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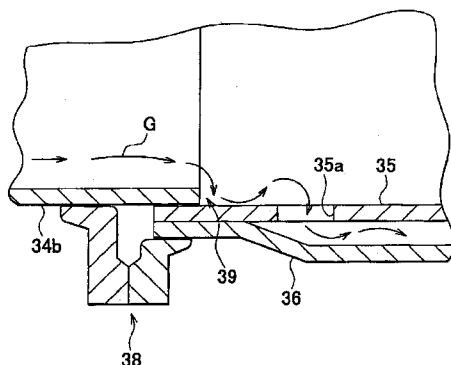
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FIG. 7



(57) Abstract: A resonance device (28) which is provided in an exhaust device (23) having a silencer (27) that silences sound of exhaust gas from an engine (21) and which silences a specific frequency sound includes: an exhaust pipe (34) which is provided downstream of the silencer (27) in an exhaust flow direction and whose first end portion (34a) is connected to the silencer (27); an inner pipe (35) connected to a second end portion (34b) of the exhaust pipe (34) and having at least one penetration hole (35a); and an outer pipe (36) that is attached to the inner pipe (35) so as to surround a periphery of the inner pipe (35) and that defines, together with an outer periphery of the inner pipe (35), space that forms a resonance chamber (37). An outer periphery of the second end portion (34b) of the exhaust pipe (34) is inserted into the inner pipe (35) so that a step (39) is formed at a connecting portion between the second end portion (34b) and the inner pipe (35).



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RESONANCE DEVICE, AND EXHAUST DEVICE FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to a resonance device, and an exhaust device for an internal combustion engine. In particular, the invention relates to a resonance device that is applied to a vehicle or the like, and that silences sound of a specific frequency that is produced by exhaust gas discharged from an internal combustion engine, and an exhaust
10 device for an internal combustion engine.

2. Description of the Related Art

[0002] Generally, an internal combustion engine provided in a vehicle, such as a motor vehicle or the like, produces exhaust sounds of various frequencies according to the rotation speed of the internal combustion engine in operation. Of the exhaust sounds, a
15 sound of a specific frequency becomes particularly loud. Therefore, in order to silence such a loud sound of a specific frequency, it is important that a silencer be effective to that frequency, and have high silencing effect for the frequency. In particular, in the case where a specific frequency sound is produced depending on the structure of the silencer or the layout of the silencer and the exhaust pipe, a resonance device is sometimes provided
20 as a measure for silencing the specific frequency sound.

[0003] An example of a related-art resonance device of this kind that silences a specific frequency sound is shown in FIG. 9A (e.g., see Japanese Patent Application Publication No. 2006-29224 (JP-A-2006-29224)). In FIG. 9A, exhaust gas discharged
25 from the combustion chambers of the cylinders of an internal combustion engine is supplied to a resonance device 1 through a silencer and an exhaust pipe (which are not shown). This resonance device 1 includes an inner pipe 2 connected to the exhaust pipe, and an outer pipe 3 that is attached to the inner pipe 2 so as to surround a periphery of the inner pipe 2 and that defines, together with an outer peripheral portion of the inner pipe 2,

space that forms a resonance chamber 4.

[0004] A penetration hole 2a is formed in a wall of the inner pipe 2. Exhaust gas having been supplied into the inner pipe 2 is radiated from the penetration hole 2a into the resonance chamber 4 defined between the inner pipe 2 and the outer pipe 3, whereby sound
5 of the exhaust gas is silenced. After that, the exhaust gas is discharged via the inner pipe 2. Besides, by suitably setting the capacity of the resonance chamber 4, the frequency of sound to be silenced can be adjusted. Concretely, the capacity of the resonance chamber 4 is made large in order to silence a low-frequency sound, and the capacity of the resonance chamber 4 is made small in order to silence a high-frequency sound.

10 [0005] In the resonance device 1 having a construction as described above, during high-speed operation of the internal combustion engine, high-speed exhaust gas being radiated from the inner pipe 2 into the resonance chamber 4 through the penetration hole 2a produces a whistling sound that is an unpleasant noise.

[0006] Concretely, when the flow speed of exhaust gas introduced from the exhaust
15 pipe into the inner pipe 2 becomes high during high-speed operation of the internal combustion engine, an eddy is formed at an edge portion of the penetration hole 2a that is at an upstream side in the direction of exhaust gas. When this eddy moves toward the downstream side, it becomes a pressure wave of a constant frequency. This pressure wave sometimes becomes a vibration source, and causes air column resonance at high
20 frequency within the resonance chamber 4, thus producing a so-called whistling sound.

[0007] In order to prevent the production of such a whistling sound, a construction has been provided in which a silencer having a sound absorbing material is provided at a downstream side of the resonance device 1. However, this construction increases the production cost of an exhaust device corresponding to the provision of the silencer that has
25 a sound absorbing material.

[0008] A device that restrains the production of a whistling sound while restraining the increase of the production cost of the exhaust device is a silencer that has a resonance device as shown in FIG. 10A (e.g., see Japanese Utility Model Publication No. 3-32735). In FIG. 10A, a silencer body 11 of a silencer 10 is separated into a resonance chamber 15

and a plurality of expanded chambers 16a, 16b, 16c by partition plates 12, 13, 14. In the silencer body 11, there are provided an inlet pipe 18 that has a plurality of penetration holes 18a, a communication pipe 19 that has a plurality of penetration holes 19a, and an outlet pipe 20 as a resonance device that has one penetration hole 20a.

5 [0009] The outlet pipe 20 is bent into a letter-U shape in order to silence low-frequency sound, and communicates with the resonance chamber 15 via the penetration hole 20a. A protruded portion 20b is formed on an inner wall at an upstream side of the penetration hole 20a in the direction of exhaust gas.

10 [0010] In the silencer constructed as described above, when the flow speed of exhaust gas becomes high during high-speed operation of the internal combustion engine, exhaust gas hits the protruded portion 20b provided on the upstream-side of the penetration hole 20a, so that the formation of an eddy is restrained. Therefore, high-frequency air column resonance, that is, production of a whistling sound, can be restrained, and unpleasant noise can be reduced.

15 [0011] However, in this related-art silencer 10 provided with the outlet pipe 20, since the protruded portion 20b is formed on the inner wall of the outlet pipe 20 on the upstream side of the penetration hole 20a in the direction of exhaust gas, there is a need to perform a process of forming the protruded portion 20b in the outlet pipe 20. Thus, there is a problem of correspondingly increased production cost of the outlet pipe 20 and,
20 consequently, increased production cost of the silencer 10.

SUMMARY OF THE INVENTION

[0012] The invention provides a resonance device and an exhaust device of an internal combustion engine which are capable of reducing unpleasant noise while restraining the
25 increase of the production cost.

[0013] A first aspect of the invention is a resonance device which is provided in an exhaust device having a silencer that silences sound of exhaust gas discharged from an internal combustion engine and which silences a specific frequency sound, the resonance device including: an exhaust pipe which is provided downstream of the silencer in an

exhaust gas flow direction and whose first end portion is connected to the silencer; an inner pipe connected to a second end portion of the exhaust pipe and having at least one penetration hole; and an outer pipe that is attached to the inner pipe so as to surround a periphery of the inner pipe and that defines, together with an outer peripheral portion of the inner pipe, space that forms a resonance chamber, wherein an outer peripheral portion of the second end portion of the exhaust pipe is inserted into the inner pipe so that a step is formed at a connecting portion between the second end portion of the exhaust pipe and the inner pipe. The penetration hole may be formed in a vicinity of the connecting portion between the second end portion of the exhaust pipe and the inner pipe.

10 [0014] Due to this construction, the exhaust gas introduced from the silencer into the inner pipe via the exhaust pipe forms a turbulence in gas flow as it passes by the step formed by the connecting portion between the second end portion of the exhaust pipe and the inner pipe. Therefore, the resonance device is able to restrain the occurrence of an eddy of a constant frequency when exhaust gas hits an edge of the penetration hole of the inner pipe that is positioned in the vicinity of the step. Therefore, the whistling sound can be restrained, and unpleasant noise can be reduced.

[0015] Besides, since the flow of exhaust gas can be disturbed or made turbulent by utilizing the step portion that is formed at the connecting portion between the second end portion of the exhaust pipe and the inner pipe, it becomes unnecessary to perform processing on the exhaust pipe or the inner pipe. Thus, increase in the production cost of the resonance device can be restrained.

20 [0016] In the first aspect, at least one penetration hole may be formed in the inner pipe. When the number of penetration holes formed in the inner pipe is one, an eddy of a constant frequency formed by exhaust gas hitting the edge of the penetration hole occurs relatively easily and therefore a whistling sound occurs relatively easily. However, since the exhaust gas introduced from into the inner pipe of the resonance device forms a turbulence in gas flow as it passes by the step formed at the connecting portion between the second end portion of the exhaust pipe and the inner pipe, the resonance device is able to restrain the occurrence of an eddy of a constant frequency when exhaust gas hits an edge of

the penetration hole of the inner pipe that is positioned in the vicinity of the step. Therefore, the whistling sound can be restrained, and unpleasant noise can be reduced.

[0017] In the first aspect, the penetration hole may be formed at a position where exhaust gas forms a turbulence in flow as the exhaust gas passes by the step. In this construction, since the penetration hole is formed at a position where a gas flow turbulence occurs as exhaust gas passes by the step, it is possible to restrain the exhaust gas introduced into the inner pipe from becoming straightened in flow before reaching the penetration hole and therefore restrain the occurrence of an eddy of a constant frequency when exhaust gas hits the edge of the penetration hole.

[0018] A second aspect of the invention is an exhaust device for an internal combustion engine that includes the resonance device for the first aspect, the exhaust device including: a first silencer connected to the internal combustion engine; a first exhaust pipe whose first end portion is connected to the first silencer; a second silencer connected to a second end portion of the first exhaust pipe; and a second exhaust pipe whose first end portion is connected to the second silencer, wherein a length of the first exhaust pipe in an extending direction and a length of the second exhaust pipe and the inner pipe in the extending direction are substantially equal, and the outer peripheral portion of the second end portion of the second exhaust pipe is inserted into the inner pipe of the resonance device.

[0019] This construction is adopted for the following reasons. In the case where the first silencer and the second silencer are disposed apart from each other in the longitudinal direction of the vehicle, the exhaust pipe connecting the first silencer and the second silencer becomes long so that the low-frequency sound is produced by the air column resonance that occurs between the first silencer and the second silencer. Besides, in the case where the first silencer and the second silencer are disposed apart from each other, the second silencer is disposed at a node of the air column resonance at which sound pressure is low, so that it becomes difficult to restrain low-frequency sound.

[0020] However, if the first silencer and the second silencer are connected by the first exhaust pipe and the length of the first exhaust pipe in the extending direction and the

length of the second exhaust pipe and the inner pipe of the resonance device in the extending direction are substantially the same length, the second silencer can be disposed at the position of a peak of the sound pressure of the low-frequency sound, so that the low-frequency sound can be silenced with good efficiency.

5 [0021] However, if the length of the first exhaust pipe in the extending direction and the length of the second exhaust pipe and the inner pipe of the resonance device in the extending direction are substantially the same length, the resonance frequency of the first exhaust pipe and the resonance frequency of the second exhaust pipe and the inner pipe combined are equal to each other, so that loud high-frequency sound at a specific high
10 frequency is produced.

[0022] Therefore, in the second aspect of the invention, the resonance frequency of the upstream side of the sub-muffler and the resonance frequency of the downstream side thereof are made unequal by connecting the resonator to the second exhaust pipe, and therefore the high-frequency sound is silenced by the resonator. Besides, since during
15 high-speed operation of the internal combustion engine, the exhaust gas introduced from the second silencer into the inner pipe via the second exhaust pipe forms a turbulence in gas flow as it passes the step that is formed at the connecting portion between the second end portion of the second exhaust pipe and the inner pipe, it is possible to restrain an eddy of a constant frequency from occurring when exhaust gas hits the edge of the penetration
20 hole of the inner pipe that is positioned in the vicinity of the step. Therefore, the whistling sound can be restrained, and unpleasant noise can be reduced.

[0023] Besides, since the flow of exhaust gas can be disturbed or made turbulent by utilizing the step portion that is formed at the connecting portion between the second end portion of the second exhaust pipe and the inner pipe, it becomes unnecessary to perform
25 processing on the exhaust pipe or the inner pipe. Thus, increase in the production cost of the resonance device can be restrained.

[0024] In the second aspect, the second silencer may include an inner pipe that is connected to the second end portion of the first exhaust pipe and to the first end portion of the second exhaust pipe and that has a plurality of penetration holes, and an outer pipe that

is attached to the inner pipe so as to surround a periphery of the inner pipe and that defines, together with an outer peripheral portion of the inner pipe, space that forms a resonance chamber, and the resonance chamber may be provided with a sound absorbing material.

[0025] In this construction, since the resonance chamber of the second silencer is
5 provided with the sound absorbing material, low-frequency sound can be silenced with good efficiency by the sound absorbing material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The foregoing and further objects, features and advantages of the invention
10 will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 shows embodiments of a resonance device and an exhaust device for an internal combustion engine in accordance with the invention, and is a top plan view of the exhaust
15 device;

FIG. 2 shows embodiments of the resonance device and the exhaust device for an internal combustion engine in accordance with the invention, and is a front elevation of the exhaust device;

FIG. 3 shows embodiments of the resonance device and the exhaust device for an
20 internal combustion engine in accordance with the invention, and is a sectional view of a sub-muffler;

FIG. 4 shows embodiments of the resonance device and the exhaust device for an internal combustion engine in accordance with the invention, and is an external view of the resonance device;

25 FIG. 5 is a sectional view taken as indicated by a line 5B-5B in FIG. 4;

FIGS. 6A and 6B show embodiments of the resonance device and the exhaust device for an internal combustion engine, and FIG. 6A shows a sound pressure mode by air column resonance in the case where a sub-muffler and a main muffler are disposed apart from each other, and FIG. 6B shows a sound pressure mode by air column resonance in the exhaust

device for the embodiment of the invention;

FIG. 7 shows embodiments of the resonance device and the exhaust device for an internal combustion engine in accordance with the invention, and shows flows of exhaust gas that flows into a stepped portion of the resonance device;

5 FIG. 8 shows embodiments of the resonance device and the exhaust device for an internal combustion engine in accordance with the invention, and also shows a relation between the rotation speed of the engine and the sound pressure level produced by the exhaust device;

FIG. 9A is a sectional view of a related-art resonance device, and FIG. 9B is a sectional
10 view taken as indicated by a line 9C-9C in FIG. 9A; and

FIG. 10A is a sectional view of a silencer that includes a resonance device according to the related art, and FIG. 10B is a sectional view taken as indicated by a line 10D-10D in FIG. 10A.

15 DETAILED DESCRIPTION OF EMBODIMENTS

[0027] Embodiments of a resonance device, and an exhaust device for an internal combustion engine which includes a resonance device will be described hereinafter with reference to the drawings. FIG. 1 to FIG. 8 show embodiments of the resonance device, and the exhaust device for an internal combustion engine which include the resonance
20 device in accordance with the invention. FIG. 1 shows a top plan view of the exhaust device, and FIG. 2 shows a front elevation of the exhaust device.

[0028] First, a construction thereof will be described. In FIGS. 1 and 2, combustion chambers of cylinders of an engine 21 as a four-cylinder internal combustion engine communicate with an exhaust manifold 22 via exhaust ports. An exhaust device 23 is
25 connected to the exhaust manifold 22. The exhaust device 23 includes a catalytic converter 24, a main muffler 26 as a first silencer, a sub-muffler 27 as a second silencer, and a resonator 28 as a resonance device. Incidentally, a catalytic converter that is separate from the catalytic converter 24 may also be provided within the main muffler 26.

[0029] The catalytic converter 24 is constructed by a honeycomb base member or a

granular active alumina-made support with a catalyst, such as platinum, palladium or the like, attached thereto which is contained in a body case. The catalytic converter 24 is designed so that NO_x is reduced or CO and HC are oxidized.

5 [0030] The main muffler 26 is connected to the catalytic converter 24 via an exhaust pipe 25, and is designed to perform primary silencing of exhaust gas. A first end portion 29a of an exhaust pipe 29 as a first exhaust pipe is connected to the main muffler 26. A second end portion 29b of the exhaust pipe 29 is connected to the sub-muffler 27.

10 [0031] As shown in FIG. 3, the sub-muffler 27 includes an inner pipe 30 which the second end portion 29b of the exhaust pipe 29 is fitted to and which has a plurality of penetration holes 30a, an outer pipe 31 which is attached to the inner pipe 30 so as to surround a periphery of the inner pipe 30 and which defines, together with an outer peripheral portion of the inner pipe 30, space that forms a resonance chamber 32, and a sound absorbing material 33 charged in the resonance chamber 32.

15 [0032] A first end portion 34a of an exhaust pipe 34 as a second exhaust pipe is connected to the sub-muffler 27. The first end portion 34a of the exhaust pipe 34 is fitted to the inner pipe 30.

20 [0033] A second end portion 34b of the exhaust pipe 34 is connected to the resonator 28, which is provided at a downstream side of the sub-muffler 27 in the direction of exhaust gas flow. As shown in FIGS. 4 and 5, the resonator 28, to which the second end portion 34b of the exhaust pipe 34 is connected, includes an inner pipe 35 that has one penetration hole 35a, and an outer pipe 36 that is attached to the inner pipe 35 so as to surround a periphery of the inner pipe 35 and that defines, together with an outer peripheral portion of the inner pipe 35, space that forms a resonance chamber 37.

25 [0034] An outer peripheral portion of the second end portion 34b of the exhaust pipe 34 is inserted into the inner pipe 35, so that a step 39 is formed in the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35. Besides, the penetration hole 35a is formed in a wall of the inner pipe 35 so as to be proximate to the step 39, that is, the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35.

[0035] The length of the exhaust pipe 29 in the direction of extension thereof is substantially the same as the length of the exhaust pipe 34 and the inner pipe 35 of the resonator 28 in the direction of extension thereof. That is, the penetration hole 35a is formed in an intermediate portion of an exhaust path of the exhaust gas discharged from
5 the sub-muffler 27.

[0036] The inner pipe 35 and the second end portion 34b of the exhaust pipe 34 are fastened together by a flange member 38. The flange member 38 is provided so as to surround outer peripheral portions of the second end portion 34b of the exhaust pipe 34 and the outer pipe 36.

10 [0037] Next, with reference to FIGS. 6A, 6B and 7, a silencing method for exhaust gas will be described. Firstly, in the case where the main muffler 26 and the sub-muffler 27 are disposed apart from each other in the longitudinal direction of the vehicle as in the related art as shown in FIG. 6A, the exhaust pipe connecting the main muffler 26 and the sub-muffler 27 is long so that the sound pressure reaches maximum in a low frequency
15 range of about 40 Hz to 50 Hz of the frequency determined by the air column resonance that occurs between the main muffler 26 and the sub-muffler 27. Then, in the case where the main muffler 26 and the sub-muffler 27 are disposed apart from each other in this manner, the sub-muffler 27 is disposed at a node of the air column resonance at which the sound pressure is low, so that it is difficult to restrain the low-frequency sound.

20 [0038] In the embodiment, on the other hand, as shown in FIG. 6B, the main muffler 26 and the sub-muffler 27 are connected by the exhaust pipe 29, and the length of the exhaust pipe 29 in the extending direction and the length of the exhaust pipe 34 and the inner pipe 35 of the resonator 28 in the extending direction are substantially equal, so that the sub-muffler 27 is disposed at the position of a peak of the sound pressure of the
25 low-frequency sound (at the position shown by A in FIG. 6A). Therefore, the low-frequency sound can be silenced with good efficiency. Besides, since the sub-muffler 27 is provided with the sound absorbing material 33, the low-frequency sound can be silenced even more efficiently.

[0039] However, if the length of the exhaust pipe 29 in the extending direction and the

length of the exhaust pipe 34 and the inner pipe 35 of the resonator 28 in the extending direction are substantially equal, the resonance frequency of the exhaust pipe 29 and the resonance frequency of the exhaust pipe 34 and the inner pipe 35 combined become equal, so that the sound pressure reaches maximum in a high frequency range of about 200 Hz.

5 [0040] Therefore, in this embodiment, the resonance frequency of the upstream side of the sub-muffler 27 and the resonance frequency of the downstream side thereof are made unequal by connecting the resonator 28 to the exhaust pipe 34, and therefore the high-frequency sound is silenced by the resonator 28.

10 [0041] Concretely, when the flow speed of the exhaust gas introduced from the exhaust pipe 34 into the inner pipe 35 becomes high during high-speed operation of the engine 21, an eddy is formed at an edge portion of the penetration hole 35a on an upstream side in the direction of exhaust gas flow. When this eddy moves toward the downstream side, it becomes a pressure wave of a constant frequency. This pressure wave sometimes becomes a vibration source, and causes air column resonance at high frequency within the
15 resonance chamber 37, thus producing a so-called whistling sound.

20 [0042] In this embodiment, the outer peripheral portion of the second end portion 34b of the exhaust pipe 34 is inserted into the inner pipe 35, so that the step 39 is formed at the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35. Besides, the penetration hole 35a is formed in the wall of the inner pipe 35 so as to be proximate to the step 39, that is, the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35. Therefore, as shown in FIG. 7, the exhaust gas G introduced from the sub-muffler 27 into the inner pipe 35 via the exhaust pipe 34 forms a turbulence in gas flow as it passes by the step 39.

25 [0043] This restrains the occurrence an eddy of a constant frequency when the exhaust gas hits the edge portion of the penetration hole 35a of the inner pipe 35 positioned in the vicinity of the step 39. Thus, the whistling sound can be restrained, and unpleasant noise can be reduced.

 [0044] Therefore, it is desirable that the penetration hole 35a be formed at a position where exhaust gas forms a turbulence in gas flow as it passes by the step 39. If the

penetration hole 35a is provided downstream of this position, there is possibility that the exhaust gas may be straightened in flow and therefore an eddy of a constant frequency may occur.

[0045] FIG 8 is a diagram showing a relation between the rotation speed of the engine 21 and the level of sound pressure occurring in the exhaust device 23. In FIG 8, broken lines show the sound pressure levels in the embodiment, and solid lines show the sound pressure levels in a related-art exhaust device that is constructed without taking into account the restraint of whistling sound.

[0046] As is apparent from FIG 8, the exhaust device for this embodiment reduced the sound pressure level by about 10 dB in a frequency range corresponding to the peak of the sound pressure level at each of two high rotation speeds of the engine 21 of 5000 rpm and 5950 rpm, in comparison with the related-art exhaust device.

[0047] As described above, in this embodiment, the exhaust device includes the main muffler 26 connected to the engine 21, the exhaust pipe 29 whose first end portion 29a is connected to the main muffler 26, the sub-muffler 27 connected to the second end portion 29b of the exhaust pipe 29, the exhaust pipe 34 whose first end portion 34a is connected to the sub-muffler 27, and the resonator 28 connected to the second end portion 34b of the exhaust pipe 34. The resonator 28 is constructed of the inner pipe 35 that is connected to the second end portion 34b of the exhaust pipe 34 and that has the penetration hole 35a, and the outer pipe 36 that is attached to the inner pipe 35 so as to surround the periphery of the inner pipe 35 and that defines, together with the outer peripheral portion of the inner pipe 35, space that forms the resonance chamber 37. Since the outer peripheral portion of the second end portion 34b of the exhaust pipe 34 is inserted into the inner pipe 35, the step 39 is formed at the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35. Besides, the penetration hole 35a is formed in the wall of the inner pipe 35 so as to be proximate to the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35. Furthermore, the length of the exhaust pipe 29 in the extending direction and the length of the exhaust pipe 34 and the inner pipe 35 of the resonator 28 in the extending direction are substantially the

same length.

[0048] Therefore, the low-frequency sound can be silenced by the sub-muffler 27 with good efficiency, and at the same time, the high-frequency sound can be silenced with good efficiency by making unequal the resonance frequencies of the upstream side and the downstream side of the sub-muffler 27.

[0049] Besides, during high-speed operation of the engine 21, the exhaust gas introduced from the sub-muffler 27 into the inner pipe 35 of the resonator 28 via the exhaust pipe 34 forms a turbulence in gas flow as it passes by the step 39 that is formed by the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35. Therefore, the exhaust device can restrain the occurrence of an eddy of a constant frequency when the exhaust gas hits the edge of the penetration hole 35a of the inner pipe 35 that is positioned in the vicinity of the step 39. Therefore, the whistling sound can be restrained, and unpleasant noise can be reduced.

[0050] Furthermore, since the flow of exhaust gas can be disturbed by utilizing the step 39 that is formed by the connecting portion between the second end portion 34b of the exhaust pipe 34 and the inner pipe 35, it becomes unnecessary to perform processing on the exhaust pipe 34 or the inner pipe 35, and therefore the increase of the production cost of the resonator 28 can be restrained.

[0051] In particular, in this embodiment, since the penetration hole 35a is formed at a position where a gas flow turbulence occurs as exhaust gas passes by the step 39, it is possible to avoid allowing the exhaust gas introduced into the inner pipe 35 to become straightened in flow before reaching the penetration hole 35a and therefore further restrain the occurrence of an eddy of a constant frequency when exhaust gas hits the edge of the penetration hole 35a.

[0052] Besides, the sub-muffler 27 in this embodiment includes the inner pipe 30 that is connected to the second end portion 29b of the exhaust pipe 29 and to the first end portion 34a of the exhaust pipe 34 and that has a plurality of penetration holes 30a, and the outer pipe 31 that is attached to the inner pipe 30 so as to surround the periphery of the inner pipe 30, and that defines, together with the outer peripheral portion of the inner pipe

30, space that forms the resonance chamber 32. The resonance chamber 32 is provided with the sound absorbing material 33. Hence, the low-frequency sound can be efficiently silenced by the sound absorbing material 33.

[0053] Although in the resonator 28 of the foregoing embodiment, only one penetration hole 35a is provided in the inner pipe 35, two or more penetration holes 35a may instead be provided. In particular, when the number of penetration holes 35a formed in the inner pipe 35 is one, the number of sites where an eddy occurs is only one, so that an eddy of a constant frequency formed by exhaust gas hitting the edge of the penetration hole 35a occurs relatively easily and therefore a whistling sound occurs relatively easily. In this embodiment, however, by utilizing the step 39, a gas flow turbulence is caused as described above, so that the occurrence of an eddy of a constant frequency can be reliably restrained.

[0054] Furthermore, in this embodiment, the length of the exhaust pipe 29 in the extending direction and the length of the exhaust pipe 34 and the inner pipe 35 of the resonator 28 in the extending direction are substantially the same length, and the high-frequency sound as a specific frequency sound is silenced by the resonator 28. However, the resonator 28 in the embodiment is able to silence a specific frequency sound that is produced upstream of the resonator 28 due to the layout of the mufflers and the exhaust pipe. The construction of the mufflers and the exhaust pipe on the upstream side of the resonator 28 is not limited to the above-described construction.

[0055] Beside, the embodiments disclosed herein are merely illustrative in all respects, and do not restrict the invention. The scope of the invention is shown not by the foregoing description only of embodiments, but by the claims for patent, and is intended to cover all the modifications and the like within the meaning and scope equivalent to the claims for patent.

CLAIMS

1. A resonance device (28) which is provided in an exhaust device (23) having a silencer (27) that silences sound of exhaust gas discharged from an internal combustion engine (21) and which silences a specific frequency sound, characterized by comprising:

an exhaust pipe (34) which is provided downstream of the silencer (27) in an exhaust pipe flow direction and whose first end portion (34a) is connected to the silencer (27);

an inner pipe (35) connected to a second end portion (34b) of the exhaust pipe (34) and having at least one penetration hole (35a); and

an outer pipe (36) that is attached to the inner pipe (35) so as to surround a periphery of the inner pipe (35) and that defines, together with an outer peripheral portion of the inner pipe (35), space that forms a resonance chamber (37), wherein an outer peripheral portion of the second end portion (34b) of the exhaust pipe (34) is inserted into the inner pipe (35) so that a step (39) is formed at a connecting portion between the second end portion (34b) of the exhaust pipe (34) and the inner pipe (35).

2. The resonance device (28) according to claim 1, wherein the penetration hole (35a) is formed in a vicinity of the connecting portion between the second end portion (34b) of the exhaust pipe (34) and the inner pipe (35).

3. The resonance device (28) according to claim 1 or 2, wherein at least one penetration hole (35a) is formed in the inner pipe (35).

4. The resonance device (28) according to any one of claims 1 to 3, wherein the penetration hole (35a) is formed at a position where exhaust gas forms a turbulence in flow as the exhaust gas passes by the step (39).

5. An exhaust device (23) for an internal combustion engine (21) that includes the resonance device (28) according to any one of claims 1 to 4, characterized by comprising:

a first silencer (26) connected to the internal combustion engine (21);

a first exhaust pipe (29) whose first end portion (29a) is connected to the first silencer (26);

a second silencer (27) connected to a second end portion (29b) of the first exhaust pipe (29); and

a second exhaust pipe (34) whose first end portion (34a) is connected to the second silencer (27), wherein a length of the first exhaust pipe (29) in an extending direction and a length of the second exhaust pipe (34) and the inner pipe (35) in the extending direction are substantially equal, and the outer peripheral portion of the second end portion (34b) of the second exhaust pipe (34) is inserted into the inner pipe (35) of the resonance device (28).

6. The exhaust device according to claim 5, wherein the second silencer (27) includes an inner pipe (30) that is connected to the second end portion (29b) of the first exhaust pipe (29) and to the first end portion (34a) of the second exhaust pipe (34) and that has a plurality of penetration holes (30a), and an outer pipe (31) that is attached to the inner pipe (30) so as to surround a periphery of the inner pipe (30) and that defines, together with an outer peripheral portion of the inner pipe (30), space that forms a resonance chamber (32), and the resonance chamber (32) is provided with a sound absorbing material (33).

7. A resonance device which is provided in an exhaust device having a silencer that silences sound of exhaust gas discharged from an internal combustion engine and which silences a specific frequency sound, comprising:

an exhaust pipe which is provided downstream of the silencer in an exhaust gas flow direction and whose first end portion is connected to the silencer;

an inner pipe connected to a second end portion of the exhaust pipe and having at least one penetration hole; and

an outer pipe that is attached to the inner pipe so as to surround a periphery of the inner pipe and that defines, together with an outer peripheral portion of the inner pipe, space that forms a resonance chamber, wherein an outer peripheral portion of the second end portion of the exhaust pipe is inserted into the inner pipe so that a step is formed at a connecting portion between the second end portion of the exhaust pipe and the inner pipe.

FIG. 1

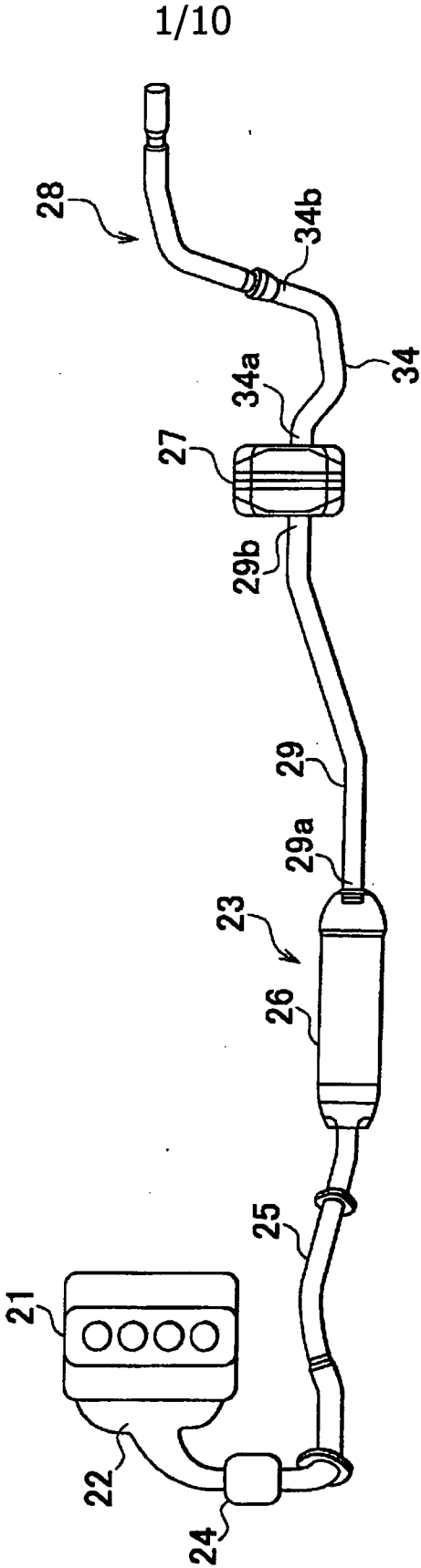
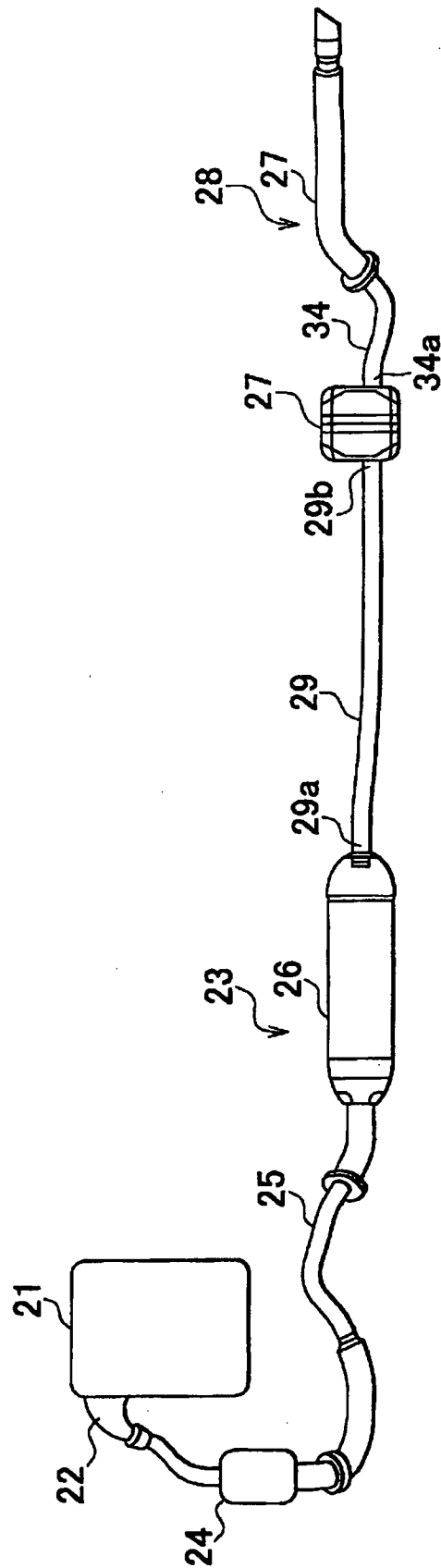
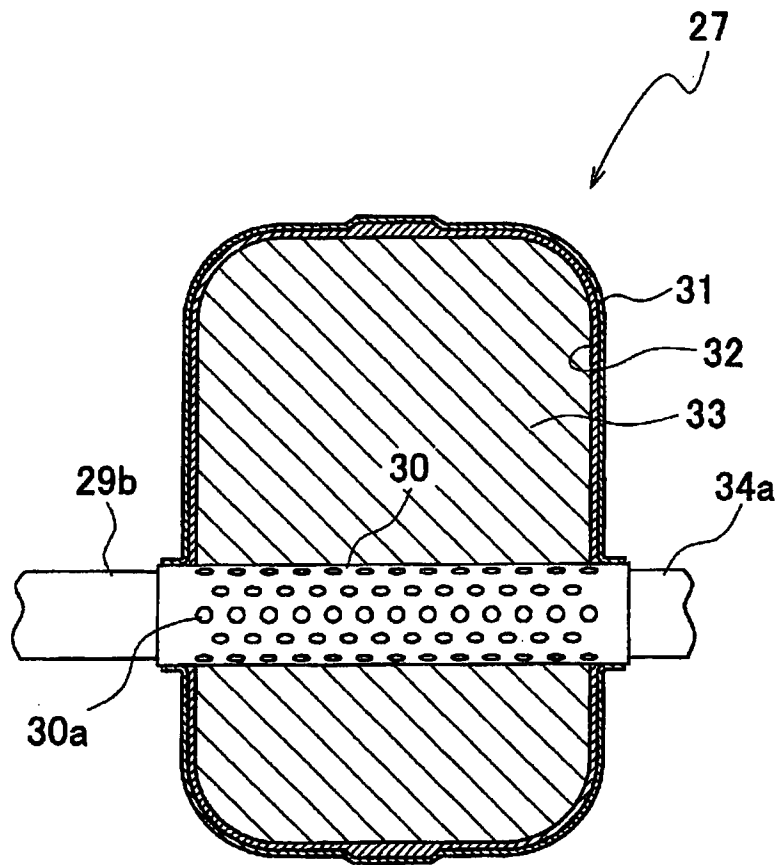


FIG. 2



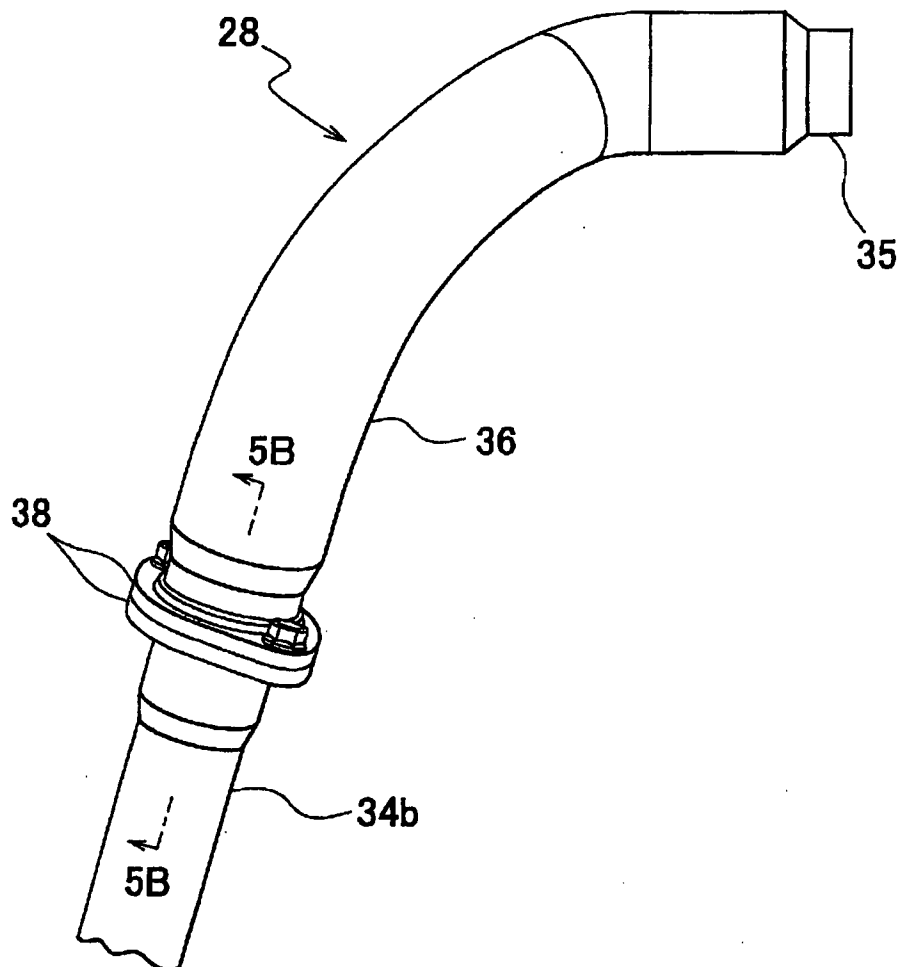
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FIG. 3



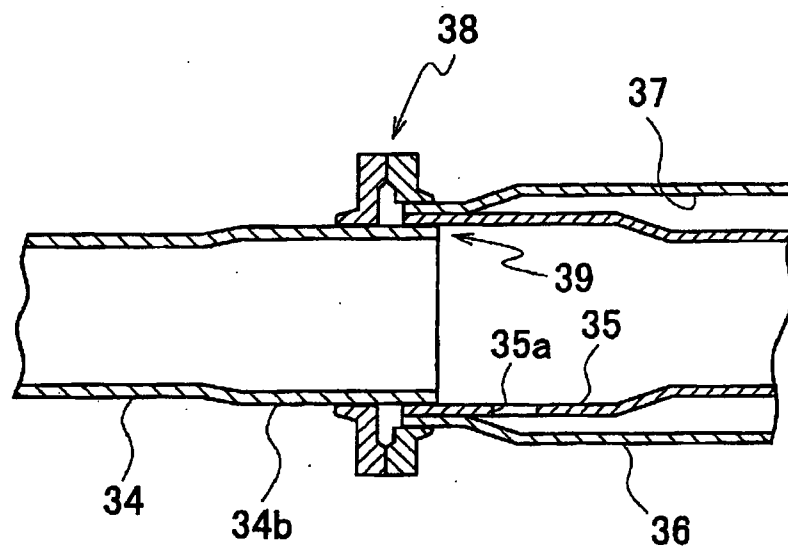
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FIG. 4



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FIG. 5



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FIG. 6A

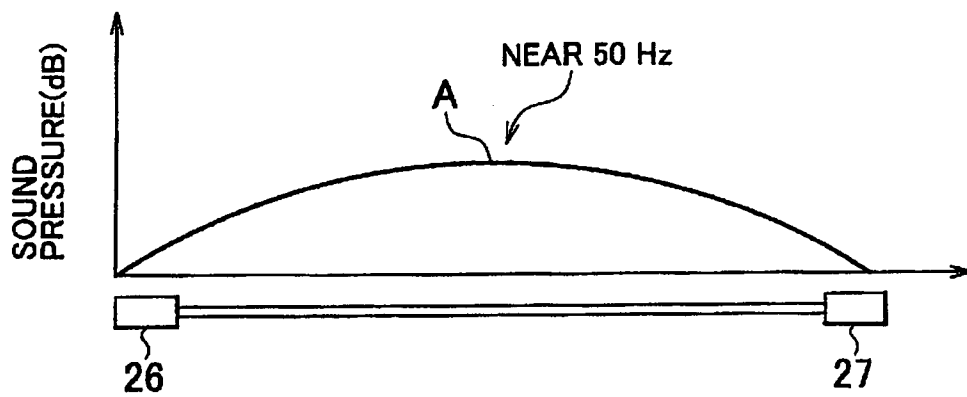
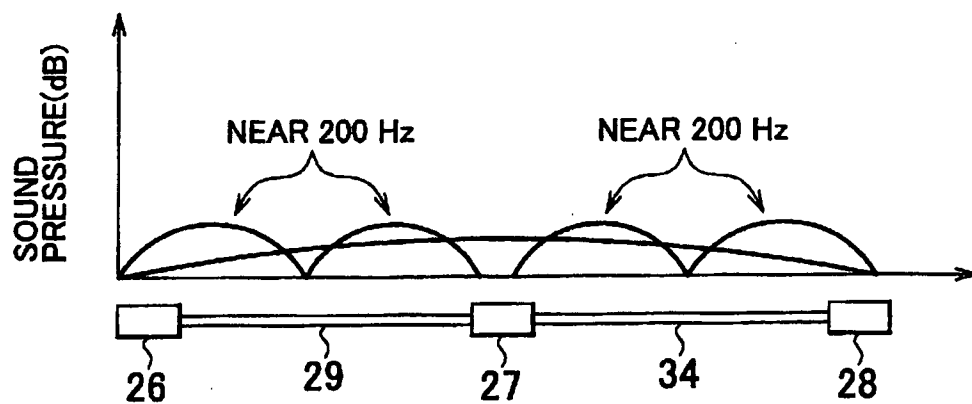
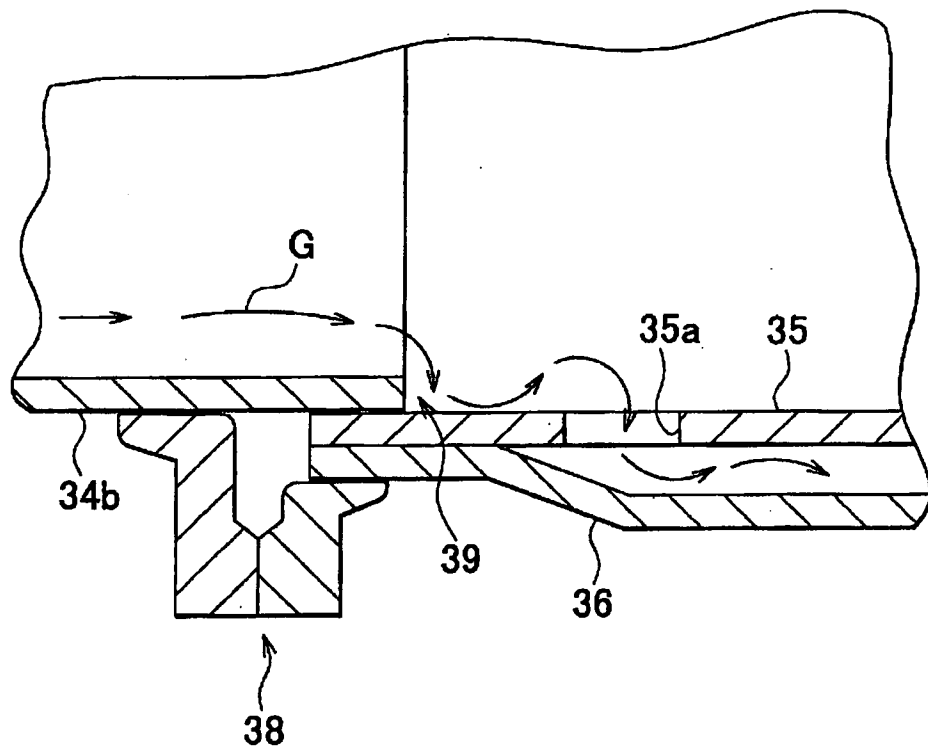


FIG. 6B



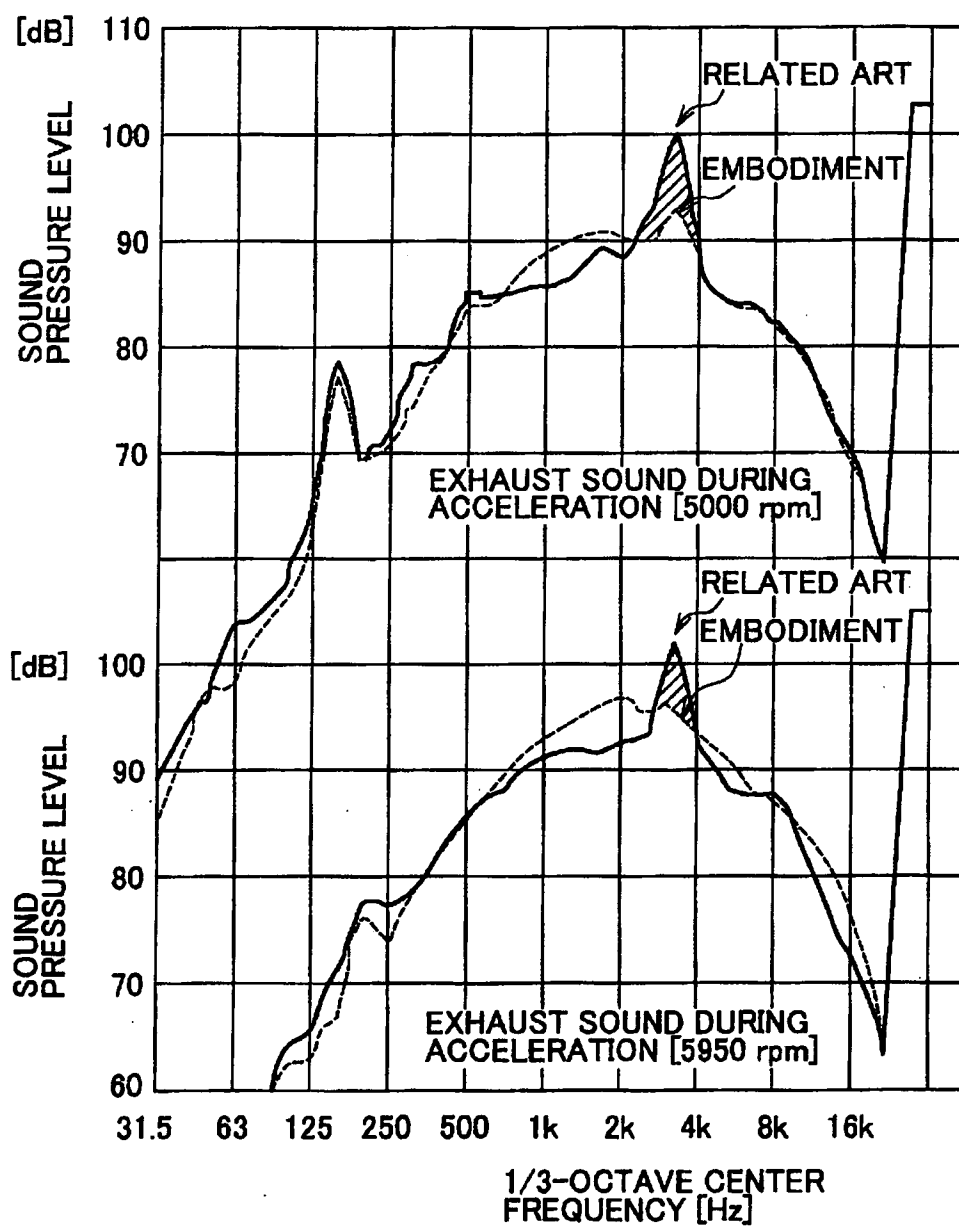
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FIG. 7



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FIG. 8



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FIG. 9A

RELATED ART

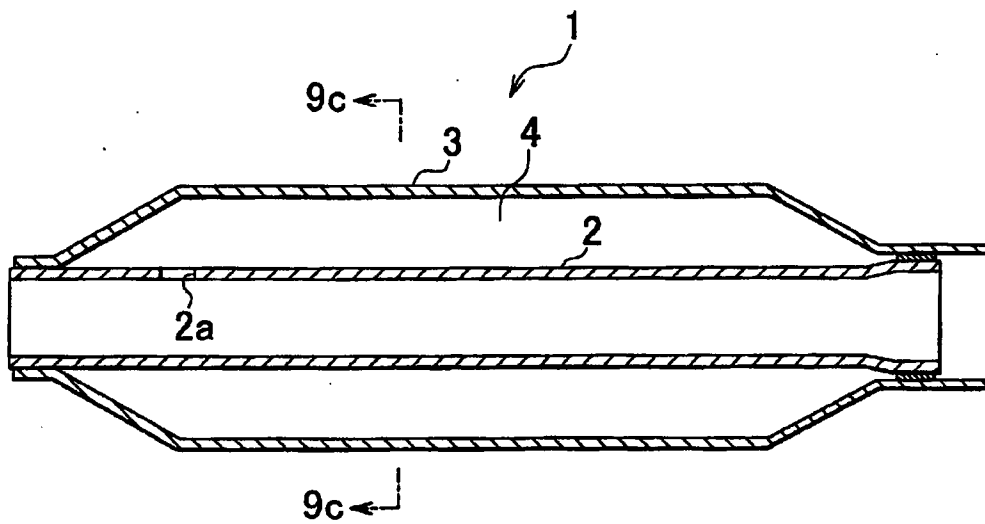
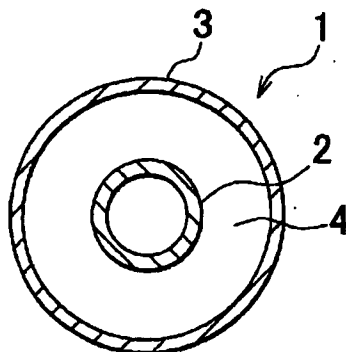


FIG. 9B



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FIG. 10A
RELATED ART

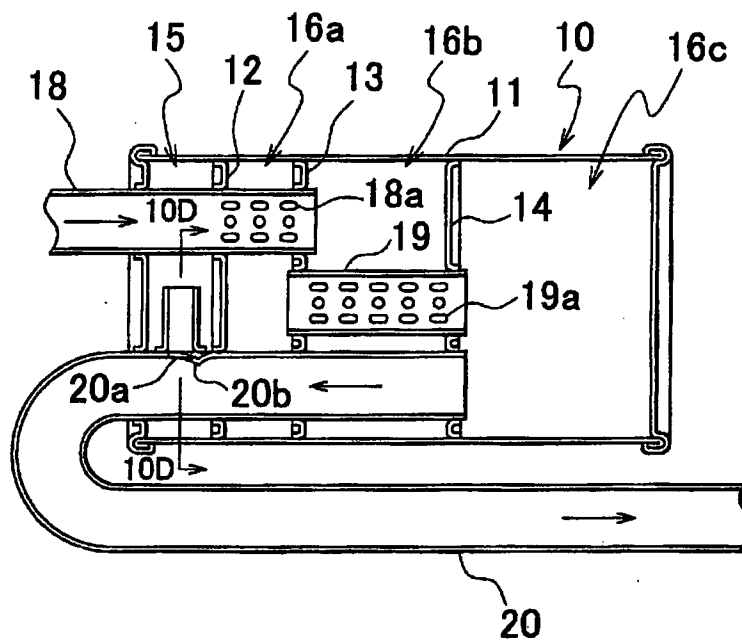


FIG. 10B

