engine starting, the engine temperature is relatively low, the temperature of the exhaust gas discharged from the engine is relatively low and thus, the temperature of EGR gas directed toward the EGR device 300 is relatively low. Under this condition, the temperature sensitive valve plates 30 and 30 take the largely bent positions as shown by the solid line. In this condition, almost all EGR gas is led to the bypass passage 10 bypassing the first and second gas cooling passages 11 and 12. Thus, the EGR gas directed to the air intake passage of the engine is not cooled.

[0066] In the EGR device of this third embodiment 300, the temperature sensitive valve plates 30 and 30 per se serve as an actuator. In other words, in this third embodiment 300, there is no need of using a separate actuator such as one that is actually used in the above-mentioned first and second embodiments 100 and 200. Thus, much compact, simple and light weight construction is expected in the EGR device 300 of this third embodiment.

[0067] In the foregoing explanation, the housing 1, the partition tube 9 and the casing 5 are described to have a cylindrical shape. However, if desired, such members 1, 9 and 5 may be of a type that has a rectangular, pentagonal or other polygonal cross section.

[0068] The entire contents of Japanese Patent Application 2004-009960 filed January 19, 2004 are incorporated herein by reference.

[0069] Although the invention has been described above with reference to the embodiments of the invention, the invention is not limited to such embodiments as described above. Various modifications and variations of such embodiments may be carried out by those skilled in the art, in light of the above description.

Claims

1. An exhaust gas recirculation device of an internal combustion engine, comprising:

a first elongate casing having gas inlet and outlet ports at axially opposed ends;
 a second elongate casing received in the first elongate casing to define therebetween an axially extending space, the second elongate casing including a first gas flow passage and a water flow passage that surrounds the first gas flow passage, the first gas flow passage having an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port;
 a third elongate casing received in the axially extending space to define between the first elongate casing and the third elongate casing a bypass passage and between the third elongate casing and the second elongate casing a

second gas flow passage, the bypass passage and the second gas flow passage having each an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port; and

a gas flow rate controller installed in either one of the gas inlet and outlet ports of the first elongate casing to control a gas flow rate among the bypass passage, the first gas flow passage and the second gas flow passage.

2. An exhaust gas recirculation device as claimed in Claim 1, in which the gas flow rate controller is constructed to control the rate between the amount of gas flowing in both the first and second gas flow passages and the amount of gas flowing in the bypass passage.

3. An exhaust gas recirculation device as claimed in Claim 1, in which the gas flow rate controller is installed in the gas inlet port of the first elongate casing and comprises:

a valve member that is movable between a first position wherein the gas flow from the inlet port toward the bypass passage, the first gas flow passage and the second gas flow passage is freely carried out without being obstructed by the valve plate and a second position wherein the gas flow from the inlet port toward the first and second gas flow passages is reduced as compared with the gas flow from the inlet port toward the bypass passage.

4. An exhaust gas recirculation device as claimed in Claim 3, further comprising an actuating mechanism that continuously moves the valve member between the first and second positions.

5. An exhaust gas recirculation device as claimed in Claim 4, in which the valve member comprises:

a pair of pivot shafts arranged in the inlet port in a parallel manner; and
 a pair of valve plates secured respectively to the pivot shafts to pivot therewith,

wherein the pivot shafts being actuated to rotate about respective axes thereof by the actuating mechanism.

6. An exhaust gas recirculation device as claimed in Claim 5, in which the actuating mechanism comprises:

an actuator mounted to the first elongate casing; and
 a pair of link mechanisms, each being opera-

tively interposed between the actuator and corresponding one of the pivot shafts.

7. An exhaust gas recirculation device as claimed in Claim 6, in which the actuator is a diaphragm type actuator powered by a negative pressure produced in a throttle zone of an intake passage of the engine. 5
8. An exhaust gas recirculation device as claimed in Claim 6, in which each of the link mechanisms comprises: 10
- a first link having one end fixed to corresponding one of the pivot shafts;
- a second link having one end pivotally connected to the other end of the first link and the other end pivotally connected to a plunger of the actuator. 15
9. An exhaust gas recirculation device as claimed in Claim 1, in which the second elongate casing is of a double tube type comprising coaxially arranged inner and outer tubes which have respective axial ends to form therebetween the water flow passage, the inner tube defining therein the first gas flow passage. 20
10. An exhaust gas recirculation device as claimed in Claim 9, in which the inner tube is formed with heat exchanging means, and in which the outer tube is formed with a bellows or corrugated portion. 30
11. An exhaust gas recirculation device as claimed in Claim 10, in which the heat exchanging means is one of a plurality of fins soldered to an inner surface of the inner tube and a bellows or corrugated portion formed on the inner tube. 35
12. An exhaust gas recirculation device as claimed in Claim 1, further comprising water inlet and outlet pipes each having an inner end exposed to the water flow passage of the second elongate casing. 40
13. An exhaust gas recirculation device as claimed in Claim 12, in which the water inlet and outlet pipes are arranged at axially opposed and diametrically same positions of the first elongate casing. 45
14. An exhaust gas recirculation device as claimed in Claim 12, in which the water inlet and outlet pipes are arranged at axially opposed and diametrically opposed positions of the first elongate casing. 50
15. An exhaust gas recirculation device as claimed in Claim 4, in which the gas flow rate controller comprises: 55
- a conical guide member secured to the third

elongate casing, the conical guide member being formed at a conical wall thereof with a plurality of first openings;

a conical valve member coaxially and rotatably received in the conical guide member, the conical valve member being formed at a conical wall thereof with a plurality of second openings, the conical valve member being turned between an open position wherein the first and second openings are mated and a close position wherein the first and second openings are not mated; and

a control rod having one end that passes through a center opening of the conical guide member to be secured to a center portion of the conical valve member, the control rod having the other end connected to the actuator.

16. An exhaust gas recirculation device as claimed in Claim 15, in which the conical wall of the conical guide member is arranged to smooth EGR gas flow from the gas inlet port of the first elongate casing toward an inlet of the bypass passage.
17. An exhaust gas recirculation device as claimed in Claim 4, in which gas flow rate controller comprises:

a frame member fitted in the gas inlet port of the first elongate casing; and

a pair of thermally sensitive valve plates, each having a base end that is held by the frame member and a free portion that shows a deformation when applied with a heat, the free portion being flexed by the heat between a first position wherein the gas flow from the gas inlet port toward the bypass passage, the first gas flow passage and the second gas flow passage is freely carried out without being obstructed by the valve plates and a second position wherein the gas flow from the gas inlet port toward the first and second gas flow passages is reduced as compared with the gas flow from the gas inlet port toward the bypass passage,

wherein the thermally sensitive valve plates are so arranged that the free portion of each valve plate takes the second position when the gas led into the gas inlet port of the first elongate casing is relatively low.

18. An exhaust gas recirculation device as claimed in Claim 17, in which the thermally sensitive valves plates are constructed of a bimetal or a shape memory alloy.
19. An exhaust gas recirculation device as claimed in Claim 18, further comprising a conical gas inlet member that is fixed to the gas inlet port of the first

elongate casing to smooth the gas flow toward the gas inlet port.

20. An exhaust gas recirculation device of an internal combustion engine, comprising:

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a first elongate casing having gas inlet and outlet ports at axially opposed ends;

a second elongate casing received in the first elongate casing to define therebetween an axially extending space, the second elongate casing including a first gas flow passage and a water flow passage that surrounds the first gas flow passage, the first gas flow passage having an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port;

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a third elongate casing received in the axially extending space to define between the first elongate casing and the third elongate casing a bypass passage and between the third elongate casing and the second elongate casing a second gas flow passage, the bypass passage and the second gas flow passage having each an inlet part exposed to the gas inlet port and an outlet part exposed to the gas outlet port;

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and

a gas flow rate controller installed in the gas inlet port of the first elongate casing to control a rate between the amount of gas flowing in both the first and second gas flow passages and the amount of gas flowing in the bypass passage.

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FIG.1

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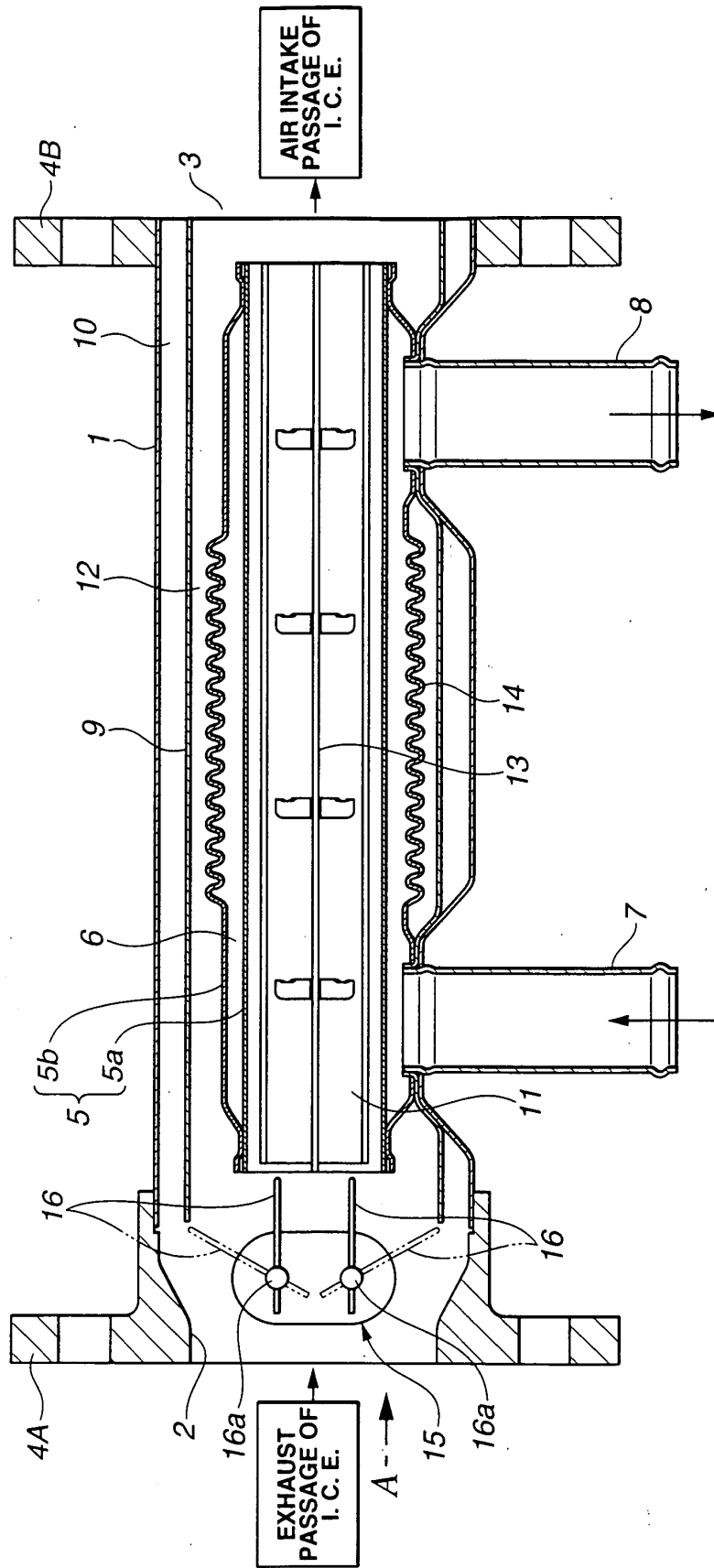


FIG.2

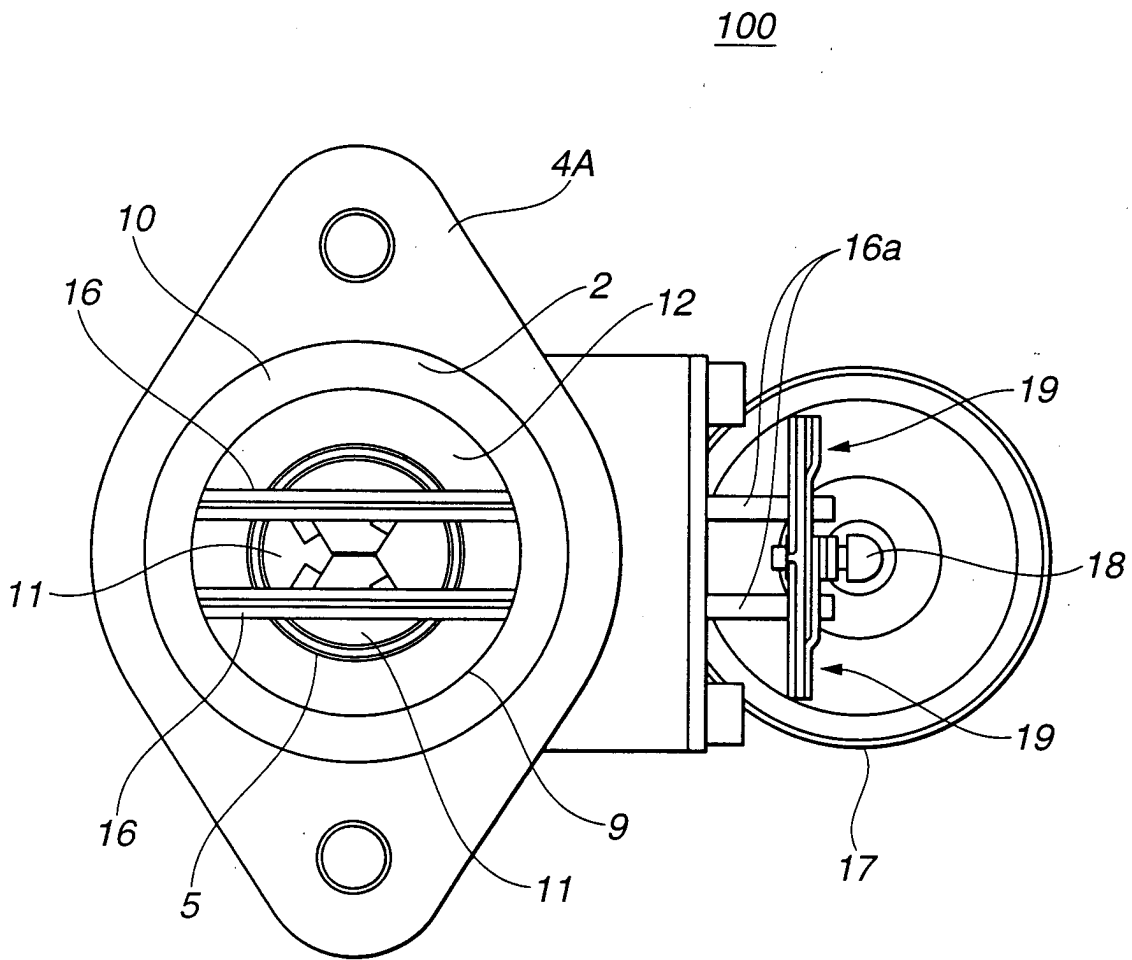


FIG.3

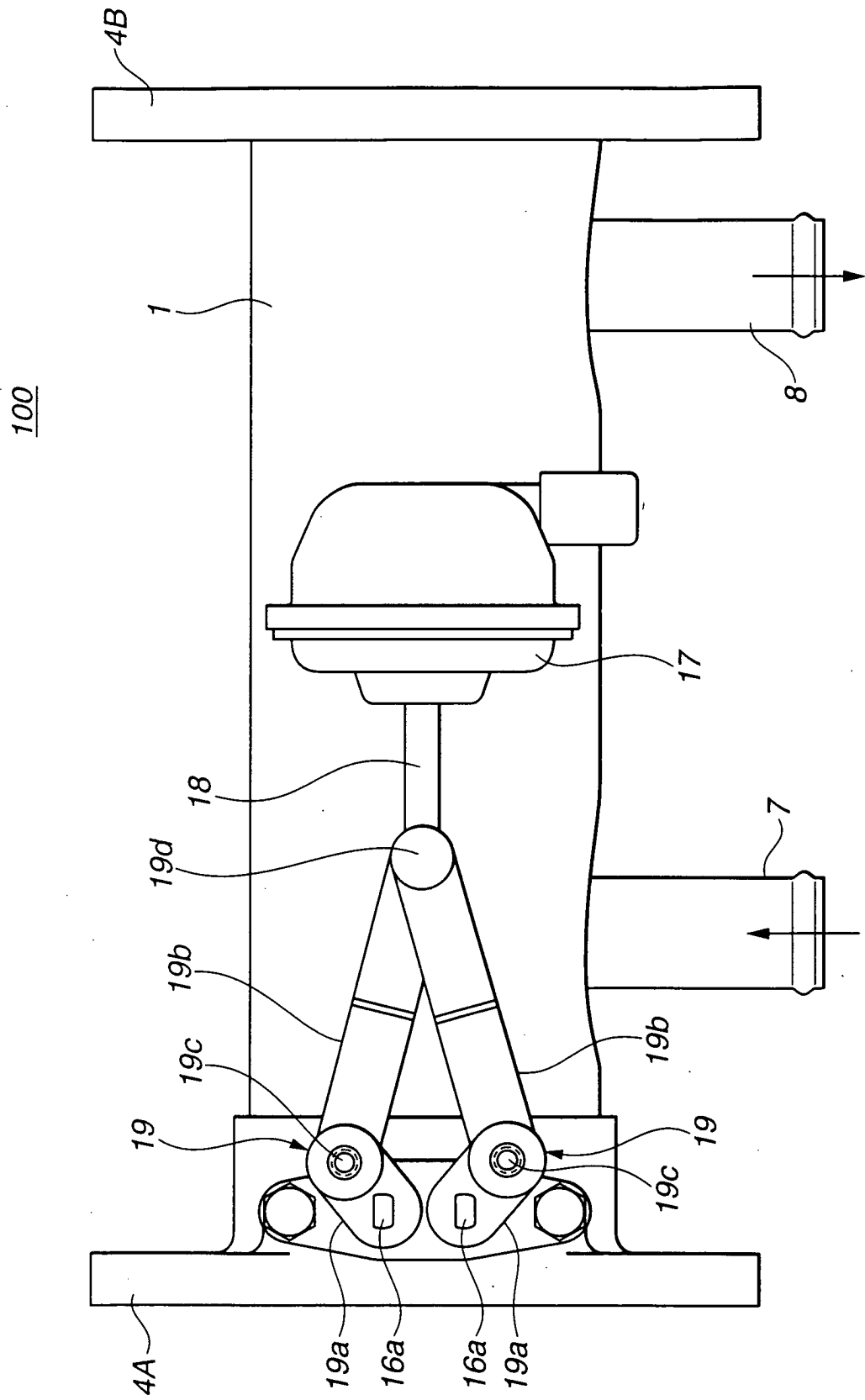


FIG.4

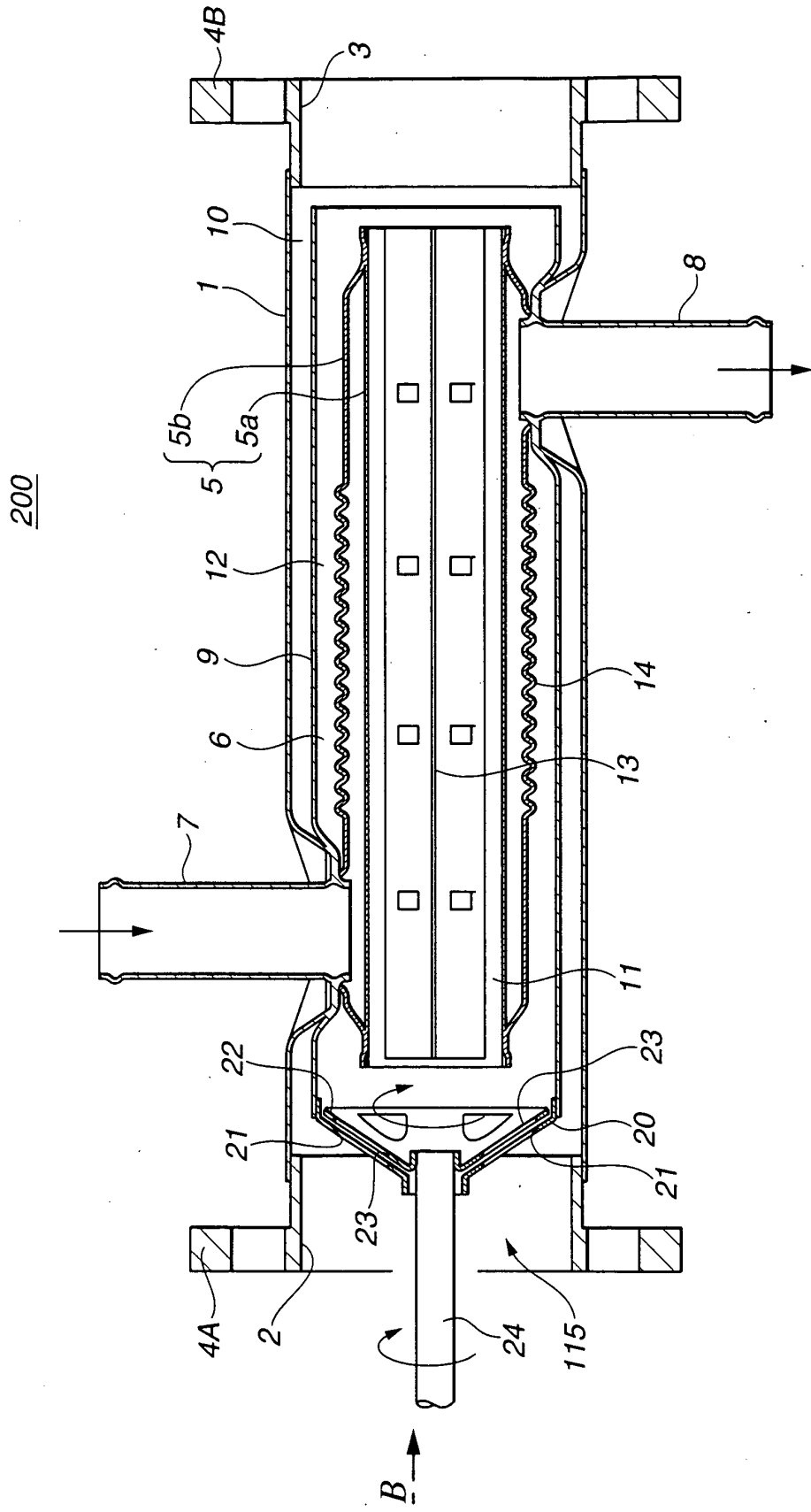


FIG.5

