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(54) Exhaust manifold for an internal combustion engine

(57) An exhaust manifold for a four-cylinder internal combustion engine, including four branches (5,6,7,8), a downstream exhaust pipe (9) connected with the four branches, and a partition wall (10,110) dividing an exhaust path in the downstream exhaust pipe (9) into first and second passages (11,12) each having a semicircular section. Each of the first and second passages (11,12) is connected with two of the branches (5,6,7,8) which are connected with two of the four engine cylinders (#1,#2,#3,#4) having non-continuous order of ignition

and communicated with first and second quarter-circular regions (A,B,C,D) in the semicircular section of the passages (11,12), respectively. An air-fuel ratio sensor (16) mounted to the downstream exhaust pipe (9) projects into both of the passages (11,12) through a cut-out (18) formed on one side of the partition wall (10,110) in a width direction perpendicular to an axial direction of the downstream exhaust pipe (9). A communication portion (21,22,23,24) formed in the partition wall (10,110) fluidly communicates the passages (11,12) with each other.

FIG.2

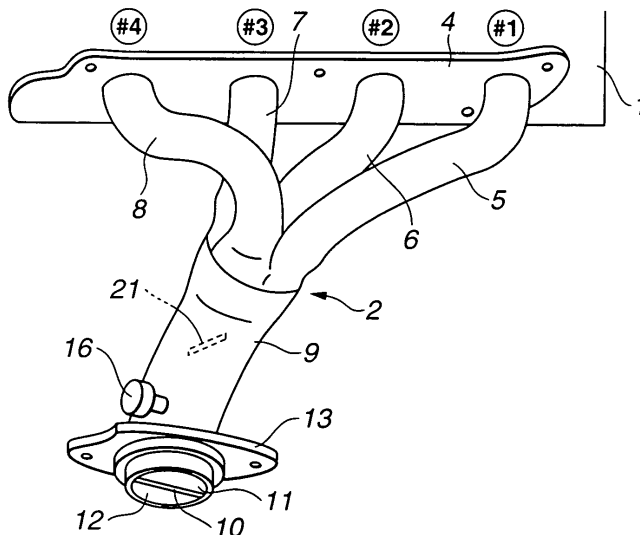
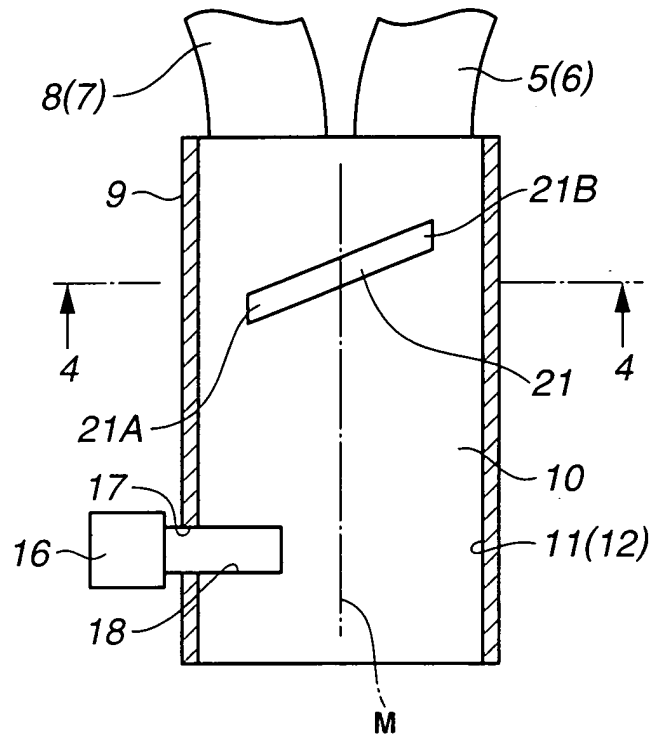


FIG.3



Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an improved exhaust manifold for an internal combustion engine having in-line four cylinders, such as an in-line four-cylinder internal combustion engine and a V-type eight-cylinder internal combustion engine.

[0002] In an in-line four-cylinder internal combustion engine, it is preferred to merge exhaust gases emitted from the four engine cylinders into one flow in a so-called 4-2-1 form in order to avoid interference between the exhaust gases. There has been proposed an exhaust manifold for in-line four-cylinder internal combustion engines, in which upstream four branches coupled to the four engine cylinders are connected with a downstream exhaust pipe having a pair of passages. The four branches are joined at the respective downstream end portions so as to form two pairs of branches. The pair of passages are divided by a partition wall disposed within the downstream exhaust pipe. Each of the passages is communicated with passages within the two branches. A downstream portion of the exhaust pipe is connected with a catalytic converter via a diffuser. In general, in order to detect the exhaust gas emitted from all the engine cylinders, a single air-fuel ratio sensor (oxygen sensor or regional air-fuel ratio sensor) is arranged in the exhaust system so as to partially project into the pair of passages of the exhaust pipe through a mount hole formed in a circumferential wall of the exhaust pipe and a cutout that is formed on one side of the partition wall in a width direction perpendicular to an axial direction of the exhaust pipe, namely, perpendicular to a direction of a stream of the exhaust gas flowing from the upstream side to the downstream side of the exhaust pipe.

[0003] United States Patent No. 6,012,315 (corresponding to Japanese Patent Application First Publication No. 9-323119) discloses an exhaust pipe with a partition wall.

The exhaust pipe has a mount hole for an oxygen sensor. The partition wall is formed with a cutout cooperating with the mount hole to receive the oxygen sensor.

[0004] Japanese Patent Application First Publication No. 2001-82140 discloses a partition wall within an exhaust pipe. The partition wall has a plurality of holes for fluid communication between passages within the exhaust pipe which are divided from each other by the partition wall.

SUMMARY OF THE INVENTION

[0005] However, in the above-described related art, the air-fuel ratio sensor is arranged on one side of the partition wall in the width direction. With this arrangement, one side of each of the pair of passages of the exhaust pipe corresponding to the one side of the par-

tion wall is positioned closer to the air-fuel ratio sensor than an opposite side of the passage. The exhaust gas from one of the two branches flows into the one side of the passage, and comes into contact with the air-fuel ratio sensor in such an amount greater than that of the exhaust gas flowing from the other of the two branches into the opposite side of the passage. Namely, the exhaust gas emitted from one of two engine cylinders which is coupled to the one of the two branches comes into contact with the air-fuel ratio sensor in an amount greater than that of the exhaust gas emitted from the other of the two engine cylinders which is coupled to the other of the two branches. As a result, the air-fuel ratio sensor cannot accurately measure a whole part of the exhaust gases emitted from the engine cylinders. There will occur deterioration in accuracy of the measurement of the exhaust gas by the air-fuel ratio sensor.

[0006] This problem cannot be resolved by the latter of the above-described related arts which discloses the partition wall having the plurality of holes.

[0007] It is an object of the present invention to provide an improved exhaust manifold for an in-line four-cylinder internal combustion engine, which is capable of preventing deterioration in accuracy of measuring an exhaust gas passing through the exhaust manifold using an air-fuel ratio sensor.

[0008] In one aspect of the present invention, there is provided an exhaust manifold connected to an internal combustion engine with four engine cylinders, the exhaust manifold comprising:

four branches for discharging exhaust gases from the four engine cylinders, respectively;

a downstream exhaust pipe connected with the four branches;

a partition wall dividing an exhaust path in the downstream exhaust pipe into a first passage and a second passage each having a semicircular section, the partition wall having a cutout formed on one side thereof in a width direction perpendicular to an axial direction of the downstream exhaust pipe, each of the first and second passages being connected with two of the four branches which are connected with two of the four engine cylinders having non-continuous order of ignition, the two of the four branches being communicated with first and second quarter-circular regions in the semicircular section of each of the first and second passages, respectively,

an air-fuel ratio sensor mounted to the downstream exhaust pipe so as to project into both of the first and second passages through the cutout of the partition wall; and

a communication portion formed in the partition wall and fluidly communicating the first and second passages with each other, the communication portion having a first part located on the one side of the partition wall and a second part located on an opposite

side of the partition wall, the first part being positioned on a downstream side relative to the second part.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a side view of an exhaust manifold according to a first embodiment of the present invention.

[0010] FIG. 2 is a perspective view of the exhaust manifold shown in FIG. 1.

[0011] FIG. 3 is a partial section of the exhaust manifold of the first embodiment, taken along an axial direction of the exhaust manifold, showing a partition wall disposed within a downstream exhaust pipe of the exhaust manifold.

[0012] FIG. 4 is a cross section taken along line 4-4 of FIG. 3.

[0013] FIGS. 5A and 5B are explanatory diagrams of a stream of the exhaust gas that is emitted from an engine cylinder and flows into the downstream exhaust pipe.

[0014] FIG. 6A is an explanatory diagram of a stream of an exhaust gas that passes through the downstream exhaust pipe and comes into contact with a carrier of a catalytic converter in a case where the partition wall has no slit.

[0015] FIG. 6B is an explanatory diagram similar to FIG. 6A, but showing the stream of the exhaust gas in a case where the partition wall has a slit.

[0016] FIG. 7 is a view similar to FIG. 3, but showing a partition wall of the exhaust manifold according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Referring to FIGS. 1 to 6B, an exhaust manifold according to a first embodiment of the present invention now is explained. In this embodiment, the exhaust manifold is applied to an in-line four-cylinder internal combustion engine of a vehicle. As illustrated in FIG. 1, exhaust manifold 2 has an upstream end coupled to one side of cylinder head 1 of the engine and a downstream end coupled to catalytic converter 3. Exhaust manifold 2 is so constructed as to merge four passages on the upstream side into two passages on the downstream side.

[0018] As illustrated in FIG. 2, exhaust manifold 2 includes upstream four branches 5, 6, 7 and 8 and downstream exhaust pipe 9 connected with upstream four branches 5 to 8. Upstream four branches 5 to 8 have upstream ends coupled to cylinder head 1 via flange 4 and downstream ends that are joined together and coupled to an upstream end of downstream exhaust pipe 9. Upstream four branches 5, 6, 7 and 8 are fluidly communicated with engine cylinders #1, #2, #3 and #4, respectively. Partition wall 10 is disposed within downstream exhaust pipe 9 and extends in an axial direction of downstream exhaust pipe 9 over an entire axial length

thereof. Partition wall 10 divides an exhaust path within downstream exhaust pipe 9 which has a generally circular section, into a pair of passages 11 and 12 each having a semicircular-shaped section. Partition wall 10 is in the form of a plate containing a central axis of downstream exhaust pipe 9. Downstream exhaust pipe 9 has a downstream end portion to which flange 13 is mounted. Flange 13 is connected with inlet flange 15 of diffuser 14 of catalytic converter 3.

[0019] Here, each of passages 11 and 12 within downstream exhaust pipe 9 is communicated with two of four engine cylinders #1 to #4 which have non-continuous order of ignition, via two of four branches 5 to 8 which are coupled to the two of four engine cylinders #1 to #4. In other words, passage 11 and 12 is communicated with two of four engine cylinders #1 to #4 which are not in series in ignition order. In this embodiment, the ignition order of four engine cylinders #1 to #4 is as follows: #1-#3-#4-#2. Passage 11 is communicated with engine cylinders #1 and #4 having non-continuous order of ignition via branches 5 and 8 that are coupled to engine cylinders #1 and #4, respectively. Exhaust gases emitted from engine cylinders #1 and #4 are discharged into branches 5 and 8, respectively. Two exhaust streams passing through branches 5 and 8 are joined together within passage 11. On the other hand, passage 12 is communicated with engine cylinders #2 and #3 having non-continuous order of ignition via branches 6 and 7 that are coupled to engine cylinders #2 and #3, respectively.

Exhaust gases emitted from engine cylinders #2 and #3 are discharged into branches 6 and 7, respectively. Two exhaust streams passing through branches 6 and 7 are joined together within passage 12. The exhaust stream within passage 11 and the exhaust stream within passage 12 are merged into one exhaust stream on an inlet side of catalytic converter 3, namely, on the side of diffuser 14.

[0020] Air-fuel ratio sensor 16 is mounted to a relatively downstream portion of downstream exhaust pipe 9 and located along partition wall 10 so as to partially project into both of passages 11 and 12 through cutout 18 formed in partition wall 10. Specifically, partition wall 10 has cutout 18 that is formed on one side of partition wall 10 in a width direction perpendicular to the axial direction of downstream exhaust pipe 9. Air-fuel ratio sensor 16 is located on the one side of partition wall 10 in the width direction. In FIG. 2, air-fuel ratio sensor 16 is disposed on the left side of the partition wall 10. Air-fuel ratio sensor 16 is inserted from an outer circumferential surface of downstream exhaust pipe 9 through mount hole 17 and partially projects into passages 11 and 12 through cutout 18 of partition wall 10. Air-fuel ratio sensor 16 is thus exposed to the exhaust gases in respective passages 11 and 12 and detects an air-fuel ratio of the exhaust gases in passages 11 and 12.

[0021] Referring to FIGS. 3 and 4, partition wall 10 within downstream exhaust pipe 9 is explained in more

detail. As illustrated in FIG. 3, partition wall 10 extends over an entire axial length of downstream exhaust pipe 9. Partition wall 10 includes a communication portion fluidly communicating passages 11 and 12 with each other. The communication portion is so arranged as to cause the exhaust gas flowing in each of passages 11 and 12 along the opposite side of partition wall 10 in the width direction to divert toward air-fuel ratio sensor 16 located on the one side of partition wall 10 in the width direction. In this embodiment, the communication portion is in the form of inclined slit 21 that is located on an upstream side of air-fuel ratio sensor 16. Slit 21 extends in the width direction of partition wall 10, namely, in a left-and-right direction in FIG. 3, and is inclined relative to the axial direction of downstream exhaust pipe 9, namely, an up-and-down direction in FIG. 3. Specifically, slit 21 has one end 21A positioned on the one side of partition wall 10 in the width direction and the other end 21B positioned on an opposed side of partition wall 10 in the width direction.

In other words, one end 21A is located on the side of air-fuel ratio sensor 16. One end 21A is located on a downstream side relative to the other end 21B. In this embodiment, slit 21 has a uniform width in a direction perpendicular to the width direction of partition wall 10. Slit 21 can be suitably modified such that the width is varied between the upstream side and the downstream side in order to adjust pressure distribution. Further, slit 21 can be in the form of a plurality of slits.

[0022] As illustrated in FIG. 4, downstream exhaust pipe 9 has a generally circular shape in section. Partition wall 10 is disposed within downstream exhaust pipe 9 so as to contain the central axis of downstream exhaust pipe 9. Partition wall 10 divides the exhaust path within downstream exhaust pipe 9 into passages 11 and 12 each having a generally semicircular-shaped section. The downstream ends of two branches 5 and 8 connected with engine cylinders #1 and #4 that have non-continuous order of ignition are connected with the upstream end of downstream exhaust pipe 9 so as to be communicated with quarter-circular regions A and B, respectively, which cooperate to form the semicircular-shaped section of passage 11. Quarter-circular regions A and B are thus in fluid communication with engine cylinders #1 and #4 via branches 5 and 8, respectively. Similarly, the downstream ends of two branches 6 and 7 connected with engine cylinders #2 and #3 that have non-continuous order of ignition are connected with the upstream end of downstream exhaust pipe 9 so as to be communicated with quarter-circular regions C and D, respectively, which cooperate to form the semicircular-shaped section of passage 12. Regions A and B and regions C and D are respectively separated by hypothetical boundary plane M as shown in FIG. 4. Regions C and D are in fluid communication with engine cylinders #2 and #3 via branches 6 and 7. Air-fuel ratio sensor 16 is arranged on the side of regions B and D into which the exhaust gases from engine cylinders #4 and #3 are

introduced. With this arrangement, the exhaust gases emitted from engine cylinders #1 and #2 and flowing into regions A and C are smaller in amount contacting with air-fuel ratio sensor 16 than the exhaust gases emitted from engine cylinders #4 and #3 and flowing into regions B and D. One end 21A of slit 21 is located near the middle of a portion of partition wall 10 which extends between regions B and D in the width direction thereof. The other end 21B of slit 21 is located at or outside the middle of the remaining portion of partition wall 10 which extends between regions A and C in the width direction thereof. Specifically, the other end 21B of slit 21 may be positioned between the middle of the remaining portion of partition wall 10 and a peripheral edge of partition wall 10 which is connected with an inner surface of downstream exhaust pipe 9. Thus, slit 21 is open to both of regions B and D at one end 21A, and open to both of regions A and C at the other end 21B.

[0023] Referring to FIGS. 5A and 5B, there is explained a stream of the exhaust gas discharged from engine cylinder #1 into passage 11 of downstream exhaust pipe 9 and then flowing into passage 12 through slit 21. FIG. 5A shows the stream of the exhaust gas discharged from engine cylinder #1 and flowing into passage 11. FIG. 5B shows the stream of the exhaust gas flowing from passage 11 into passage 12 via slit 21. When the exhaust gas emitted from engine cylinder #1 flows into passage 11 via branch 5, the exhaust gas flows in region A of passage 11. At this time, passage 12 has a pressure lower than that in passage 11, which is caused immediately after the exhaust gas emitted from engine cylinder #2 passes through passage 12. Owing to the lower pressure in passage 12, a part of the exhaust gas passing through region A of passage 11 is caused to flow into passage 12 via slit 21 as shown in FIG. 5B. Upon passing through slit 21, the part of the exhaust gas flows along the inclined periphery of slit 21. The part of the exhaust gas then enters into passage 12 and flows toward air-fuel ratio sensor 16 in a dispersed state as shown in FIG. 5B.

[0024] On the other hand, when the exhaust gas from engine cylinder #1 flows in region A of passage 11, slit 21 forms a certain low-pressure portion. Since slit 21 is inclined such that the downstream side of slit 21 is closer to air-fuel ratio sensor 16, namely, the low-pressure portion on the downstream side is more offset toward air-fuel ratio sensor 16 than that on the upstream side, the stream of the exhaust gas flowing in region A is caused to divert to region B disposed close to air-fuel ratio sensor 16, in a dispersed state as shown in FIG. 5A. Thus, the amount of the exhaust gas emitted from engine cylinder #1 and coming into contact with air-fuel ratio sensor 16 is increased. As a result, air-fuel ratio sensor 16 can detect the exhaust gas emitted from engine cylinder #1 with an increased accuracy.

[0025] A stream of the exhaust gas discharged from engine cylinder #2 into passage 12 of downstream exhaust pipe 9 and then flowing into passage 11 via slit 21

is symmetric with respect to the above-explained stream of the exhaust gas discharged from engine cylinder #1 into passage 11. The exhaust gas emitted from engine cylinder #2 flows into region C of passage 12 via branch 6. At this time, passage 11 has a lower pressure caused immediately after the exhaust gas emitted from engine cylinder #1 passes through passage 11. Therefore, a part of the exhaust gas passing through region C of passage 12 is caused to flow into passage 11 via slit 21. With the arrangement of inclined slit 21, the part of the exhaust gas is caused to flow toward air-fuel ratio sensor 16 in a dispersed state. On the other hand, since slit 21 forms the low-pressure portion, the stream of the exhaust gas flowing in region C is caused to divert to region D disposed close to air-fuel ratio sensor 16, in a dispersed state. Further, a part of the exhaust gas discharged from engine cylinder #4 into region B of passage 11 is caused to disperse into passage 12 via slit 21. A part of the exhaust gas discharged from engine cylinder #3 into region D of passage 12 is caused to disperse into passage 11 via slit 21.

[0026] Referring to FIGS. 6A and 6B, there is shown the stream of the exhaust gas flowing toward catalytic converter 3 and impinging on ceramic monolithic carrier 3A. FIG. 6A illustrates the stream of the exhaust gas which is caused when partition wall 10 without slit 21 is used. FIG. 6B illustrates the stream of the exhaust gas which is caused when partition wall 10 with slit 21 is used. As illustrated in an upper part of FIG. 6A, since partition wall 10 is not formed with slit 21, the exhaust gas emitted from engine cylinders #1 and #4 passes through only passage 11. As shown in a lower part of FIG. 6A, the exhaust gas flows from passage 11 toward catalytic converter 3 via diffuser 14 and is diffused at a portion of diffuser 14 which is disposed on the side of passage 11. The exhaust gas is then impinged on only a part of an inlet portion of carrier 3A. This will adversely affect carrier 3A so as to form cracks therein.

In contrast, in a case where partition wall 10 has slit 21 as illustrated in an upper part of FIG. 6B, a part of the exhaust gas discharged into passage 11 flows into passage 12 through slit 21. As illustrated in a lower part of FIG. 6B, the streams of the exhaust gas which pass through passages 11 and 12 flow toward catalytic converter 3 via diffuser 14. The exhaust gas is homogeneously diffused at diffuser 14 and impinged on the whole of the inlet portion of carrier 3A.

[0027] As is appreciated from the above explanation, exhaust manifold 2 of the present invention can prevent interference of the exhaust gases emitted from four cylinders #1 to #4. Further, the exhaust gas flowing in downstream exhaust pipe 9 can be detected with an enhanced accuracy by single air-fuel ratio sensor 16. Specifically, in a case where inclined slit 21 is formed in partition wall 10, the exhaust gases flowing from branches 5 and 6 positioned away from air-fuel ratio sensor 16 are caused to flow and deflect toward air-fuel ratio sensor 16. This can enhance the accuracy of detecting the

exhaust gas in downstream exhaust pipe 9 by means of air-fuel ratio sensor 16. Further, the exhaust gas can be widely diffused from downstream exhaust pipe 9 toward catalytic converter 3.

This prevents the exhaust gas from impinging on only a part of the inlet portion of catalytic converter 3. Thus, exhaust manifold 2 of the present invention can achieve homogeneous impingement of the exhaust gas on a wide area of carrier 3A of catalytic converter 3.

[0028] Referring to FIG. 7, a second embodiment of exhaust manifold 2 of the present invention is explained. The second embodiment differs in that the partition wall has a plurality of holes from the first embodiment. As illustrated in FIG. 7, three holes 22, 23 and 24 are formed in partition wall 110 and act as the communication portion for fluid communication between passages 11 and 12. In this embodiment, three holes 22, 23 and 24 have a same diameter. Three holes 22, 23 and 24 are arranged along an inclined line relative to the axial direction of downstream exhaust pipe 9 and the width direction of partition wall 110.

Middle hole 23 between holes 22 and 24 is arranged across boundary plane M. Hole 22 is located on a downstream side of middle hole 23 and on the one side of partition wall 110 in the width direction on which air-fuel ratio sensor 16 is arranged. Hole 22 is located in the middle of a portion of partition wall 110 which extends between regions B and D. Hole 22 is open to both of regions B and D. Hole 24 is disposed on an upstream side of middle hole 23 and on the opposite side of partition wall 110 in the width direction. Hole 24 is located in the middle of a portion of partition wall 110 which extends between regions A and C. Hole 24 is open to both of regions A and C. These holes 22, 23 and 24 are so arranged as to act substantially equivalent to slit 21 of partition wall 10 of the first embodiment.

[0029] The plurality of holes acting as the communication portion are not limited to this invention. The diameter of the holes can be set different from one another by considering pressure distribution. Further, the number of the holes may be not limited to three in this embodiment. A larger number of holes can be arranged in multiple lines. The exhaust manifold of the second embodiment can perform the same effects as explained in the first embodiment.

[0030] This application is based on a prior Japanese Patent Application No. 2002-372510 filed on December 24, 2002. The entire contents of the Japanese Patent Application No. 2002-372510 is hereby incorporated by reference.

[0031] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art in light of the above teachings. The scope of the invention is defined with reference to the following claims.

Claims

1. An exhaust manifold connected to an internal combustion engine with four engine cylinders, the exhaust manifold comprising:

four branches (5,6,7,8) for discharging exhaust gases from the four engine cylinders (#1,#2,#3,#4), respectively;
a downstream exhaust pipe (9) connected with the four branches;

a partition wall (10;110) dividing an exhaust path in the downstream exhaust pipe (9) into a first passage (11) and a second passage (12) each having a semicircular section, the partition wall (10;110) having a cutout (18) formed on one side thereof in a width direction perpendicular to an axial direction of the downstream exhaust pipe (9),

each of the first and second passages (11,12) being connected with two of the four branches (5,6,7,8) which are connected with two of the four engine cylinders (#1,#2,#3,#4) having non-continuous order of ignition, the two of the four branches (5,6,7,8) being communicated with first and second quarter-circular regions (A,B; C,D) in the semicircular section of each of the first and second passages (11,12), respectively,

an air-fuel ratio sensor (16) mounted to the downstream exhaust pipe (9) so as to project into both of the first and second passages (11,12) through the cutout (18) of the partition wall (10;110); and

a communication portion (21;22,23,24) formed in the partition wall (10;110) and fluidly communicating the first and second passages (11,12) with each other, the communication portion (21; 22,23,24) having a first part (21A;22) located on the one side of the partition wall and a second part (21B;24) located on an opposite side of the partition wall (10;110), the first part (21A; 22) being positioned on a downstream side relative to the second part (21B;24).

2. The exhaust manifold as claimed in claim 1, wherein the communication portion comprises a slit (21) extending in the width direction of the partition wall (10) and inclined relative to the axial direction of the downstream exhaust pipe (9).

3. The exhaust manifold as claimed in claim 2, wherein the slit (21) has substantially a uniform width in a direction perpendicular to the width direction of the partition wall (10).

4. The exhaust manifold as claimed in claim 1, wherein the communication portion comprises a plurality

of holes (22,23,24) including a hole (22) located on the one side of the partition wall (10) and on a downstream side relative to the remaining holes (23,24).

5. The exhaust manifold as claimed in claim 4, wherein the plurality of holes (22,23,24) have substantially a same diameter.

6. The exhaust manifold as claimed in any one of claims 1 to 5, wherein the first quarter-circular region (A,C) of each of the first and second passages (11,12) is located on the opposite side of the partition wall (10;110), the second part (21B;24) of the communication portion being open to the first quarter-circular region (A,C).

7. The exhaust manifold as claimed in claim 6, wherein the second quarter-circular region (B,D) of each of the first and second passages (11,12) is located on the one side of the partition wall (10;110), the first part (21A;22) of the communication portion being open to the second quarter-circular region (B, D).

8. The exhaust manifold as claimed in any one of claims 1 to 7, wherein the partition wall (10;110) extends over an entire axial length of the downstream exhaust pipe (9).

FIG.1

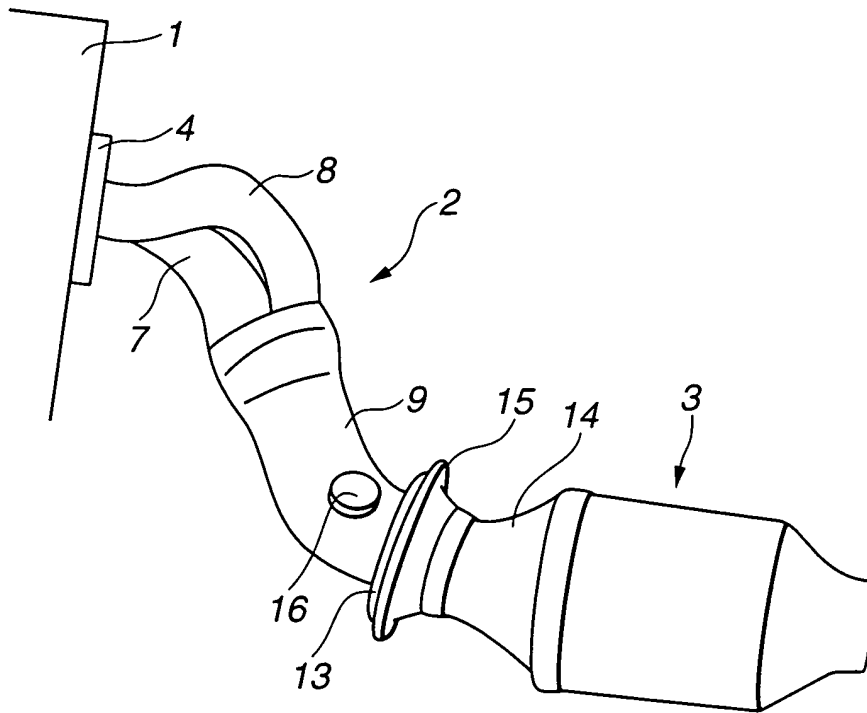


FIG.2

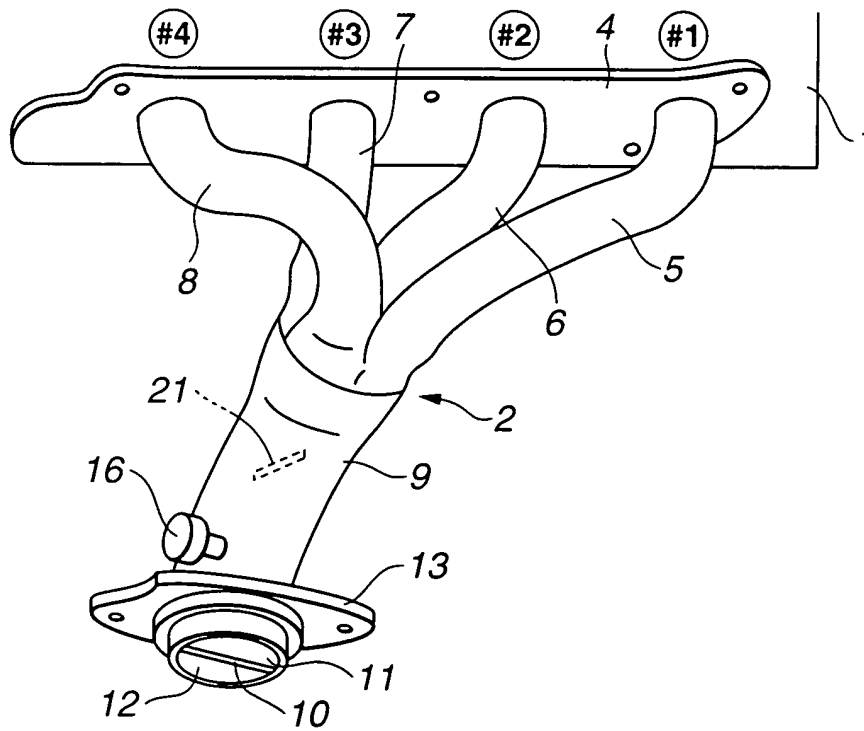


FIG.3

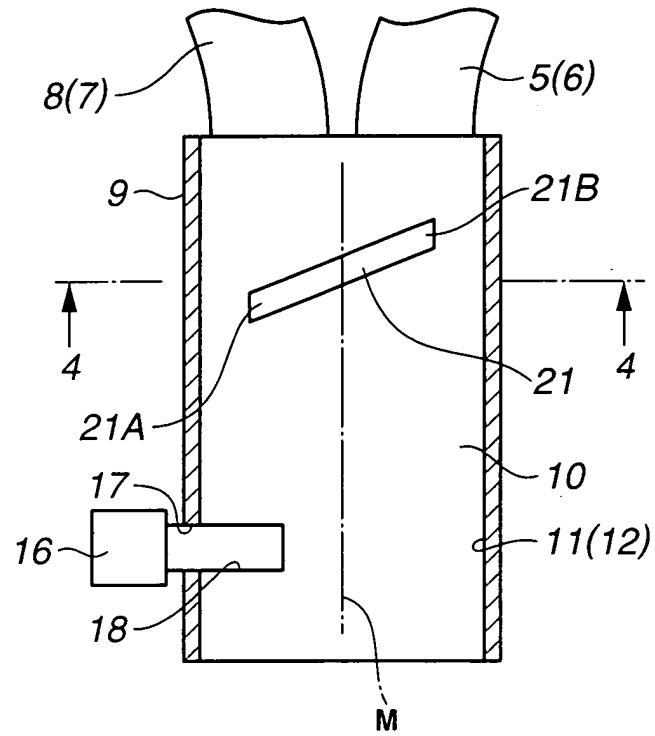


FIG.4

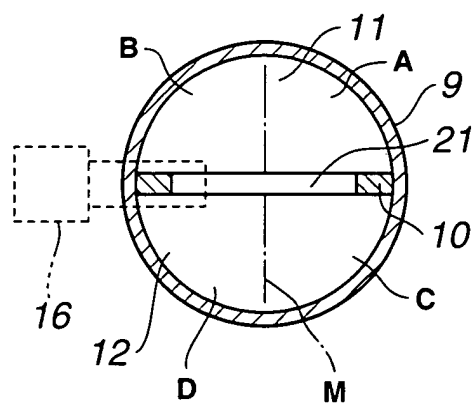


FIG.5A

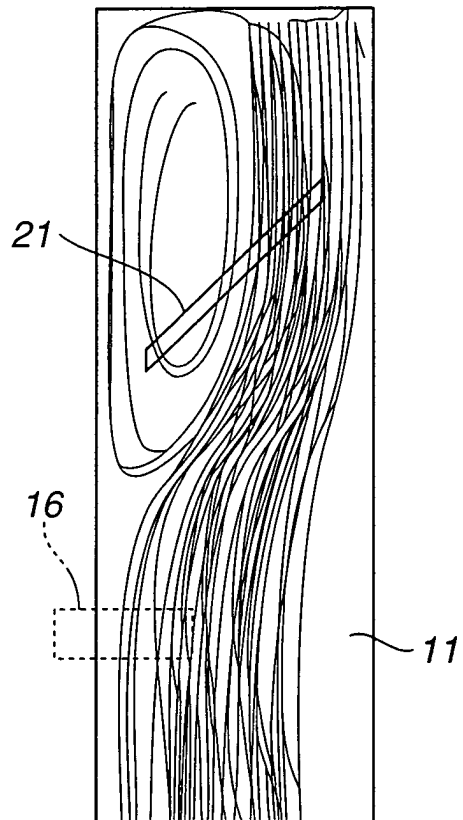
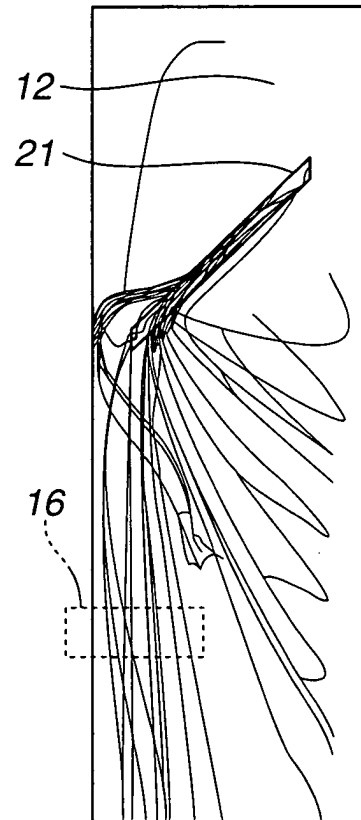


FIG.5B



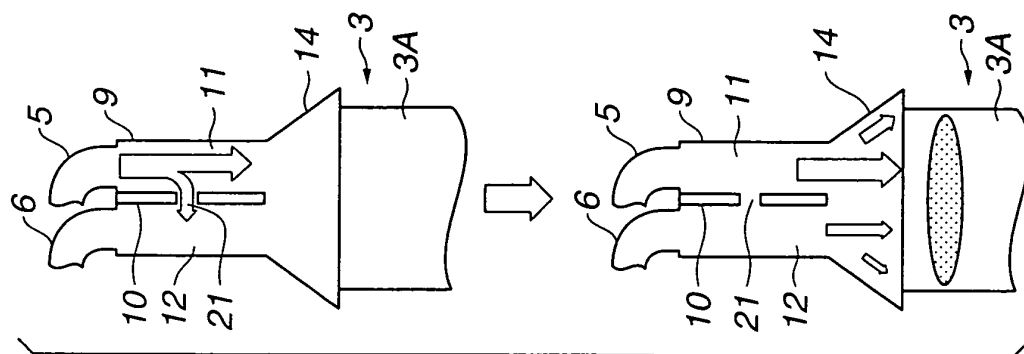


FIG. 6B

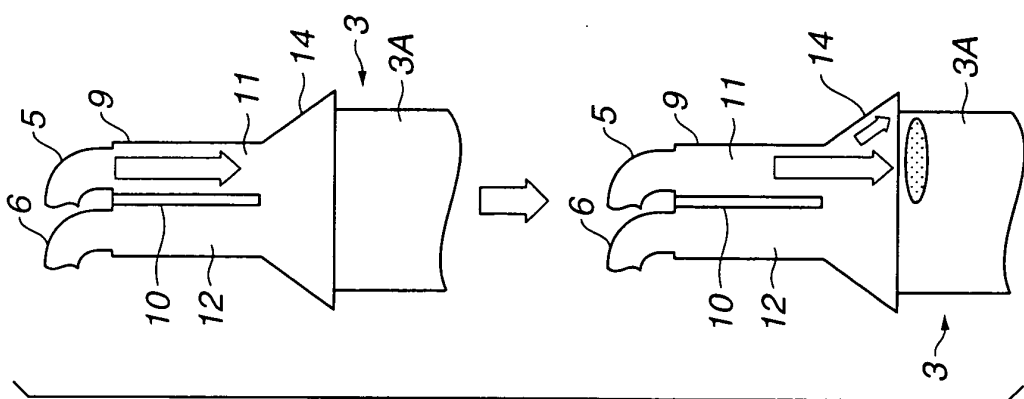


FIG. 6A

FIG.7

