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(54) **VEHICLE AND SINGLE-CYLINDER FOUR-STROKE ENGINE UNIT**

FAHRZEUG UND EINZYLINDRIGE VIERTAKTMOTOREINHEIT

VÉHICULE ET GROUPE MOTEUR À QUATRE TEMPS MONOCYLINDRIQUE

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Description

[Technical Field]

[0001] The present invention relates to a vehicle and a single-cylinder four-stroke engine unit.

[Background Art]

[0002] Patent Literature 1 discloses a vehicle on which a single-cylinder four-stroke engine unit is mounted. In this single-cylinder four-stroke engine unit, a catalyst is provided in a silencer. The catalyst is configured to purify exhaust gas exhausted from an engine main body. The silencer is configured to restrain the volume of the sound generated by the exhaust gas.

[Citation List]

[Patent Literatures]

[0003] [Patent Literature 1] Japanese Unexamined Patent Publication No. 2007-85234

[Summary of Invention]

[Technical Problem]

[0004] In the vehicle on which the single-cylinder four-stroke engine unit is mounted, improvement in the purification performance of the exhaust gas is desired. To achieve this, the catalyst may be provided further upstream. In other words, at least a part of the catalyst may be provided upstream of the silencer.

[0005] Furthermore, the catalyst may be upsized to maintain the purification performance for a long time. In this regard, when an upsized catalyst is provided upstream of the silencer, the number of supporting structures must be increased in order to obtain sufficient vibration resistance. The silencer and the engine main body are supported by a vehicle body frame. In the meanwhile, an exhaust pipe which connects the engine main body with the silencer is typically not supported by the vehicle body frame. For this reason, the exhaust pipe is more likely to vibrate when the upsized catalyst is provided in the exhaust pipe. It is therefore necessary to increase the number of supporting structures in order to obtain sufficient vibration resistance.

[0006] Further vehicles on which an engine unit is mounted are described, e.g., in JP 2007 187004 A, US 2014/060963 A1, DE 10 2006 003 116 A1, and JP 2006 207571 A.

[0007] An object of the present invention is to provide a vehicle which includes a single-cylinder four-stroke engine unit capable of improving the purification performance of purifying exhaust gas by a catalyst and maintaining the initial performance of a vehicle regarding the purification of exhaust gas, while the supporting structure

is simplified, and the said single-cylinder four-stroke engine unit.

[Solution to Problem]

[0008] Increase in the size of a catalyst has been considered as a means for maintaining the initial performance of the vehicle in connection with the exhaust gas purification for a long time. Inventors of the present application reconsidered the reasons for increasing the size of the catalyst.

[0009] The degree of deterioration of the catalyst varies in accordance with the working condition of the vehicle. In other words, the deterioration of the catalyst may advance, depending on the working condition of the vehicle. A margin is typically set for the purification capability in order to maintain the initial performance of the vehicle in connection with the exhaust gas purification for a longer time even if the deterioration of the catalyst advances. The increase in the size of the catalyst is due to the setting of a margin for the purification capability of the catalyst.

[0010] In this connection, research by the inventors of the present application proved that the advance of deterioration did not frequently occur. Based on this, the inventors of the present application have reached an idea to maintain the initial performance of the vehicle in connection with the exhaust gas purification performance for a longer time based on the following two different technical ideas, rather than setting a margin for the purification capability of the catalyst with the assumption of the advance of deterioration which does not frequently occur.

[0011] The first technical idea is such that an engine is controlled so that the advance of the deterioration of the catalyst is restrained. As the progress of the deterioration of the catalyst is restrained, the frequency of the occurrence of the advance of the deterioration is reduced. The second technical idea is such that the replacement of the catalyst is prompted before the deterioration of the catalyst reaches a predetermined level.

[0012] To achieve such technical ideas, the inventors conceived of employing the following arrangements. That is to say, the inventors conceived of providing oxygen detectors upstream and downstream of a catalyst and providing a controller for processing signals from the two oxygen detectors.

[0013] Based on the technical ideas, the inventors considered that the initial performance of the vehicle in connection with the exhaust gas purification was maintained for a longer time if the size of the catalyst was maintained. Furthermore, as the increase in size of the catalyst is restrained, vibrations of the exhaust pipe are restrained even if the catalyst is provided on the exhaust pipe. With this arrangement, the inventors considered that the supporting structure of the single-cylinder four-stroke engine unit can be simplified, while at the same time improving the purification performance of the catalyst.

[0014] A system according to claim 1 is provided.

[0015] According to this arrangement, the single-cylinder four-stroke engine unit mounted on the vehicle includes the engine main body, the single-combustion-chamber exhaust pipe, the single-combustion-chamber silencer, the single-combustion-chamber main catalyst, the single-combustion-chamber upstream oxygen detector, the single-combustion-chamber downstream oxygen detector, and the controller. The engine main body includes a cylinder member in which one combustion chamber and a single-combustion-chamber cylinder exhaust passage member are formed. Exhaust gas exhausted from the one combustion chamber flows in the single-combustion-chamber cylinder exhaust passage member. The single-combustion-chamber exhaust pipe is connected to the downstream end of the single-combustion-chamber cylinder exhaust passage member of the engine main body. The single-combustion-chamber silencer is provided with a discharge port which is exposed to the atmosphere. The single-combustion-chamber silencer is connected to the single-combustion-chamber exhaust pipe and allows the exhaust gas flowing from the downstream end of the single-combustion-chamber exhaust pipe to flow to the discharge port. The single-combustion-chamber silencer reduces noise generated by the exhaust gas. The single-combustion-chamber main catalyst is provided in the single-combustion-chamber cylinder exhaust passage member or the single-combustion-chamber exhaust pipe. The single-combustion-chamber main catalyst purifies the exhaust gas exhausted from one combustion chamber most in the exhaust path extending from the one combustion chamber to the discharge port. The upstream end of the single-combustion-chamber main catalyst is provided upstream of the upstream end of the single-combustion-chamber silencer. The single-combustion-chamber main catalyst is therefore positioned to be relatively close to the combustion chamber. Due to this, the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be improved.

[0016] In addition to the above, the single-combustion-chamber upstream oxygen detector is provided in the single-combustion-chamber cylinder exhaust passage member or the single-combustion-chamber exhaust pipe. The single-combustion-chamber upstream oxygen detector is provided upstream of the single-combustion-chamber main catalyst. The single-combustion-chamber downstream oxygen detector is provided in the single-combustion-chamber cylinder exhaust passage member, the single-combustion-chamber exhaust pipe, or the single-combustion-chamber silencer. The single-combustion-chamber downstream oxygen detector is provided downstream of the single-combustion-chamber main catalyst. The controller processes a signal from the single-combustion-chamber upstream oxygen detector and a signal from the single-combustion-chamber downstream oxygen detector.

[0017] Deterioration of the single-combustion-chamber main catalyst is detectable by a signal from the single-

combustion-chamber downstream oxygen detector which is provided downstream of the single-combustion-chamber main catalyst. This makes it possible to suggest the replacement of the single-combustion-chamber main catalyst by providing information before the deterioration of the single-combustion-chamber main catalyst reaches a predetermined level. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time by using multiple single-combustion-chamber main catalysts. The detection of the deterioration of the single-combustion-chamber main catalyst may be carried out without using a signal from the single-combustion-chamber upstream oxygen detector. Furthermore, deterioration of the single-combustion-chamber main catalyst may be detected based on a signal from the single-combustion-chamber downstream oxygen detector and a signal from the single-combustion-chamber upstream oxygen detector. The degree of deterioration of the single-combustion-chamber main catalyst can be more precisely detectable when signals from the two oxygen detectors are used. It is therefore possible to suggest the replacement of the single-combustion-chamber main catalyst at a more suitable time as compared to cases where the deterioration of the single-combustion-chamber main catalyst is determined based solely on a signal from the single-combustion-chamber downstream oxygen detector. One single-combustion-chamber main catalyst can therefore be used for a longer time.

[0018] Furthermore, the actual state of purification by the single-combustion-chamber main catalyst may be described based on a signal from the single-combustion-chamber upstream oxygen detector and a signal from the single-combustion-chamber downstream oxygen detector. The precision of the combustion control can therefore be improved when control of an amount of fuel supplied to the combustion chamber (hereinafter, combustion control) is carried out based on signals from the two oxygen detectors. This makes it possible to restrain the progress of the deterioration of the single-combustion-chamber main catalyst. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time.

Due to this, the initial performance of the vehicle in connection with the exhaust gas purification can be maintained for a longer time without increasing the size of the single-combustion-chamber main catalyst. Furthermore, the initial performance of the vehicle in connection with the exhaust gas purification can be maintained for a longer time while the supporting structure is simplified.

[0019] Because of the above, in the vehicle including the single-cylinder four-stroke engine unit of the present teaching, the purification performance of purifying the exhaust gas by the catalyst can be improved and the initial performance of the vehicle regarding the exhaust purification is maintained for a longer time, while the supporting structure is simplified.

[0020] In the vehicle of the present teaching, prefera-

bly, the engine main body includes a crankcase member including a crankshaft extending in a left-right direction of the vehicle, the one combustion chamber of the cylinder member is at least partially provided frontward of a central axis of the crankshaft in a front-rear direction of the vehicle, the discharge port of the single-combustion-chamber silencer is provided rearward of the central axis of the crankshaft in the front-rear direction of the vehicle, and the single-combustion-chamber main catalyst is at least partially provided frontward of the central axis of the crankshaft in the front-rear direction of the vehicle.

[0021] According to this arrangement, the combustion chamber of the cylinder member is at least partially provided frontward of the central axis of the crankshaft. The discharge port of the single-combustion-chamber silencer is positioned rearward of the central axis of the crankshaft. The single-combustion-chamber main catalyst is provided between the combustion chamber and the discharge port. The single-combustion-chamber main catalyst is at least partially provided frontward of the central axis of the crankshaft. The single-combustion-chamber main catalyst is therefore positioned to be closer to the combustion chamber. Due to this, the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be further improved.

[0022] The vehicle of the present teaching may be arranged such that the engine main body includes a crankcase member including a crankshaft extending in a left-right direction of the vehicle, the one combustion chamber of the cylinder member is at least partially provided frontward of a central axis of the crankshaft in a front-rear direction of the vehicle, the discharge port of the single-combustion-chamber silencer is provided rearward of the central axis of the crankshaft in the front-rear direction of the vehicle, and the single-combustion-chamber main catalyst is at least partially provided rearward of the central axis of the crankshaft in the front-rear direction of the vehicle.

[0023] In the vehicle of the present teaching, preferably, the engine main body includes a crankcase member including a crankshaft extending in a left-right direction of the vehicle, the cylinder member of the engine main body has a cylinder hole in which a piston is provided, the one combustion chamber of the cylinder member is at least partially provided frontward of a central axis of the crankshaft in a front-rear direction of the vehicle, the discharge port of the single-combustion-chamber silencer is provided rearward of the central axis of the crankshaft in the front-rear direction of the vehicle, and when the vehicle is viewed in the left-right direction, the single-combustion-chamber main catalyst is at least partially in front in the front-rear direction of a linear line which is orthogonal to the central axis of the cylinder hole and orthogonal to the central axis of the crankshaft.

[0024] According to this arrangement, the combustion chamber of the cylinder member is at least partially provided frontward of the central axis of the crankshaft. The discharge port of the single-combustion-chamber silencer

is positioned rearward of the central axis of the crankshaft. The single-combustion-chamber main catalyst is provided between the combustion chamber and the discharge port. The central axis of the cylinder hole passes the central axis of the crankshaft and the combustion chamber. The central axis of the cylinder hole extends upward, frontward and upward, or frontward from the crankshaft. It is assumed that a linear line which is orthogonal to the central axis of the cylinder hole and orthogonal to the central axis of the crankshaft is a linear line L. The linear line L extends frontward, frontward and downward, or downward from the crankshaft. When viewed in the left-right direction, the single-combustion-chamber main catalyst is at least partially positioned in front of the linear line L. The single-combustion-chamber main catalyst is therefore positioned to be closer to the combustion chamber. Due to this, the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be further improved.

[0025] The vehicle of the present teaching may be arranged such that the engine main body includes a crankcase member including a crankshaft extending in a left-right direction of the vehicle, the cylinder member of the engine main body has a cylinder hole in which a piston is provided, the one combustion chamber of the cylinder member is at least partially provided frontward of a central axis of the crankshaft in a front-rear direction of the vehicle, the discharge port of the single-combustion-chamber silencer is provided rearward of the central axis of the crankshaft in the front-rear direction of the vehicle, and when the vehicle is viewed in the left-right direction, the single-combustion-chamber main catalyst is at least partially behind in the front-rear direction of a linear line which is orthogonal to the central axis of the cylinder hole and orthogonal to the central axis of the crankshaft.

[0026] In the vehicle of the present teaching, preferably, the single-combustion-chamber main catalyst is provided so that a path length from the one combustion chamber to the upstream end of the single-combustion-chamber main catalyst is shorter than a path length from the downstream end of the single-combustion-chamber main catalyst to the discharge port.

[0027] According to this arrangement, the path length from the one combustion chamber to the upstream end of the single-combustion-chamber main catalyst is shorter than the path length from the downstream end of the single-combustion-chamber main catalyst to the discharge port. It is therefore possible to provide the single-combustion-chamber main catalyst at a position closer to the combustion chamber. Due to this, the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be further improved.

[0028] In the vehicle of the present teaching, preferably, the single-combustion-chamber main catalyst is provided so that a path length from the one combustion chamber to the upstream end of the single-combustion-chamber main catalyst is shorter than a path length from

the downstream end of the single-combustion-chamber main catalyst to the downstream end of the single-combustion-chamber exhaust pipe.

[0029] According to this arrangement, the path length from the one combustion chamber to the upstream end of the single-combustion-chamber main catalyst is shorter than the path length from the downstream end of the single-combustion-chamber main catalyst to the downstream end of the single-combustion-chamber exhaust pipe. It is therefore possible to provide the single-combustion-chamber main catalyst at a position closer to the combustion chamber. Due to this, the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be further improved.

[0030] The vehicle of the present teaching may be arranged such that the single-combustion-chamber main catalyst is provided so that a path length from the one combustion chamber to the upstream end of the single-combustion-chamber main catalyst is longer than a path length from the downstream end of the single-combustion-chamber main catalyst to the downstream end of the single-combustion-chamber exhaust pipe.

[0031] The vehicle of the present teaching may be arranged such that the single-combustion-chamber upstream oxygen detector is provided so that a path length from the one combustion chamber to the upstream end of the single-combustion-chamber upstream oxygen detector is shorter than a path length from the single-combustion-chamber upstream oxygen detector to the upstream end of the single-combustion-chamber main catalyst.

[0032] According to this arrangement, the path length from the one combustion chamber to the single-combustion-chamber upstream oxygen detector is shorter than the path length from the single-combustion-chamber upstream oxygen detector to the upstream end of the single-combustion-chamber main catalyst. The single-combustion-chamber upstream oxygen detector is therefore positioned to be closer to the combustion chamber. The temperature of the single-combustion-chamber upstream oxygen detector can therefore be rapidly increased to the activation temperature when the engine starts. The detection accuracy of the single-combustion-chamber upstream oxygen detector can therefore be improved. Due to this, the combustion control based on a signal from the single-combustion-chamber upstream oxygen detector can be more precisely carried out. Therefore the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be improved. Moreover, because of the improvement in the precision of the combustion control, the progress of the deterioration of the single-combustion-chamber main catalyst can be restrained. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0033] The vehicle of the present teaching may be arranged such that the single-combustion-chamber up-

stream oxygen detector is provided so that a path length from the one combustion chamber to the upstream end of the single-combustion-chamber upstream oxygen detector is longer than a path length from the single-combustion-chamber upstream oxygen detector to the upstream end of the single-combustion-chamber main catalyst.

[0034] According to this arrangement, the path length from the one combustion chamber to the single-combustion-chamber upstream oxygen detector is longer than the path length from the single-combustion-chamber upstream oxygen detector to the upstream end of the single-combustion-chamber main catalyst. The single-combustion-chamber upstream oxygen detector is therefore positioned to be close to the single-combustion-chamber main catalyst. Due to this, the oxygen density of the exhaust gas flowing into the single-combustion-chamber main catalyst can be more precisely detected. Due to this, the combustion control based on a signal from the single-combustion-chamber upstream oxygen detector can therefore be more precisely carried out. Therefore the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be further improved. Moreover, because of the improvement in the precision of the combustion control, the progress of the deterioration of the single-combustion-chamber main catalyst can be restrained. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0035] In the vehicle of the present teaching, preferably, the single-combustion-chamber exhaust pipe includes a catalyst-provided passage member in which the single-combustion-chamber main catalyst is provided and an upstream passage member connected to an upstream end of the catalyst-provided passage member, and in at least a part of the upstream passage member, a cross-sectional area of the upstream passage member cut along a direction orthogonal to the flow direction of the exhaust gas is smaller than a cross-sectional area of the catalyst-provided passage member cut along the direction orthogonal to the flow direction of the exhaust gas.

[0036] According to this arrangement, the single-combustion-chamber exhaust pipe includes the catalyst-provided passage member and the upstream passage member. The single-combustion-chamber main catalyst is provided in the catalyst-provided passage member. The upstream passage member is connected to the upstream end of the catalyst-provided passage member. It is assumed that the cross-sectional area of the catalyst-provided passage member cut along the direction orthogonal to the flow direction of the exhaust gas is S_a . In at least a part of the upstream passage member, the cross-sectional area of the upstream passage member cut along the direction orthogonal to the flow direction of the exhaust gas is smaller than the area S_a . It is therefore possible to use a catalyst with a large cross-sectional area as the single-combustion-chamber main catalyst. Due to this, the purification performance of purifying the

exhaust gas by the single-combustion-chamber main catalyst can be improved.

[0037] In the vehicle of the present teaching, preferably, at least a part of the single-combustion-chamber exhaust pipe, which is upstream in the flow direction of the single-combustion-chamber main catalyst, is formed by a multi-walled pipe which includes an inner pipe and at least one outer pipe covering the inner pipe.

[0038] According to this arrangement, at least a part of the single-combustion-chamber exhaust pipe, which is upstream of the single-combustion-chamber main catalyst, is formed by a multi-walled pipe. The multi-walled pipe includes an inner pipe and at least one outer pipe which covers the inner pipe. The multi-walled pipe is able to restrain the decrease in the temperature of the exhaust gas. The temperature of the single-combustion-chamber upstream oxygen detector can therefore be rapidly increased to the activation temperature when the engine starts. The detection accuracy of the single-combustion-chamber upstream oxygen detector can therefore be improved. Due to this, the combustion control based on a signal from the single-combustion-chamber upstream oxygen detector can therefore be more precisely carried out. Therefore the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be further improved. Moreover, because of the improvement in the precision of the combustion control, the progress of the deterioration of the single-combustion-chamber main catalyst can be restrained. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0039] In the vehicle of the present teaching, preferably, the single-combustion-chamber exhaust pipe includes a catalyst-provided passage member in which the single-combustion-chamber main catalyst is provided, and the single-cylinder four-stroke engine unit includes a catalyst protector which at least partially covers an outer surface of the catalyst-provided passage member.

[0040] According to this arrangement, the single-combustion-chamber exhaust pipe includes the catalyst-provided passage member. The single-combustion-chamber main catalyst is provided in the catalyst-provided passage member. The outer surface of the catalyst-provided passage member is at least partially covered with the catalyst protector. The catalyst protector makes it possible to more rapidly increase the temperature of the single-combustion-chamber main catalyst. Due to this, the purification performance of purifying the exhaust gas by the single-combustion-chamber main catalyst can be improved.

[0041] In the vehicle of the present teaching, preferably, the single-cylinder four-stroke engine unit includes a single-combustion-chamber upstream sub-catalyst which is provided upstream in the flow direction of the single-combustion-chamber main catalyst in the single-combustion-chamber cylinder exhaust passage member or the single-combustion-chamber exhaust pipe and is

configured to purify the exhaust gas.

[0042] According to this arrangement, the single-combustion-chamber upstream sub-catalyst is provided in the single-combustion-chamber cylinder exhaust passage member or the single-combustion-chamber exhaust pipe. The single-combustion-chamber upstream sub-catalyst is provided upstream of the single-combustion-chamber main catalyst. The single-combustion-chamber upstream sub-catalyst therefore deteriorates more rapidly than the single-combustion-chamber main catalyst. However, even if the deterioration of the single-combustion-chamber upstream sub-catalyst reaches a predetermined level, the purification performance of purifying the exhaust gas can be maintained by the single-combustion-chamber main catalyst. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0043] The vehicle of the present teaching may be arranged such that the single-combustion-chamber upstream oxygen detector is provided upstream in the flow direction of the single-combustion-chamber upstream sub-catalyst.

[0044] According to this arrangement, the single-combustion-chamber upstream oxygen detector is provided upstream of the single-combustion-chamber upstream sub-catalyst. The single-combustion-chamber upstream oxygen detector is therefore able to detect the oxygen density of the exhaust gas flowing into the single-combustion-chamber upstream sub-catalyst. The purification performance of purifying the exhaust gas by the single-combustion-chamber upstream sub-catalyst can therefore be improved because combustion control is performed based on a signal from the single-combustion-chamber upstream oxygen detector.

[0045] In the vehicle of the present teaching, preferably, the single-cylinder four-stroke engine unit includes a single-combustion-chamber downstream sub-catalyst which is provided downstream in the flow direction of the single-combustion-chamber main catalyst in the single-combustion-chamber exhaust pipe or the single-combustion-chamber silencer and is configured to purify the exhaust gas.

[0046] According to this arrangement, the single-combustion-chamber downstream sub-catalyst is provided in the single-combustion-chamber exhaust pipe or the single-combustion-chamber silencer. The single-combustion-chamber downstream sub-catalyst is provided downstream of the single-combustion-chamber main catalyst. The single-combustion-chamber main catalyst therefore deteriorates more rapidly than the single-combustion-chamber downstream sub-catalyst. However, even if the deterioration of the single-combustion-chamber main catalyst reaches a predetermined level, the purification performance of purifying the exhaust gas can be maintained by the single-combustion-chamber downstream sub-catalyst. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0047] The vehicle of the present teaching may be arranged such that the single-combustion-chamber downstream oxygen detector is provided downstream in the flow direction of the single-combustion-chamber main catalyst and upstream in the flow direction of the single-combustion-chamber downstream sub-catalyst.

[0048] The vehicle of the present teaching may be arranged such that the single-combustion-chamber downstream oxygen detector is provided downstream in the flow direction of the single-combustion-chamber downstream sub-catalyst.

[0049] In the vehicle of the present teaching, preferably, the controller is configured to determine the purification capability of the single-combustion-chamber main catalyst based on a signal from the single-combustion-chamber downstream oxygen detector, and a notification unit is provided to perform the notification when the controller determines that the purification capability of the single-combustion-chamber main catalyst has lowered to a predetermined level.

[0050] According to this arrangement, the controller determines the purification capability of the single-combustion-chamber main catalyst based on a signal from the single-combustion-chamber downstream oxygen detector. When the controller determines that the purification capability of the catalyst has lowered to a predetermined level, the notification unit performs the notification. This makes it possible to suggest the replacement of the single-combustion-chamber main catalyst by providing information before the deterioration of the single-combustion-chamber main catalyst reaches a predetermined level. The initial performance of the vehicle in connection with the exhaust gas purification can therefore be maintained for a longer time by using multiple single-combustion-chamber main catalysts.

[0051] In the vehicle of the present teaching, preferably, the single-cylinder four-stroke engine unit includes a fuel supplier which is configured to supply fuel to the one combustion chamber, and the controller is configured to control the amount of fuel supplied to the one combustion chamber by the fuel supplier based on a signal from the single-combustion-chamber upstream oxygen detector and a signal from the single-combustion-chamber downstream oxygen detector.

[0052] The actual state of purification by the single-combustion-chamber main catalyst may be described based on a signal from the single-combustion-chamber upstream oxygen detector and a signal from the single-combustion-chamber downstream oxygen detector. Due to this, the precision of the combustion control can be improved as the combustion control is carried out based on signals from the two oxygen detectors. This makes it possible to restrain the progress of the deterioration of the single-combustion-chamber main catalyst. The initial performance of the vehicle in connection with the exhaust gas purification performance can therefore be maintained for a longer time.

[0053] The single-cylinder four-stroke engine unit of

the present teaching mounted on the vehicle includes: an engine main body including a cylinder member in which one combustion chamber and a single-combustion-chamber cylinder exhaust passage member, into which exhaust gas exhausted from the one combustion chamber flows, are formed; a single-combustion-chamber exhaust pipe connected to a downstream end of the single-combustion-chamber cylinder exhaust passage member of the engine main body; a single-combustion-chamber silencer including a discharge port exposed to the atmosphere, the silencer being connected to the single-combustion-chamber exhaust pipe to allow the exhaust gas to flow from a downstream end of the single-combustion-chamber exhaust pipe to the discharge port, and the silencer being configured to reduce noise generated by the exhaust gas; a single-combustion-chamber main catalyst provided in the single-combustion-chamber cylinder exhaust passage member or the single-combustion-chamber exhaust pipe, the single-combustion-chamber main catalyst having an upstream end provided upstream of an upstream end of the single-combustion-chamber silencer in a flow direction of the exhaust gas, and the single-combustion-chamber main catalyst being configured to purify the exhaust gas exhausted from the one combustion chamber most in an exhaust path extending from the one combustion chamber to the discharge port; a single-combustion-chamber upstream oxygen detector provided upstream of the single-combustion-chamber main catalyst in the flow direction of the exhaust gas in the single-combustion-chamber cylinder exhaust passage member or the single-combustion-chamber exhaust pipe, the single-combustion-chamber upstream oxygen detector being configured to detect oxygen density in the exhaust gas; a single-combustion-chamber downstream oxygen detector provided downstream in the flow direction of the single-combustion-chamber main catalyst in the single-combustion-chamber cylinder exhaust passage member, the single-combustion-chamber exhaust pipe, or the single-combustion-chamber silencer, the single-combustion-chamber downstream oxygen detector being configured to detect oxygen density in the exhaust gas, and a controller configured to process a signal from the single-combustion-chamber upstream oxygen detector and a signal from the single-combustion-chamber downstream oxygen detector.

[0054] According to this arrangement, effects similar to the above-described vehicle of the present teaching are achieved.

[Advantageous Effects]

[0055] According to the present teaching, in the vehicle including the single-cylinder four-stroke engine unit, the purification performance of purifying the exhaust gas by the catalyst can be improved and the initial performance of the vehicle regarding the exhaust purification can be maintained for a longer time, while the supporting struc-

ture is simplified.

[Brief Description of Drawings]

[0056]

[FIG. 1] FIG. 1 is a side view of a motorcycle related to Embodiment 1 of the present teaching.

[FIG. 2] FIG. 2 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of FIG. 1.

[FIG. 3] FIG. 3 is a bottom view of FIG. 2.

[FIG. 4] FIG. 4 is a control block diagram of the motorcycle of FIG. 1.

[FIG. 5] FIG. 5 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 1.

[FIG. 6] FIG. 6 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 1-1 of Embodiment 1.

[FIG. 7] FIG. 7 is a bottom view of FIG. 6.

[FIG. 8] FIG. 8 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 6.

[FIG. 9] FIG. 9 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 1-2 of Embodiment 1.

[FIG. 10] FIG. 10 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 9.

[FIG. 11] FIG. 11 is a side view of a motorcycle related to Embodiment 2 of the present teaching.

[FIG. 12] FIG. 12 is a bottom view of FIG. 11.

[FIG. 13] FIG. 13 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of FIG. 11.

[FIG. 14] FIG. 14 is a bottom view of FIG. 13.

[FIG. 15] FIG. 15 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 11.

[FIG. 16] FIG. 16 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 2-1 of Embodiment 2.

[FIG. 17] FIG. 17 is a bottom view of FIG. 16.

[FIG. 18] FIG. 18 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 16.

[FIG. 19] FIG. 19 is a side view of a motorcycle related to Embodiment 3 of the present teaching.

[FIG. 20] FIG. 20 is a bottom view of FIG. 19.

[FIG. 21] FIG. 21 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of FIG. 19.

[FIG. 22] FIG. 22 is a bottom view of FIG. 21.

[FIG. 23] FIG. 23 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 19.

[FIG. 24] FIG. 24 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 3-1 of Embodiment 3.

[FIG. 25] FIG. 25 is a bottom view of FIG. 24.

[FIG. 26] FIG. 26 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 24.

[FIG. 27] FIG. 27 is a side view of a motorcycle related to Embodiment 4 of the present teaching.

[FIG. 28] FIG. 28 is a bottom view of FIG. 27.

[FIG. 29] FIG. 29 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of FIG. 27.

[FIG. 30] FIG. 30 is a bottom view of FIG. 29.

[FIG. 31] FIG. 31 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 27.

[FIG. 32] FIG. 32 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 4-1 of Embodiment 4.

[FIG. 33] FIG. 33 is a bottom view of FIG. 32.

[FIG. 34] FIG. 34 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of FIG. 32.

[FIG. 35] FIG. 35 is a schematic view around a silencer of a motorcycle related to another embodiment of the present teaching.

[FIG. 36] FIG. 36 is a cross-section of a silencer of a motorcycle related to another embodiment of the present teaching.

[FIG. 37] FIG. 37 is a cross-section of a silencer of a motorcycle related to another embodiment of the present teaching.

[FIG. 38] FIG. 38 is a cross-section of a silencer of a motorcycle related to another embodiment of the present teaching.

[FIG. 39] FIG. 39 is a schematic diagram of an engine main body and an exhaust system of the motorcycle of another embodiment of the present teaching.

[FIG. 40] FIG. 40 is a schematic view of an engine main body of a motorcycle related to another embodiment of the present teaching.

[FIG. 41] FIG. 41 is a partial cross-section of an exhaust pipe used in the motorcycle of another embodiment of the present teaching.

[FIG. 42] FIG. 42 is a partial enlarged view of the side view of the motorcycle related to another embodiment of the present teaching.

[Description of Embodiments]

[0057] The following describes an embodiment of the present teaching with reference to figures. Described below is an example in which a vehicle of the present teaching is applied to a motorcycle. Hereinafter, frontward, rearward, leftward, and rightward indicate frontward,

rearward, leftward, and rightward of a rider of the motorcycle. In this regard, it is assumed that the motorcycle is provided on a horizontal plane. The signs F, Re, L, and R in the figures indicate frontward, rearward, leftward, and rightward, respectively.

(Embodiment 1)

[Overall Structure]

[0058] FIG. 1 is a side view of a motorcycle related to Embodiment 1 of the present teaching. FIG. 2 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Embodiment 1. FIG. 3 is a bottom view showing the state in which the vehicle body cover, etc. have been removed from the motorcycle of Embodiment 1. FIG. 5 is a schematic diagram of an engine and an exhaust system of the motorcycle of Embodiment 1.

[0059] A vehicle of Embodiment 1 is a so-called underbone-type motorcycle 1. As shown in FIG. 2, the motorcycle 1 is provided with a vehicle body frame 2. The vehicle body frame 2 includes a head pipe 3, a main frame 4, and a seat rail 5. The main frame 4 extends rearward and downward from the head pipe 3. The seat rail 5 extends rearward and upward from an intermediate portion of the main frame 4.

[0060] A steering shaft is rotatably inserted into the head pipe 3. A handlebar 7 is provided at an upper part of the steering shaft (see FIG. 1). A display (not illustrated) is provided in the vicinity of the handlebar 7. The display is configured to display vehicle speed, engine rotation speed, warnings, and the like.

[0061] Paired left and right front forks 6 are supported at a lower part of the steering shaft. An axle shaft 8a is fixed to a lower end portion of each front fork 6. A front wheel 8 is rotatably attached to the axle shaft 8a. A fender 10 is provided above and behind the front wheel 8.

[0062] The seat rail 5 supports a seat 9 (see FIG. 1). As shown in FIG. 2, the seat rail 5 is connected to the upper end of paired left and right rear shock absorbers 13. The lower end of the rear shock absorbers 13 is supported by rear portions of paired left and right rear arms 14. Front portions of the rear arms 14 are connected with the vehicle body frame 2 via pivot shafts 14a. The rear arms 14 are swingable about the pivot shafts 14a in an up-down direction. A rear wheel 15 is supported by rear portions of the rear arms 14.

[0063] As shown in FIG. 2, an engine main body 20 is provided below the main frame 4. The engine main body 20 is supported by the vehicle body frame 2. To be specific, an upper portion of the engine main body 20 is fixed, by a bolt 4b, to a bracket 4a of the main frame 4. To be more specific, an upper front portion of a subsequently-described crankcase member 21 of the engine main body 20 is fixed to the bracket 4a. A rear portion of the engine main body 20 is also fixed to another bracket of the vehicle body frame 2. An air cleaner 32 is provided at a

location which is below the main frame 4 and above the engine main body 20.

[0064] As shown in FIG. 1, the motorcycle 1 is provided with a vehicle body cover 11 which covers the vehicle body frame 2, etc. The vehicle body cover 11 includes a main cover 16 and a front cover 17. The front cover 17 is provided in front of the head pipe 3. The main cover 16 is provided behind the head pipe 3. The main cover 16 covers the main frame 4 and the seat rail 5. The main cover 16 and the front cover 17 covers left and right portions of a front portion of the engine main body 20. The front cover 17 covers left and right portions of the air cleaner 32.

[0065] The main frame 4 and the vehicle body cover 11 are low in height at portions between the seat 9 and the head pipe 3. For this reason, when viewed in a vehicle left-right direction, the underbone-type motorcycle 1 has a recess 12 at a location which is behind the head pipe 3, in front of the seat 9, and above the main frame 4. This recess 12 allows a rider to easily straddle the motorcycle 1.

[0066] The motorcycle 1 includes a single-cylinder four-stroke engine unit 19. The single-cylinder four-stroke engine unit 19 includes the engine main body 20, the air cleaner 32, an intake pipe 33, an exhaust pipe 34, a silencer 35, a main catalyst 39 (a single-combustion-chamber main catalyst), an upstream oxygen detector 36 (a single-combustion-chamber upstream oxygen detector), and a downstream oxygen detector 37 (a single-combustion-chamber downstream oxygen detector). As detailed later, the main catalyst 39 is provided in the exhaust pipe 34. The main catalyst 39 is configured to purify exhaust gas flowing in the exhaust pipe 34. In the exhaust pipe 34, the upstream oxygen detector 36 is provided upstream of the main catalyst 39. In the exhaust pipe 34, the downstream oxygen detector 37 is provided downstream of the main catalyst 39. The upstream oxygen detector 36 and the downstream oxygen detector 37 are configured to detect the oxygen amount or the oxygen density in the exhaust gas flowing in the exhaust pipe 34.

[0067] The engine main body 20 is a single-cylinder four-stroke engine. As shown in FIG. 2 and FIG. 3, the engine main body 20 includes the crankcase member 21 and a cylinder member 22. The cylinder member 22 extends frontward from the crankcase member 21.

[0068] The crankcase member 21 includes a crankcase main body 23. The crankcase member 21 includes a crankshaft 27, a transmission mechanism, and the like which are housed in the crankcase main body 23. Hereinafter, the central axis Cr1 of the crankshaft 27 is referred to as a crankshaft axis Cr1. The crankshaft axis Cr1 extends in the left-right direction. Lubricating oil is stored in the crankcase main body 23. The oil is conveyed by an oil pump (not illustrated) and is circulated in the engine main body 20.

[0069] The cylinder member 22 includes a cylinder body 24, a cylinder head 25, a head cover 26, and components housed in the members 24 to 26. As shown in

FIG. 2, the cylinder body 24 is connected to a front portion of the crankcase main body 23. The cylinder head 25 is connected to a front portion of the cylinder body 24. The head cover 26 is connected to a front portion of the cylinder head 25.

[0070] As shown in FIG. 5, a cylinder hole 24a is made in the cylinder body 24. The cylinder hole 24a houses a piston 28 so that the piston 28 is able to reciprocate. The piston 28 is connected to the crankshaft 27 via a connecting rod. Hereinafter, the central axis Cy1 of the cylinder hole 24a is referred to as a cylinder axis Cy1. As shown in FIG. 2, the engine main body 20 is disposed so that the cylinder axis Cy1 extends in the front-rear direction (horizontal direction). To be more specific, the direction in which the cylinder axis Cy1 extends from the crankcase member 21 to the cylinder member 22 is frontward and upward. The angle of inclination of the cylinder axis Cy1 with respect to the horizontal direction is 0 degrees or greater and 45 degrees or less.

[0071] As shown in FIG. 5, one combustion chamber 29 is formed in the cylinder member 22. The combustion chamber 29 is formed by an inner surface of the cylinder hole 24a of the cylinder body 24, the cylinder head 25, and the piston 28. In other words, a part of the combustion chamber 29 is formed by the inner surface of the cylinder hole 24a. A leading end portion of an ignition plug (not illustrated) is provided in the combustion chamber 29. The ignition plug ignites a gas mixture of fuel and air in the combustion chamber 29. As shown in FIG. 2, the combustion chamber 29 is positioned frontward of the crankshaft axis Cr1. In other words, it is assumed that a linear line which passes the crankshaft axis Cr1 and is in parallel to the up-down direction is L1. When viewed in the left-right direction, the combustion chamber 29 is positioned in front of the linear line L1.

[0072] As shown in FIG. 5, a cylinder intake passage member 30 and a cylinder exhaust passage member 31 (a single-combustion-chamber cylinder exhaust passage member) are formed in the cylinder head 25. In this specification, the passage member is a structure forming a space (path) through which gas or the like passes. In the cylinder head 25, an intake port 30a and an exhaust port 31a are formed in a wall portion forming the combustion chamber 29. The cylinder intake passage member 30 extends from the intake port 30a to an inlet formed in the outer surface (upper surface) of the cylinder head 25. The cylinder exhaust passage member 31 extends from the exhaust port 31a to an outlet formed in the outer surface (lower surface) of the cylinder head 25. Air passes through the inside of the cylinder intake passage member 30 and is then supplied to the combustion chamber 29. Exhaust gas exhausted from the combustion chamber 29 passes through the cylinder exhaust passage member 31.

[0073] An intake valve V1 is provided in the cylinder intake passage member 30. An exhaust valve V2 is provided in the cylinder exhaust passage member 31. The intake valve V1 and the exhaust valve V2 are activated

by a valve operating mechanism (not illustrated) which is linked with the crankshaft 27. The intake port 30a is opened and closed by the movement of the intake valve V1. The exhaust port 31a is opened and closed by the movement of the exhaust valve V2. The intake pipe 33 is connected to an end portion (inlet) of the cylinder intake passage member 30. The exhaust pipe 34 is connected to an end portion (outlet) of the cylinder exhaust passage member 31. The path length of the cylinder exhaust passage member 31 is referred to as a1.

[0074] An injector 48 (see FIG. 4) is provided in the cylinder intake passage member 30 or the intake pipe 33. The injector 48 is provided to supply fuel to the combustion chamber 29. To be more specific, the injector 48 injects fuel in the cylinder intake passage member 30 or the intake pipe 33. The injector 48 may be provided to inject fuel in the combustion chamber 29. A throttle valve (not illustrated) is provided in the intake pipe 33.

[0075] As shown in FIG. 2, when viewed in the left-right direction, the intake pipe 33 extends upward from the upper surface of the cylinder head 25. The intake pipe 33 is connected to the air cleaner 32. The air cleaner 32 is configured to purify the air supplied to the engine main body 20. The air purified while passing through the air cleaner 32 is supplied to the engine main body 20 via the intake pipe 33.

[0076] The structure of the exhaust system will be detailed later.

[0077] Subsequently, control of the single-cylinder four-stroke engine unit 19 will be described. FIG. 4 is a control block diagram of the motorcycle of Embodiment 1.

[0078] As shown in FIG. 4, the single-cylinder four-stroke engine unit 19 includes an engine rotation speed sensor 46a, a throttle position sensor 46b, an engine temperature sensor 46c, an intake pressure sensor 46d, and an intake temperature sensor 46e. The engine rotation speed sensor 46a detects the rotation speed of the crankshaft 27, i.e., the engine rotation speed. The throttle position sensor 46b detects the opening degree of a throttle valve (not illustrated) (hereinafter, throttle opening degree). The engine temperature sensor 46c detects the temperature of the engine main body. The intake pressure sensor 46d detects the pressure (intake pressure) in the intake pipe 33. The intake temperature sensor 46e detects the temperature (intake temperature) in the intake pipe 33.

[0079] The single-cylinder four-stroke engine unit 19 includes an electronic control unit (ECU) 45 which is configured to control the engine main body 20. The electronic control unit 45 is equivalent to a controller of the present teaching. The electronic control unit 45 is connected to sensors such as the engine rotation speed sensor 46a, the engine temperature sensor 46c, the throttle position sensor 46b, the intake pressure sensor 46d, the intake temperature sensor 46e, and a vehicle speed sensor. The electronic control unit 45 is further connected to an ignition coil 47, the injector 48, a fuel pump 49, a display (not illustrated), and the like. The electronic control unit

45 includes a control unit 45a and an activation instruction unit 45b. The activation instruction unit 45b includes an ignition driving circuit 45c, an injector driving circuit 45d, and a pump driving circuit 45e.

[0080] Upon receiving a signal from the control unit 45a, the ignition driving circuit 45c, the injector driving circuit 45d, and the pump driving circuit 45e drive the ignition coil 47, the injector 48, and the fuel pump 49, respectively. As the ignition coil 47 is driven, spark discharge occurs at the ignition plug and the gas mixture is ignited. The fuel pump 49 is connected to the injector 48 via a fuel hose. As the fuel pump 49 is driven, fuel in a fuel tank (not illustrated) is pressure-fed to the injector 48.

[0081] The control unit 45a is a microcomputer, for example. Based on a signal from the upstream oxygen detector 36, a signal from the engine rotation speed sensor 46a or the like, the control unit 45a controls the ignition driving circuit 45c, the injector driving circuit 45d, and the pump driving circuit 45e. The control unit 45a controls an ignition timing by controlling the ignition driving circuit 45c. The control unit 45a controls a fuel injection amount by controlling the injector driving circuit 45d and the pump driving circuit 45e.

[0082] To improve the purification efficiency of the main catalyst 39 and the combustion efficiency, the air-fuel ratio of the air-fuel mixture in the combustion chamber 29 is preferably equal to the theoretical air-fuel ratio (stoichiometry). The control unit 45a increases or decreases the fuel injection amount according to need.

[0083] The following describes an example of control of the fuel injection amount by the control unit 45a.

To begin with, the control unit 45a calculates a basic fuel injection amount based on signals from the engine rotation speed sensor 46a, the throttle position sensor 46b, the engine temperature sensor 46c, and the intake pressure sensor 46d. To be more specific, an intake air amount is calculated by using a map in which a throttle opening degree and an engine rotation speed are associated with an intake air amount and a map in which an intake pressure and an engine rotation speed are associated with an intake air amount. Based on the intake air amount calculated from the maps, the basic fuel injection amount with which a target air-fuel ratio is achieved is determined. When the throttle opening degree is small, the map in which an intake pressure and an engine rotation speed are associated with an intake air amount is used. When the throttle opening degree is great, the map in which a throttle opening degree and an engine rotation speed are associated with an intake air amount is used.

[0084] In addition to the above, based on a signal from the upstream oxygen detector 36, the control unit 45a calculates a feedback correction value for correcting the basic fuel injection amount. To be more specific, based on a signal from the upstream oxygen detector 36, whether or not the air-fuel mixture is lean or rich is determined. The term "rich" indicates a state in which fuel is excessive as compared to the theoretical air-fuel ratio. The term "lean" indicates a state in which air is excessive as com-

pared to the theoretical air-fuel ratio. When determining that the air-fuel mixture is lean, the control unit 45a calculates the feedback correction value so that the next fuel injection amount is increased. In the meanwhile, when determining that the air-fuel mixture is rich, the control unit 45a calculates the feedback correction value so that the next fuel injection amount is decreased.

[0085] In addition to the above, the control unit 45a calculates a correction value for correcting the basic fuel injection amount, based on the engine temperature, the outside temperature, the outside atmosphere, or the like. Furthermore, the control unit 45a calculates a correction value in accordance with transient characteristics at acceleration and deceleration.

[0086] The control unit 45a calculates the fuel injection amount based on the basic fuel injection amount and the correction values such as the feedback correction value. Based on the fuel injection amount calculated in this way, the fuel pump 49 and the injector 48 are driven. As such, the electronic control unit 45 (controller) processes a signal from the upstream oxygen detector 36. Furthermore, the electronic control unit 45 (controller) performs combustion control based on a signal from the upstream oxygen detector 36.

[0087] The electronic control unit 45 (controller) processes a signal from the downstream oxygen detector 37. The electronic control unit 45 (controller) determines the purification capability of the main catalyst 39 based on a signal from the downstream oxygen detector 37. The following describes an example of how the purification capability of the main catalyst 39 is specifically determined based on a signal from the downstream oxygen detector 37.

[0088] To begin with, a fuel injection amount is controlled so that the gas mixture repeatedly alternates between rich and lean. Then the delay of a change in a signal from the downstream oxygen detector 37 from a change in the fuel injection amount is detected. When the change in the signal from the downstream oxygen detector 37 is significantly delayed, it is determined that the purification capability of the main catalyst 39 is lower than a predetermined level. In this case, a signal is sent from the electronic control unit 45 to the display. A warning lamp (not illustrated) of the display is turned on. This prompts the rider to replace the main catalyst 39.

[0089] As such, the purification capability of the main catalyst 39 can be determined by means of a signal from the downstream oxygen detector 37 provided downstream of the main catalyst 39. This makes it possible to suggest the replacement of the main catalyst 39 by providing information before the deterioration of the main catalyst 39 reaches a predetermined level. The initial performance of the motorcycle 1 in connection with the exhaust gas purification can therefore be maintained for a longer time by using multiple main catalysts.

[Structure of Exhaust System]

[0090] The following describes an exhaust system of the motorcycle 1 of Embodiment 1. In the description of the exhaust system in this specification, the term "upstream" indicates the upstream direction in which exhaust gas flows. The term "downstream" indicates the downstream direction in which exhaust gas flows. Furthermore, in the description of the exhaust system in this specification, the term "path direction" indicates the direction in which exhaust gas flows.

[0091] As described above, the single-cylinder four-stroke engine unit 19 includes the engine main body 20, the exhaust pipe 34, the silencer 35, the main catalyst 39, the upstream oxygen detector 36, and the downstream oxygen detector 37. The silencer 35 is provided with a discharge port 35e which is exposed to the atmosphere. The path extending from the combustion chamber 29 to the discharge port 35e is referred to as an exhaust path 41 (see FIG. 5). The exhaust path 41 is formed by the cylinder exhaust passage member 31, the exhaust pipe 34, and the silencer 35. The exhaust path 41 is a space through which exhaust gas passes.

[0092] As shown in FIG. 5, the upstream end portion of the exhaust pipe 34 is connected to the cylinder exhaust passage member 31. The downstream end portion of the exhaust pipe 34 is connected to the silencer 35. A catalyst unit 38 is provided in the middle of the exhaust pipe 34. A part of the exhaust pipe 34, which is upstream of the catalyst unit 38, is referred to as an upstream exhaust pipe 34a. A part of the exhaust pipe 34, which is downstream of the catalyst unit 38, is referred to as a downstream exhaust pipe 34b. While FIG. 5 depicts the exhaust pipe 34 as a linear pipe for simplification, the exhaust pipe 34 is not a linear pipe.

[0093] As shown in FIG. 3, the exhaust pipe 34 is provided on the right side of the motorcycle 1. As shown in FIG. 2, a part of the exhaust pipe 34 is positioned below the crankshaft axis Cr1. The exhaust pipe 34 has two bended portions. The upstream one of the two bended portions is simply referred to as an upstream bended portion. The downstream one of the two bended portions is simply referred to as a downstream bended portion. When viewed in the left-right direction, the upstream bended portion changes the flow direction of the exhaust gas from a direction along the up-down direction to a direction along the front-rear direction. To be more specific, when viewed in the left-right direction, the bended portion changes the flow direction of the exhaust gas from downward to rearward and upward. When viewed in the left-right direction, the downstream bended portion changes the flow direction of the exhaust gas from rearward and upward to rearward. A part which is slightly downstream of the downstream bended portion is positioned below the crankshaft axis Cr1. The main catalyst 39 is provided between the two bended portions.

[0094] The exhaust gas exhausted from the downstream end of the exhaust pipe 34 flows into the silencer

35. The silencer 35 is connected to the exhaust pipe 34. The silencer 35 is configured to restrain pulsation in the exhaust gas. With this, the silencer 35 makes it possible to restrain the volume of the sound (exhaust sound) generated by the exhaust gas. Multiple expansion chambers and multiple pipes connecting the expansion chambers with one another are provided inside the silencer 35. The downstream end portion of the exhaust pipe 34 is provided inside an expansion chamber of the silencer 35. The discharge port 35e exposed to the atmosphere is provided at the downstream end of the silencer 35. As shown in FIG. 5, the path length of the exhaust path extending from the downstream end of the exhaust pipe 34 to the discharge port 35e is referred to as e1. The path length of the expansion chamber in the silencer 35 is the length of the path which connects the center of the inflow port of the expansion chamber to the center of the outflow port of the expansion chamber in the shortest distance. The exhaust gas having passed the silencer 35 is discharged to the atmosphere via the discharge port 35e. As shown in FIG. 2, the discharge port 35e is positioned rearward of the crankshaft axis Cr1.

[0095] The main catalyst 39 is provided in the exhaust pipe 34. The upstream end of the main catalyst 39 is provided upstream of the upstream end 35a of the silencer 35. The catalyst unit 38 includes a hollow cylindrical casing 40 and the main catalyst 39. The upstream end of the casing 40 is connected to the upstream exhaust pipe 34a. The downstream end of the casing 40 is connected to the downstream exhaust pipe 34b. The casing 40 forms a part of the exhaust pipe 34. The main catalyst 39 is fixed to the inside of the casing 40. The exhaust gas is purified when passing through the main catalyst 39. All exhaust gas exhausted from the exhaust port 31a of the combustion chamber 29 passes through the main catalyst 39. The main catalyst 39 purifies the exhaust gas exhausted from the combustion chamber 29 most in the exhaust path 41.

[0096] The main catalyst 39 is a so-called three-way catalyst. The three-way catalyst removes three substances in exhaust gas, namely hydrocarbon, carbon monoxide, and nitrogen oxide, by oxidation or reduction. The three-way catalyst is a type of oxidation-reduction catalyst. The main catalyst 39 includes a base and catalytic materials attached to the surface of the base. The catalytic materials are formed of a carrier and noble metal. The carrier is provided between the noble metal and the base. The carrier supports the noble metal. This noble metal purifies the exhaust gas. Examples of the noble metal include platinum, palladium, and rhodium which remove hydrocarbon, carbon monoxide, and nitrogen oxide, respectively.

[0097] The main catalyst 39 has a porous structure. The porous structure implies a structure in which many pores are formed cross-sectionally vertical to the path direction of the exhaust path 41. An example of a porous structure is a honeycomb structure. In the main catalyst 39, pores which are sufficiently narrower than the width

of the path in the upstream exhaust pipe 34a are formed.

[0098] The main catalyst 39 may be a metal-base catalyst or a ceramic-base catalyst. The metal-base catalyst is a catalyst in which the base is made of metal. The ceramic-base catalyst is a catalyst in which the base is made of ceramic. The base of the metal-base catalyst is formed, for example, by alternately stacking metal corrugated plates and metal flat plates and winding them. The base of the ceramic-base catalyst is, for example, a honeycomb structured body.

[0099] As shown in FIG. 5, the length of the main catalyst 39 in the path direction is referred to as $c1$. Furthermore, the maximum width of the main catalyst 39 in the direction vertical to the path direction is referred to as $w1$. The length $c1$ of the main catalyst 39 is longer than the maximum width $w1$ of the main catalyst 39. The cross-sectional shape of the main catalyst 39 in the direction orthogonal to the path direction is, for example, circular. The cross-sectional shape may be arranged such that the length in the up-down direction is longer than the length in the left-right direction.

[0100] As shown in FIG. 5, the casing 40 includes a catalyst-provided passage member 40b, an upstream passage member 40a, and a downstream passage member 40c. The main catalyst 39 is provided in the catalyst-provided passage member 40b. In the path direction, the upstream end and the downstream end of the catalyst-provided passage member 40b are respectively at the same positions as the upstream end and the downstream end of the main catalyst 39. The cross-sectional area of the catalyst-provided passage member 40b cut along the direction orthogonal to the path direction is substantially constant in the path direction. The upstream passage member 40a is connected to the upstream end of the catalyst-provided passage member 40b. The downstream passage member 40c is connected to the upstream end of the catalyst-provided passage member 40b.

[0101] The upstream passage member 40a is at least partially tapered. The tapered part increases its inner diameter toward the downstream side. The downstream passage member 40c is at least partially tapered. The tapered part decreases its inner diameter toward the downstream side. The cross-sectional area of the catalyst-provided passage member 40b cut along the direction orthogonal to the path direction is referred to as $S1$. In at least a part of the upstream passage member 40a, the cross-sectional area of the upstream passage member 40a cut along the direction orthogonal to the path direction is smaller than the area $S1$. The at least part of the upstream passage member 40a includes the upstream end of the upstream passage member 40a. In at least a part of the downstream passage member 40c, the cross-sectional area of the downstream passage member 40c cut along the direction orthogonal to the path direction is smaller than the area $S1$. The at least part of the downstream passage member 40c includes the downstream end of the downstream passage mem-

ber 40c.

[0102] As shown in FIG. 2 and FIG. 3, the main catalyst 39 is provided frontward of the crankshaft axis $Cr1$. In other words, when viewed in the left-right direction, the main catalyst 39 is provided in front of the linear line $L1$. As described above, the linear line $L1$ is a linear line which passes the crankshaft axis $Cr1$ and is in parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 39 is positioned in front of (below) the cylinder axis $Cy1$.

[0103] As shown in FIG. 2, it is assumed that a linear line which is orthogonal to the cylinder axis $Cy1$ and orthogonal to the crankshaft axis $Cr1$ is $L2$. When viewed in the left-right direction, the main catalyst 39 is positioned in front of the linear line $L2$.

[0104] As shown in FIG. 5, the path length from the upstream end of the exhaust pipe 34 to the upstream end of the main catalyst 39 is referred to as $b1$. The path length $b1$ is a path length of a passage member formed by the upstream exhaust pipe 34a and the upstream passage member 40a of the catalyst unit 38. In other words the path length $b1$ is a path length from the downstream end of the cylinder exhaust passage member 31 to the upstream end of the main catalyst 39. Furthermore, the path length from the downstream end of the main catalyst 39 to the downstream end of the exhaust pipe 34 is referred to as $d1$. The path length $d1$ is the path length of a passage member formed by the downstream passage member 40c of the catalyst unit 38 and the downstream exhaust pipe 34b. The path length from the combustion chamber 29 to the upstream end of the main catalyst 39 is $a1+b1$. The path length from the downstream end of the main catalyst 39 to the discharge port 35e is $d1+e1$.

[0105] The main catalyst 39 is provided so that the path length $a1+b1$ is shorter than the path length $d1+e1$. Furthermore, the main catalyst 39 is provided so that the path length $a1+b1$ is shorter than the path length $d1$. Furthermore, the main catalyst 39 is provided so that the path length $b1$ is shorter than the path length $d1$.

[0106] The upstream oxygen detector 36 is provided on the exhaust pipe 34. The upstream oxygen detector 36 is provided upstream of the main catalyst 39. The upstream oxygen detector 36 is provided on an upstream exhaust pipe 34a (see FIG. 5). The upstream oxygen detector 36 is a sensor configured to detect the oxygen density in the exhaust gas. The upstream oxygen detector 36 may be an oxygen sensor configured to detect whether the oxygen density is higher than a predetermined value or not. Alternatively, the upstream oxygen detector 36 may be a sensor (e.g., an A/F sensor: Air Fuel ratio sensor) configured to output a detection signal representing the oxygen density in steps or linearly. The upstream oxygen detector 36 is arranged such that one end portion (detecting portion) is provided inside the exhaust pipe 34 whereas the other end portion is provided outside the exhaust pipe 34. The detecting portion of the upstream oxygen detector 36 is able to detect the oxygen density when it is heated to a high temperature and ac-

tivated. A detection result of the upstream oxygen detector 36 is output to the electronic control unit 45.

[0107] As shown in FIG. 5, the path length from the combustion chamber 29 to the upstream oxygen detector 36 is referred to as h1. Furthermore, the path length from the upstream oxygen detector 36 to the upstream end of the main catalyst 39 is referred to as h2. The upstream oxygen detector 36 is provided so that the path length h1 is shorter than the path length h2.

[0108] The downstream oxygen detector 37 is provided on the exhaust pipe 34. The downstream oxygen detector 37 is provided downstream of the main catalyst 39. The downstream oxygen detector 37 is provided on a downstream exhaust pipe 34b (see FIG. 5). The downstream oxygen detector 37 is provided upstream of the silencer 35. The downstream oxygen detector 37 is a sensor configured to detect the oxygen density in the exhaust gas. The downstream oxygen detector 37 may be an oxygen sensor configured to detect whether the oxygen density is higher than a predetermined value or not. Alternatively, the downstream oxygen detector 37 may be a sensor (e.g., an A/F sensor: Air Fuel ratio sensor) configured to output a detection signal representing the oxygen density in steps or linearly. The downstream oxygen detector 37 is arranged such that one end portion (detecting portion) is provided inside the exhaust pipe 34 whereas the other end portion is provided outside the exhaust pipe 34. A detection result of the downstream oxygen detector 37 is output to the electronic control unit 45.

[0109] The structure of the motorcycle 1 of Embodiment 1 has been described. The motorcycle 1 of Embodiment 1 has the following characteristics.

[0110] The combustion chamber 29 is at least partially positioned frontward of the crankshaft axis Cr1. The discharge port 35e of the silencer 35 is positioned rearward of the crankshaft axis Cr1. The main catalyst 39 is at least partially positioned frontward of the crankshaft axis Cr1. The upstream end of the main catalyst 39 is provided upstream of the upstream end 35a of the silencer 35. The main catalyst 39 is therefore positioned to be relatively close to the combustion chamber 29. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be improved.

[0111] The downstream oxygen detector 37 is provided downstream of the main catalyst 39. The deterioration of the main catalyst 39 is detectable by a signal from the downstream oxygen detector 37. This makes it possible to suggest the replacement of the main catalyst 39 by providing information before the deterioration of the main catalyst 39 reaches a predetermined level. The initial performance of the motorcycle 1 in connection with the exhaust gas purification can therefore be maintained for a longer time by using multiple main catalysts 39. The deterioration of the main catalyst 39 may be detected based on a signal from the downstream oxygen detector 37 and a signal from the upstream oxygen detector 36 which is provided upstream of the main catalyst 39. The degree

of deterioration of the main catalyst 39 is more precisely detectable when signals from two oxygen detectors 36 and 37 are used. It is therefore possible to use one main catalyst 39 for a longer time while maintaining the initial performance of the exhaust purification of the motorcycle 1, as compared to cases where the deterioration of the main catalyst 39 is detected based solely on a signal from the downstream oxygen detector 37.

[0112] The actual purification capability of the main catalyst 39 is detectable by a signal from the upstream oxygen detector 36 provided upstream of the main catalyst 39 and a signal from the downstream oxygen detector 37 provided downstream of the main catalyst 39. The precision of the combustion control can therefore be improved when the combustion control is carried out based on signals from two oxygen detectors 36 and 37. This makes it possible to restrain the progress of the deterioration of the main catalyst 39. The initial performance of the motorcycle 1 in connection with the exhaust gas purification can therefore be maintained for a longer time. As such, the initial performance of the motorcycle 1 in connection with the exhaust gas purification can be maintained for a longer time without increasing the size of the main catalyst 39. The initial performance of the motorcycle 1 in connection with the exhaust gas purification can therefore be maintained for a longer time while the supporting structure is simplified.

[0113] As described above, in the motorcycle 1 including the single-cylinder four-stroke engine unit 19 of the present embodiment, the purification performance of purifying the exhaust gas by the catalyst can be improved and the initial performance of the motorcycle 1 regarding the exhaust purification can be maintained for a longer time, while the supporting structure is simplified.

[0114] The main catalyst 39 is at least partially positioned frontward of the crankshaft axis Cr1. The main catalyst 39 is therefore positioned to be closer to the combustion chamber 29. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be improved.

[0115] The linear line L2 is a linear line which is orthogonal to the cylinder axis Cy1 and orthogonal to the crankshaft axis Cr1. The linear line L2 extends downward from the crankshaft 27. When viewed in the left-right direction, at least a part of the main catalyst 39 is located in front of the linear line L2. The main catalyst 39 is therefore positioned to be closer to the combustion chamber 29. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be further improved.

[0116] The path length (a1+b1) from one combustion chamber 29 to the upstream end of the main catalyst 39 is shorter than the path length (d1+e1) from the downstream end of the main catalyst 39 to the discharge port 35e. It is therefore possible to provide the main catalyst 39 at a position closer to the combustion chamber 29. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be further im-

proved.

[0117] The path length ($a1+b1$) from one combustion chamber 29 to the upstream end of the main catalyst 39 is shorter than the path length ($d1$) from the downstream end of the main catalyst 39 to the downstream end of the exhaust pipe 34. It is therefore possible to provide the main catalyst 39 at a position closer to the combustion chamber 29. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be further improved.

[0118] The path length ($h1$) from one combustion chamber 29 to the upstream oxygen detector 36 is longer than the path length ($h2$) from the upstream oxygen detector 36 to the upstream end of the main catalyst 39. The upstream oxygen detector is therefore positioned to be closer to the combustion chamber 29. The upstream oxygen detector 36 can therefore be rapidly heated to the activation temperature when starting the engine. The detection accuracy of the upstream oxygen detector 36 can therefore be improved. The combustion control based on a signal from the upstream oxygen detector 36 can therefore be more precisely carried out. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be further improved. Moreover, because of the improvement in the precision of the combustion control, the progress of the deterioration of the main catalyst 39 can be restrained. The initial performance of the motorcycle 1 in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0119] In at least a part of the upstream passage member 40a, the cross-sectional area of the upstream passage member 40a cut along the direction orthogonal to the flow direction of the exhaust gas is smaller than the area $S1$. The area $S1$ is a cross-sectional area of the catalyst-provided passage member 40b cut along the direction orthogonal to the flow direction of the exhaust gas. It is therefore possible to use a catalyst with a large cross-sectional area as the main catalyst 39. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 39 can be improved.

(Modification 1-1 of Embodiment 1)

[0120] FIG. 6 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 1-1 of Embodiment 1. FIG. 7 is a bottom view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 1-1 of Embodiment 1. FIG. 8 is a schematic diagram of an engine main body and an exhaust system of Modification 1-1 of Embodiment 1. In Modification 1-1, items identical to those in Embodiment 1 are indicated by the same reference numerals and detailed descriptions thereof are omitted.

[0121] As shown in FIG. 6, as compared to Embodiment 1 above, the main catalyst 39 is provided downstream in Modification 1-1. The specific structure of the

main catalyst 39 is identical to the structure in Embodiment 1 above. The main catalyst 39 of Modification 1-1 is provided in the exhaust pipe 234. In the same manner as in Embodiment 1 above, the upstream end of the main catalyst 39 is provided upstream of the upstream end 35a of the silencer 35.

[0122] Being similar to the exhaust pipe 34 of Embodiment 1, the exhaust pipe 234 is connected to the cylinder exhaust passage member 31 (see FIG. 8) and the silencer 35. The catalyst unit 38 is provided in the middle of the exhaust pipe 234. As shown in FIG. 8, a part of the exhaust pipe 234, which is upstream of the catalyst unit 38, is referred to as an upstream exhaust pipe 234a. A part of the exhaust pipe 234, which is downstream of the catalyst unit 38, is referred to as a downstream exhaust pipe 234b. The downstream exhaust pipe 234b is provided in the silencer 35. While FIG. 8 depicts the exhaust pipe 234 as a linear pipe for simplification, the exhaust pipe 234 is not a linear pipe.

[0123] As shown in FIG. 6, the main catalyst 39 is provided rearward of the crankshaft axis $Cr1$. In other words, when viewed in the left-right direction, the main catalyst 39 is provided behind the linear line $L1$. As described above, the linear line $L1$ is a linear line which passes the crankshaft axis $Cr1$ and is in parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 39 is positioned in front of (below) the cylinder axis $Cy1$.

[0124] As shown in FIG. 6, when viewed in the left-right direction, the main catalyst 39 is provided in front of the linear line $L2$. The linear line $L2$ is a linear line which is orthogonal to the cylinder axis $Cy1$ and orthogonal to the crankshaft axis $Cr1$.

[0125] As shown in FIG. 8, the path length from the upstream end of the exhaust pipe 234 to the upstream end of the main catalyst 39 is referred to as $b11$. Furthermore, the path length from the downstream end of the main catalyst 39 to the downstream end of the exhaust pipe 234 is referred to as $d11$. The path length from the combustion chamber 29 to the upstream end of the main catalyst 39 is $a1+b11$. The path length from the downstream end of the main catalyst 39 to the discharge port 35e is $d11+e1$.

[0126] In the same manner as in Embodiment 1 above, the main catalyst 39 of Modification 1-1 is provided so that the path length $a1+b11$ is shorter than the path length $d11+e1$. Being different from Embodiment 1 above, the main catalyst 39 of Modification 1-1 is provided so that the path length $a1+b11$ is longer than the path length $d11$. Being different from Embodiment 1 above, the main catalyst 39 of Modification 1-1 is provided so that the path length $b11$ is longer than the path length $d11$.

[0127] The upstream oxygen detector 36 is provided on the exhaust pipe 234. The upstream oxygen detector 36 is provided upstream of the main catalyst 39. The upstream oxygen detector 36 is provided on an upstream exhaust pipe 234a (see FIG. 8).

[0128] As shown in FIG. 8, the path length from the

combustion chamber 29 to the upstream oxygen detector 36 is referred to as h11. Furthermore, the path length from the upstream oxygen detector 36 to the upstream end of the main catalyst 39 is referred to as h12. Being similar to Embodiment 1, the upstream oxygen detector 36 is provided so that the path length h11 is shorter than the path length h12.

[0129] The downstream oxygen detector 37 is provided on the exhaust pipe 234. The downstream oxygen detector 37 is provided downstream of the main catalyst 39. The downstream oxygen detector 37 is provided on a downstream exhaust pipe 234a (see FIG. 8). The downstream oxygen detector 37 penetrates a side wall of the silencer 35. One end portion (detecting portion) of the downstream oxygen detector 37 is provided in the downstream exhaust pipe 234a. The other end portion of the downstream oxygen detector 37 is provided outside the silencer 35.

[0130] In Modification 1-1, arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

(Modification 1-2 of Embodiment 1)

[0131] FIG. 9 is a side view of a motorcycle of Modification 1-2 of Embodiment 1. FIG. 10 is a schematic diagram of an engine main body and an exhaust system of Modification 1-2 of Embodiment 1. In Modification 1-2, items identical to those in Embodiment 1 are indicated by the same reference numerals and detailed descriptions thereof are omitted.

[0132] As shown in FIG. 9 and FIG. 10, an upstream sub-catalyst 300 (a single-combustion-chamber upstream sub-catalyst), the main catalyst 39, the upstream oxygen detector 36, and the downstream oxygen detector 37 are provided in an exhaust pipe 334. Being similar to the exhaust pipe 34 of Embodiment 1, the exhaust pipe 334 is connected to the cylinder exhaust passage member 31 (see FIG. 10) and the silencer 35. A catalyst unit 38 is provided in the middle of the exhaust pipe 334. As shown in FIG. 10, a part of the exhaust pipe 334, which is upstream of the catalyst unit 38, is referred to as an upstream exhaust pipe 334a. A part of the exhaust pipe 334, which is downstream of the catalyst unit 38, is referred to as a downstream exhaust pipe 334b. While FIG. 10 depicts the exhaust pipe 334 as a linear pipe for simplification, the exhaust pipe 334 is not a linear pipe.

[0133] The upstream sub-catalyst 300 is provided upstream of the main catalyst 39. The upstream sub-catalyst 300 is provided in the upstream exhaust pipe 334a (exhaust pipe 334). The upstream sub-catalyst 300 may be formed solely of catalytic materials attached to an inner wall of the exhaust pipe 334. In such a case, the base to which the catalytic materials of the upstream sub-catalyst 300 are attached is the inner wall of the exhaust pipe 334. The upstream sub-catalyst 300 may include a base which is provided on the inner side of the exhaust pipe 334. In such a case, the upstream sub-catalyst 300

is formed of the base and the catalytic materials. The base of the upstream sub-catalyst 300 is, for example, plate-shaped. The plate-shaped base may be S-shaped, circular in shape, or C-shaped in cross-section in the direction orthogonal to the path direction. Regardless of whether the upstream sub-catalyst 300 includes the base or not, the upstream sub-catalyst 300 does not have a porous structure. For this reason, deflection of pressure pulsation of the exhaust gas is not as effectively generated by the upstream sub-catalyst 300 when compared to the main catalyst 39. Furthermore, the upstream sub-catalyst 200 does not greatly resist the flow of the exhaust gas as compared to the main catalyst 39.

[0134] The main catalyst 39 purifies the exhaust gas exhausted from the combustion chamber 29 most in the exhaust path 41. In other words, the main catalyst 39 purifies the exhaust gas exhausted from the combustion chamber 29 in the exhaust path 41 more than the upstream sub-catalyst 300. That is, the degree of contribution of the upstream sub-catalyst 300 to the purification of the exhaust gas is lower than that of the main catalyst 39.

[0135] The degree of contribution to the purification of each of the main catalyst 39 and the upstream sub-catalyst 300 may be measured by the following method. The explanation of the measuring method presupposes that, among the main catalyst 39 and the upstream sub-catalyst 300, a catalyst acting upstream is a front catalyst whereas a catalyst acting downstream is a rear catalyst. In Modification 1-2, the upstream sub-catalyst 300 is the front catalyst whereas the main catalyst 39 is the rear catalyst.

[0136] When the engine unit of Modification 1 is operated, and in a warm-up state, the density of harmful substances in the exhaust gas exhausted from the discharge port 35e is measured. The method of measuring the exhaust gas is in compliance with European regulations. In the warm-up state, the main catalyst 39 and the upstream sub-catalyst 200 are hot and activated. The main catalyst 39 and the upstream sub-catalyst 200 can therefore sufficiently exert their purification performances in the warm-up state.

[0137] Subsequently, the rear catalyst of the engine unit used in the experiment is detached, and only the base of the rear catalyst is attached. The engine unit in this state is assumed to be a measurement engine unit A. In a manner similar to above, the density of harmful substances in the exhaust gas exhausted from the discharge port 35e in a warm-up state is measured.

[0138] Furthermore, the front catalyst of the measurement engine unit A is detached, and only the base of the front catalyst is attached. The engine unit in this state is assumed to be measurement engine unit B. In a manner similar to above, the density of harmful substances in the exhaust gas exhausted from the discharge port 35e in a warm-up state is measured. In the case where the upstream sub-catalyst 200 (front catalyst) is arranged such that catalytic materials are directly attached to the inner

wall of the exhaust pipe 234, the exhaust pipe 234 corresponds to the base. Attaching only the base of an upstream sub-catalyst 200 instead of attaching the above-described upstream sub-catalyst 200 is equivalent to not attaching catalytic materials to the inner wall of the exhaust pipe 234.

[0139] The measurement engine unit A includes the front catalyst and does not include the rear catalyst. The measurement engine unit B includes neither the front catalyst nor the rear catalyst. Due to this, the degree of contribution to the purification by the front catalyst (upstream sub-catalyst 300) is calculated as a difference between a measurement result from the measurement engine unit A and a measurement result from the measurement engine unit B. Furthermore, the degree of contribution to the purification by the rear catalyst (main catalyst 39) is calculated as a difference between a measurement result from the measurement engine unit A and a measurement result from the engine unit of Modification 1-2.

[0140] The purification capability of the upstream sub-catalyst 200 may be higher or lower than that of the main catalyst 39. When the purification capability of the upstream sub-catalyst 200 is lower than the purification capability of the main catalyst 39, the purification rate of the exhaust gas when only the upstream sub-catalyst 200 is provided is lower than the purification rate of the exhaust gas when only the main catalyst 39 is provided.

[0141] As shown in FIG. 9, the main catalyst 39 is provided frontward of the crankshaft axis Cr1. When viewed in the left-right direction, the main catalyst 39 is positioned in front of the linear line L2. The definition of the linear line L2 is identical to the definition in Embodiment 1. That is to say, the linear line L2 is a linear line which is orthogonal to the cylinder axis Cy1 and orthogonal to the crankshaft axis Cr1.

[0142] As shown in FIG. 10, the path length from the upstream end of the exhaust pipe 334 to the upstream end of the main catalyst 39 is referred to as b21. The path length from the downstream end of the main catalyst 39 to the downstream end of the exhaust pipe 334 is referred to as d21. The path length from the combustion chamber 29 to the upstream end of the main catalyst 39 is a1+b21. The path length from the downstream end of the main catalyst 39 to the discharge port 35e is d21+e1.

[0143] Being similar to Embodiment 1, the main catalyst 39 is provided so that the path length a1+b21 is shorter than the path length d21+e1. Being similar to Embodiment 1, the main catalyst 39 is provided so that the path length a1+b21 is shorter than the path length d21. Furthermore, being similar to Embodiment 1, the main catalyst 39 is provided so that the path length b21 is shorter than the path length d21.

[0144] The upstream oxygen detector 36 is provided on the exhaust pipe 334. The upstream oxygen detector 36 is provided upstream of the upstream sub-catalyst 300. The upstream oxygen detector 36 is provided on an upstream exhaust pipe 334a (see FIG. 13).

[0145] The path length from the combustion chamber

29 to the upstream oxygen detector 36 is referred to as h21. The path length from the upstream oxygen detector 36 to the upstream end of the main catalyst 39 is referred to as h22. Being similar to Embodiment 1, the upstream oxygen detector 36 is provided so that the path length h21 is shorter than the path length h22.

[0146] The downstream oxygen detector 37 is provided on the exhaust pipe 334. The downstream oxygen detector 37 is provided downstream of the main catalyst 39. The downstream oxygen detector 37 is provided on a downstream exhaust pipe 334b (see FIG. 13). The downstream oxygen detector 37 is provided upstream of the silencer 35.

[0147] In Modification 1-2, arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

[0148] In Modification 1-2, the upstream sub-catalyst 300 is provided upstream of the main catalyst 39. The upstream sub-catalyst 300 deteriorates more rapidly than the main catalyst 39. However, even if the deterioration of the upstream sub-catalyst 300 reaches a predetermined level, the purification performance of purifying the exhaust gas can be maintained by the main catalyst 39. The initial performance of the motorcycle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0149] The upstream oxygen detector 36 is provided upstream of the upstream sub-catalyst 300. The upstream oxygen detector 36 is therefore able to detect the oxygen density of the exhaust gas flowing into the upstream sub-catalyst 300. As the combustion control is carried out based on a signal from the upstream oxygen detector 36, the purification performance of purifying the exhaust gas by the upstream sub-catalyst 300 can be improved.

(Embodiment 2)

[0150] FIG. 11 is a side view of a motorcycle of Embodiment 2 of the present teaching. FIG. 12 is a bottom view of the motorcycle of Embodiment 2. FIG. 13 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Embodiment 2. FIG. 14 is a bottom view showing the state in which the vehicle body cover, etc. have been removed from the motorcycle of Embodiment 2. FIG. 15 is a schematic diagram of an engine and an exhaust system of the motorcycle of Embodiment 2.

[0151] A vehicle of Embodiment 2 is a so-called street-type motorcycle 50. As shown in FIG. 13, the motorcycle 50 is provided with a vehicle body frame 53. The vehicle body frame 53 includes a head pipe 53a, an upper main frame 53b, a lower main frame 53c, and a seat frame 53d. From an end on the head pipe 53a side to the other end, the upper main frame 53b extends rearward and downward, and is then curved downward and extends downward. The lower main frame 53c is positioned below the upper main frame 53b. The lower main frame 53c

extends rearward and downward from the head pipe 53a. The seat frame 53d extends downward from an intermediate part of the upper main frame 53b.

[0152] A steering shaft is rotatably inserted into the head pipe 53a. A handlebar 55 is provided at an upper part of the steering shaft. A display (not illustrated) is provided in the vicinity of the handlebar 55. The display is configured to display vehicle speed, engine rotation speed, warnings, and the like.

[0153] The upper and lower end portions of the steering shaft are connected to paired left and right front forks 56 via brackets. The lower end portions of the front forks 56 support a front wheel 57 in a rotatable manner.

[0154] Front end portions of paired left and right rear arms 58 are swingably supported by a rear portion of the vehicle body frame 53. Rear end portions of the rear arms 58 support a rear wheel 59 in a rotatable manner.

[0155] The upper main frame 53b supports a fuel tank 51 (see FIG. 11). The seat frame 53d supports a seat 52 (see FIG. 11). The vehicle body frame 53 supports an engine main body 61. The vehicle body frame 53 supports an air cleaner 73 (see FIG. 13). As shown in FIG. 13, when viewed in the left-right direction, an upper part of the engine main body 61 is provided between the upper main frame 53b and the lower main frame 53c. The air cleaner 73 is provided behind the engine main body 61.

[0156] As shown in FIG. 11, the motorcycle 50 is provided with a vehicle body cover 54 which covers the vehicle body frame 53 and the like. The vehicle body cover 54 covers an upper part of the engine main body 61 and the air cleaner 73.

[0157] The motorcycle 50 includes a single-cylinder four-stroke engine unit 60. The single-cylinder four-stroke engine unit 60 includes the engine main body 61, the air cleaner 73 (see FIG. 13), an intake pipe 74, an exhaust pipe 75, a silencer 76, a main catalyst 180 (a single-combustion-chamber main catalyst), an upstream oxygen detector 77 (a single-combustion-chamber upstream oxygen detector), and a downstream oxygen detector 78 (a single-combustion-chamber downstream oxygen detector). The single-cylinder four-stroke engine unit 60 further includes an electronic control unit which is similar to the electronic control unit 45 of Embodiment 1. The electronic control unit controls the engine main body 61.

[0158] The engine main body 61 is a single-cylinder four-stroke engine. As shown in FIG. 13, the engine main body 61 includes a crankcase member 62 and a cylinder member 63. The cylinder member 63 extends frontward and upward from the crankcase member 62.

[0159] The crankcase member 62 includes a crankcase main body 64. The crankcase member 62 includes a crankshaft 68, a transmission mechanism, and the like which are housed in the crankcase main body 64. The central axis (crankshaft axis) Cr2 of the crankshaft 68 extends in the left-right direction. Lubricating oil is stored in the crankcase main body 64. The oil is conveyed by an oil pump (not illustrated) and is circulated in the engine

main body 61.

[0160] The cylinder member 63 includes a cylinder body 65, a cylinder head 66, a head cover 67, and components housed in the members 65 to 67. As shown in FIG. 13, the cylinder body 65 is connected to an upper part of the crankcase main body 64. The cylinder head 66 is connected to an upper part of the cylinder body 65. The head cover 67 is connected to an upper part of the cylinder head 66.

[0161] As shown in FIG. 15, a cylinder hole 65a is made in the cylinder body 65. The cylinder hole 65a houses a piston 69 so that the piston 69 is able to reciprocate. The piston 69 is connected to the crankshaft 68 via a connecting rod. Hereinafter, the central axis Cy2 of the cylinder hole 65a is referred to as a cylinder axis Cy2. As shown in FIG. 13, the engine main body 61 is disposed so that the cylinder axis Cy2 extends in the vertical direction. To be more specific, the direction in which the cylinder axis Cy2 extends from the crankcase member 62 to the cylinder member 63 is frontward and upward. The angle of inclination of the cylinder axis Cy2 with respect to the horizontal direction is 45 degrees or greater and 90 degrees or less.

[0162] As shown in FIG. 15, one combustion chamber 70 is formed in the cylinder member 63. The combustion chamber 70 is formed by an inner surface of the cylinder hole 65a of the cylinder body 65, the cylinder head 66, and the piston 69. As shown in FIG. 13, the combustion chamber 70 is positioned frontward of the crankshaft axis Cr2. In other words, it is assumed that a linear line which passes the crankshaft axis Cr2 and is in parallel to the up-down direction is L3. When viewed in the left-right direction, the combustion chamber 70 is positioned in front of the linear line L3.

[0163] As shown in FIG. 15, a cylinder intake passage member 71 and a cylinder exhaust passage member 72 (a single-combustion-chamber cylinder exhaust passage member) are formed in the cylinder head 66. In the cylinder head 66, an intake port 71a and an exhaust port 72a are formed in a wall portion forming the combustion chamber 70. The cylinder intake passage member 71 extends from the intake port 71a to an inlet formed in the outer surface (rear surface) of the cylinder head 66. The cylinder exhaust passage member 72 extends from the exhaust port 72a to an outlet formed in the outer surface (front surface) of the cylinder head 66. Air passes through the inside of the cylinder intake passage member 71 and is then supplied to the combustion chamber 70. Exhaust gas exhausted from the combustion chamber 70 passes through the cylinder exhaust passage member 72.

[0164] An intake valve V3 is provided in the cylinder intake passage member 71. An exhaust valve V4 is provided in the cylinder exhaust passage member 72. The intake port 71a is opened and closed by the movement of the intake valve V3. The exhaust port 72a is opened and closed by the movement of the exhaust valve V4. An intake pipe 74 is connected to an end portion (inlet) of the cylinder intake passage member 71. An exhaust

pipe 75 is connected to an end portion (outlet) of the cylinder exhaust passage member 72. The path length of the cylinder exhaust passage member 72 is referred to as a2.

[0165] The single-cylinder four-stroke engine unit 60 includes an ignition plug, a valve operating mechanism, an injector, and a throttle valve in the same manner as the engine main body 20 of Embodiment 1. Furthermore, in the same manner as Embodiment 1, the single-cylinder four-stroke engine unit 60 includes sensors such as an engine rotation speed sensor and a throttle position sensor.

[0166] As described above, the single-cylinder four-stroke engine unit 60 includes the engine main body 61, the exhaust pipe 75, the silencer 76, the main catalyst 180, the upstream oxygen detector 77, and the downstream oxygen detector 78. The silencer 76 is provided with a discharge port 76e which is exposed to the atmosphere. The path extending from the combustion chamber 70 to the discharge port 76e is referred to as an exhaust path 182 (see FIG. 15). The exhaust path 182 is formed by the cylinder exhaust passage member 72, the exhaust pipe 75, and the silencer 76. The exhaust path 182 is a space through which exhaust gas passes.

[0167] As shown in FIG. 15, the upstream end portion of the exhaust pipe 75 is connected to the cylinder exhaust passage member 72. The downstream end portion of the exhaust pipe 75 is connected to the silencer 76. A catalyst unit 79 is provided in the middle of the exhaust pipe 75. A part of the exhaust pipe 75, which is upstream of the catalyst unit 79, is referred to as an upstream exhaust pipe 75a. A part of the exhaust pipe 75, which is downstream of the catalyst unit 79, is referred to as a downstream exhaust pipe 75b. While FIG. 15 depicts the exhaust pipe 75 as a linear pipe for simplification, the exhaust pipe 75 is not a linear pipe.

[0168] As shown in FIG. 12 and FIG. 14, most of the exhaust pipe 75 is provided on the right side of the motorcycle 50. As shown in FIG. 13, a part of the exhaust pipe 75 is positioned below the crankshaft axis Cr2. The exhaust pipe 75 has two bended portions. The upstream one of the two bended portions is simply referred to as an upstream bended portion. The downstream one of the two bended portions is simply referred to as a downstream bended portion. When viewed in the left-right direction, the upstream bended portion changes the flow direction of the exhaust gas from a direction along the front-rear direction to a direction along the up-down direction. To be more specific, when viewed in the left-right direction, the upstream bended portion changes the flow direction of the exhaust gas from frontward and downward to rearward and downward. When viewed in the left-right direction, the downstream bended portion changes the flow direction of the exhaust gas from a direction along the up-down direction to a direction along the front-rear direction. To be more specific, when viewed in the left-right direction, the downstream bended portion changes the flow direction of the exhaust gas from rear-

ward and downward to rearward. A part which is downstream of the downstream bended portion is positioned below the crankshaft axis Cr2. The main catalyst 180 is provided between the two bended portions.

[0169] The exhaust gas exhausted from the downstream end of the exhaust pipe 75 flows into the silencer 76. The silencer 76 is connected to the exhaust pipe 75. The silencer 76 is configured to restrain pulsation in the exhaust gas. With this, the silencer 76 restrains the volume of the sound (exhaust sound) generated by the exhaust gas. Multiple expansion chambers and multiple pipes connecting the expansion chambers with one another are provided inside the silencer 76. The downstream end portion of the exhaust pipe 75 is provided inside an expansion chamber of the silencer 76. The discharge port 76e exposed to the atmosphere is provided at the downstream end of the silencer 76. As shown in FIG. 15, the path length of the exhaust path extending from the downstream end of the exhaust pipe 75 to the discharge port 76e is referred to as e2. The exhaust gas having passed the silencer 76 is discharged to the atmosphere via the discharge port 76e. As shown in FIG. 13, the discharge port 76e is positioned rearward of the crankshaft axis Cr2.

[0170] The main catalyst 180 is provided in the exhaust pipe 75. The upstream end of the main catalyst 180 is provided upstream of the upstream end 76a of the silencer 76. The catalyst unit 79 includes a hollow cylindrical casing 181 and the main catalyst 180. The upstream end of the casing 181 is connected to the upstream exhaust pipe 75a. The downstream end of the casing 181 is connected to the downstream exhaust pipe 75b. The casing 181 forms a part of the exhaust pipe 75. The main catalyst 180 is fixed to the inside of the casing 181. The exhaust gas is purified when passing through the main catalyst 180. All exhaust gas exhausted from the exhaust port 72a of the combustion chamber 70 passes through the main catalyst 180. The main catalyst 180 purifies the exhaust gas exhausted from the combustion chamber 70 most in the exhaust path 182.

[0171] The materials of the main catalyst 180 are identical to those of the main catalyst 39 of Embodiment 1. The main catalyst 180 has a porous structure. In the main catalyst 180, pores which are sufficiently narrower than the width of the path in the upstream exhaust pipe 75a are formed. As shown in FIG. 15, the length of the main catalyst 180 in the path direction is referred to as c2. Furthermore, the maximum width of the main catalyst 180 in the direction orthogonal to the path direction is referred to as w2. The length c2 of the main catalyst 180 is longer than the maximum width w2 of the main catalyst 180.

[0172] As shown in FIG. 15, the casing 181 includes a catalyst-provided passage member 181b, an upstream passage member 181a, and a downstream passage member 181c. The main catalyst 180 is provided in the catalyst-provided passage member 181b. In the path direction, the upstream end and the downstream end of

the catalyst-provided passage member 181b are respectively at the same positions as the upstream end and the downstream end of the main catalyst 180. The cross-sectional area of the catalyst-provided passage member 181b cut along the direction orthogonal to the path direction is substantially constant. The upstream passage member 181a is connected to the upstream end of the catalyst-provided passage member 181b. The downstream passage member 181c is connected to the upstream end of the catalyst-provided passage member 181b.

[0173] The upstream passage member 181a is at least partially tapered. The tapered part increases its inner diameter toward the downstream side. The downstream passage member 181c is at least partially tapered. The tapered part decreases its inner diameter toward the downstream side. The cross-sectional area of the catalyst-provided passage member 181b cut along the direction orthogonal to the path direction is referred to as S2. In at least a part of the upstream passage member 181a, the cross-sectional area of the upstream passage member 181a cut along the direction orthogonal to the path direction is smaller than the area S2. The at least part of the upstream passage member 181a includes the upstream end of the upstream passage member 181a. In at least a part of the downstream passage member 181c, the cross-sectional area of the downstream passage member 181c cut along the direction orthogonal to the path direction is smaller than the area S2. The at least part of the downstream passage member 181c includes the downstream end of the downstream passage member 181c.

[0174] As shown in FIG. 13, the main catalyst 180 is provided frontward of the crankshaft axis Cr2. In other words, when viewed in the left-right direction, the main catalyst 180 is provided in front of the linear line L3. As described above, the linear line L3 is a linear line which passes the crankshaft axis Cr2 and is parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 180 is positioned in front of the cylinder axis Cy2.

[0175] As shown in FIG. 13, it is assumed that a linear line which is orthogonal to the cylinder axis Cy2 and orthogonal to the crankshaft axis Cr2 is L4. When viewed in the left-right direction, the main catalyst 180 is positioned in front of the linear line L4.

[0176] As shown in FIG. 15, the path length from the upstream end of the exhaust pipe 75 to the upstream end of the main catalyst 180 is referred to as b2. The path length b2 is a path length of a passage member formed by the upstream exhaust pipe 75a and the upstream passage member 181a of the catalyst unit 79. In other words, the path length b2 is a path length from the downstream end of the cylinder exhaust passage member 72 to the upstream end of the main catalyst 180. Furthermore, the path length from the downstream end of the main catalyst 180 to the downstream end of the exhaust pipe 75 is referred to as d2. The path length d2 is the path length

of a passage member formed by the downstream passage member 181c of the catalyst unit 79 and the downstream exhaust pipe 75b. The path length from the combustion chamber 70 to the upstream end of the main catalyst 180 is $a2+b2$. The path length from the downstream end of the main catalyst 180 to the discharge port 76e is $d2+e2$.

[0177] Furthermore, being similar to Embodiment 1, the main catalyst 180 is provided so that the path length $a2+b2$ is shorter than the path length $d2+e2$. Furthermore, being similar to Embodiment 1, the main catalyst 180 is provided so that the path length $a2+b2$ is shorter than the path length d2. Furthermore, being similar to Embodiment 1, the main catalyst 180 is provided so that the path length b2 is shorter than the path length d2.

[0178] The upstream oxygen detector 77 is provided on the exhaust pipe 75. The upstream oxygen detector 77 is provided upstream of the main catalyst 180. The upstream oxygen detector 77 is provided on an upstream exhaust pipe 75a (see FIG. 15). The upstream oxygen detector 77 is a sensor configured to detect the oxygen density in the exhaust gas. The structure of the upstream oxygen detector 77 is identical to that of the upstream oxygen detector 37 of Embodiment 1.

[0179] As shown in FIG. 15, the path length from the combustion chamber 70 to the upstream oxygen detector 77 is referred to as h3. The path length from the upstream oxygen detector upstream oxygen detector 77 to the upstream end of the main catalyst 180 is referred to as h4. Being similar to Embodiment 1, the upstream oxygen detector 77 is provided so that the path length h3 is shorter than the path length h4.

[0180] The downstream oxygen detector 78 is provided on the exhaust pipe 75. The downstream oxygen detector 78 is provided downstream of the main catalyst 180. The downstream oxygen detector 78 is provided on a downstream exhaust pipe 75b (see FIG. 15). The downstream oxygen detector 78 is provided upstream of the silencer 76. The downstream oxygen detector 78 is a sensor configured to detect the oxygen density in the exhaust gas. The structure of the downstream oxygen detector 78 is identical to that of the upstream oxygen detector 37 of Embodiment 1.

[0181] As described above, in the motorcycle 50 of Embodiment 2, the upstream oxygen detector 77 and the downstream oxygen detector 78 are provided upstream and downstream of the main catalyst 180, respectively. Apart from the above, the arrangements of the components are similar to those in the motorcycle 1 of Embodiment 1. The arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

[0182] The structure of the exhaust system of Modification 1-2 described above may be used in the motorcycle 50 of Embodiment 2. Effects similar to those in Modification 1-2 are obtained in such a case.

(Modification 2-1 of Embodiment 2)

[0183] FIG. 16 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 2-1 of Embodiment 2. FIG. 17 is a bottom view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 2-1 of Embodiment 2. FIG. 18 is a schematic diagram of an engine main body and an exhaust system of Modification 2-1 of Embodiment 2. In Modification 2-1, items identical to those in Embodiment 2 are indicated by the same reference numerals and detailed descriptions thereof are omitted.

[0184] As shown in FIG. 16, as compared to Embodiment 2 above, the main catalyst 180 is provided downstream in Modification 2-1. The specific structure of the main catalyst 180 is identical to the structure in Embodiment 2 above. The main catalyst 180 of Modification 2-1 is provided in the exhaust pipe 275. In the same manner as in Embodiment 2 above, the upstream end of the main catalyst 180 is provided upstream of the upstream end 76a of the silencer 76.

[0185] Being similar to the exhaust pipe 75 of Embodiment 2, the exhaust pipe 275 is connected to the cylinder exhaust passage member 72 (see FIG. 18) and the silencer 76. A catalyst unit 79 is provided in the middle of the exhaust pipe 275. As shown in FIG. 18, a part of the exhaust pipe 275, which is upstream of the catalyst unit 79, is referred to as an upstream exhaust pipe 275a. A part of the exhaust pipe 275, which is downstream of the catalyst unit 79, is referred to as a downstream exhaust pipe 275b. The downstream exhaust pipe 275b is provided in the silencer 76. While FIG. 18 depicts the exhaust pipe 275 as a linear pipe for simplification, the exhaust pipe 275 is not a linear pipe.

[0186] As shown in FIG. 16, the main catalyst 180 is provided rearward of the crankshaft axis Cr2. In other words, when viewed in the left-right direction, the main catalyst 180 is provided behind the linear line L3. As described above, the linear line L3 is a linear line which passes the crankshaft axis Cr2 and is in parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 180 is positioned in front of the cylinder axis Cy2.

[0187] As shown in FIG. 16, when viewed in the left-right direction, the main catalyst 180 is provided behind the linear line L4. The linear line L4 is a linear line which is orthogonal to the cylinder axis Cy2 and orthogonal to the crankshaft axis Cr2.

[0188] As shown in FIG. 18, the path length from the upstream end of the exhaust pipe 275 to the upstream end of the main catalyst 180 is referred to as b12. The path length from the downstream end of the main catalyst 180 to the downstream end of the exhaust pipe 275 is referred to as d12. The path length from the combustion chamber 70 to the upstream end of the main catalyst 180 is a2+b12. The path length from the downstream end of the main catalyst 180 to the discharge port 76e is d12+e2.

[0189] In the same manner as in Embodiment 2 above, the main catalyst 180 of Modification 2-1 is provided so that the path length a2+b12 is shorter than the path length d12+e2. Being different from Embodiment 2 above, the main catalyst 180 of Modification 2-1 is provided so that the path length a2+b12 is longer than the path length d12. Being different from Embodiment 2 above, the main catalyst 180 of Modification 2-1 is provided so that the path length b12 is longer than the path length d12.

[0190] The upstream oxygen detector 77 is provided on the exhaust pipe 275. The upstream oxygen detector 77 is provided upstream of the main catalyst 180. The upstream oxygen detector 77 is provided upstream exhaust pipe 275a (see FIG. 18).

[0191] As shown in FIG. 18, the path length from the combustion chamber 70 to the upstream oxygen detector 77 is referred to as h13. Furthermore, the path length from the upstream oxygen detector 77 to the upstream end of the main catalyst 180 is referred to as h14. Being similar to Embodiment 2, the upstream oxygen detector 77 is provided so that the path length h13 is shorter than the path length h14.

[0192] The downstream oxygen detector 78 is provided on the exhaust pipe 275. The downstream oxygen detector 78 is provided downstream of the main catalyst 180. The downstream oxygen detector 78 is provided downstream exhaust pipe 275a (see FIG. 18). The downstream oxygen detector 78 is provided upstream of the silencer 76.

[0193] In Modification 2-1, arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

(Embodiment 3)

[0194] FIG. 19 is a side view of a motorcycle of Embodiment 3 of the present teaching. FIG. 20 is a bottom view of the motorcycle of Embodiment 3. FIG. 21 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Embodiment 3. FIG. 22 is a bottom view showing the state in which the vehicle body cover, etc. have been removed from the motorcycle of Embodiment 3. FIG. 23 is a schematic diagram of an engine and an exhaust system of the motorcycle of Embodiment 3.

[0195] A vehicle of Embodiment 3 is a so-called scooter-type motorcycle 80. As shown in FIG. 21, the motorcycle 80 is provided with a vehicle body frame 81. The vehicle body frame 81 includes a head pipe 81a, a main frame 81b, paired left and right side frames 81c, paired left and right rear frames 81d, and paired left and right seat frames 81e. The main frame 81b extends rearward and downward from the head pipe 81a. The paired left and right side frames 81c extend substantially horizontally rearward from a lower end portion of the main frame 81b. The paired left and right rear frame 81d extend rearward and upward from lower end portions of the side frames 81c. The paired left and right seat frames 81e

extend horizontally rearward from rear end portions of the rear frames 81d.

[0196] A steering shaft is rotatably inserted into the head pipe 81a. A handlebar 82 is provided at an upper part of the steering shaft. A display (not illustrated) is provided in the vicinity of the handlebar 82. The display is configured to display vehicle speed, engine rotation speed, warnings, and the like.

[0197] Paired left and right front forks 83 are supported at a lower part of the steering shaft. The lower end portions of the front forks 83 support a front wheel 84 in a rotatable manner.

[0198] A foot board 85 (see FIG. 19) is attached to the paired left and right side frames 81c. A rider seated on a subsequently-described seat 86 places his/her feet on this foot board 85.

[0199] The seat frames 81e support the seat 86 (see FIG. 19). In the vehicle front-rear direction, the seat 86 extends from an intermediate part to a rear end part of the vehicle body frame 81.

[0200] A space G1 (see FIG. 21) is formed below the seat 86. A storage box (not illustrated) is provided in this space G1. The storage box is an open-top box. The seat 86 functions as a lid for opening and closing the upper opening of the storage box. The storage box is provided between the left and right seat frames 81e. The storage box is supported by the rear frames 81d and the seat frames 81e.

[0201] As shown in FIG. 19, the motorcycle 80 is provided with a vehicle body cover 87 which covers the vehicle body frame 81, and the like. The vehicle body cover 87 includes a front cover 87a, a leg shield 87b, a main cover 87c, and an under cover 87d. The front cover 87a is provided in front of the head pipe 81a. The leg shield 87b is provided behind the head pipe 81a. The front cover 87a and the leg shield 87b covers the head pipe 81a and the main frame 81b. The main cover 87c extends upward from a rear portion of the foot board 85. The main cover 87c covers the storage box substantially entirely. The under cover 87d is provided below the front cover 87a, the leg shield 87b, and the main cover 87c. The under cover 87d covers an upper front part of a subsequently-described engine main body 94 from the front, left, and right.

[0202] A unit-swinging single-cylinder four-stroke engine unit 93 is attached to the vehicle body frame 81. The single-cylinder four-stroke engine unit 93 includes the engine main body 94 and a power transmission unit 95 (see FIG. 20 and FIG. 22). The power transmission unit 95 is connected to a rear portion of the engine main body 94. The power transmission unit 95 is provided to the left of the engine main body 94. The power transmission unit 95 houses a transmission. The power transmission unit 95 supports a rear wheel 88 in a rotatable manner.

[0203] The engine main body 94 and the power transmission unit 95 are configured to be integrally swingable with respect to the vehicle body frame 81. To be more specific, as shown in FIG. 21 and FIG. 22, a right link

component 90R and a left link component 90L are connected to left and right end portions of a lower part of the engine main body 94. The right link component 90R and the left link component 90L extend frontward from the engine main body 94. The leading end portions of the right link component 90R and the left link component 90L are rotatably connected to the vehicle body frame 81 via pivot shafts 89. Furthermore, the right link component 90R and the left link component 90L are rotatably connected to the engine main body 94 via pivot shafts 91 (see FIG. 21). It is noted that FIG. 20 does not show some parts such as a subsequently-described shroud 96 of the right link component 90R and the engine main body 94.

[0204] The single-cylinder four-stroke engine unit 93 includes the engine main body 94, the power transmission unit 95, an air cleaner (not illustrated), an intake pipe 110 (see FIG. 23), an exhaust pipe 111, a silencer 112, a main catalyst 116 (a single-combustion-chamber main catalyst), an upstream oxygen detector 113 (a single-combustion-chamber upstream oxygen detector), and a downstream oxygen detector 114 (single-combustion-chamber upstream oxygen detector). The single-cylinder four-stroke engine unit 93 further includes an electronic control unit which is similar to the electronic control unit 45 of Embodiment 1. The electronic control unit controls the engine main body 94.

[0205] The engine main body 94 is a single-cylinder four-stroke engine. The engine main body 94 is a forced air-cooled engine. The engine main body 94 includes the shroud 96, a fan 97, a crankcase member 98, and a cylinder member 99.

[0206] The cylinder member 99 extends frontward from the crankcase member 98. The shroud 96 covers the whole circumference of a rear portion of the cylinder member 99. To be more specific, the shroud 96 covers the whole circumference of the entire subsequently-described cylinder body 101 and the entire subsequently-described cylinder head 102. However, the circumference of the exhaust pipe 111 connected to the cylinder head 102 is not covered. The shroud 96 covers the right part of the crankcase member 98.

[0207] The fan 97 is provided between the shroud 96 and the crankcase member 98. An inflow port for air intake is formed at a part of the shroud 96 opposite the fan 97. The fan 97 generates an air flow for cooling the engine main body 94. To be more specific, air is introduced into the shroud 96 by the rotation of the fan 97. As this air flow collides with the engine main body 94, the crankcase member 98 and the cylinder member 99 are cooled.

[0208] The crankcase member 98 includes a crankcase main body 100 and a crankshaft 104 or the like housed in the crankcase main body 100. The central axis (crankshaft axis) Cr3 of the crankshaft 104 extends in the left-right direction. The fan 97 is integrally and rotatably connected to a right end portion of the crankshaft 104. The fan 97 is driven by the rotation of the crankshaft 104. Lubricating oil is stored in the crankcase main body 100. The oil is conveyed by an oil pump (not illustrated)

and is circulated in the engine main body 94.

[0209] The cylinder member 99 includes a cylinder body 101, a cylinder head 102, a head cover 103, and components housed in members 101 to 103. As shown in FIG. 20, the cylinder body 101 is connected to a front portion of the crankcase main body 100. The cylinder head 102 is connected to a front portion of the cylinder body 101. The head cover 103 is connected to a front portion of the cylinder head 102.

[0210] As shown in FIG. 23, a cylinder hole 101a is made in the cylinder body 101. The cylinder hole 101a houses a piston 105 so that the piston 105 is able to reciprocate. The piston 105 is connected to the crankshaft 104 via a connecting rod. Hereinafter, the central axis Cy3 of the cylinder hole 101a is referred to as a cylinder axis Cy3. As shown in FIG. 21, the engine main body 94 is disposed so that the cylinder axis Cy3 extends in the front-rear direction. To be more specific, the direction in which the cylinder axis Cy3 extends from the crankcase member 98 to the cylinder member 99 is frontward and upward. The angle of inclination of the cylinder axis Cy3 with respect to the horizontal direction is 0 degrees or greater and 45 degrees or less.

[0211] As shown in FIG. 23, one combustion chamber 106 is formed in the cylinder member 99. The combustion chamber 106 is formed by an inner surface of the cylinder hole 101a of the cylinder body 101, the cylinder head 102, and the piston 105. As shown in FIG. 21, the combustion chamber 106 is positioned frontward of the crankshaft axis Cr3. In other words, it is assumed that a linear line which passes the crankshaft axis Cr3 and is parallel to the up-down direction is L5 so that when viewed in the left-right direction, the combustion chamber 106 is positioned in front of the linear line L5.

[0212] As shown in FIG. 23, a cylinder intake passage member 107 and a cylinder exhaust passage member 108 (a single-combustion-chamber cylinder exhaust passage member) are formed in the cylinder head 102. In the cylinder head 102, an intake port 107a and an exhaust port 108a are formed in a wall portion forming the combustion chamber 106. The cylinder intake passage member 107 extends from the intake port 107a to an inlet formed in the outer surface (upper surface) of the cylinder head 102. The cylinder exhaust passage member 108 extends from the exhaust port 108a to an outlet formed in the outer surface (lower surface) of the cylinder head 102. Air passes through the inside of the cylinder intake passage member 107 and is then supplied to the combustion chamber 106. Exhaust gas exhausted from the combustion chamber 106 passes through the cylinder exhaust passage member 108.

[0213] An intake valve V5 is provided in the cylinder intake passage member 107. An exhaust valve V6 is provided in the cylinder exhaust passage member 108. The intake port 107a is opened and closed by movement of the intake valve V5. The exhaust port 108a is opened and closed by movement of the exhaust valve V6. An intake pipe 110 is connected to an end portion (inlet) of

the cylinder intake passage member 107. An exhaust pipe 111 is connected to an end portion (outlet) of the cylinder exhaust passage member 108. The path length of the cylinder exhaust passage member 108 is referred to as a3.

[0214] As described above, FIG. 20 does not show some parts such as the right link component 90R and the shroud 96. With this arrangement, a connection part of the lower surface of the cylinder head 102 and the exhaust pipe 111 is viewable. As shown in FIG. 20 and FIG. 22, when viewed from below, an upstream end portion of the exhaust pipe 111 is positioned between the right link component 90R and the left link component 90L. However, as shown in FIG. 21, when viewed in the left-right direction, the exhaust pipe 111 passes above the right link component 90R and the left link component 90L. The exhaust pipe 111 therefore does not pass between the right link component 90R and the left link component 90L.

[0215] The single-cylinder four-stroke engine unit 93 includes an ignition plug, a valve operating mechanism, an injector, and a throttle valve in the same manner as the engine main body 20 of Embodiment 1. Furthermore, in the same manner as Embodiment 1, the single-cylinder four-stroke engine unit 93 includes sensors such as an engine rotation speed sensor and a throttle position sensor.

[0216] As described above, the single-cylinder four-stroke engine unit 93 includes the engine main body 94, the exhaust pipe 111, the silencer 112, the main catalyst 116, the upstream oxygen detector 113, and the downstream oxygen detector 114. The silencer 112 is provided with a discharge port 112e which is exposed to the atmosphere. The path extending from the combustion chamber 106 to the discharge port 112e is referred to as an exhaust path 118 (see FIG. 23). The exhaust path 118 is formed by the cylinder exhaust passage member 108, the exhaust pipe 111, and the silencer 112. The exhaust path 118 is a space through which exhaust gas passes.

[0217] As shown in FIG. 23, the upstream end portion of the exhaust pipe 111 is connected to the cylinder exhaust passage member 108. The downstream end portion of the exhaust pipe 111 is connected to the silencer 112. A catalyst unit 115 is provided in the middle of the exhaust pipe 111. A part of the exhaust pipe 111, which is upstream of the catalyst unit 115, is referred to as an upstream exhaust pipe 111a. A part of the exhaust pipe 111, which is downstream of the catalyst unit 115, is referred to as a downstream exhaust pipe 111b. While FIG. 23 depicts the exhaust pipe 111 as a linear pipe for simplification, the exhaust pipe 111 is not a linear pipe.

[0218] As shown in FIG. 20, the exhaust pipe 111 is provided on the right side of the motorcycle 80. As shown in FIG. 21, a part of the exhaust pipe 111 is provided below the crankshaft axis Cr3. The exhaust pipe 111 has two bended portions. The upstream one of the two bend-

ed portions is simply referred to as an upstream bended portion. The downstream one of the two bended portions is simply referred to as a downstream bended portion. When viewed in the left-right direction, the upstream bended portion changes the flow direction of the exhaust gas from downward to rearward and downward. When viewed in the left-right direction, the downstream bended portion changes the flow direction of the exhaust gas from downward and rearward to rearward and upward. A part which is downstream of the downstream bended portion is positioned below the crankshaft axis Cr3. The downstream end of the main catalyst 116 is provided at the downstream bended portion.

[0219] The exhaust gas exhausted from the downstream end of the exhaust pipe 111 flows into the silencer 112. The silencer 112 is connected to the exhaust pipe 111. The silencer 112 is configured to restrain pulsation in the exhaust gas. With this, the silencer 112 restrains the volume of the sound (exhaust sound) generated by the exhaust gas. Multiple expansion chambers and multiple pipes connecting the expansion chambers with one another are provided inside the silencer 112. The downstream end portion of the exhaust pipe 111 is provided inside an expansion chamber of the silencer 112. The discharge port 112e exposed to the atmosphere is provided at the downstream end of the silencer 112. As shown in FIG. 23, the path length of the exhaust path extending from the downstream end of the exhaust pipe 111 to the discharge port 112e is referred to as e3. The exhaust gas having passed the silencer 112 is discharged to the atmosphere via the discharge port 112e. As shown in FIG. 21, the discharge port 112e is positioned rearward of the crankshaft axis Cr3.

[0220] The main catalyst 116 is provided inside the exhaust pipe 111. The upstream end of the main catalyst 116 is provided upstream of the upstream end 112a of the silencer 112. The catalyst unit 115 includes a hollow cylindrical casing 117 and the main catalyst 116. The upstream end of the casing 117 is connected to the upstream exhaust pipe 111a. The downstream end of the casing 117 is connected to the downstream exhaust pipe 111b. The casing 117 forms a part of the exhaust pipe 111. The main catalyst 116 is fixed to the inside of the casing 117. The exhaust gas is purified when passing through the main catalyst 116. All exhaust gas exhausted from the exhaust port 108a of the combustion chamber 106 passes through the main catalyst 116. The main catalyst 116 purifies the exhaust gas exhausted from the combustion chamber 106 most in the exhaust path 118.

[0221] The materials of the main catalyst 116 are identical to those of the main catalyst 39 of Embodiment 1. The main catalyst 116 has a porous structure. In the main catalyst 116, pores which are sufficiently narrower than the width of the path in the upstream exhaust pipe 111a are formed. As shown in FIG. 23, the length of the main catalyst 116 in the path direction is referred to as c3. Furthermore, the maximum width of the main catalyst 116 in the direction orthogonal to the path direction is

referred to as w3. The length c3 of the main catalyst 116 is longer than the maximum width w3 of the main catalyst 116.

[0222] As shown in FIG. 23, the casing 117 includes a catalyst-provided passage member 117b, an upstream passage member 117a, and a downstream passage member 117c. The main catalyst 116 is provided in the catalyst-provided passage member 117b. In the path direction, the upstream end and the downstream end of the catalyst-provided passage member 117b are respectively in the same positions as the upstream end and the downstream end of the main catalyst 116. The cross-sectional area of the catalyst-provided passage member 117b cut along the direction orthogonal to the path direction is substantially constant. The upstream passage member 117a is connected to the upstream end of the catalyst-provided passage member 117b. The downstream passage member 117c is connected to the upstream end of the catalyst-provided passage member 117b.

[0223] The upstream passage member 117a is at least partially tapered. The tapered part increases its inner diameter toward the downstream side. The downstream passage member 117c is at least partially tapered. The tapered part decreases its inner diameter toward the downstream side. The cross-sectional area of the catalyst-provided passage member 117b cut along the direction orthogonal to the path direction is referred to as S3. The cross-sectional area of the upstream end of (at least a part of) the upstream passage member 117a cut along the direction orthogonal to the path direction is smaller than the area S3. In at least a part of the downstream passage member 117c, the cross-sectional area of the downstream passage member 117c cut along the direction orthogonal to the path direction is smaller than the area S3. The at least part of the downstream passage member 117c includes the downstream end of the downstream passage member 117c.

[0224] As shown in FIG. 21, the main catalyst 116 is provided frontward of the crankshaft axis Cr3. In other words, when viewed in the left-right direction, the main catalyst 116 is provided in front of the linear line L5. As described above, the linear line L5 is a linear line which passes the crankshaft axis Cr3 and is in parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 116 is positioned in front of (below) the cylinder axis Cy3.

[0225] As shown in FIG. 21, it is assumed that a linear line which is orthogonal to the cylinder axis Cy3 and orthogonal to the crankshaft axis Cr3 is L6. When viewed in the left-right direction, the main catalyst 116 is positioned in front of the linear line L6.

[0226] As shown in FIG. 23, the path length from the upstream end of the exhaust pipe 111 to the upstream end of the main catalyst 116 is referred to as b3. The path length b3 is a path length of a passage member formed by the upstream exhaust pipe 111a and the upstream passage member 117a of the catalyst unit 115.

In other words, the path length b_3 is a path length from the downstream end of the cylinder exhaust passage member 108 to the upstream end of the main catalyst 116. Furthermore, the path length from the downstream end of the main catalyst 116 to the downstream end of the exhaust pipe 111 is referred to as d_3 . The path length d_3 is the path length of a passage member formed by the downstream passage member 117c of the catalyst unit 115 and the downstream exhaust pipe 111b. The path length from the combustion chamber 106 to the upstream end of the main catalyst 116 is a_3+b_3 . The path length from the downstream end of the main catalyst 116 to the discharge port 112e is d_3+e_3 .

[0227] Being similar to Embodiment 1, the main catalyst 116 is provided so that the path length a_3+b_3 is shorter than the path length d_3+e_3 . Furthermore, being similar to Embodiment 1, the main catalyst 116 is provided so that the path length a_3+b_3 is shorter than the path length d_3 . Furthermore, being similar to Embodiment 1, the main catalyst 116 is provided so that the path length b_3 is shorter than the path length d_3 .

[0228] The upstream oxygen detector 113 is provided on the exhaust pipe 111. The upstream oxygen detector 113 is provided upstream of the main catalyst 116. The upstream oxygen detector 113 is provided upstream exhaust pipe 111a (see FIG. 23). The upstream oxygen detector 113 is a sensor configured to detect the oxygen density in the exhaust gas. The structure of the upstream oxygen detector 113 is identical to that of the upstream oxygen detector of Embodiment 1.

[0229] As shown in FIG. 23, the path length from the combustion chamber 106 to the upstream oxygen detector 113 is referred to as h_5 . Furthermore, the path length from the upstream oxygen detector 113 to the upstream end of the main catalyst 116 is referred to as h_6 . Being different from Embodiment 1, the upstream oxygen detector 113 is provided so that the path length h_5 is longer than the path length h_6 .

[0230] The downstream oxygen detector 114 is provided on the exhaust pipe 111. The downstream oxygen detector 114 is provided downstream of the main catalyst 116. The downstream oxygen detector 114 is provided in the casing 117 of the catalyst unit 115. To be more specific, the downstream oxygen detector 114 is provided on a downstream passage member 117c (see FIG. 23). The downstream oxygen detector 114 is a sensor configured to detect the oxygen density in the exhaust gas. The structure of the downstream oxygen detector 114 is identical to that of the upstream oxygen detector 37 of Embodiment 1.

[0231] As described above, in the motorcycle 80 of Embodiment 3, the upstream oxygen detector 113 and the downstream oxygen detector 114 are provided upstream and downstream of the main catalyst 116, respectively. Apart from the above, the arrangements of the components are similar to those in the motorcycle 1 of Embodiment 1. The arrangements similar to those in Embodiment 1 exert effects similar to the effects described in

Embodiment 1.

[0232] The path length (h_5) from one combustion chamber 106 to the upstream oxygen detector 113 is longer than the path length (h_6) from the upstream oxygen detector 113 to the upstream end of the main catalyst 116. The upstream oxygen detector 113 is therefore positioned to be close to the main catalyst 116. Due to this, the oxygen density of the exhaust gas flowing into the main catalyst 116 can be more precisely detected. The combustion control, based on a signal from the upstream oxygen detector 113, can therefore be more precisely carried out. Due to this, the purification performance of purifying the exhaust gas by the main catalyst 116 can be further improved. Moreover, because of the improvement in the precision of the combustion control, the progress of the deterioration of the main catalyst 116 can be restrained. The initial performance of the motorcycle 80 in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0233] The structure of the exhaust system of Modification 1-2 described above may be used in the motorcycle 80 of Embodiment 3. Effects similar to those in Modification 1-2 are obtained in such a case.

(Modification 3-1 of Embodiment 3)

[0234] FIG. 24 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 3-1 of Embodiment 3. FIG. 25 is a bottom view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 3-1 of Embodiment 3. FIG. 26 is a schematic diagram of an engine main body and an exhaust system of Modification 3-1 of Embodiment 3. In Modification 3-1, items identical to those in Embodiment 3 are indicated by the same reference numerals and detailed descriptions thereof are omitted.

[0235] As shown in FIG. 24, as compared to Embodiment 3 above, the main catalyst 116 is provided downstream in Modification 3-1. The specific structure of the main catalyst 116 is identical to the structure in Embodiment 3 above. The main catalyst 116 of Modification 3-1 is provided in the exhaust pipe 211. In the same manner as in Embodiment 3 above, the upstream end of the main catalyst 116 is provided upstream of the upstream end 112a of the silencer 112.

[0236] Being similar to the exhaust pipe 111 of Embodiment 3, the exhaust pipe 211 is connected to the cylinder exhaust passage member 108 (see FIG. 26) and the silencer 112. A catalyst unit 2115 is provided in the middle of the exhaust pipe 211. As shown in FIG. 26, a part of the exhaust pipe 211, which is upstream of the catalyst unit 2115, is referred to as an upstream exhaust pipe 2111a. A part of the exhaust pipe 211, which is downstream of the catalyst unit 2115, is referred to as a downstream exhaust pipe 2111b. The downstream exhaust pipe 2111b is provided in the silencer 112. While FIG. 26 depicts the exhaust pipe 211 as a linear pipe

for simplification, the exhaust pipe 2111 is not a linear pipe.

[0237] The catalyst unit 2115 includes a main catalyst 116 and a casing 2117. The casing 2117 includes an upstream passage member 2117a, a catalyst-provided passage member 2117b, and a downstream passage member 2117c. In the path direction, the upstream end and the downstream end of the catalyst-provided passage member 2117b are respectively in the same positions as the upstream end and the downstream end of the main catalyst 116.

[0238] As shown in FIG. 24, the main catalyst 116 is provided rearward of the crankshaft axis Cr3. In other words, when viewed in the left-right direction, the main catalyst 116 is provided behind the linear line L5. As described above, the linear line L5 is a linear line which passes the crankshaft axis Cr3 and is in parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 116 is positioned in front of (below) the cylinder axis Cy3.

[0239] As shown in FIG. 24, when viewed in the left-right direction, the main catalyst 116 is provided behind the linear line L6. The linear line L6 is a linear line which is orthogonal to the cylinder axis Cy3 and orthogonal to the crankshaft axis Cr3.

[0240] As shown in FIG. 26, the path length from the upstream end of the exhaust pipe 2111 to the upstream end of the main catalyst 116 is referred to as b13. The path length from the downstream end of the main catalyst 116 to the downstream end of the exhaust pipe 2111 is referred to as d13. The path length from the combustion chamber 106 to the upstream end of the main catalyst 116 is a3+b13. The path length from the downstream end of the main catalyst 116 to the discharge port 112e is d13+e3.

[0241] In the same manner as in Embodiment 3 above, the main catalyst 116 of Modification 3-1 is provided so that the path length a3+b13 is shorter than the path length d13+e3. Being different from Embodiment 3 above, the main catalyst 116 of Modification 3-1 is provided so that the path length a3+b13 is longer than the path length d13. Being different from Embodiment 3 above, the main catalyst 116 of Modification 3-1 is provided so that the path length b13 is longer than the path length d13.

[0242] The upstream oxygen detector 113 is provided on the exhaust pipe 2111. The upstream oxygen detector 113 is provided upstream of the main catalyst 116. The upstream oxygen detector 113 is provided upstream exhaust pipe 2111a (see FIG. 26).

[0243] As shown in FIG. 26, the path length from the combustion chamber 106 to the upstream oxygen detector 113 is referred to as h15. Furthermore, the path length from the upstream oxygen detector 113 to the upstream end of the main catalyst 116 is referred to as h16. Being different from Embodiment 3, the upstream oxygen detector 113 is provided so that the path length h15 is longer than the path length h16. This structure is identical to that of Embodiment 1 above.

[0244] The downstream oxygen detector 114 is provided on the exhaust pipe 2111. The downstream oxygen detector 114 is provided downstream of the main catalyst 116. The downstream oxygen detector 114 is provided downstream exhaust pipe 2111b (see FIG. 26). The downstream oxygen detector 114 penetrates a side wall of the silencer 112. One end portion (detecting portion) of the downstream oxygen detector 114 is provided in the downstream exhaust pipe 2111b. The other end portion of the downstream oxygen detector 114 is provided outside the silencer 112.

[0245] In Modification 3-1, arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

(Embodiment 4)

[0246] FIG. 27 is a side view of a motorcycle of Embodiment 4 of the present teaching. FIG. 28 is a bottom view of the motorcycle of Embodiment 4. FIG. 29 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Embodiment 4. FIG. 30 is a bottom view showing the state in which the vehicle body cover, etc. have been removed from the motorcycle of Embodiment 4. FIG. 31 is a schematic diagram of an engine and an exhaust system of the motorcycle of Embodiment 4.

[0247] A vehicle of Embodiment 4 is a so-called sport-scooter-type motorcycle 120. As shown in FIG 29, the motorcycle 120 is provided with a vehicle body frame 121. The vehicle body frame 121 includes a head pipe 121a, a main frame 121b, a right seat rail 122R, a left seat rail 122L, paired left and right under frames 121c, and a crosswise member 121d (see FIG. 30). The main frame 121b extends rearward and downward from the head pipe 121a. From ends at intermediate parts of the main frame 121b to the other ends, the under frames 121c extend rearward and downward and are then curved downward and extend downward in a substantially horizontal direction. As shown in FIG. 30, the crosswise member 121d is connected to the left and right under frames 121c. The crosswise member 121d extends in the left-right direction. As shown in FIG. 29, the left seat rail 122L extends rearward and upward from an intermediate portion of the main frame 121b. As shown in FIG. 30, the right seat rail 122R is connected to a right end portion of the crosswise member 121d. As shown in FIG. 29, from an end on the crosswise member 121d side to the other end, the right seat rail 122R extends upward and is then curved rearward. A rear portion of the right seat rail 122R extends substantially in parallel with the left seat rail 122L.

[0248] A steering shaft is rotatably inserted into the head pipe 121a. A handlebar 123 is provided at an upper part of the steering shaft. A display (not illustrated) is provided in the vicinity of the handlebar 123. The display is configured to display vehicle speed, engine rotation speed, warnings, and the like.

[0249] Paired left and right front forks 124 are supported at a lower part of the steering shaft. The lower end portions of the front forks 124 support a front wheel 125 in a rotatable manner.

[0250] The left and right seat rails 122L and 122R support a seat 126 (see FIG. 27).

[0251] As shown in FIG. 27, the motorcycle 120 is provided with a vehicle body cover 127 which covers the vehicle body frame 121, and the like. The vehicle body cover 127 includes a front cowling 127a, a main cover 127b, and an under cover 127c. The front cowling 127a covers the head pipe 121a and an upper part of the main frame 121b. The main cover 127b and the under cover 127c cover a lower part of the main frame 121b. The main cover 127b covers the right seat rail 122R and the left seat rail 122L. The under cover 127c covers the under frames 121c and the crosswise member 121d. The main cover 127b covers an air cleaner 147 (see FIG. 29) and a front portion of a subsequently-described engine main body 133. The air cleaner 147 is provided in front of the engine main body 133.

[0252] A unit-swinging single-cylinder four-stroke engine unit 132 is attached to the vehicle body frame 121. The single-cylinder four-stroke engine unit 132 includes the engine main body 133 and a power transmission unit 134 (see FIG. 28 and FIG. 30). The power transmission unit 134 is connected to a rear portion of the engine main body 133. The power transmission unit 134 is provided leftward of the engine main body 133. The power transmission unit 134 houses a transmission. The power transmission unit 134 supports a rear wheel 128 in a rotatable manner.

[0253] The engine main body 133 and the power transmission unit 134 are configured to be integrally swingable with respect to the vehicle body frame 121. To be more specific, as shown in FIG. 29 and FIG. 30, a right link component 130R and a left link component 130L are connected to left and right end portions of a lower part of the engine main body 133. The right link component 130R and the left link component 130L extend frontward from the engine main body 133. The leading end portions of the right link component 130R and the left link component 130L are rotatably connected to the vehicle body frame 121 (the under frames 121c) via pivot shafts 129. Furthermore, the right link component 130R and the left link component 130L are rotatably connected to the engine main body 133 via pivot shafts 131.

[0254] The single-cylinder four-stroke engine unit 132 is a water-cooled engine. The single-cylinder four-stroke engine unit 132 includes the engine main body 133, a water cooler 135, the power transmission unit 134, the air cleaner 147 (see FIG. 29 and FIG. 30), an intake pipe 148 (see FIG. 29), an exhaust pipe 149, a silencer 150, a main catalyst 154 (a single-combustion-chamber main catalyst), an upstream oxygen detector 151 (a single-combustion-chamber upstream oxygen detector), and a downstream oxygen detector 152 (a single-combustion-chamber upstream oxygen detector). The single-cylinder

four-stroke engine unit 132 further includes an electronic control unit which is similar to the electronic control unit 45 of Embodiment 1. The electronic control unit controls the engine main body 133.

[0255] The water cooler 135 includes a radiator (not illustrated), a water pump (not illustrated), a fan (not illustrated), and a cover member 135a. The fan is provided to the right of a rear portion of the engine main body 133. The radiator is provided to the right of the fan. The cover member 135a covers the radiator from the right. Furthermore, the cover member 135a covers the radiator and the fan from above, below, front, and rear.

[0256] The engine main body 133 is a single-cylinder four-stroke engine. As shown in FIG. 29, the engine main body 133 includes a crankcase member 136 and a cylinder member 137. The cylinder member 137 extends frontward from the crankcase member 136.

[0257] The crankcase member 136 includes a crankcase main body 138 and a crankshaft 142 or the like housed in the crankcase main body 138. The central axis (crankshaft axis) Cr4 of the crankshaft 142 extends in the left-right direction. Lubricating oil is stored in the crankcase main body 138. The oil is conveyed by an oil pump (not illustrated) and is circulated in the engine main body 133.

[0258] The fan of the water cooler 135 is connected to a right end portion of the crankshaft 142 to be rotatable in an integrated manner. The fan is driven by the rotation of the crankshaft 142. The fan generates an air flow for cooling the engine main body 133. To be more specific, air is introduced into the cover member 135a by the rotation of the fan. As heat exchange occurs between the introduced air and the coolant in the radiator, the coolant is cooled. The engine main body 133 is cooled by the cooled coolant.

[0259] The cylinder member 137 includes a cylinder body 139, a cylinder head 140, a head cover 141, and components housed in the members 139 to 141. As shown in FIG. 29 and FIG. 30, the cylinder body 139 is connected to a front portion of the crankcase main body 138. The cylinder head 140 is connected to a front portion of the cylinder body 139. As shown in FIG. 29, the head cover 141 is connected to a front portion of the cylinder head 140.

[0260] As shown in FIG. 31, a cylinder hole 139a is made in the cylinder body 139. The cylinder hole 139a houses a piston 143 so that the piston 143 is able to reciprocate. The piston 143 is connected to the crankshaft 142 via a connecting rod. Hereinafter, the central axis Cy4 of the cylinder hole 139a is referred to as a cylinder axis Cy4. As shown in FIG. 29, the engine main body 133 is disposed so that the cylinder axis Cy4 extends in the front-rear direction. To be more specific, the direction in which the cylinder axis Cy4 extends from the crankcase member 136 to the cylinder member 137 is frontward and upward. The angle of inclination of the cylinder axis Cy4 with respect to the horizontal direction is 0 degrees or greater and 45 degrees or less.

[0261] As shown in FIG. 31, one combustion chamber 144 is formed in the cylinder member 137. The combustion chamber 144 is formed by an inner surface of the cylinder hole 139a of the cylinder body 139, the cylinder head 140, and the piston 143. As shown in FIG. 29, the combustion chamber 144 is positioned frontward of the crankshaft axis Cr4. In other words, it is assumed that a linear line which passes the crankshaft axis Cr4 and is parallel to the up-down direction is L7 so that when viewed in the left-right direction, the combustion chamber 144 is positioned in front of the linear line L7.

[0262] As shown in FIG. 31, a cylinder intake passage member 145 and a cylinder exhaust passage member 146 (a single-combustion-chamber cylinder exhaust passage member) are formed in the cylinder head 140. In the cylinder head 140, an intake port 145a and an exhaust port 146a are formed in a wall portion forming the combustion chamber 144. The cylinder intake passage member 145 extends from the intake port 145a to an inlet formed in the outer surface (upper surface) of the cylinder head 140. The cylinder exhaust passage member 146 extends from the exhaust port 146a to an outlet formed in the outer surface (lower surface) of the cylinder head 140. Air passes through the inside of the cylinder intake passage member 145 and is then supplied to the combustion chamber 144. Exhaust gas exhausted from the combustion chamber 144 passes through the cylinder exhaust passage member 146.

[0263] An intake valve V7 is provided in the cylinder intake passage member 145. An exhaust valve V8 is provided in the cylinder exhaust passage member 146. The intake port 145a is opened and closed by movement of the intake valve V7. The exhaust port 146a is opened and closed by movement of the exhaust valve V8. An intake pipe 148 is connected to an end portion (inlet) of the cylinder intake passage member 145. An exhaust pipe 149 is connected to an end portion (outlet) of the cylinder exhaust passage member 146. The path length of the cylinder exhaust passage member 146 is referred to as a4.

[0264] As shown in FIG. 30, the exhaust pipe 149 is connected to the lower surface of the cylinder head 140. When viewed from below, an upstream end portion of the exhaust pipe 149 is positioned between the right link component 130R and the left link component 130L. Furthermore, as shown in FIG. 29, when viewed in the left-right direction, a part of the exhaust pipe 149 is overlapped with the right link component 130R and the left link component 130L. The exhaust pipe 149 therefore passes between the right link component 130R and the left link component 130L.

[0265] The single-cylinder four-stroke engine unit 132 includes an ignition plug, a valve operating mechanism, an injector, and a throttle valve in the same manner as Embodiment 1. Furthermore, in the same manner as Embodiment 1, the single-cylinder four-stroke engine unit 132 includes sensors such as an engine rotation speed sensor and a throttle position sensor.

[0266] As described above, the single-cylinder four-stroke engine unit 132 includes the engine main body 133, the exhaust pipe 149, the silencer 150, the main catalyst 154, the upstream oxygen detector 151, and the downstream oxygen detector 152. The silencer 150 is provided with a discharge port 150e which is exposed to the atmosphere. The path extending from the combustion chamber 144 to the discharge port 150e is referred to as an exhaust path 156 (see FIG. 31). The exhaust path 156 is formed by the cylinder exhaust passage member 146, the exhaust pipe 149, and the silencer 150. The exhaust path 156 is a space through which exhaust gas passes.

[0267] As shown in FIG. 31, the upstream end portion of the exhaust pipe 149 is connected to the cylinder exhaust passage member 146. The downstream end portion of the exhaust pipe exhaust pipe exhaust pipe 149 is connected to the silencer 150. A catalyst unit 153 is provided in the middle of the exhaust pipe 149. A part of the exhaust pipe 149, which is upstream of the catalyst unit 153, is referred to as an upstream exhaust pipe 149a. A part of the exhaust pipe 149, which is downstream of the catalyst unit 153, is referred to as a downstream exhaust pipe 149b. While FIG. 31 depicts the exhaust pipe 149 as a linear pipe for simplification, the exhaust pipe 149 is not a linear pipe.

[0268] As shown in FIG. 28 and FIG. 30, most of the exhaust pipe 149 is provided on the right side of the motorcycle 120. An upstream end portion of the exhaust pipe 149 is positioned at a substantially central part in the left-right direction of the motorcycle 120. As shown in FIG. 29, a part of the exhaust pipe 149 is positioned below the crankshaft axis Cr4. The exhaust pipe 149 has two bended portions. The upstream one of the two bended portions is simply referred to as an upstream bended portion. The downstream one of the two bended portions is simply referred to as a downstream bended portion. When viewed in the left-right direction, the upstream bended portion changes the flow direction of the exhaust gas from a direction along the up-down direction to a direction along the front-rear direction. To be more specific, when viewed in the left-right direction, the upstream bended portion changes the flow direction of the exhaust gas from downward to rearward and downward. When viewed in the left-right direction, the downstream bended portion changes the flow direction of the exhaust gas from rearward and downward to rearward. A part which is downstream of the downstream bended portion is positioned below the crankshaft axis Cr4. The main catalyst 154 is provided between the two bended portions.

[0269] The exhaust gas exhausted from the downstream end of the exhaust pipe 149 flows into the silencer 150. The silencer 150 is connected to the exhaust pipe 149. The silencer 150 is configured to restrain pulsation in the exhaust gas. With this, the silencer 150 restrains the volume of the sound (exhaust sound) generated by the exhaust gas. Multiple expansion chambers and multiple pipes connecting the expansion chambers with one

another are provided inside the silencer 150. The downstream end portion of the exhaust pipe exhaust pipe 149 is provided inside an expansion chamber of the silencer 150. The discharge port 150e exposed to the atmosphere is provided at the downstream end of the silencer 150. As shown in FIG. 31, the path length of the exhaust path extending from the downstream end of the exhaust pipe 149 to the discharge port 150e is referred to as e_4 . The exhaust gas having passed the silencer 150 is discharged to the atmosphere via the discharge port 150e. As shown in FIG. 29, the discharge port 150e is rearward of the crankshaft axis Cr4.

[0270] The main catalyst main catalyst 154 is provided in the exhaust pipe 149. The upstream end of the main catalyst 154 is provided upstream of the upstream end 150a of the silencer 150. The catalyst unit 153 includes a hollow cylindrical casing 155 and the catalyst unit 153. The upstream end of the casing 155 is connected to the upstream exhaust pipe 149a. The downstream end of the casing 155 is connected to the downstream exhaust pipe 149b. The casing 155 forms a part of the exhaust pipe 149. The main catalyst 154 is fixed to the inside of the casing 155. The exhaust gas is purified while passing through the main catalyst 154. All exhaust gas exhausted from the exhaust port 146a of the combustion chamber 144 passes through the main catalyst 154. The main catalyst 154 purifies the exhaust gas exhausted from the combustion chamber 144 most in the exhaust path 156.

[0271] The materials of the main catalyst 154 are identical to those of the main catalyst 39 of Embodiment 1. The main catalyst 154 has a porous structure. In the main catalyst 154, pores which are sufficiently narrower than the width of the path in the upstream exhaust pipe 149a are formed. As shown in FIG. 31, the length of the main catalyst 154 in the path direction is referred to as c_4 . Furthermore, the maximum width of the main catalyst 154 in the direction orthogonal to the path direction is referred to as w_4 . The length c_4 of the main catalyst 154 is longer than the maximum width w_4 of the main catalyst 154.

[0272] As shown in FIG. 31, the casing 155 includes a catalyst-provided passage member 155b, an upstream passage member 155a, and a downstream passage member 155c. The main catalyst 154 is provided in the catalyst-provided passage member 155b. In the path direction, the upstream end and the downstream end of the catalyst-provided passage member 155b are respectively in the same positions as the upstream end and the downstream end of the main catalyst 154. The cross-sectional area of the catalyst-provided passage member 155b cut along the direction orthogonal to the path direction is substantially constant. The upstream passage member 155a is connected to the upstream end of the catalyst-provided passage member 155b. The downstream passage member 155c is connected to the upstream end of the catalyst-provided passage member 155b.

[0273] The upstream passage member 155a is at least

partially tapered. The tapered part increases its inner diameter toward the downstream side. The downstream passage member 155c is at least partially tapered. The tapered part decreases its inner diameter toward the downstream side. The cross-sectional area of the catalyst-provided passage member 155b cut along the direction orthogonal to the path direction is referred to as S_4 . In at least a part of the upstream passage member 155a, the cross-sectional area of the upstream passage member 155a cut along the direction orthogonal to the path direction is smaller than the area S_4 . The at least part of the upstream passage member 155a includes the upstream end of the upstream passage member 155a. In at least a part of the downstream passage member 155c, the cross-sectional area of the downstream passage member 155c cut along the direction orthogonal to the path direction is smaller than the area S_4 . The at least part of the downstream passage member 155c includes the downstream end of the downstream passage member 155c.

[0274] As shown in FIG. 29, the main catalyst 154 is provided frontward of the crankshaft axis Cr4. In other words, when viewed in the left-right direction, the main catalyst 154 is provided in front of the linear line L7. As described above, the linear line L7 is a linear line which passes the crankshaft axis Cr4 and is in parallel to the up-down direction. As a matter of course, the upstream end of the main catalyst 154 is provided frontward of the crankshaft axis Cr4. When viewed in the left-right direction, the main catalyst 154 is positioned in front of (below) the cylinder axis Cy4.

[0275] As shown in FIG. 29, it is assumed that a linear line which is orthogonal to the cylinder axis Cy4 and orthogonal to the crankshaft axis Cr4 is L8. When viewed in the left-right direction, the main catalyst 154 is positioned in front of the linear line L8.

[0276] As shown in FIG. 31, the path length from the upstream end of the exhaust pipe 149 to the upstream end of the main catalyst 154 is referred to as b_4 . The path length b_4 is a path length of a passage member formed by the upstream exhaust pipe 149a and the upstream passage member 155a of the catalyst unit 153. In other words, the path length b_4 is a path length from the downstream end of the cylinder exhaust passage member 146 to the upstream end of the main catalyst 154. Furthermore, the path length from the downstream end of the main catalyst 154 to the downstream end of the exhaust pipe 149 is referred to as d_4 . The path length d_4 is the path length of a passage member formed by the downstream passage member 155c of the catalyst unit 153 and the downstream exhaust pipe 149b. The path length from the combustion chamber 144 to the upstream end of the main catalyst 154 is a_4+b_4 . The path length from the downstream end of the main catalyst 154 to the discharge port 150e is d_4+e_4 .

[0277] Being similar to Embodiment 1, the main catalyst 154 is provided so that the path length a_4+b_4 is shorter than the path length d_4+e_4 . Being similar to Embodi-

ment 1, the main catalyst 154 is provided so that the path length $a4+b4$ is shorter than the path length $d4$. Furthermore, being similar to Embodiment 1, the main catalyst 154 is provided so that the path length $b4$ is shorter than the path length $d4$.

[0278] The upstream oxygen detector 151 is provided on the exhaust pipe 149. The upstream oxygen detector 151 is provided upstream of the main catalyst 154. The upstream oxygen detector 151 is a sensor configured to detect the oxygen density in the exhaust gas. The structure of the upstream oxygen detector 151 is identical to that of the upstream oxygen detector of Embodiment 1.

[0279] As shown in FIG. 31, the path length from the combustion chamber 144 to the upstream oxygen detector 151 is referred to as $h7$. Furthermore, the path length from the upstream oxygen detector 151 to the upstream end of the main catalyst 154 is referred to as $h8$. Being similar to Embodiment 1, the upstream oxygen detector 151 is provided so that the path length $h7$ is shorter than the path length $h8$.

[0280] As described above, in the motorcycle 120 of Embodiment 4, the upstream oxygen detector 151 and the downstream oxygen detector 152 are provided upstream and downstream of the main catalyst 154, respectively. Apart from the above, the arrangements of the components are similar to those in the motorcycle 1 of Embodiment 1. The arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

[0281] The structure of the exhaust system of Modification 1-2 described above may be used in the motorcycle 120 of Embodiment 4. Effects similar to those in Modification 1-2 are obtained in such a case.

(Modification 4-1 of Embodiment 4)

[0282] FIG. 32 is a side view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 4-1 of Embodiment 4. FIG. 33 is a bottom view showing a state in which a vehicle body cover, etc. have been removed from the motorcycle of Modification 4-1 of Embodiment 4. FIG. 34 is a schematic diagram of an engine main body and an exhaust system of Modification 4-1 of Embodiment 4. In Modification 4-1, items identical to those in Embodiment 4 are indicated by the same reference numerals and detailed descriptions thereof are omitted.

[0283] As shown in FIG. 32, as compared to Embodiment 4 above, the main catalyst 154 is provided downstream in Modification 4-1. The specific structure of the main catalyst 154 is identical to the structure in Embodiment 4 above. The main catalyst 154 of Modification 4-1 is provided in the exhaust pipe 2149. In the same manner as in Embodiment 4 above, the upstream end of the main catalyst 154 is provided upstream of the upstream end 150a of the silencer 150.

[0284] Being similar to the exhaust pipe 149 of Embodiment 4, the exhaust pipe 2149 is connected to the

cylinder exhaust passage member 146 (see FIG. 34) and the silencer 150. A catalyst unit 153 is provided in the middle of the exhaust pipe 2149. As shown in FIG. 34, a part of the exhaust pipe 2149, which is upstream of the catalyst unit 153, is referred to as an upstream exhaust pipe 2149a. A part of the exhaust pipe 2149, which is downstream of the catalyst unit 153, is referred to as a downstream exhaust pipe 2149b. The downstream exhaust pipe 2149b is provided in the silencer 150. While FIG. 34 depicts the exhaust pipe 2149 as a linear pipe for simplification, the exhaust pipe 2149 is not a linear pipe.

[0285] As shown in FIG. 32, the main catalyst 154 is provided rearward of the crankshaft axis $Cr4$. In other words, when viewed in the left-right direction, the main catalyst 154 is provided behind the linear line $L7$. As described above, the linear line $L7$ is a linear line which passes the crankshaft axis $Cr4$ and is in parallel to the up-down direction. When viewed in the left-right direction, the main catalyst 154 is positioned in front of (below) the cylinder axis $Cy4$.

[0286] As shown in FIG. 32, when viewed in the left-right direction, the main catalyst 154 is provided behind the linear line $L8$. The linear line $L8$ is a linear line which is orthogonal to the cylinder axis $Cy4$ and orthogonal to the crankshaft axis $Cr4$.

[0287] As shown in FIG. 34, the path length from the upstream end of the exhaust pipe 2149 to the upstream end of the main catalyst 154 is referred to as $b14$. The path length from the downstream end of the main catalyst 154 to the downstream end of the exhaust pipe 2149 is referred to as $d14$. The path length from the combustion chamber 144 to the upstream end of the main catalyst 154 is $a4+b14$. The path length from the downstream end of the main catalyst 154 to the discharge port 150e is $d14+e4$.

[0288] In the same manner as in Embodiment 4 above, the main catalyst 154 of Modification 4-1 is provided so that the path length $a4+b14$ is shorter than the path length $d14+e4$. Being different from Embodiment 4 above, the main catalyst 154 of Modification 4-1 is provided so that the path length $a4+b14$ is longer than the path length $d14$. Furthermore, being different from Embodiment 4 above, the main catalyst 154 of Modification 4-1 is provided so that the path length $b14$ is longer than the path length $d14$.

[0289] The upstream oxygen detector 151 is provided on the exhaust pipe 2149. The upstream oxygen detector 151 is provided upstream of the main catalyst 154. The upstream oxygen detector 151 is provided upstream exhaust pipe 2149a (see FIG. 34).

[0290] As shown in FIG. 34, the path length from the combustion chamber 144 to the upstream oxygen detector 151 is referred to as $h17$. Furthermore, the path length from the upstream oxygen detector 151 to the upstream end of the main catalyst 154 is referred to as $h18$. Being similar to Embodiment 4, the upstream oxygen detector 151 is provided so that the path length $h17$ is shorter than

the path length h18.

[0291] The downstream oxygen detector 152 is provided on the exhaust pipe 2149. The downstream oxygen detector 152 is provided downstream of the main catalyst 154. The downstream oxygen detector 152 is provided downstream exhaust pipe 2149b (see FIG. 34). The downstream oxygen detector 152 penetrates a side wall of the silencer 150. One end portion (detecting portion) of the downstream oxygen detector 152 is provided in the downstream exhaust pipe 2149b. The other end portion of the downstream oxygen detector 152 is provided outside the silencer 150.

[0292] In Modification 4-1, arrangements similar to those in Embodiment 1 exert effects similar to the effects described in Embodiment 1.

[0293] Preferred embodiments of the present teaching have been described above. However, the present teaching is not limited to the above-described embodiments, and various changes can be made within the scope of the claims. Further, modifications described below may be used in combination as needed.

[0294] In Embodiment 1 to Embodiment 4 above, the casing 40, 181, 117, 155 of the catalyst unit 38, 79, 115, 153 and the upstream exhaust pipe 34a, 75a, 111a, 149a are joined with each other after they are independently formed. Alternatively, the casing 40, 181, 117, 155 of the catalyst unit 38, 79, 115, 153 and the upstream exhaust pipe 34a, 75a, 111a, 149a may be integrally formed.

[0295] In Embodiment 1 to Embodiment 4 above, the casing 40, 181, 117, 155 of the catalyst unit 38, 79, 115, 153 and the downstream exhaust pipe 34b, 75b, 111b, 149b are joined with each other after they are independently formed. Alternatively, the casing 40, 181, 117, 155 of the catalyst unit 38, 79, 115, 153 and the downstream exhaust pipe 34b, 75b, 111b, 149b may be integrally formed.

[0296] The shape of the exhaust pipe 34 in Embodiment 1 above is not limited to the shape shown in FIG. 1 to FIG. 3. Furthermore, the internal structure of the silencer 35 is not limited to the structure indicated by the schematic diagram of FIG. 5. The same holds true for the exhaust pipes 75, 111, and 149 and the silencers 76, 112, and 150 in Embodiment 2 to 4 above.

[0297] In Embodiments 1 to 4 above, the main catalyst 39, 116, 180, 154 and the silencer 35, 76, 112, 150 are provided rightward of the center in the left-right direction of the motorcycle 1, 50, 80, 120. Alternatively, the main catalyst and the silencer may be provided leftward of the center in the left-right direction of the motorcycle. The center in the left-right direction of the motorcycle indicates the position of a linear line which passes the center in the left-right direction of the front wheel and the center in the left-right direction of the rear wheel, when viewed in the up-down direction.

[0298] In Embodiments 1 to 4 above, a part of the exhaust pipe 34, 75, 111, 149 is provided below the crankshaft axis Cr1 to Cr4. Alternatively, the exhaust pipe (a single-combustion-chamber exhaust pipe) may be par-

tially positioned above the crankshaft axis.

[0299] In Embodiments 1 to 4 above, the main catalyst 39, 180, 116, 154 is a three-way catalyst. The single-combustion-chamber main catalyst of the present teaching, however, may not be a three-way catalyst. The single-combustion-chamber main catalyst may be a catalyst which removes one or two of hydrocarbon, carbon monoxide, and nitrogen oxide. The single-combustion-chamber main catalyst may not be an oxidation-reduction catalyst. The main catalyst may be an oxidation catalyst or a reduction catalyst which removes harmful substances by only oxidation or reduction. An example of the reduction catalyst is a catalyst which removes nitrogen oxide by reduction. This modification may be used in the upstream sub-catalyst 300.

[0300] In Embodiment 1 above, the length c1 in the path direction of the main catalyst 39 is longer than the maximum width w1 of the main catalyst 39. The same holds true for the main catalysts 180, 116, and 154 of Embodiments 2 to 4 above. The single-combustion-chamber main catalyst of the present teaching may be arranged such that the length in the path direction is shorter than the maximum width in the direction vertical to the path direction. However, the single-combustion-chamber main catalyst of the present teaching is arranged so that the exhaust gas is purified the most in the exhaust path. The exhaust path is a path extending from the combustion chamber to the discharge port exposed to the atmosphere.

[0301] The single-combustion-chamber main catalyst of the present teaching may comprise multiple catalysts arranged to be close to one another. Each catalyst includes a base and a catalyst material. The catalysts are close to one another in the sense that the distance between neighboring catalysts is short, rather than the length of each catalyst is short in the path direction. The bases of the catalysts may be made of one type or multiple types of materials. The noble metal of the catalytic materials of the catalysts may be one type or multiple types of noble metals. The carriers of the catalytic materials may be made of one type or multiple types of materials. This modification may be used in the upstream sub-catalyst 200.

[0302] In Modification 1-2 of Embodiment 1 above, the upstream sub-catalyst 300 does not have a porous structure. The upstream sub-catalyst 300 may have a porous structure.

[0303] The position of the main catalyst 39, 180, 116, 154 is not limited to the position shown in each figure. The upstream end of the main catalyst, however, is provided upstream of the upstream end of the silencer. The following describes specific modifications to the position of the main catalyst.

[0304] In Embodiments 1 to 4 above, the main catalyst 39, 180, 116, 154 is provided on the exhaust pipe 34, 75, 111, 149. Alternatively, the main catalyst may be provided on the cylinder exhaust passage member 31, 72, 108, 146 of the cylinder member 22, 63, 99, 137.

[0305] In Embodiments 1 to 4 and Modifications 1-1, 1-2, 2-1, 3-1, and 4-1 above, the downstream end of the main catalyst 39, 180, 116, 154 is upstream of the upstream end of the silencer 35, 76, 112, 150. For example, as shown in FIG. 35, the downstream end of the main catalyst 39 and the upstream end 435a of the silencer 435 may be substantially at the same position in the path direction. Furthermore, as shown in FIG. 36, FIG. 37, and FIG. 38, for example, the downstream end of the main catalyst 39 may be downstream of the upstream end 535a of the silencer 535.

[0306] The main catalyst 39, 180, 116, 154 may be positioned at least partially frontward of the crankshaft axis Cr1 to Cr4. The main catalyst 39, 180, 116, 154 may be positioned at least partially rearward of the crankshaft axis Cr1 to Cr4.

[0307] At least a part of the main catalyst 39, 180, 116, 154 may be provided in front of the linear line L2, L4, L6, L8 when viewed in the left-right direction. At least a part of the main catalyst 39, 180, 116, 154 may be provided behind the linear line L2, L4, L6, L8 when viewed in the left-right direction.

[0308] The main catalyst 39 of Embodiment 1 above is provided so that the path length $a1+b1$ is shorter than the path length $d1+e1$. Alternatively, the main catalyst 39 may be provided so that the path length $a1+b1$ is longer than the path length $d1+e1$. The path length $a1+b1$ is the path length from the combustion chamber 29 to the upstream end of the main catalyst 39. The path length $d1+e1$ is the path length from the downstream end of the main catalyst 39 to the discharge port 35e. This modification may be used in the main catalysts 180, 116, and 154 of Embodiments 2 to 4.

[0309] The upstream sub-catalyst 300 in Modification 1-2 of the embodiment above is provided upstream of the main catalyst 39. To be more specific, the upstream sub-catalyst 300 is provided in the upstream exhaust pipe 34a. The upstream sub-catalyst (a single-combustion-chamber upstream sub-catalyst) provided upstream of the main catalyst 39, however, may not be upstream exhaust pipe 34a. The upstream sub-catalyst may be provided on the cylinder exhaust passage member 31. Alternatively, the upstream sub-catalyst may be provided upstream passage member 40a of the catalyst unit 38. This modification may be used in Embodiments 2 to 4 above.

[0310] A downstream sub-catalyst (a single-combustion-chamber downstream sub-catalyst) may be provided downstream of the main catalyst. The downstream sub-catalyst may be identical in structure to the upstream sub-catalyst 300 of Modification 1-2 of the embodiment above. The downstream sub-catalyst may have a porous structure. For example, as shown in FIG. 39(c) and FIG. 39(d), a downstream sub-catalyst 301 is provided on the exhaust pipe 34. The downstream sub-catalyst may be provided inside the silencer 35. The downstream sub-catalyst may be provided downstream of the downstream end of the exhaust pipe 34. When the main catalyst is

provided on the cylinder exhaust passage member, the downstream sub-catalyst may be provided on the cylinder exhaust passage member. These modifications may be used in Embodiments 2 to 4 above. When the downstream sub-catalyst is provided, the upstream sub-catalyst 300 may be provided upstream of the main catalyst. The downstream sub-catalyst is provided downstream of the main catalyst. The main catalyst therefore deteriorates more rapidly than the downstream sub-catalyst. However, even if the deterioration of the main catalyst reaches a predetermined level, the purification performance of purifying the exhaust gas by the downstream sub-catalyst can be maintained. The initial performance of the motorcycle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0311] When the downstream sub-catalyst is provided downstream of the main catalyst, the main catalyst purifies the exhaust gas exhausted from the combustion chamber most in the exhaust path. The degree of contribution to the purification of each of the main catalyst and the downstream sub-catalyst can be measured by the measuring method mentioned in Modification 1-2. The front catalyst in the method mentioned in Modification 1-2 is deemed to be a main catalyst, whereas the rear catalyst is deemed to be a downstream sub-catalyst.

[0312] When the downstream sub-catalyst is provided downstream of the main catalyst, the purification capability of the downstream sub-catalyst may be higher than or lower than the purification capability of the main catalyst. In other words, the purification rate of the exhaust gas when only the downstream sub-catalyst is provided may be higher than or lower than the purification rate of the exhaust gas when only the main catalyst is provided.

[0313] When the downstream sub-catalyst is provided downstream of the main catalyst, the main catalyst rapidly deteriorates compared to the downstream sub-catalyst. For this reason, even if the degree of contribution to the purification of the main catalyst is at first higher than that of the downstream sub-catalyst, the degree of contribution to the purification of the downstream sub-catalyst may become higher than that of the main catalyst when the accumulative mileage becomes great. The single-combustion-chamber main catalyst of the present teaching purifies the exhaust gas exhausted from the combustion chamber most in the exhaust path. This holds true before the occurrence of the reversal above. In other words, the arrangement holds true before the accumulative mileage reaches a predetermined distance (e.g., 1000km).

[0314] In the present teaching, the number of catalysts provided in the single-cylinder four-stroke engine unit may be one or many. When multiple catalysts are provided, a catalyst which purifies the exhaust gas exhausted from the combustion chamber most in the exhaust path is equivalent to the single-combustion-chamber main catalyst of the present teaching. When the number of catalysts is one, that catalyst is the single-combustion-chamber main catalyst of the present teaching. An up-

stream sub-catalyst and a downstream sub-catalyst may be provided upstream and downstream of the main catalyst. Two or more upstream sub-catalysts may be provided upstream of the main catalyst. Two or more downstream sub-catalysts may be provided downstream of the main catalyst.

[0315] The position of the upstream oxygen detector 36, 77, 113, 151 (the single-combustion-chamber upstream oxygen detector) is not limited to the position shown in each figure. However, the upstream oxygen detector 36, 77, 113, 151 must be provided upstream of the main catalyst 39, 180, 116, 154. Subsequently, modifications of the position of the upstream oxygen detector will be specifically described.

[0316] In Embodiments 1 to 4 above, the upstream oxygen detector 36, 77, 113, 151 is provided on the exhaust pipe 34, 75, 111, 149, 334. Alternatively, as shown in FIG. 40, for example, the upstream oxygen detector 36 may be provided on the cylinder exhaust passage member 31.

[0317] In Embodiment 3 above, the path length (h5) from the combustion chamber 106 to the upstream oxygen detector 113 is longer than the path length (h6) from the upstream oxygen detector 113 to the upstream end of the main catalyst 116. Among Embodiments 1 to 4 and modifications thereof, only Embodiment 3 employs this structure. The structure, however, may be used in Embodiments 1, 2, and 4.

[0318] The upstream oxygen detector 36 of Modification 1-2 above is provided upstream of the upstream sub-catalyst 300. However, when the upstream sub-catalyst 300 is provided upstream of the main catalyst 39, the position of the upstream oxygen detector 36 may be arranged as below. For example, as shown in FIG 39(a), the upstream oxygen detector 36 may be provided downstream of the upstream sub-catalyst 300. Furthermore, for example, as shown in FIG. 39(b), upstream oxygen detectors 36A and 36B may be provided upstream and downstream of the upstream sub-catalyst 300, respectively. The upstream oxygen detector 36A is provided upstream of the upstream sub-catalyst 300. The upstream oxygen detector 36B is provided downstream of the main catalyst upstream sub-catalyst 300 and upstream of the main catalyst 39.

[0319] Providing the upstream oxygen detector upstream of the upstream sub-catalyst produces the following effects. The upstream oxygen detector is able to detect the oxygen density of the exhaust gas flowing into the upstream sub-catalyst. As the combustion control is carried out based on a signal from the upstream oxygen detector, the purification performance of purifying the exhaust gas by the upstream sub-catalyst can be improved.

[0320] In Embodiments 1 to 4 and Modifications 1-1, 1-2, 2-1, 3-1, and 4-1 above, only one upstream oxygen detector 36, 77, 113, 151 is provided upstream of the main catalyst 39, 180, 116, 154. In this regard, the number of the single-combustion-chamber upstream oxygen detectors provided in a vehicle of the present teach-

ing may be two or more.

[0321] The position of the downstream oxygen detector 37, 78, 114, 152 (the single-combustion-chamber downstream oxygen detector) is not limited to the position shown in each figure. However, the downstream oxygen detector 37, 78, 114, 152 must be provided downstream of the main catalyst 39, 180, 116, 154. Subsequently, modifications of the position of the downstream oxygen detector will be specifically described.

[0322] In Embodiments 1 to 4 above, the downstream oxygen detector 37, 78, 114, 152 is provided on the exhaust pipe 34, 75, 111, 149, 334. Alternatively, as shown in, for example, FIG. 35, FIG. 36, FIG. 37, and FIG. 38, the downstream oxygen detector 37 may be provided so that the target of detection is exhaust gas downstream of the downstream end of the exhaust pipe 434, 534, 1534, 2534. Subsequently, the positions of the downstream oxygen detectors 37 in FIG. 35, FIG. 36, FIG. 37, and FIG. 38 will be specifically described.

[0323] To begin with, FIG. 35 is described. A silencer 435 shown in FIG. 35 includes three expansion chambers 400, 401, and 402 and three pipes 403, 404, and 405. The third expansion chamber 402 is formed between the first expansion chamber 400 and the second expansion chamber 401. The downstream end of the catalyst unit 38 is provided inside the first expansion chamber 400. The first expansion chamber 400 and the second expansion chamber 401 communicate with each other via the first pipe 403. The second expansion chamber 401 and the third expansion chamber 402 communicate with each other via the second pipe 404. The upstream end of the third pipe 405 is provided inside the third expansion chamber 402. The third pipe 405 penetrates a side wall of the silencer 435. The third pipe 405 is provided with a discharge port 435e which is exposed to the atmosphere. The first pipe 403 is provided in the vicinity of the side wall of the silencer 435. A detecting portion (leading end portion) of the downstream oxygen detector 37 is provided in the vicinity of the downstream end of the first pipe 403. Exhaust gas exhausted from the first pipe 403 is blown onto the detecting portion of the downstream oxygen detector 37.

[0324] Subsequently, FIG. 36 is described. A silencer 535 shown in FIG. 36 includes three expansion chambers 500, 501, and 502 and three pipes 503, 504, and 505. The first expansion chamber 500 is formed between the second expansion chamber 501 and the third expansion chamber 502. The downstream end of the downstream exhaust pipe 534b is provided inside the first expansion chamber 500. The first expansion chamber 500 and the second expansion chamber 501 communicate with each other via the first pipe 503. The second expansion chamber 501 and the third expansion chamber 502 communicate with each other via the second pipe 504. The upstream end of the third pipe 505 is provided inside the third expansion chamber 502. The third pipe 505 penetrates a side wall of the silencer 535. The third pipe 505 is provided with a discharge port 535e which is exposed

to the atmosphere. In a cross section cut along the direction orthogonal to the path direction of the main catalyst 39, the main catalyst 39 is provided substantially at the center of the silencer 535. The flow direction of the exhaust gas passing through the main catalyst 39 is referred to as an L direction. The downstream exhaust pipe 534b extends in a direction inclined with respect to the L direction. The downstream end of the downstream exhaust pipe 534b is provided in the vicinity of the side wall of the silencer 535. A detecting portion (leading end portion) of the downstream oxygen detector 37 is provided in the vicinity of the downstream end of the downstream exhaust pipe 534b. Exhaust gas exhausted from the downstream exhaust pipe 534b is blown onto the detecting portion of the downstream oxygen detector 37.

[0325] Subsequently, FIG. 37 is described. In FIG. 37, items identical to those in FIG. 36 are indicated by the same reference numerals and detailed descriptions thereof are omitted. The downstream end of the downstream exhaust pipe 1534b is provided inside the first expansion chamber 500. The main catalyst 39 is provided in the vicinity of the side wall of the silencer 535. The downstream end of the downstream exhaust pipe 1534b is provided in the vicinity of the side wall of the silencer 535, too. A detecting portion (leading end portion) of the downstream oxygen detector 37 is provided in the vicinity of the downstream end of the downstream exhaust pipe 1534b. Exhaust gas exhausted from the downstream exhaust pipe 1534b is blown onto the detecting portion of the downstream oxygen detector 37.

[0326] Subsequently, FIG. 38 is described. In FIG. 38, items identical to those in FIG. 36 are indicated by the same reference numerals and detailed descriptions thereof are omitted. The downstream end of the downstream exhaust pipe 2534b is provided inside the first expansion chamber 500. The downstream oxygen detector 37 is provided on the third pipe 505.

[0327] When a downstream sub-catalyst 301 is provided downstream of the main catalyst 39, the position of the downstream oxygen detector may be one of the following two positions. For example, as shown in FIG. 39(c), the downstream oxygen detector 37 is provided downstream of the main catalyst 39 and upstream of the downstream sub-catalyst 301. Alternatively, for example, as shown in FIG. 39(d), the downstream oxygen detector 37 is provided downstream of the downstream sub-catalyst 301. Alternatively, the downstream oxygen detectors may be provided upstream and downstream of the downstream sub-catalyst 301, respectively.

[0328] In Embodiments 1 to 4 above, the number of the downstream oxygen detector 37, 78, 114, 152 provided upstream of the main catalyst 39, 180, 116, 154 is one. In this regard, the number of the single-combustion-chamber downstream oxygen detector provided in a vehicle of the present teaching may be two or more.

[0329] In Embodiments 1 to 4 above, the purification capability of the main catalyst is determined based on a signal from the downstream oxygen detector. The use of

the signal from the downstream oxygen detector, however, is not limited to this. The electronic control unit (controller) may determine the purification capability of the main catalyst based on a signal from the upstream oxygen detector and a signal from the downstream oxygen detector. Furthermore, the electronic control unit (controller) may perform combustion control based on a signal from the upstream oxygen detector and a signal from the downstream oxygen detector.

[0330] The following describes an example of how the purification capability of the main catalyst is specifically determined based on a signal from the upstream oxygen detector and a signal from the downstream oxygen detector. For example, the purification capability of the main catalyst may be determined by comparing a change in a signal from the upstream oxygen detector with a change in a signal from the downstream oxygen detector. The degree of deterioration of the main catalyst is more precisely detectable when signals from two oxygen detectors upstream and downstream of the main catalyst, respectively, are used. It is therefore possible to suggest the replacement of the single-combustion-chamber main catalyst at a more suitable time as compared to cases where the deterioration of the main catalyst is determined based solely on a signal from the downstream oxygen detector. One main catalyst can therefore be used for a longer time while the initial performance of the vehicle in connection with the exhaust gas purification is maintained.

[0331] The following describes an example of how combustion control is specifically carried out based on a signal from the upstream oxygen detector and a signal from the downstream oxygen detector. To begin with, in a manner similar to Embodiment 1 above, a basic fuel injection amount is corrected based on a signal from the upstream oxygen detector 37 and fuel is injected from the injector 48. The exhaust gas generated due to the combustion of the fuel is detected by the downstream oxygen detector. The fuel injection amount is then corrected based on a signal from the downstream oxygen detector. In this way, a deviation of the air-fuel ratio of the gas mixture from a target air-fuel ratio can be further restrained.

[0332] The actual state of purification by the main catalyst may be described using signals from two oxygen detectors provided upstream and downstream of the main catalyst. Due to this, the precision of the combustion control can be improved as the combustion control is carried out based on signals from two oxygen detectors. This makes it possible to restrain the progress of the deterioration of the main catalyst. The initial performance of the motorcycle in connection with the exhaust gas purification performance can therefore be maintained for a longer time.

[0333] In Embodiment 1 above, the ignition timing and the fuel injection amount are controlled based on a signal from the upstream oxygen detector 36. This applies to Embodiments 2 to 4 above. However, the control process

based on a signal from the upstream oxygen detector 36 is not particularly limited, and may be carried out for only one of the ignition timing and the fuel injection amount. Furthermore, the control process based on a signal from the upstream oxygen detector 36 may include a control process other than that mentioned above.

[0334] The downstream oxygen detector 37, 78, 114, 152 may include a heater. The detecting portion of the downstream oxygen detector 37, 78, 114, 152 is able to detect the oxygen density when it is heated to a high temperature and activated. Due to this, when the downstream oxygen detector 37, 78, 114, 152 includes the heater, the detection portion is able to detect oxygen more rapidly as the heater heats the detecting portion at the same time as the start of the engine running. The upstream oxygen detector 36, 77, 113, 151 may include a heater.

[0335] At least a part of the exhaust pipe, which is upstream of the main catalyst, may be formed by a multi-walled pipe. The multi-walled pipe includes an inner pipe and at least one outer pipe which covers the inner pipe. FIG. 41 shows an example in which at least a part of an exhaust pipe 634, which is upstream of the main catalyst, is formed by a double-walled pipe 600. The double-walled pipe 600 includes an inner pipe 601 and an outer pipe 602 covering the inner pipe 601. In FIG. 41, the inner pipe 601 and the outer pipe 602 are in contact with each other only at end portions. The inner pipe and the outer pipe of the multi-walled pipe may be in contact with each other at a portion other than the end portions. For example, the inner pipe and the outer pipe may be in contact with each other at a bended portion. The contact area is preferably smaller than the non-contact area. The inner pipe and the outer pipe may be entirely in contact with each other. The multi-walled pipe makes it possible to restrain the decrease in the temperature of the exhaust gas. The temperature of the upstream oxygen detector can therefore be rapidly increased to the activation temperature when the engine starts. The detection accuracy of the upstream oxygen detector can therefore be improved. The combustion control based on a signal from the upstream oxygen detector can therefore be more precisely carried out. Due to this, the purification performance of purifying the exhaust gas by the main catalyst can be further improved. Moreover, because of the improvement in the precision of the combustion control, the progress of the deterioration of the main catalyst can be restrained. The initial performance of the motorcycle in connection with the exhaust gas purification can therefore be maintained for a longer time.

[0336] For example, as shown in FIG. 42, at least a part of the outer surface of the catalyst-provided passage member 40b may be covered with a catalyst protector 700. The catalyst protector 700 is formed to be substantially cylindrical in shape. The catalyst protector makes it possible to more rapidly increase the temperature of the main catalyst 39. Due to this, the purification performance of purifying the exhaust gas by the main catalyst

39 can be further improved. This modification may be used in Embodiments 2 to 4 above.

[0337] In Embodiments 1 to 4 above, gas flowing in the exhaust path 41, 182, 118, 156 during engine driving is only the exhaust gas exhausted from the combustion chamber 29, 70, 106, 144. In this regard, the single-cylinder four-stroke engine unit of the present teaching may include a secondary air supply mechanism which is configured to supply air to the exhaust path. A known arrangement is used for the specific arrangement of the secondary air supply mechanism. The secondary air supply mechanism may forcibly supply air to the exhaust path by means of an air pump. Furthermore, the secondary air supply mechanism may take air into the exhaust path by means of negative pressure in the exhaust path. In this case, the secondary air supply mechanism includes a reed valve which opens and closes in accordance with the pressure pulsation of the exhaust gas. When the secondary air supply mechanism is included, the upstream oxygen detector may be provided upstream or downstream of the air inflow position.

[0338] In Embodiments 1 to 4 above, the injector is provided to supply fuel to the combustion chamber 29, 70, 106, 144. A fuel supplier for supplying fuel to the combustion chamber is not limited to the injector. For example, a fuel supplier configured to supply fuel to the combustion chamber by negative pressure may be provided.

[0339] In Embodiments 1 to 4 above, only one exhaust port 31a, 72a, 108a, 146a is provided for one combustion chamber 29, 70, 106, 144. Alternatively, multiple exhaust ports may be provided for one combustion chamber. For example, this modification applies to cases where a variable valve mechanism is included. The exhaust paths extending from the respective exhaust ports are gathered at a location upstream of the main catalyst. The exhaust paths extending from the respective exhaust ports are preferably gathered at the cylinder member.

[0340] The combustion chamber of the present teaching may include a main combustion chamber and an auxiliary combustion chamber connected to the main combustion chamber. In this case, one combustion chamber is formed by the main combustion chamber and the auxiliary combustion chamber.

[0341] In Embodiments 1 to 4 and Modification 1-2 above, the entirety of the combustion chamber 29, 70, 106, 144 is positioned frontward of the crankshaft axis Cr1, Cr2, Cr3, Cr4. The combustion chamber of the present teaching, however, may be differently positioned on condition that at least a part thereof is positioned frontward of the crankshaft axis. In other words, a part of the combustion chamber may be provided rearward of the crankshaft axis. This modification is applicable when the cylinder axis extends in the up-down direction.

[0342] In Embodiments 1 to 4 and Modification 1-2 above, the crankcase main body 23, 64, 100, 138 and the cylinder body 24, 65, 101, 139 are different members. Alternatively, the crankcase main body and the cylinder

body may be integrally formed. In Embodiments 1 to 4 and Modification 1-2 above, the cylinder body 24, 65, 101, 139, the cylinder head 25, 66, 102, 140, and the head cover 26, 67, 103, 141 are different members. Alternatively, two or three of the cylinder body, the cylinder head, and the head cover may be integrally formed.

[0343] In Embodiments 1 to 4 and Modification 1-2 above, the motorcycles are exemplified as a vehicle including the single-cylinder four-stroke engine unit. The vehicle of the present teaching, however, may be any type of vehicle on condition that the vehicle is powered by a single-cylinder four-stroke engine unit. The vehicle of the present teaching may be a straddled vehicle which is not a motorcycle. A straddled vehicle indicates all types of vehicles on which a rider rides in a manner of straddling a saddle. A straddled vehicle includes motorcycles, tri-cycles, four-wheeled buggies (ATVs: All Terrain Vehicles), personal water crafts, snowmobiles, and the like. The vehicle of the present teaching may not be a straddled vehicle. Furthermore, no rider may ride the vehicle of the present teaching. Furthermore, the vehicle of the present teaching may operate without any rider or passenger. In these cases, the frontward direction of the vehicle indicates the direction in which the vehicle advances.

[0344] The single-cylinder four-stroke engine units 93 and 132 of Embodiments 3 and 4 above are of a unit-swing type. The engine main body 94, 133 is arranged to be swingable with respect to the vehicle body frame 81, 121. Due to this, the position of the crankshaft axis Cr3, Cr4 with respect to the main catalyst 116, 154 changes in accordance with the engine running state. In this specification and the present teaching, the expression "the main catalyst is positioned in front of the crankshaft axis" indicates that the main catalyst is positioned in front of the crankshaft axis when the engine main body is at a position within a movable range. Positional relations other than this positional relation between the main catalyst and the crankshaft axis in the front-rear direction are also realized within the movable range of the engine main body.

[0345] In this specification and the present teaching, the upstream end of the main catalyst is an end of the main catalyst, at which the path length from the combustion chamber is the shortest. The downstream end of the main catalyst indicates an end of the main catalyst, at which the path length from the combustion chamber is the longest. The upstream ends and the downstream ends of elements other than the main catalyst are similarly defined, too.

[0346] In this specification and the present teaching, a passage member indicates walls and the like which form a path by surrounding the path. A path indicates a space through which a target passes. The exhaust passage member indicates walls or the like which form the exhaust path by surrounding the exhaust path. The exhaust path indicates a space through which exhaust gas passes.

[0347] In this specification and the present teaching,

the path length of the exhaust path indicates the path length of the center of the exhaust path. The path length of the expansion chamber in the silencer indicates the length of the path which connects the center of the inflow port of the expansion chamber with the center of the outflow port of the expansion chamber in the shortest distance.

[0348] In this specification, the path direction indicates the direction of the path which passes the center of the exhaust path and the direction in which the exhaust gas flows.

[0349] This specification uses an expression "the cross-sectional area of the passage member cut along the direction orthogonal to the path direction". Furthermore, the specification and the present teaching use an expression "the cross-sectional area of the passage member cut along the direction orthogonal to the flow direction of the exhaust gas". The cross-sectional area of the passage member may be the area of the inner circumferential surface of the passage member or the area of the outer circumferential surface of the passage member.

[0350] In this specification and the present teaching, expressions stating that a member or a linear line extends in a direction A and a direction along the direction A are not limited to cases where the member or the linear line is parallel to the direction A. The expression that a member or a linear line extends in a direction A includes cases where the member or the linear line intersects with the direction A at an angle which falls within the range from -45 degrees to 45 degrees, and the expression that a direction is along a direction A includes cases where the direction intersects with the direction A at an angle which falls within the range from -45 degrees to 45 degrees. The direction A does not indicate any specific direction. The direction A may be the horizontal direction or the front-rear direction.

[0351] The crankcase main bodies 23, 64, 100, and 138 of this specification are equivalent to the crankcase members 18, 61, 95, and 135 of the specification of the basic application (priority application) of the present application, respectively. The cylinder bodies 24, 65, 101, and 139 of this specification are equivalent to the cylinder members 24, 62, 96, and 136 of the specification of the basic application above, respectively. The engine main bodies 20, 61, 94, and 133 of this specification are equivalent to the engines 20, 60, 93, and 131 of the specification of the basic application above, respectively. The cylinder exhaust passage member 31 of this specification is equivalent to the passage member forming the passage P2 for exhaust gas in the specification of the basic application above.

[0352] The present teaching includes any and all embodiments including equivalent elements, modifications, omissions, combinations (e.g., of features across various embodiments), adaptations and/or alterations which can be understood by those skilled in the art on the basis of the present disclosure. The limitations in the claims are

to be interpreted broadly on the basis of the language used in the claims. The limitations in the claims are not limited to the embodiments described herein or during the prosecution of the application. Such embodiments are to be construed as non-exclusive. For example, the term "preferably" or "preferable" herein is non-exclusive and means "preferably/preferable, but not limited to."

[Reference Signs List]

[0353]

1, 50, 80, 120 motorcycle (vehicle)
 2, 53, 81, 121 vehicle body frame
 19, 60, 93, 132 single-cylinder four-stroke engine unit
 20, 61, 94, 133 engine main body
 21, 62, 98, 136 crankcase member
 22, 63, 99, 137 cylinder member
 24a, 65a, 101a, 139a cylinder hole
 27, 68, 104, 142 crankshaft
 28, 69, 105, 143 piston
 29, 70, 106, 144 combustion chamber
 31, 72, 108, 146 cylinder exhaust passage member (single-combustion-chamber cylinder exhaust passage member)
 34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149 exhaust pipe (single-combustion-chamber exhaust pipe)
 35, 76, 112, 150, 435, 535 silencer (single-combustion-chamber silencer)
 35e, 76e, 112e, 150e, 435e, 535e discharge port
 36, 77, 113, 151 upper oxygen detector (single-combustion-chamber upstream oxygen detector)
 37, 78, 114, 152 downstream oxygen detector (single-combustion-chamber downstream oxygen detector)
 38, 79, 115, 153, 2115 catalyst unit
 39, 116, 154, 180 main catalyst (single-combustion-chamber main catalyst)
 40a, 117a, 155a, 181a, 2117a upstream passage member
 40b, 117b, 155b, 181b, 2117b catalyst-provided passage member
 40c, 117c, 155c, 181c, 2117c downstream passage member
 41, 118, 156, 182 exhaust path
 300 upstream sub-catalyst (single-combustion-chamber upstream sub-catalyst)
 301 downstream sub-catalyst (single-combustion-chamber downstream sub-catalyst)
 600 double-walled pipe
 601 inner pipe
 602 outer pipe
 700 catalyst protector
 Cr1, Cr2, Cr3, Cr4 crankshaft axis (central axis of crankshaft)
 Cy1, Cy2, Cy3, Cy4 cylinder axis (central axis of cyl-

inder hole)

L2, L4, L6, L8 linear line orthogonal to crankshaft axis and cylinder axis

Claims

1. A vehicle (1, 50, 80, 120) on which a single-cylinder four-stroke engine unit (19, 60, 93, 132) is mounted, the single-cylinder four-stroke engine unit (19, 60, 93, 132) comprising:

an engine main body (20, 61, 94, 133) including a cylinder member (22, 63, 99, 137) in which one combustion chamber (29, 70, 106, 144) and a single-combustion-chamber cylinder exhaust passage member (31, 72, 108, 146), into which exhaust gas exhausted from the one combustion chamber (29, 70, 106, 144) flows, are formed;

a single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) connected to a downstream end of the single-combustion-chamber cylinder exhaust passage member (31, 72, 108, 146) of the engine main body (20, 61, 94, 133); a single-combustion-chamber silencer (35, 76, 112, 150, 435, 535) including a discharge port (35e, 76e, 112e, 150e, 435e, 535e) exposed to the atmosphere, the silencer being connected to the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) to allow the exhaust gas to flow from a downstream end of the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) to the discharge port (35e, 76e, 112e, 150e, 435e, 535e), and the silencer being configured to reduce noise generated by the exhaust gas;

a single-combustion-chamber main catalyst (39, 116, 154, 180) provided in the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), the single-combustion-chamber main catalyst (39, 116, 154, 180) having an upstream end provided upstream of an upstream end of the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535) in a flow direction of the exhaust gas, and the single-combustion-chamber main catalyst (39, 116, 154, 180) being configured to purify the exhaust gas exhausted from the one combustion chamber (29, 70, 106, 144) most in an exhaust path (41, 118, 156, 182) extending from the one combustion chamber (29, 70, 106, 144) to the discharge port (35e, 76e, 112e, 150e, 435e, 535e); a single-combustion-chamber upstream oxygen

detector (36, 77, 113, 151) provided upstream of the single-combustion-chamber main catalyst (39, 116, 154, 180) in the flow direction of the exhaust gas in the single-combustion-chamber cylinder exhaust passage member (31, 72, 108, 146) or the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) being configured to detect oxygen density in the exhaust gas; and a controller configured to process a signal from the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151),

characterized by

a single-combustion-chamber downstream oxygen detector (37, 78, 114, 152) provided downstream in the flow direction of the single-combustion-chamber main catalyst (39, 116, 154, 180) in the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), or the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535), the single-combustion-chamber downstream oxygen detector (37, 78, 114, 152) being configured to detect oxygen density in the exhaust gas.

wherein the controller is configured to process a signal from the single-combustion-chamber downstream oxygen detector (37, 78, 114, 152), wherein the single-combustion-chamber cylinder exhaust passage member (31, 72, 108, 146) extends from the one combustion chamber (29, 70, 106, 144) to one out-let formed in the outer surface of the cylinder member (22, 63, 99, 137), and the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) is connected to the one outlet formed in the outer surface of the cylinder member (22, 63, 99, 137),

wherein the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) has an upstream bended portion provided upstream of the single-combustion-chamber main catalyst (39, 116, 154, 180), and

wherein

(a) when viewed in the left-right direction, a first bending of the upstream bended portion downstream of the cylinder exhaust passage member (31) changes the flow direction of the exhaust gas from downward to rearward and upward, or

(b) when viewed in the left-right direction, a first bending of the upstream bended portion downstream of the cylinder exhaust passage member (72) changes the flow di-

rection of the exhaust gas from frontward and downward to rearward and downward, or

(c) when viewed in the left-right direction, a first bending of the upstream bended portion downstream of the cylinder exhaust passage member (108, 146) changes the flow direction of the exhaust gas from downward to rearward and downward.

2. The vehicle (1, 50, 80, 120) according to claim 1, wherein the engine main body (20, 61, 94, 133) includes a crankcase member (21, 62, 98, 136) including a crankshaft (27, 68, 104, 142) extending in a left-right direction of the vehicle (1, 50, 80, 120), the one combustion chamber (29, 70, 106, 144) of the cylinder member (22, 63, 99, 137) is at least partially provided frontward of a central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in a front-rear direction of the vehicle (1, 50, 80, 120), the discharge port (35e, 76e, 112e, 150e, 435e, 535e) of the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535) is provided rearward of the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in the front-rear direction of the vehicle (1, 50, 80, 120), and the single-combustion-chamber main catalyst (39, 116, 154, 180) is at least partially provided frontward of the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in the front-rear direction of the vehicle (1, 50, 80, 120).
3. The vehicle (1, 50, 80, 120) according to claim 1 or 2, wherein the engine main body (20, 61, 94, 133) includes a crankcase member (21, 62, 98, 136) including a crankshaft (27, 68, 104, 142) extending in a left-right direction of the vehicle (1, 50, 80, 120), the one combustion chamber (29, 70, 106, 144) of the cylinder member (22, 63, 99, 137) is at least partially provided frontward of a central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in a front-rear direction of the vehicle (1, 50, 80, 120), the discharge port (35e, 76e, 112e, 150e, 435e, 535e) of the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535) is provided rearward of the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in the front-rear direction of the vehicle (1, 50, 80, 120), and the single-combustion-chamber main catalyst (39, 116, 154, 180) is at least partially provided rearward of the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in the front-rear direction of the vehicle (1, 50, 80, 120).
4. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 3, wherein

- the engine main body (20, 61, 94, 133) includes a crankcase member (21, 62, 98, 136) including a crankshaft (27, 68, 104, 142) extending in a left-right direction of the vehicle (1, 50, 80, 120), the cylinder member (22, 63, 99, 137) of the engine main body (20, 61, 94, 133) has a cylinder hole (24a, 65a, 101a, 139a) in which a piston (28, 69, 105, 143) is provided,
- the one combustion chamber (29, 70, 106, 144) of the cylinder member (22, 63, 99, 137) is at least partially provided frontward of a central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in a front-rear direction of the vehicle (1, 50, 80, 120), the discharge port (35e, 76e, 112e, 150e, 435e, 535e) of the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535) is provided rearward of the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in the front-rear direction of the vehicle (1, 50, 80, 120), and
- when the vehicle (1, 50, 80, 120) is viewed in the left-right direction, the single-combustion-chamber main catalyst (39, 116, 154, 180) is at least partially in front in the front-rear direction of a linear line (L2, L4, L6, L8) which is orthogonal to the central axis (Cy1, Cy2, Cy3, Cy4) of the cylinder hole (24a, 65a, 101a, 139a) and orthogonal to the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142).
5. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 3, wherein
- the engine main body (20, 61, 94, 133) includes a crankcase member (21, 62, 98, 136) including a crankshaft (27, 68, 104, 142) extending in a left-right direction of the vehicle (1, 50, 80, 120), the cylinder member (22, 63, 99, 137) of the engine main body (20, 61, 94, 133) has a cylinder hole (24a, 65a, 101a, 139a) in which a piston (28, 69, 105, 143) is provided,
- the one combustion chamber (29, 70, 106, 144) of the cylinder member (22, 63, 99, 137) is at least partially provided frontward of a central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in a front-rear direction of the vehicle (1, 50, 80, 120), the discharge port (35e, 76e, 112e, 150e, 435e, 535e) of the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535) is provided rearward of the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142) in the front-rear direction of the vehicle (1, 50, 80, 120), and
- when the vehicle (1, 50, 80, 120) is viewed in the left-right direction, the single-combustion-chamber main catalyst (39, 116, 154, 180) is at least partially behind in the front-rear direction of a linear line (L2, L4, L6, L8) which is orthogonal to the central axis (Cy1, Cy2, Cy3, Cy4) of the cylinder hole (24a, 65a, 101a, 139a) and orthogonal to the central axis (Cr1, Cr2, Cr3, Cr4) of the crankshaft (27, 68, 104, 142).
6. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 5, wherein the single-combustion-chamber main catalyst (39, 116, 154, 180) is provided so that a path length from the one combustion chamber (29, 70, 106, 144) to the upstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180) is shorter than a path length from the downstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180) to the discharge port (35e, 76e, 112e, 150e, 435e, 535e).
7. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 6, wherein the single-combustion-chamber main catalyst (39, 116, 154, 180) is provided so that a path length from the one combustion chamber (29, 70, 106, 144) to the upstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180) is shorter than a path length from the downstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180) to the downstream end of the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149).
8. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 6, wherein the single-combustion-chamber main catalyst (39, 116, 154, 180) is provided so that a path length from the one combustion chamber (29, 70, 106, 144) to the upstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180) is longer than a path length from the downstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180) to the downstream end of the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149).
9. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 8, wherein the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) is provided so that a path length from the one combustion chamber (29, 70, 106, 144) to the upstream end of the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) is shorter than a path length from the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) to the upstream end of the single-combustion-chamber main catalyst (39, 116, 154, 180).
10. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 8, wherein the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) is provided so that a path length from the one combustion chamber (29, 70, 106, 144) to the upstream end of the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) is longer than a path length from the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) to the up-

stream end of the single-combustion-chamber main catalyst (39, 116, 154, 180).

11. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 10, wherein
the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) includes a catalyst-provided passage member (40b, 117b, 155b, 181b, 2117b) in which the single-combustion-chamber main catalyst (39, 116, 154, 180) is provided and an upstream passage member (40a, 117a, 155a, 181a, 2117a) connected to an upstream end of the catalyst-provided passage member (40b, 117b, 155b, 181b, 2117b), and
in at least a part of the upstream passage member (40a, 117a, 155a, 181a, 2117a), a cross-sectional area of the upstream passage member (40a, 117a, 155a, 181a, 2117a) cut along a direction orthogonal to the flow direction of the exhaust gas is smaller than a cross-sectional area of the catalyst-provided passage member (40b, 117b, 155b, 181b, 2117b) cut along the direction orthogonal to the flow direction of the exhaust gas.
12. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 11, wherein at least a part of the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), which is upstream in the flow direction of the single-combustion-chamber main catalyst (39, 116, 154, 180), is formed by a multi-walled pipe (600) which includes an inner pipe (601) and at least one outer pipe (602) covering the inner pipe (601).
13. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 12, wherein
the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) includes a catalyst-provided passage member (40b, 117b, 155b, 181b, 2117b) in which the single-combustion-chamber main catalyst (39, 116, 154, 180) is provided, and
the single-cylinder four-stroke engine unit (19, 60, 93, 132) includes a catalyst protector (700) which at least partially covers an outer surface of the catalyst-provided passage member (40b, 117b, 155b, 181b, 2117b).
14. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 13, wherein the single-cylinder four-stroke engine unit (19, 60, 93, 132) includes a single-combustion-chamber upstream sub-catalyst (300) which is provided upstream in the flow direction of the single-combustion-chamber main catalyst (39, 116, 154, 180) in the single-combustion-chamber cylinder exhaust passage member (31, 72, 108, 146) or the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), the single-combustion-chamber upstream sub-catalyst (300) being configured to purify the exhaust gas.
15. The vehicle (1, 50, 80, 120) according to claim 14, wherein the single-combustion-chamber upstream oxygen detector (36, 77, 113, 151) is provided upstream in the flow direction of the single-combustion-chamber upstream sub-catalyst (300).
16. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 15, wherein the single-cylinder four-stroke engine unit (19, 60, 93, 132) includes a single-combustion-chamber downstream sub-catalyst (301) which is provided downstream in the flow direction of the single-combustion-chamber main catalyst (39, 116, 154, 180) in the single-combustion-chamber exhaust pipe (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) or the single-combustion-chamber silencer (35, 76, 112, 150, 435, 535), the single-combustion-chamber downstream sub-catalyst (301) being configured to purify the exhaust gas.
17. The vehicle (1, 50, 80, 120) according to claim 16, wherein the single-combustion-chamber downstream oxygen detector (37, 78, 114, 152) is provided downstream in the flow direction of the single-combustion-chamber main catalyst (39, 116, 154, 180) and upstream in the flow direction of the single-combustion-chamber downstream sub-catalyst (301).
18. The vehicle (1, 50, 80, 120) according to claim 16, wherein the single-combustion-chamber downstream oxygen detector (37, 78, 114, 152) is provided downstream in the flow direction of the single-combustion-chamber downstream sub-catalyst (301).
19. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 18, wherein
the controller configured to determine the purification capability of the single-combustion-chamber main catalyst (39, 116, 154, 180) based on a signal from the single-combustion-chamber downstream oxygen detector (37, 78, 114, 152), and
a notification unit is provided to perform the notification when the controller configured to determine that the purification capability of the single-combustion-chamber main catalyst (39, 116, 154, 180) has lowered to a predetermined level.
20. The vehicle (1, 50, 80, 120) according to any one of claims 1 to 19, wherein
the single-cylinder four-stroke engine unit (19, 60, 93, 132) includes a fuel supplier which is configured

to supply fuel to the one combustion chamber (29, 70, 106, 144), and
the controller is configured to control the amount of
fuel supplied to the one combustion chamber (29,
70, 106, 144) by the fuel supplier based on a signal
from the single-combustion-chamber upstream oxy-
gen detector (36, 77, 113, 151) and a signal from
the single-combustion-chamber downstream oxy-
gen detector (37, 78, 114, 152).

Patentansprüche

1. Ein Fahrzeug (1, 50, 80, 120), an dem eine Einzylinderviertaktmotoreinheit (19, 60, 93, 132) montiert ist, wobei die Einzylinderviertaktmotoreinheit (19, 60, 93, 132) folgende Merkmale aufweist:

einen Motorhauptkörper (20, 61, 94, 133), der ein Zylinderbauglied (22, 63, 99, 137) umfasst, in dem eine Verbrennungskammer (29, 70, 106, 144) und ein Einzelverbrennungskammer-Zylinderabgasdurchgangsbauglied (31, 72, 108, 146), in das aus der einen Verbrennungskammer (29, 70, 106, 144) ausgeströmtes Abgas fließt, gebildet sind;

ein Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), das mit einem stromabwärtigen Ende des Einzelverbrennungskammer-Zylinderabgasdurchgangsbauglieds (31, 72, 108, 146) des Motorhauptkörpers (20, 61, 94, 133) verbunden ist;

einen Einzelverbrennungskammer-Schalldämpfer (35, 76, 112, 150, 435, 535), der eine der Atmosphäre ausgesetzte Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) umfasst, wobei der Schalldämpfer mit dem Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) verbunden ist, um zu ermöglichen, dass das Abgas von einem stromabwärtigen Ende des Einzelverbrennungskammer-Abgasrohrs (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) zu der Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) fließt, und wobei der Schalldämpfer dazu ausgebildet ist, ein durch das Abgas erzeugtes Geräusch zu reduzieren;

einen Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180), der in dem Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) bereitgestellt ist, wobei der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) ein stromaufwärtiges Ende aufweist, das in einer Strömungsrichtung des Abgases stromaufwärts bezüglich eines stromauf-

wärtigen Endes des Einzelverbrennungskammer-Schalldämpfers (35, 76, 112, 150, 435, 535) bereitgestellt ist, und wobei der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) dazu ausgebildet ist, das Abgas, das aus der einen Verbrennungskammer (29, 70, 106, 144) ausgeströmt wird, größtenteils in einem Abgasweg (41, 118, 156, 182) zu reinigen, der sich von der einen Verbrennungskammer (29, 70, 106, 144) zu der Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) erstreckt; einen stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151), der in dem Einzelverbrennungskammer-Zylinderabgasdurchgangsbauglied (31, 72, 108, 146) oder dem Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) in der Strömungsrichtung des Abgases stromaufwärts bezüglich des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) bereitgestellt ist, wobei der stromaufwärtige Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) dazu ausgebildet ist, eine Sauerstoffdichte in dem Abgas zu erfassen; und eine Steuerung, die dazu ausgebildet ist, ein Signal von dem stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) zu verarbeiten,

gekennzeichnet durch

einen stromabwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152), der in dem Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) oder dem Einzelverbrennungskammer-Schalldämpfer (35, 76, 112, 150, 435, 535) in der Strömungsrichtung des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) stromabwärts bereitgestellt ist, wobei der stromabwärtige Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152) dazu ausgebildet ist, eine Sauerstoffdichte in dem Abgas zu erfassen, wobei die Steuerung dazu ausgebildet ist, ein Signal von dem stromabwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152) zu verarbeiten, wobei sich das Einzelverbrennungskammer-Zylinderabgasdurchgangsbauglied (31, 72, 108, 146) von der einen Verbrennungskammer (29, 70, 106, 144) zu einem in der Außenoberfläche des Zylinderbauglieds (22, 63, 99, 137) gebildeten Auslass erstreckt und das Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) mit dem einen in der Außenoberfläche des Zylinderbauglieds (22, 63, 99, 137) gebildeten Auslass verbunden ist,

wobei das Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) einen stromaufwärts gebogenen Abschnitt aufweist, der stromaufwärts bezüglich des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) bereitgestellt ist, und
wobei

- (a) bei Betrachtung in der Links-Rechts-Richtung eine erste Biegung des stromaufwärts gebogenen Abschnitts stromabwärts bezüglich des Zylinderabgasdurchgangsbauglieds (31) die Strömungsrichtung des Abgases von einer Ausrichtung nach unten zu einer Ausrichtung nach hinten und nach oben ändert, oder
 - (b) bei Betrachtung in der Links-Rechts-Richtung eine erste Biegung des stromaufwärts gebogenen Abschnitts stromabwärts bezüglich des Zylinderabgasdurchgangsbauglieds (72) die Strömungsrichtung des Abgases von einer Ausrichtung nach vorne und nach unten zu einer Ausrichtung nach hinten und nach unten ändert, oder
 - (c) bei Betrachtung in der Links-Rechts-Richtung eine erste Biegung des stromaufwärts gebogenen Abschnitts stromabwärts bezüglich des Zylinderabgasdurchgangsbauglieds (108, 146) die Strömungsrichtung des Abgases von einer Ausrichtung nach unten zu einer Ausrichtung nach hinten und nach unten ändert.
2. Das Fahrzeug (1, 50, 80, 120) gemäß Anspruch 1, bei dem
- der Motorhauptkörper (20, 61, 94, 133) ein Kurbelgehäusebauglied (21, 62, 98, 136) mit einer Kurbelwelle (27, 68, 104, 142) umfasst, die sich in einer Links-Rechts-Richtung des Fahrzeugs (1, 50, 80, 120) erstreckt,
- die eine Verbrennungskammer (29, 70, 106, 144) des Zylinderbauglieds (22, 63, 99, 137) zumindest teilweise vor einer Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in einer Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist,
- die Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) des Einzelverbrennungskammer-Schalldämpfers (35, 76, 112, 150, 435, 535) hinter der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in der Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist, und
- der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) zumindest teilweise vor der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in der Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist.

3. Das Fahrzeug (1, 50, 80, 120) gemäß Anspruch 1 oder 2, bei dem
 - der Motorhauptkörper (20, 61, 94, 133) ein Kurbelgehäusebauglied (21, 62, 98, 136) mit einer Kurbelwelle (27, 68, 104, 142) umfasst, die sich in einer Links-Rechts-Richtung des Fahrzeugs (1, 50, 80, 120) erstreckt,
 - die eine Verbrennungskammer (29, 70, 106, 144) des Zylinderbauglieds (22, 63, 99, 137) zumindest teilweise vor einer Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in einer Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist,
 - die Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) des Einzelverbrennungskammer-Schalldämpfers (35, 76, 112, 150, 435, 535) hinter der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in der Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist, und
 - der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) zumindest teilweise hinter der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in der Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist.
4. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 3, bei dem der Motorhauptkörper (20, 61, 94, 133) ein Kurbelgehäusebauglied (21, 62, 98, 136) mit einer Kurbelwelle (27, 68, 104, 142) umfasst, die sich in einer Links-Rechts-Richtung des Fahrzeugs (1, 50, 80, 120) erstreckt,
- das Zylinderbauglied (22, 63, 99, 137) des Motorhauptkörpers (20, 61, 94, 133) ein Zylinderloch (24a, 65a, 101a, 139a) aufweist, in dem ein Kolben (28, 69, 105, 143) bereitgestellt ist,
- die eine Verbrennungskammer (29, 70, 106, 144) des Zylinderbauglieds (22, 63, 99, 137) zumindest teilweise vor einer Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in einer Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist,
- die Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) des Einzelverbrennungskammer-Schalldämpfers (35, 76, 112, 150, 435, 535) hinter der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in der Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist, und
- bei Betrachtung des Fahrzeugs (1, 50, 80, 120) in der Links-Rechts-Richtung der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) zumindest teilweise in der Vorne-Hinten-Richtung vor einer linearen Linie (L2, L4, L6, L8) ist, die orthogonal zu der Mittelachse (Cy1, Cy2, Cy3, Cy4) des Zylinderlochs (24a, 65a, 101a, 139a) ist und orthogonal zu der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) ist.
5. Das Fahrzeug (1, 50, 80, 120) gemäß einem der

- Ansprüche 1 bis 3, bei dem
 der Motorhauptkörper (20, 61, 94, 133) ein Kurbelgehäusebauglied (21, 62, 98, 136) mit einer Kurbelwelle (27, 68, 104, 142) umfasst, die sich in einer Links-Rechts-Richtung des Fahrzeugs (1, 50, 80, 120) erstreckt,
 das Zylinderbauglied (22, 63, 99, 137) des Motorhauptkörpers (20, 61, 94, 133) ein Zylinderloch (24a, 65a, 101a, 139a) aufweist, in dem ein Kolben (28, 69, 105, 143) bereitgestellt ist,
 die eine Verbrennungskammer (29, 70, 106, 144) des Zylinderbauglieds (22, 63, 99, 137) zumindest teilweise vor einer Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in einer Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist,
 die Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e) des Einzelverbrennungskammer-Schalldämpfers (35, 76, 112, 150, 435, 535) hinter der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) in der Vorne-Hinten-Richtung des Fahrzeugs (1, 50, 80, 120) bereitgestellt ist, und
 bei Betrachtung des Fahrzeugs (1, 50, 80, 120) in der Links-Rechts-Richtung der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) zumindest teilweise in der Vorne-Hinten-Richtung hinter einer linearen Linie (L2, L4, L6, L8) ist, die orthogonal zu der Mittelachse (Cy1, Cy2, Cy3, Cy4) des Zylinderlochs (24a, 65a, 101a, 139a) ist und orthogonal zu der Mittelachse (Cr1, Cr2, Cr3, Cr4) der Kurbelwelle (27, 68, 104, 142) ist.
6. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 5, bei dem der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) derart bereitgestellt ist, dass eine Weglänge von der einen Verbrennungskammer (29, 70, 106, 144) zu dem stromaufwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) kürzer ist als eine Weglänge von dem stromabwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) zu der Ausstoßöffnung (35e, 76e, 112e, 150e, 435e, 535e).
7. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 6, bei dem der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) derart bereitgestellt ist, dass eine Weglänge von der einen Verbrennungskammer (29, 70, 106, 144) zu dem stromaufwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) kürzer ist als eine Weglänge von dem stromabwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) zu dem stromabwärtigen Ende des Einzelverbrennungskammer-Abgasrohrs (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149).
8. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 6, bei dem der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) derart bereitgestellt ist, dass eine Weglänge von der einen Verbrennungskammer (29, 70, 106, 144) zu dem stromaufwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) länger ist als eine Weglänge von dem stromabwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) zu dem stromabwärtigen Ende des Einzelverbrennungskammer-Abgasrohrs (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149).
9. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 8, bei dem der stromaufwärtige Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) derart bereitgestellt ist, dass eine Weglänge von der einen Verbrennungskammer (29, 70, 106, 144) zu dem stromaufwärtigen Ende des stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektors (36, 77, 113, 151) kürzer ist als eine Weglänge von dem stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) zu dem stromaufwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180).
10. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 8, bei dem der stromaufwärtige Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) derart bereitgestellt ist, dass eine Weglänge von der einen Verbrennungskammer (29, 70, 106, 144) zu dem stromaufwärtigen Ende des stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektors (36, 77, 113, 151) länger ist als eine Weglänge von dem stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) zu dem stromaufwärtigen Ende des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180).
11. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 10, bei dem
 das Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) ein durch den Katalysator bereitgestelltes Durchgangsbauglied (40b, 117b, 155b, 181b, 2117b), in dem der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) bereitgestellt ist, und ein stromaufwärtiges Durchgangsbauglied (40a, 117a, 155a, 181a, 2117a) umfasst, das mit einem stromaufwärtigen Ende des durch den Katalysator bereitgestellten Durchgangsbauglieds (40b, 117b, 155b, 181b, 2117b) verbunden ist, und
 in zumindest einem Teil des stromaufwärtigen Durchgangsbauglieds (40a, 117a, 155a, 181a, 2117a) ein Querschnittsbereich des stromaufwärtigen

- gen Durchgangsbauglieds (40a, 117a, 155a, 181a, 2117a), das entlang einer Richtung geschnitten ist, die orthogonal zu der Strömungsrichtung des Abgases ist, kleiner ist als ein Querschnittsbereich des durch den Katalysator bereitgestellten Durchgangsbauglieds (40b, 117b, 155b, 181b, 2117b), das entlang der Richtung geschnitten ist, die orthogonal zu der Strömungsrichtung des Abgases ist.
12. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 11, bei dem zumindest ein Teil des Einzelverbrennungskammer-Abgasrohrs (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), das in der Strömungsrichtung des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) stromaufwärts ist, durch eine mehrwandiges Rohr (600) gebildet ist, das ein Innenrohr (601) und zumindest ein Außenrohr (602) umfasst, welches das Innenrohr (601) bedeckt.
13. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 12, bei dem das Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) ein durch den Katalysator bereitgestelltes Durchgangsbauglied (40b, 117b, 155b, 181b, 2117b) umfasst, in dem der Einzelverbrennungskammer-Hauptkatalysator (39, 116, 154, 180) bereitgestellt ist, und die Einzylinderviertaktmotoreinheit (19, 60, 93, 132) eine Katalysatorschutzeinrichtung (700) umfasst, die zumindest teilweise eine Außenoberfläche des durch den Katalysator bereitgestellten Durchgangsbauglieds (40b, 117b, 155b, 181b, 2117b) bedeckt.
14. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 13, bei dem die Einzylinderviertaktmotoreinheit (19, 60, 93, 132) einen stromaufwärtigen Einzelverbrennungskammer-Unterkatalysator (300) umfasst, der in der Strömungsrichtung des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) stromaufwärts in dem Einzelverbrennungskammer-Zylinderabgasdurchgangsbauglied (31, 72, 108, 146) oder dem Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) bereitgestellt ist, wobei der stromaufwärtige Einzelverbrennungskammer-Unterkatalysator (300) dazu ausgebildet ist, das Abgas zu reinigen.
15. Das Fahrzeug (1, 50, 80, 120) gemäß Anspruch 14, bei dem der stromaufwärtige Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) in der Strömungsrichtung des stromaufwärtigen Einzelverbrennungskammer-Unterkatalysators (300) stromaufwärts bereitgestellt ist.
16. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 15, bei dem die Einzylinderviertaktmotoreinheit (19, 60, 93, 132) einen stromabwärtigen Einzelverbrennungskammer-Unterkatalysator (301) umfasst, der in der Strömungsrichtung des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) stromabwärts in dem Einzelverbrennungskammer-Abgasrohr (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) oder dem Einzelverbrennungskammer-Schalldämpfer (35, 76, 112, 150, 435, 535) bereitgestellt ist, wobei der stromabwärtige Einzelverbrennungskammer-Unterkatalysator (301) dazu ausgebildet ist, das Abgas zu reinigen.
17. Das Fahrzeug (1, 50, 80, 120) gemäß Anspruch 16, bei dem der stromabwärtige Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152) in der Strömungsrichtung des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) stromabwärts und in der Strömungsrichtung des stromabwärtigen Einzelverbrennungskammer-Unterkatalysators (301) stromaufwärts bereitgestellt ist.
18. Das Fahrzeug (1, 50, 80, 120) gemäß Anspruch 16, bei dem der stromabwärtige Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152) in der Strömungsrichtung des stromabwärtigen Einzelverbrennungskammer-Unterkatalysators (301) stromabwärts bereitgestellt ist.
19. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 18, bei dem die Steuerung dazu ausgebildet ist, die Reinigungsfähigkeit des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) auf der Basis eines Signals von dem stromabwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152) zu bestimmen, und eine Benachrichtigungseinheit bereitgestellt ist, um die Benachrichtigung durchzuführen, wenn die Steuerung dazu ausgebildet ist, zu bestimmen, dass die Reinigungsfähigkeit des Einzelverbrennungskammer-Hauptkatalysators (39, 116, 154, 180) auf einen vorbestimmten Pegel abgesunken ist.
20. Das Fahrzeug (1, 50, 80, 120) gemäß einem der Ansprüche 1 bis 19, bei dem die Einzylinderviertaktmotoreinheit (19, 60, 93, 132) eine Kraftstoffzufuhreinrichtung umfasst, die dazu ausgebildet ist, der einen Verbrennungskammer (29, 70, 106, 144) Kraftstoff zuzuführen, und die Steuerung dazu ausgebildet ist, die Kraftstoffmenge, die der einen Verbrennungskammer (29, 70, 106, 144) durch die Kraftstoffzufuhreinrichtung zugeführt wird, auf der Basis eines Signals von dem stromaufwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (36, 77, 113, 151) und eines Si-

gnals von dem stromabwärtigen Einzelverbrennungskammer-Sauerstoffdetektor (37, 78, 114, 152) zu steuern.

Revendications

1. Véhicule (1, 50, 80, 120) sur lequel est montée une unité de moteur monocylindre à quatre temps (19, 60, 93, 132), l'unité de moteur monocylindre à quatre temps (19, 60, 93, 132) comprenant:

un corps principal de moteur (20, 61, 94, 133) comportant un élément de cylindre (22, 63, 99, 137) dans lequel sont formés une chambre de combustion (29, 70, 106, 144) et un élément de passage d'échappement de cylindre à chambre de combustion unique (31, 72, 108, 146) vers lequel circulent les gaz d'échappement évacués de l'une chambre de combustion (29, 70, 106, 144);

un tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) connecté à une extrémité aval de l'élément de passage d'échappement de cylindre à chambre de combustion unique (31, 72, 108, 146) du corps principal de moteur (20, 61, 94, 133);

un silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535) comportant un orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e) exposé à l'atmosphère, le silencieux étant raccordé au tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) pour permettre que les gaz d'échappement circulent d'une extrémité aval du tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) vers l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e), et le silencieux étant configuré pour réduire le bruit généré par les gaz d'échappement;

un catalyseur principal de chambre de combustion unique (39, 116, 154, 180) prévu dans le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) présentant une extrémité amont prévue en amont d'une extrémité amont du silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535) dans une direction de circulation des gaz d'échappement, et le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) étant configuré pour purifier les gaz d'échappement évacués de l'une chambre de combustion (29, 70,

106, 144) pour la plupart dans un trajet d'échappement (41, 118, 156, 182) s'étendant de l'une chambre de combustion (29, 70, 106, 144) à l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e);

un détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) prévu en amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) dans la direction de circulation des gaz d'échappement dans l'élément de passage d'échappement de cylindre de chambre de combustion (31, 72, 108, 146) ou dans le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), le détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) étant configuré pour détecter la densité d'oxygène dans les gaz d'échappement; et un contrôleur configuré pour traiter un signal du détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151),

caractérisé par

un détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152) prévu en aval dans la direction de circulation du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) dans le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) ou dans le silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535), le détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152) étant configuré pour détecter la densité d'oxygène dans les gaz d'échappement, dans lequel le contrôleur est configuré pour traiter un signal du détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152),

dans lequel l'élément de passage d'échappement de cylindre à chambre de combustion unique (31, 72, 108, 146) s'étend de l'une chambre de combustion (29, 70, 106, 144) à une sortie formée dans la surface extérieure de l'élément de cylindre (22, 63, 99, 137), et le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) est connecté à l'une sortie formée dans la surface extérieure de l'élément de cylindre (22, 63, 99, 137),

dans lequel le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) présente une partie courbée amont prévue en amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180), et dans lequel

- (a) lorsque vue dans la direction gauche-droite, une première courbure de la partie courbée amont en aval de l'élément de passage d'échappement de cylindre (31) change la direction de circulation des gaz d'échappement de vers le bas à vers l'arrière et vers le haut, ou
- (b) lorsque vue dans la direction gauche-droite, une première courbure de la partie courbée amont en aval de l'élément de passage d'échappement de cylindre (72) change la direction de circulation des gaz d'échappement de vers l'avant et vers le bas à vers l'arrière et vers le bas, ou
- (c) lorsque vue dans la direction gauche-droite, une première courbure de la partie courbée amont en aval de l'élément de passage d'échappement de cylindre (108, 146) change la direction de circulation des gaz d'échappement de vers le bas à vers l'arrière et vers le bas.
2. Véhicule (1, 50, 80, 120) selon la revendication 1, dans lequel
le corps principal de moteur (20, 61, 94, 133) comporte un élément de carter (21, 62, 98, 136) comportant un vilebrequin (27, 68, 104, 142) s'étendant dans une direction gauche-droite du véhicule (1, 50, 80, 120),
l'une chambre de combustion (29, 70, 106, 144) de l'élément de cylindre (22, 63, 99, 137) est au moins partiellement prévue à l'avant d'un axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans une direction avant-arrière du véhicule (1, 50, 80, 120),
l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e) du silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535) est prévu en arrière de l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans la direction avant-arrière du véhicule (1, 50, 80, 120), et
le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu au moins partiellement à l'avant de l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans la direction avant-arrière du véhicule (1, 50, 80, 120).
3. Véhicule (1, 50, 80, 120) selon la revendication 1 ou 2, dans lequel
le corps principal du moteur (20, 61, 94, 133) comporte un élément de carter (21, 62, 98, 136) comportant un vilebrequin (27, 68, 104, 142) s'étendant dans une direction gauche-droite du véhicule (1, 50, 80, 120),
l'une chambre de combustion (29, 70, 106, 144) de l'élément de cylindre (22, 63, 99, 137) est prévue au moins partiellement à l'avant d'un axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans une direction avant-arrière du véhicule (1, 50, 80, 120),
l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e) du silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535) est prévu à l'arrière de l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans la direction avant-arrière du véhicule (1, 50, 80, 120), et
le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu au moins partiellement à l'avant de l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans la direction avant-arrière du véhicule (1, 50, 80, 120).
4. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 3, dans lequel
le corps principal de moteur (20, 61, 94, 133) comporte un élément de carter (21, 62, 98, 136) comportant un vilebrequin (27, 68, 104, 142) s'étendant dans une direction gauche-droite du véhicule (1, 50, 80, 120),
l'élément de cylindre (22, 63, 99, 137) du corps principal de moteur (20, 61, 94, 133) présente un trou de cylindre (24a, 65a, 101a, 139a) dans lequel est prévu un piston (28, 69, 105, 143),
l'une chambre de combustion (29, 70, 106, 144) de l'élément de cylindre (22, 63, 99, 137) est prévue au moins partiellement à l'avant d'un axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans une direction avant-arrière du véhicule (1, 50, 80, 120),
l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e) du silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535) est prévu à l'arrière de l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans la direction avant-arrière du véhicule (1, 50, 80, 120), et
lorsque le véhicule (1, 50, 80, 120) est vu dans la direction gauche-droite, le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu au moins partiellement à l'avant dans la direction avant-arrière d'une ligne linéaire (L2, L4, L6, L8) qui est orthogonale à l'axe central (Cy1, Cy2, Cy3, Cy4) du trou de cylindre (24a, 65a, 101a, 139a) et orthogonale à l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142).
5. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 3, dans lequel
le corps principal de moteur (20, 61, 94, 133) comporte un élément de carter (21, 62, 98, 136) comportant un vilebrequin (27, 68, 104, 142) s'étendant dans une direction gauche-droite du véhicule (1, 50, 80, 120),
l'élément de cylindre (22, 63, 99, 137) du corps principal de moteur (20, 61, 94, 133) présente un trou de cylindre (24a, 65a, 101a, 139a) dans lequel est prévu un piston (28, 69, 105, 143),

- l'une chambre de combustion (29, 70, 106, 144) de l'élément de cylindre (22, 63, 99, 137) est prévue au moins partiellement à l'avant d'un axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans une direction avant-arrière du véhicule (1, 50, 80, 120),
l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e) du silencieux de chambre de combustion unique (35, 76, 112, 150, 435, 535) est prévu à l'arrière de l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142) dans la direction avant-arrière du véhicule (1, 50, 80, 120), et
lorsque le véhicule (1, 50, 80, 120) est vu dans la direction gauche-droite, le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu au moins partiellement à l'arrière dans la direction avant-arrière d'une ligne linéaire (L2, L4, L6, L8) qui est orthogonale à l'axe central (Cyl, Cy2, Cy3, Cy4) du trou de cylindre (24a, 65a, 101a, 139a) et orthogonale à l'axe central (Cr1, Cr2, Cr3, Cr4) du vilebrequin (27, 68, 104, 142).
6. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 5, dans lequel le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu de sorte qu'une longueur de trajet de l'une chambre de combustion (29, 70, 106, 144) à l'extrémité amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) soit plus courte qu'une longueur de trajet de l'extrémité aval du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) à l'orifice de décharge (35e, 76e, 112e, 150e, 435e, 535e).
7. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 6, dans lequel le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu de sorte qu'une longueur de trajet de l'une chambre de combustion (29, 70, 106, 144) à l'extrémité amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) soit plus courte qu'une longueur de trajet de l'extrémité aval du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) à l'extrémité aval du tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149).
8. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 6, dans lequel le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est prévu de sorte qu'une longueur de trajet de l'une chambre de combustion (29, 70, 106, 144) à l'extrémité amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) soit plus longue qu'une longueur de trajet de l'extrémité aval du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) à l'extrémité
- aval du tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149).
9. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 8, dans lequel le détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) est prévu de sorte qu'une longueur de trajet de l'une chambre de combustion (29, 70, 106, 144) à l'extrémité amont du détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) soit plus courte qu'une longueur de trajet du détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) à l'extrémité amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180).
10. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 8, dans lequel le détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) est prévu de sorte qu'une longueur de trajet de l'une chambre de combustion (29, 70, 106, 144) à l'extrémité amont du détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) soit plus longue qu'une longueur de trajet du détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) à l'extrémité amont du catalyseur principal de chambre de combustion unique (39, 116, 154, 180).
11. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 10, dans lequel le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) comporte un élément de passage muni d'un catalyseur (40b, 117b, 155b, 181b, 2117b) dans lequel est prévu le catalyseur principal de chambre de combustion unique (39, 116, 154, 180) et un élément de passage amont (40a, 117a, 155a, 181a, 2117a) connecté à une extrémité amont de l'élément de passage muni d'un catalyseur (40b, 117b, 155b, 181b, 2117b), et dans au moins une partie de l'élément de passage amont (40a, 117a, 155a, 181a, 2117a), une surface de section transversale de l'élément de passage amont (40a, 117a, 155a, 181a, 2117a) coupée dans une direction orthogonale à la direction de circulation des gaz d'échappement est plus petite qu'une surface de coupe transversale de l'élément de passage muni d'un catalyseur (40b, 117b, 155b, 181b, 2117b) coupée dans la direction orthogonale à la direction de circulation des gaz d'échappement.
12. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 11, dans lequel au moins une partie du tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), qui se trouve en

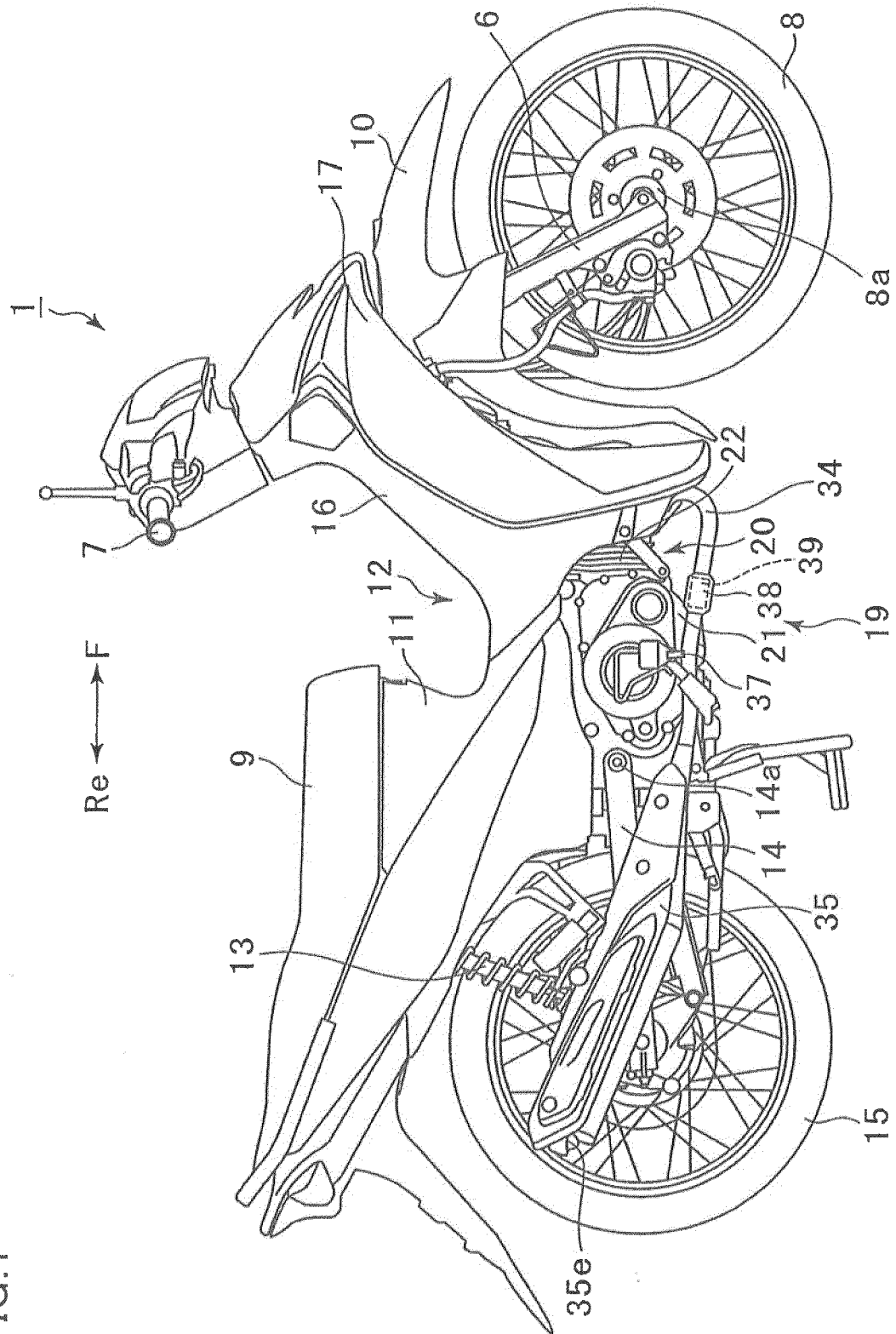
amont dans la direction de circulation du catalyseur principal de chambre de combustion unique (39, 116, 154, 180), est formée par un tuyau à parois multiples (600) qui comporte un tuyau intérieur (601) et au moins un tuyau extérieur (602) recouvrant le tuyau intérieur (601).

13. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 12, dans lequel le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) comporte un élément de passage muni d'un catalyseur (40b, 117b, 155b, 181b, 2117b) dans lequel est prévu le catalyseur principal de chambre de combustion unique (39, 116, 154, 180), et l'unité de moteur monocylindre à quatre temps (19, 60, 93, 132) comporte un protecteur de catalyseur (700) qui recouvre au moins partiellement une surface extérieure de l'élément de passage muni d'un catalyseur (40b, 117b, 155b, 181b, 2117b). 10
14. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 13, dans lequel l'unité de moteur monocylindre à quatre temps (19, 60, 93, 132) comporte un sous-catalyseur amont de chambre de combustion unique (300) qui est prévu en amont dans la direction de circulation du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) dans l'élément de passage d'échappement de cylindre à chambre de combustion unique (31, 72, 108, 146) ou dans le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149), le sous-catalyseur amont de chambre de combustion unique (300) étant configuré pour purifier les gaz d'échappement. 25 30
15. Véhicule (1, 50, 80, 120) selon la revendication 14, dans lequel le détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) est prévu en amont dans la direction de circulation du sous-catalyseur amont de chambre de combustion unique (300). 40
16. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 15, dans lequel l'unité de moteur monocylindre à quatre temps (19, 60, 93, 132) comporte un sous-catalyseur aval de chambre de combustion unique (301) qui est prévu en aval dans la direction de circulation du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) dans le tuyau d'échappement de chambre de combustion unique (34, 75, 111, 149, 234, 275, 334, 434, 534, 634, 1534, 2534, 2111, 2149) ou dans le silencieux de chambre de combustion (35, 76, 112, 150, 435, 535), le sous-catalyseur aval de chambre de combustion unique (301) étant configuré pour puri- 50 55

fier les gaz d'échappement.

17. Véhicule (1, 50, 80, 120) selon la revendication 16, dans lequel le détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152) est prévu en aval dans la direction de circulation du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) et en amont dans la direction de circulation du sous-catalyseur aval de chambre de combustion unique (301). 5
18. Véhicule (1, 50, 80, 120) selon la revendication 16, dans lequel le détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152) est prévu en aval dans la direction de circulation du sous-catalyseur aval de chambre de combustion unique (301). 10
19. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 18, dans lequel le contrôleur est configuré pour déterminer la capacité de purification du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) sur base d'un signal du détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152), et une unité de notification est prévue pour effectuer la notification lorsque le contrôleur est configuré pour déterminer que la capacité de purification du catalyseur principal de chambre de combustion unique (39, 116, 154, 180) est descendue à un niveau prédéterminé. 15 20
20. Véhicule (1, 50, 80, 120) selon l'une quelconque des revendications 1 à 19, dans lequel l'unité de moteur monocylindre à quatre temps (19, 60, 93, 132) comporte un alimentateur de carburant qui est configuré pour alimenter du carburant vers l'une chambre de combustion (29, 70, 106, 144), et le contrôleur est configuré pour contrôler la quantité de carburant alimentée vers la chambre de combustion (29, 70, 106, 144) par l'alimentateur de carburant sur base d'un signal du détecteur d'oxygène amont de chambre de combustion unique (36, 77, 113, 151) et d'un signal du détecteur d'oxygène aval de chambre de combustion unique (37, 78, 114, 152). 25 30 35 40 45

FIG.1



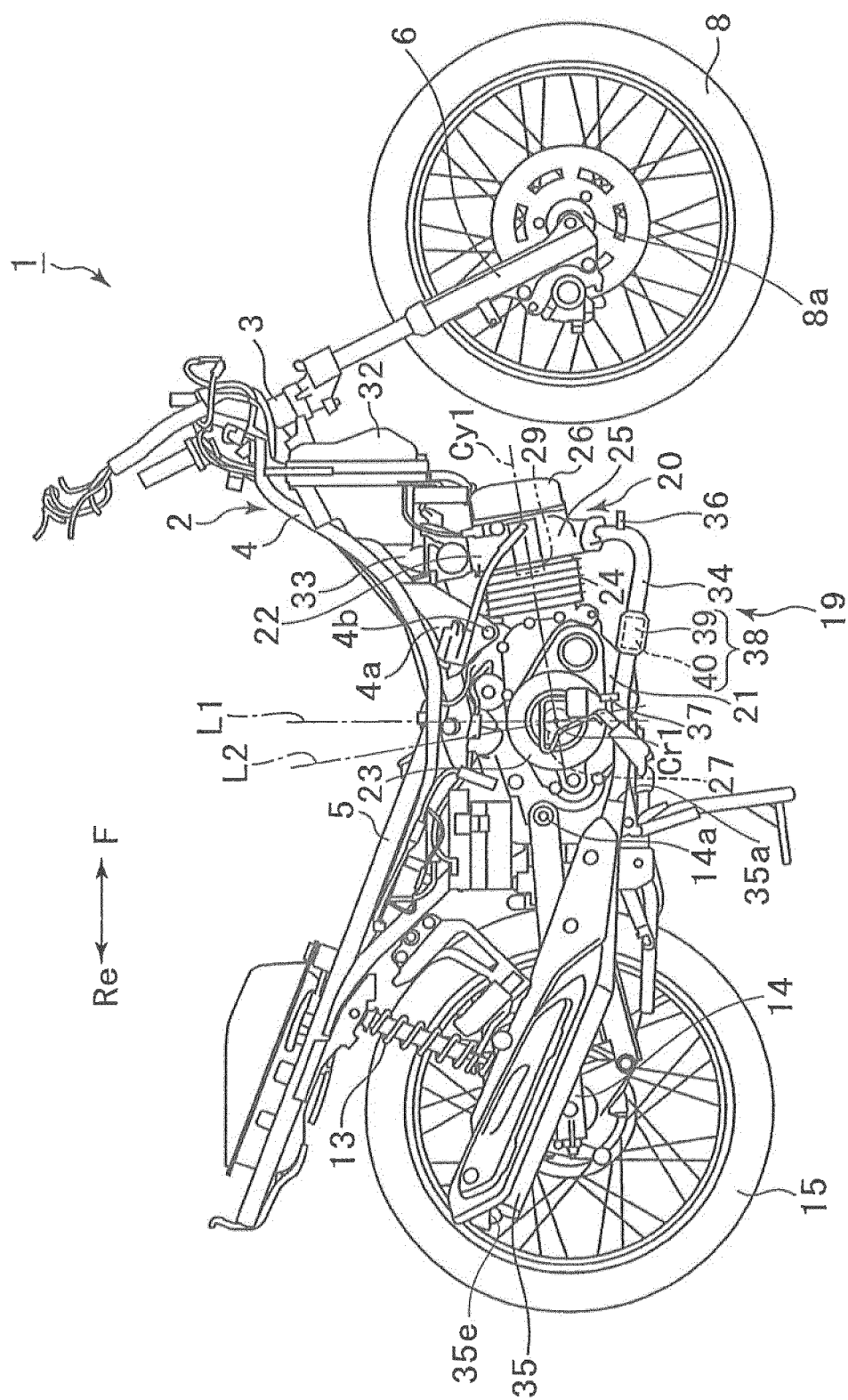
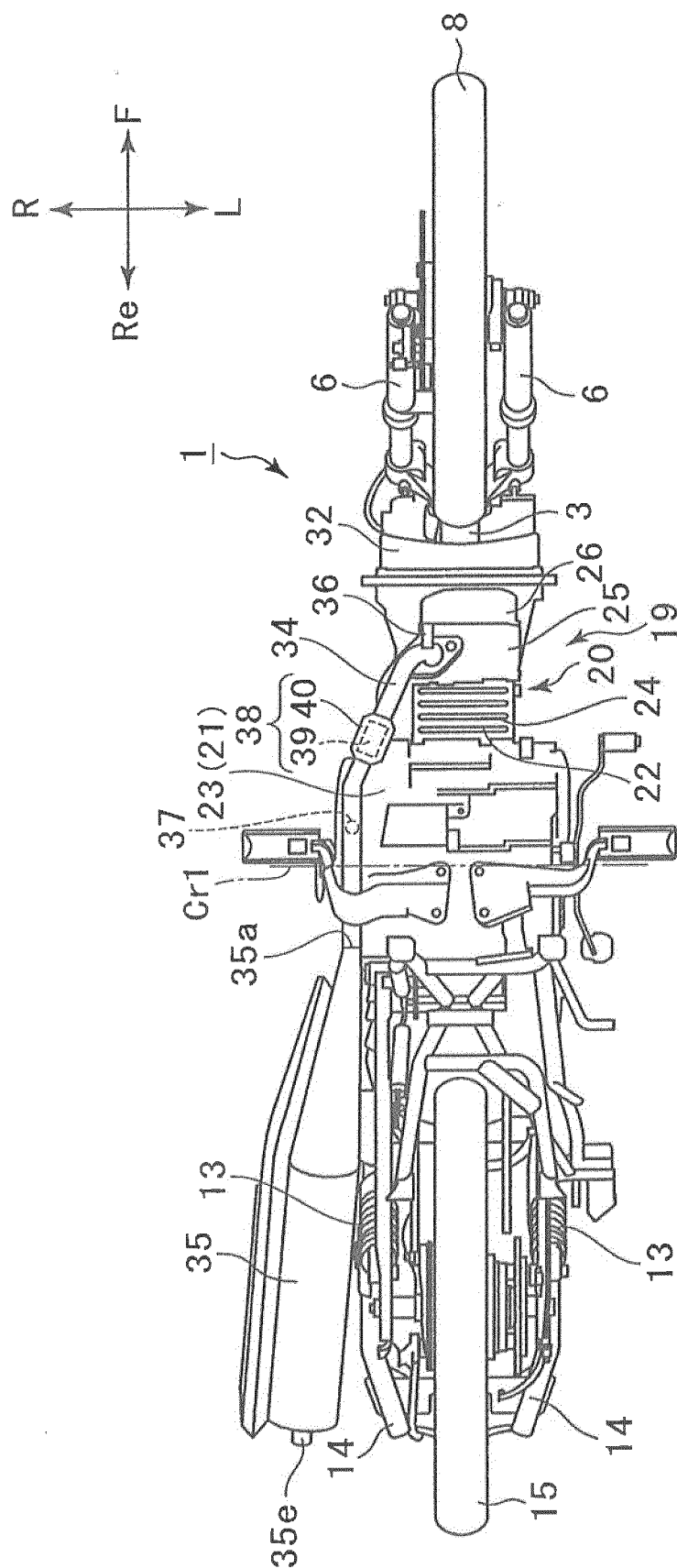


FIG. 2



FILE

FIG.4

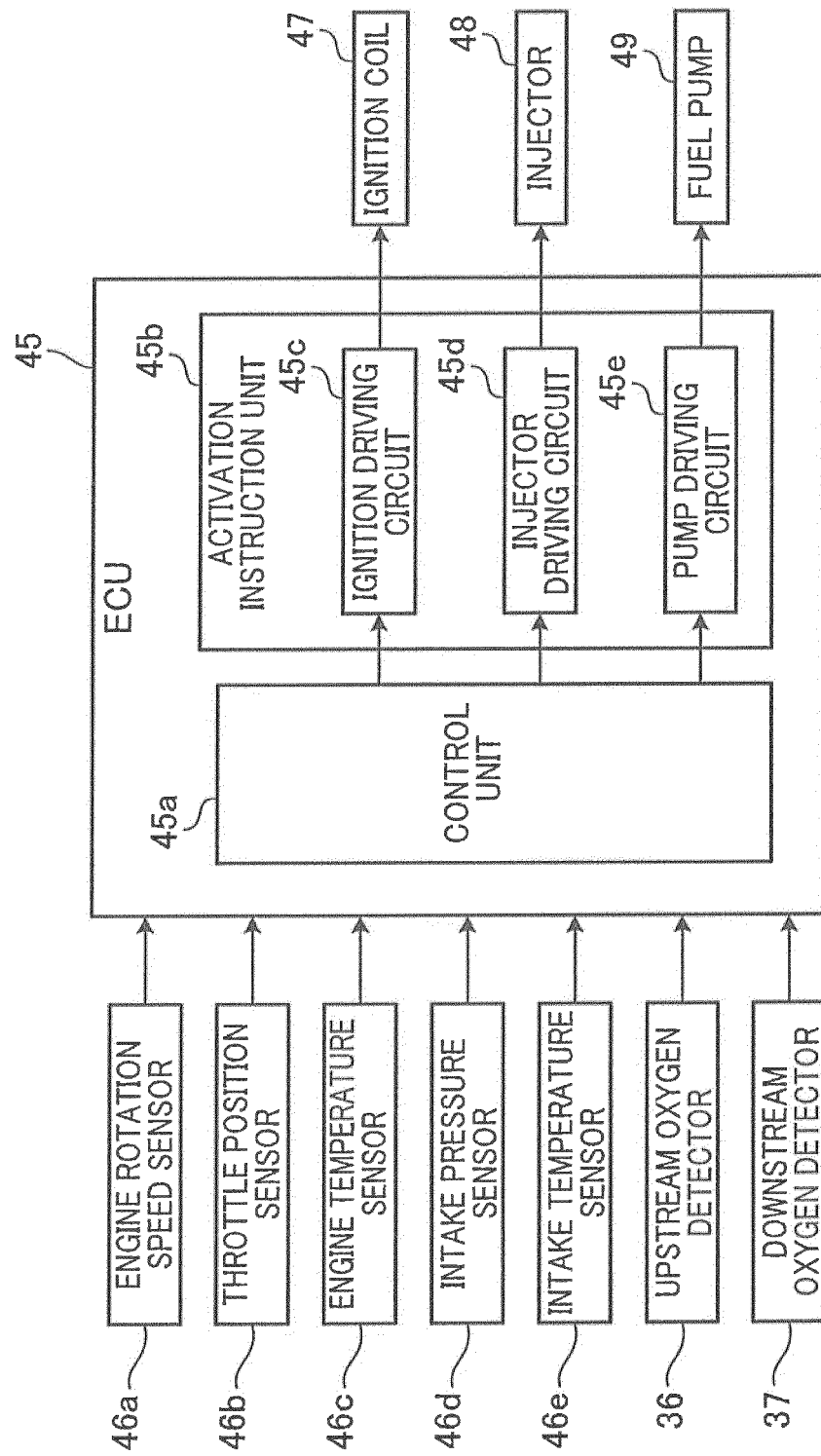


FIG.5

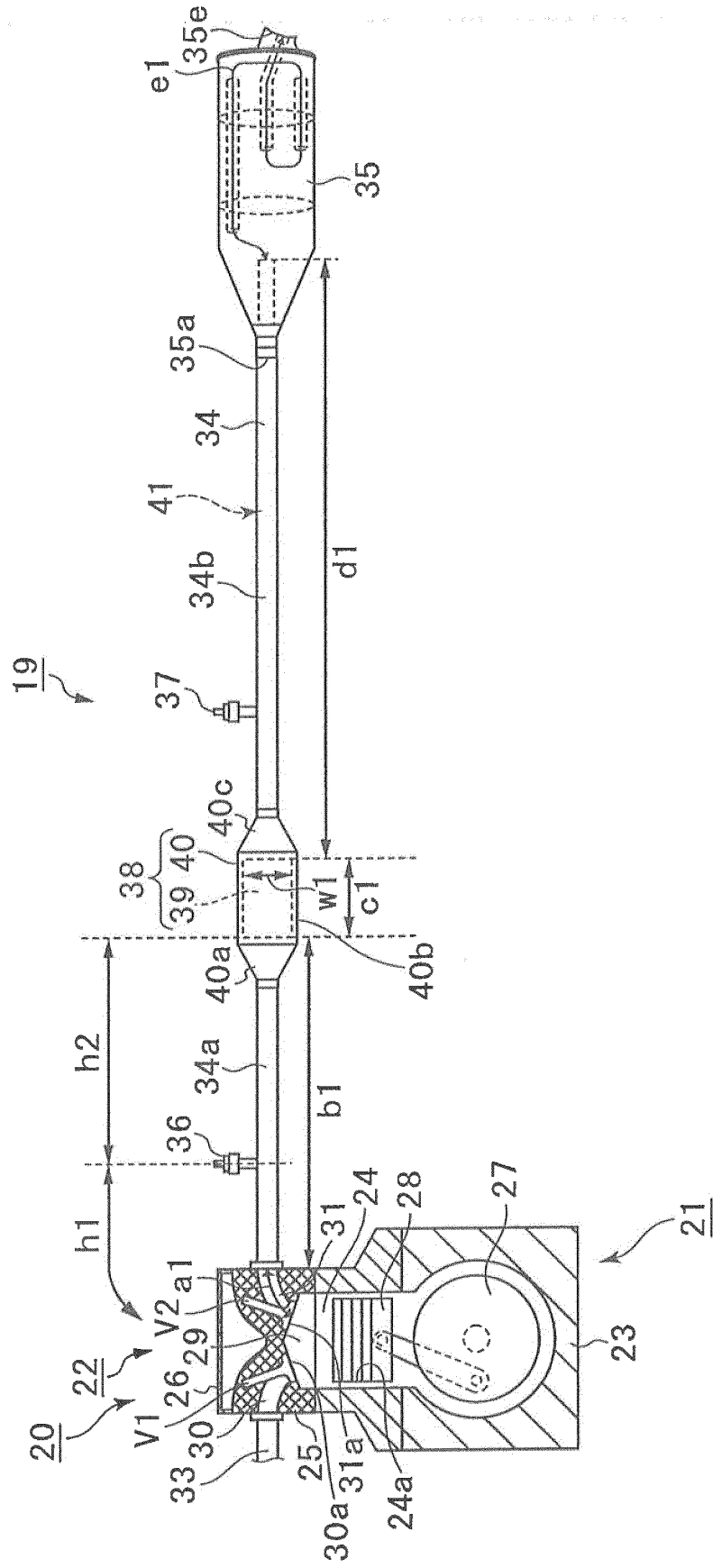
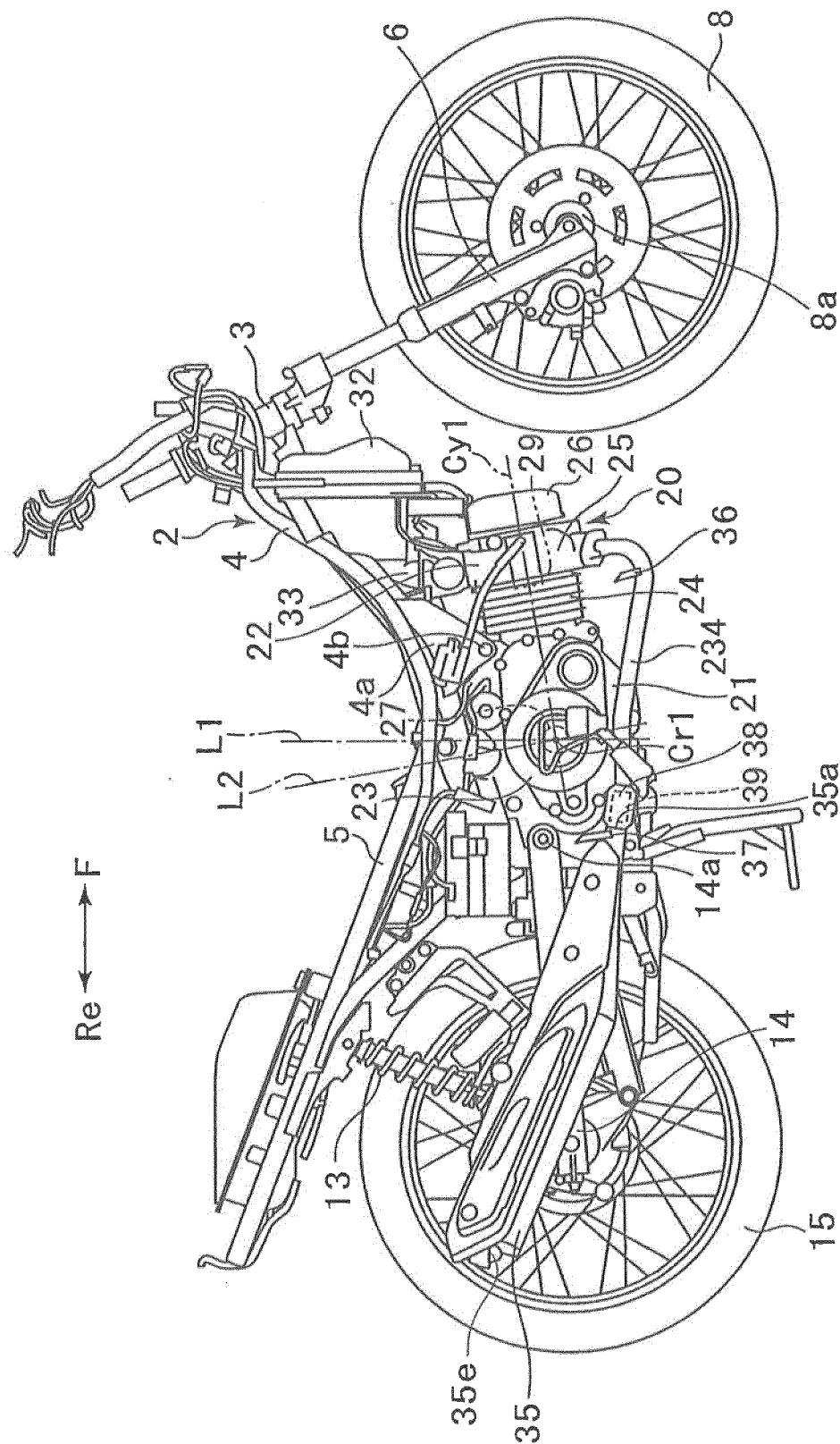


FIG.6



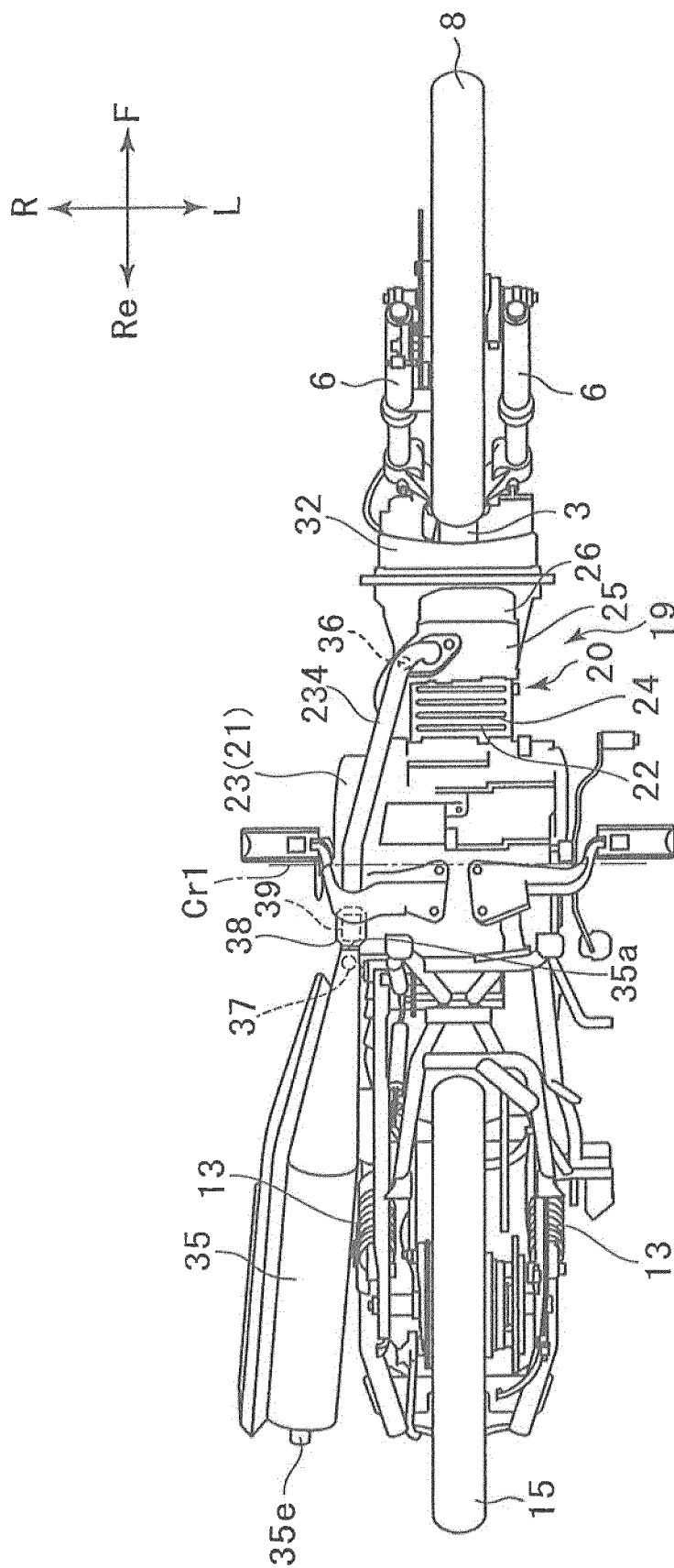


FIG. 7

FIG. 8.

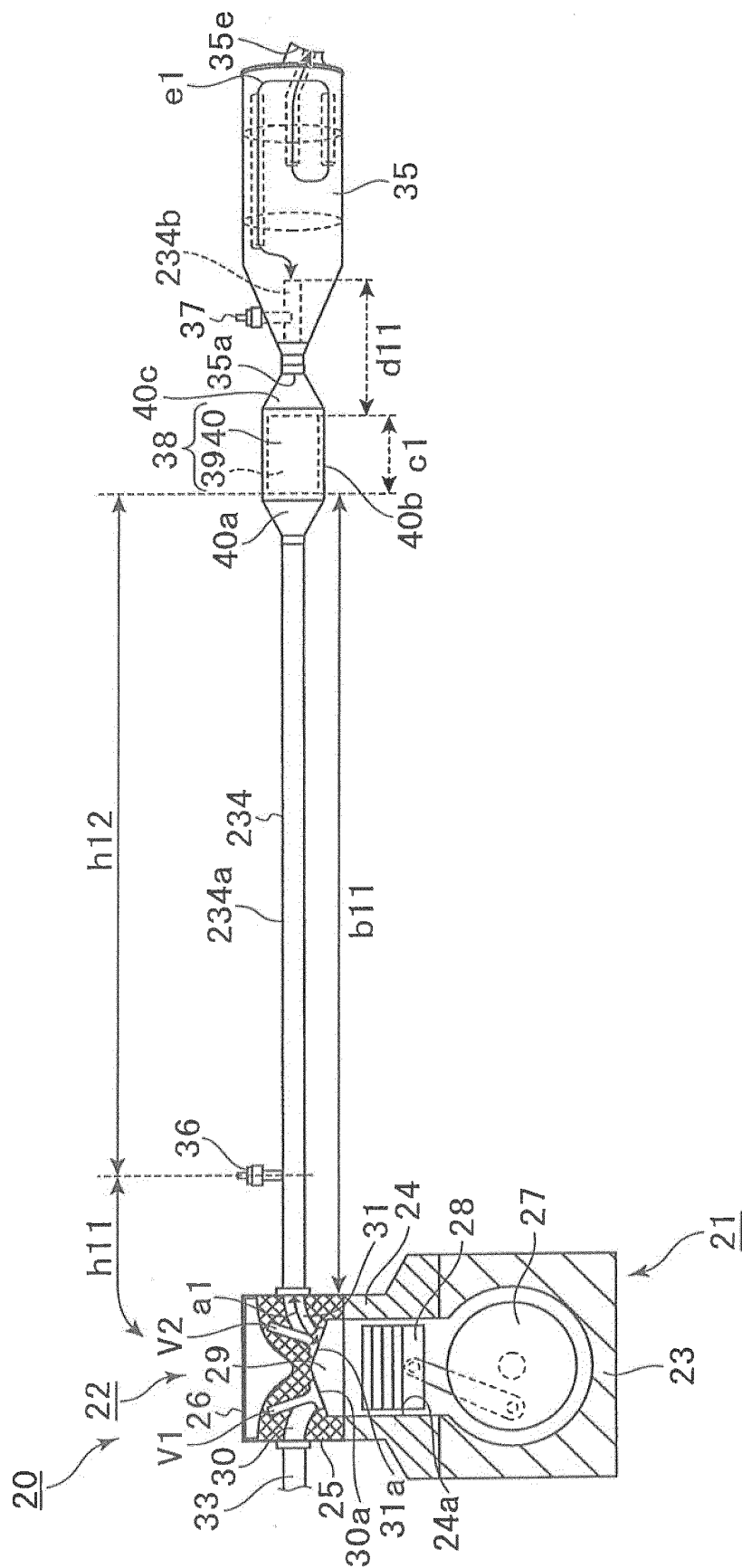


FIG.9

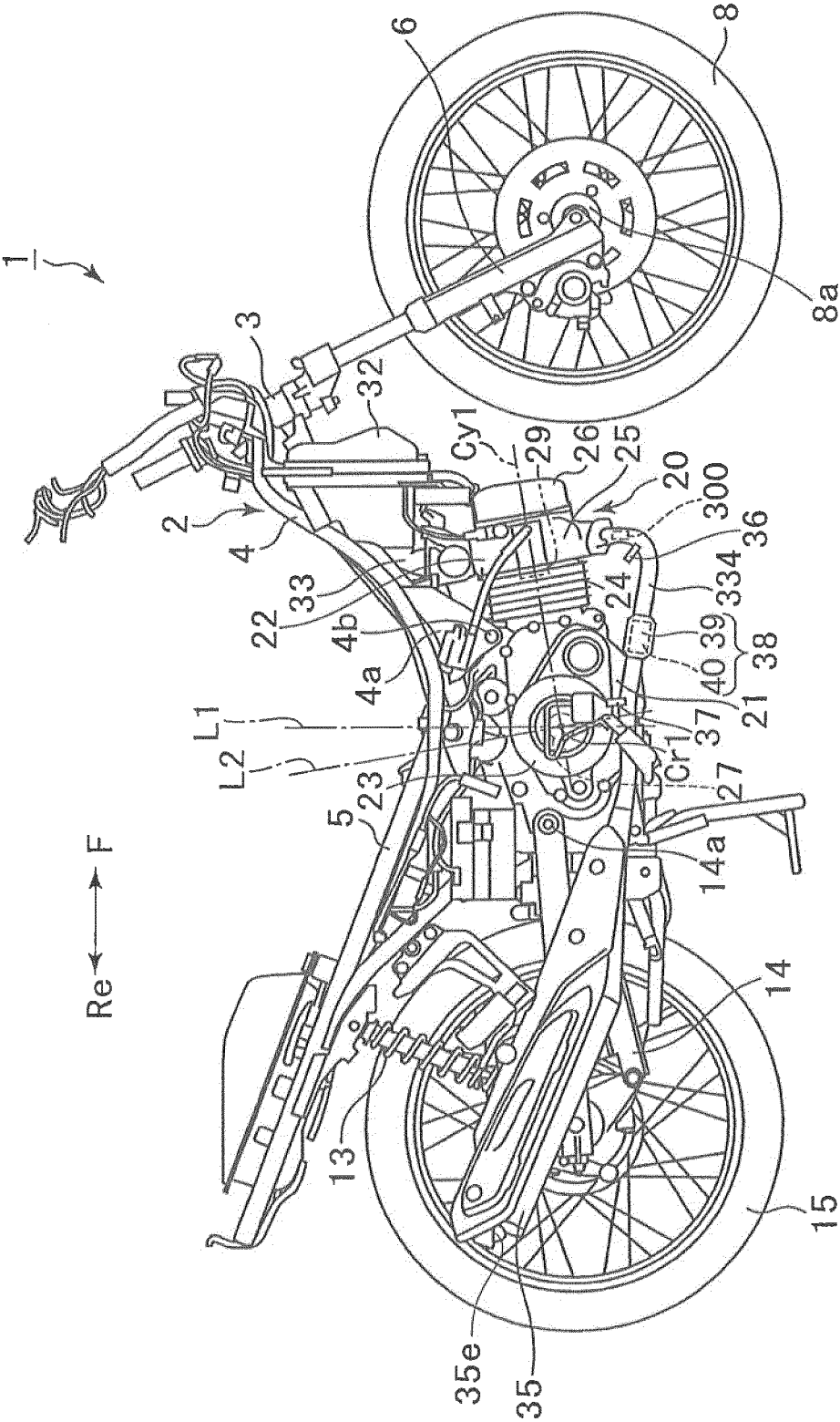


FIG.10

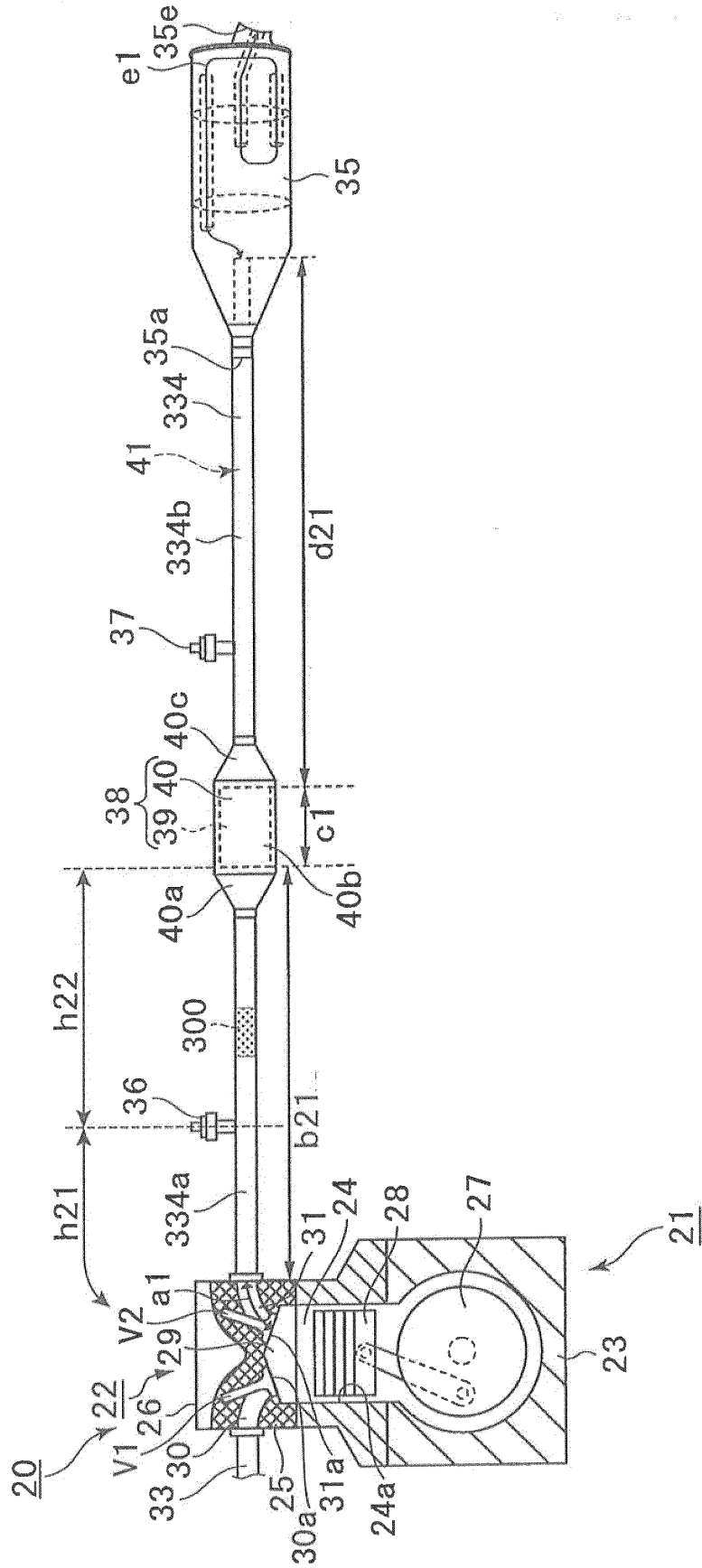


FIG.11

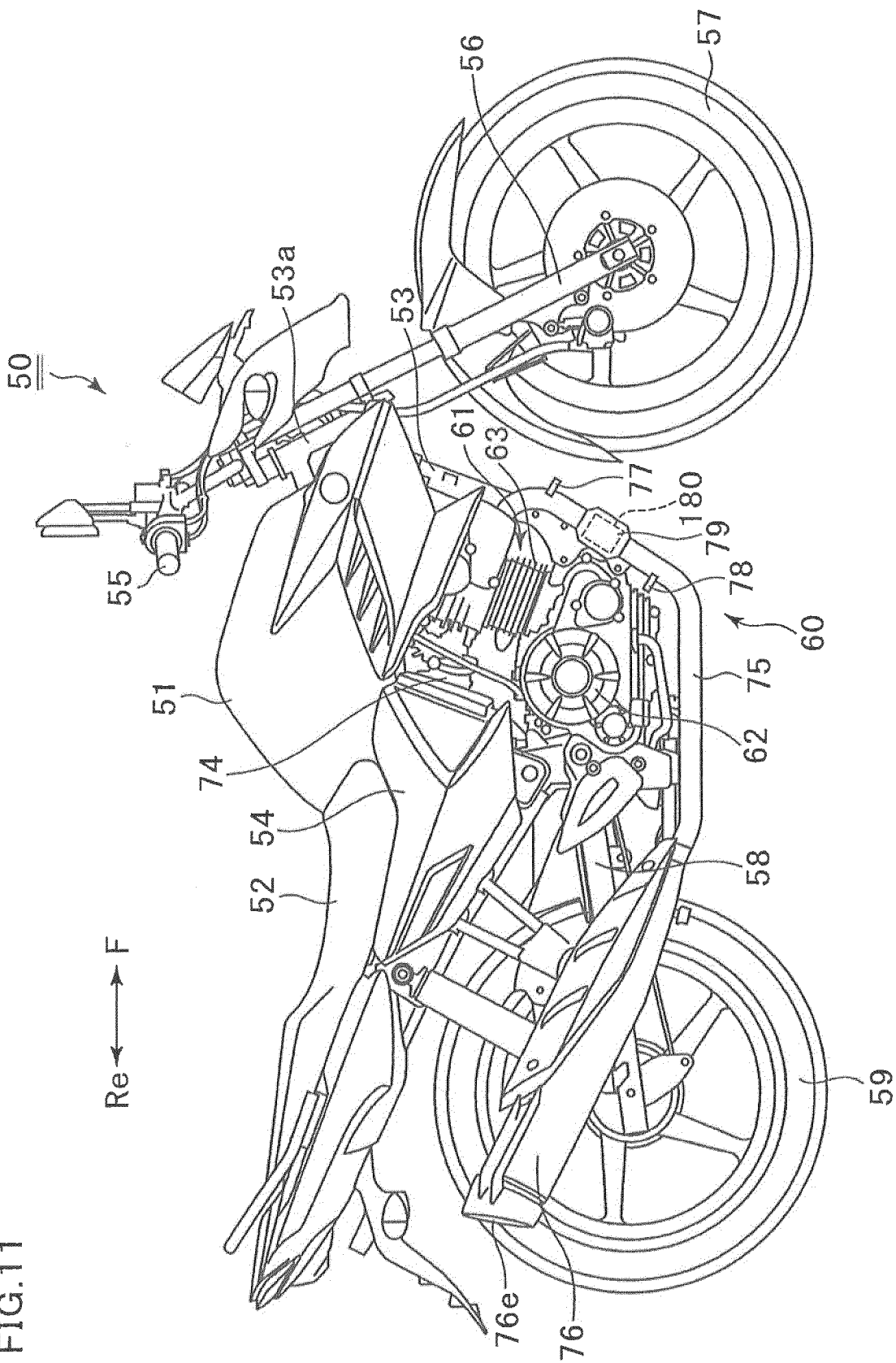


FIG.12

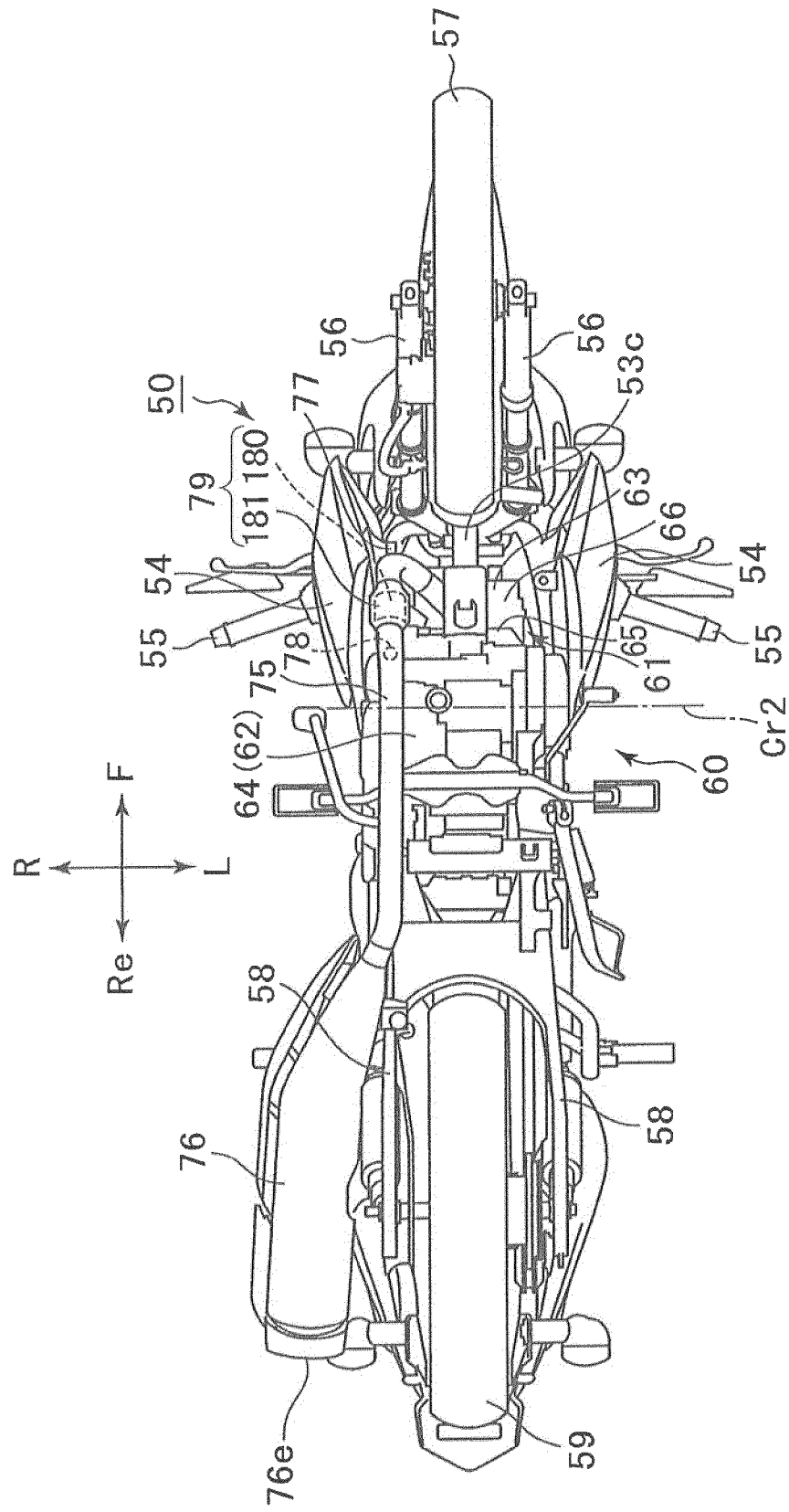


FIG.13

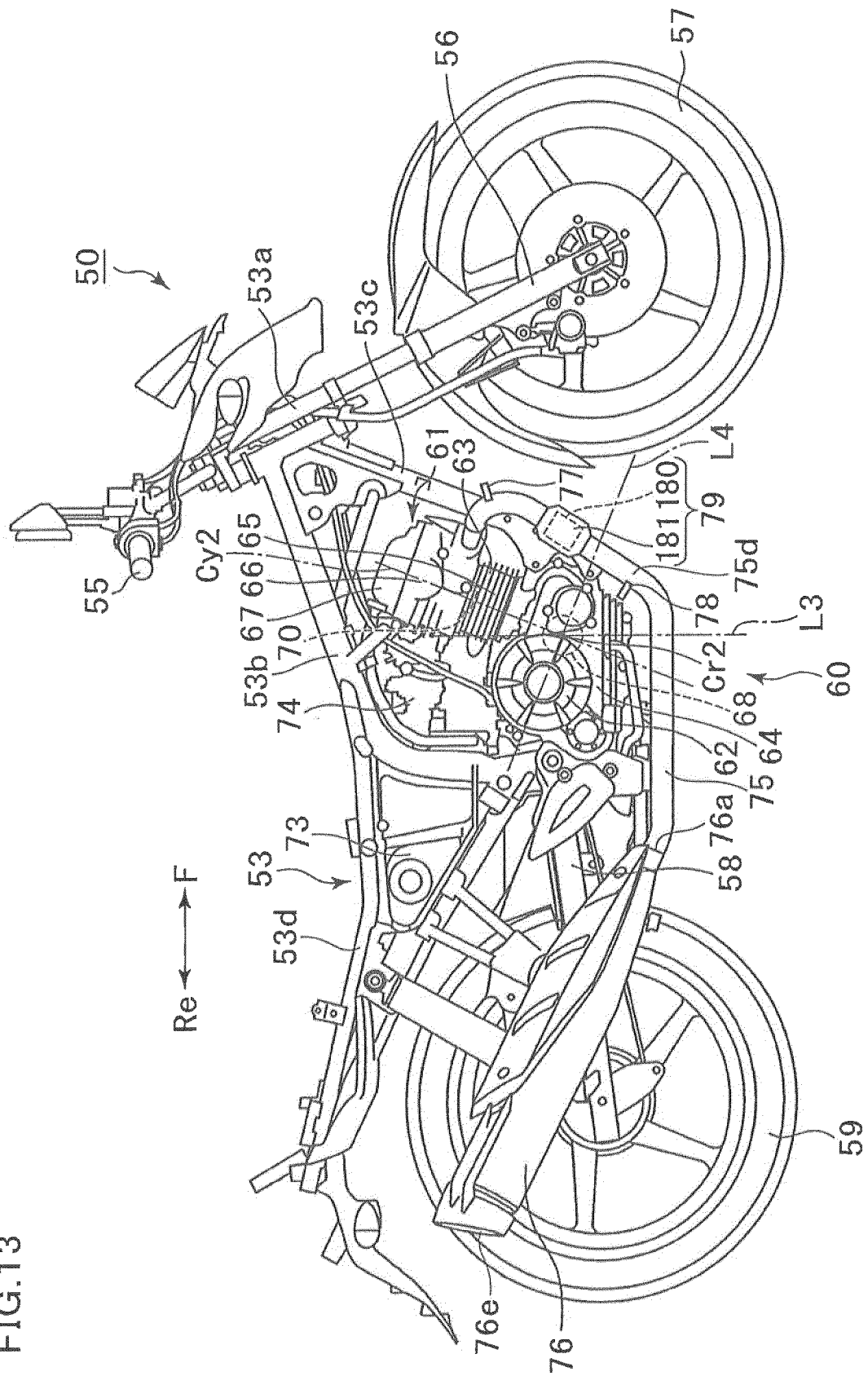


FIG.14

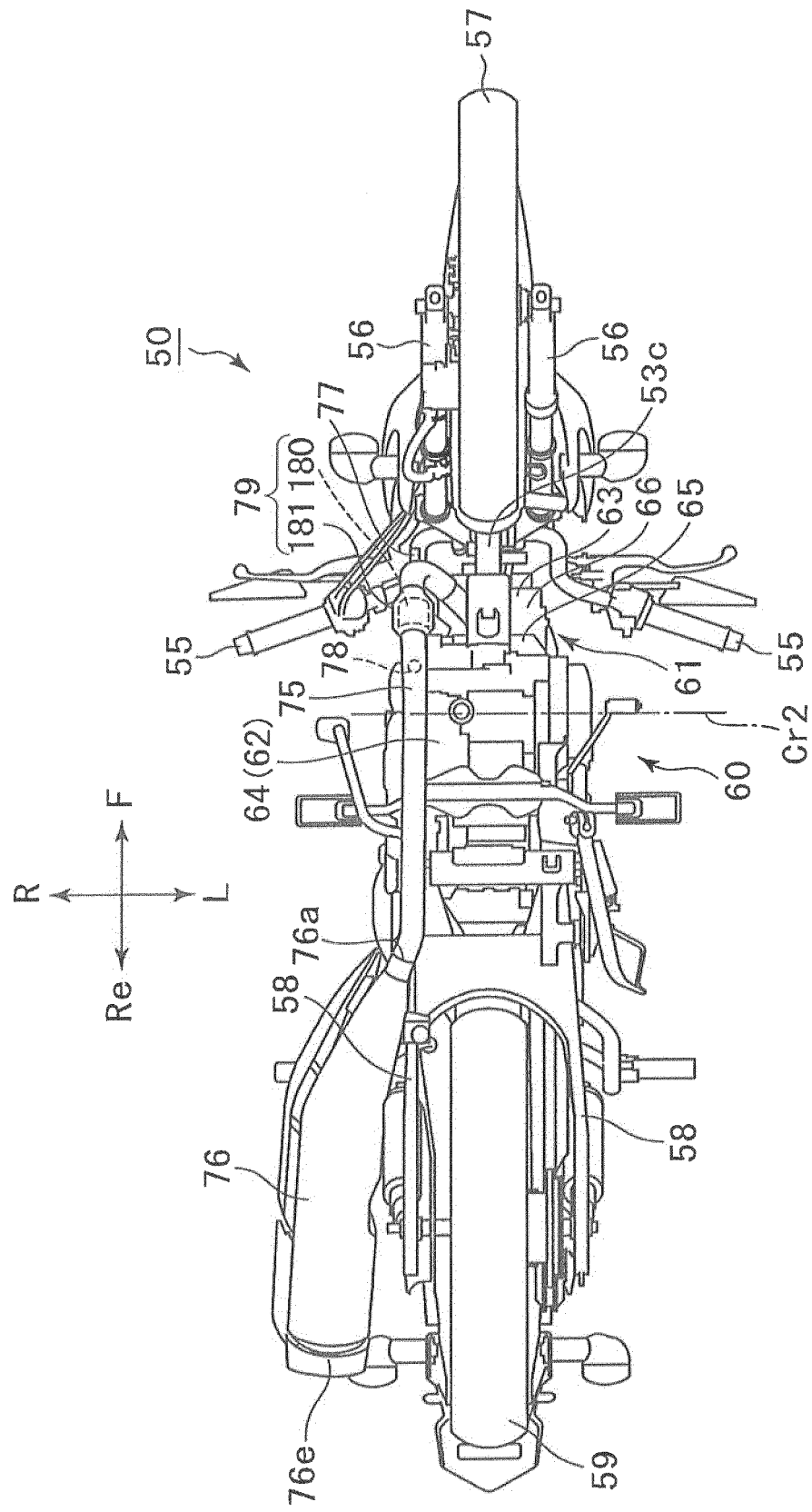
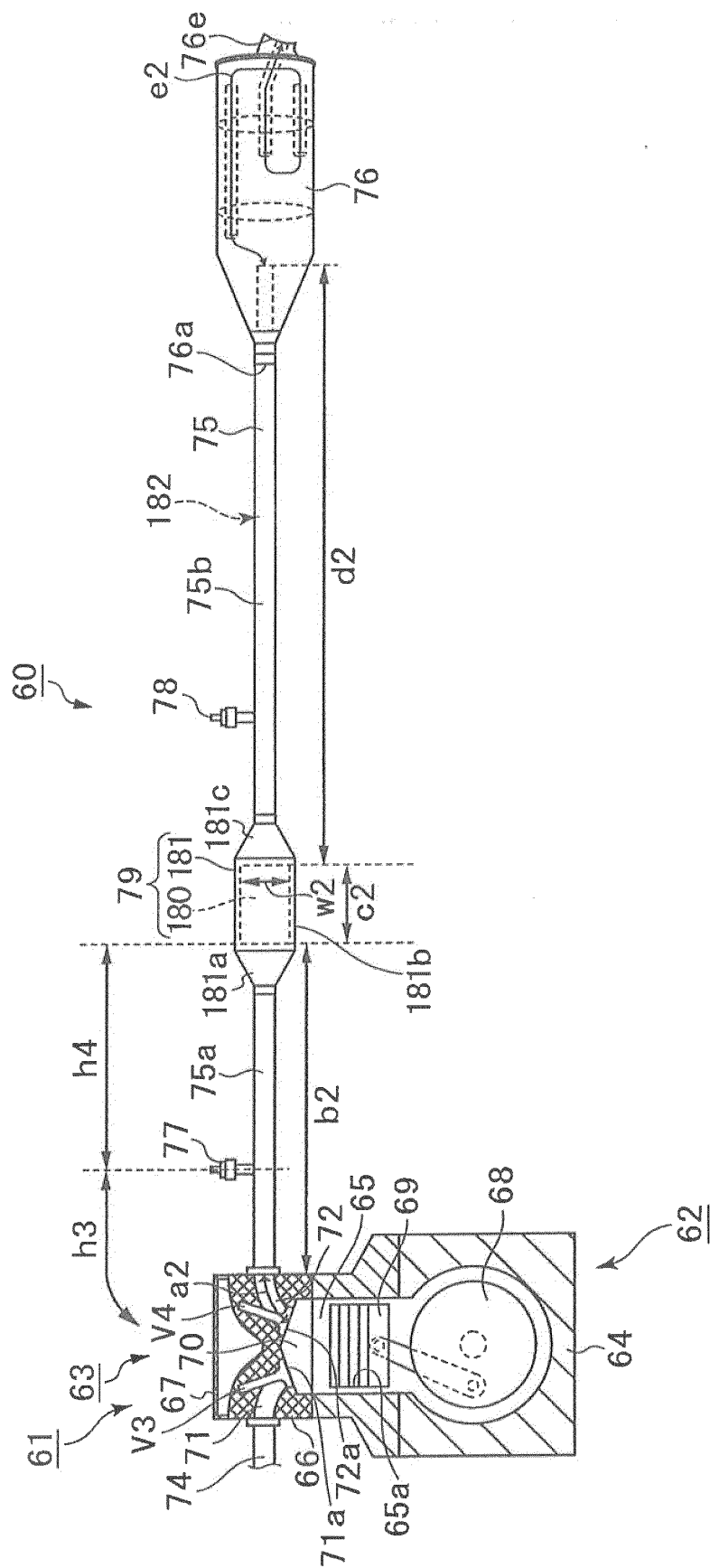


FIG.15



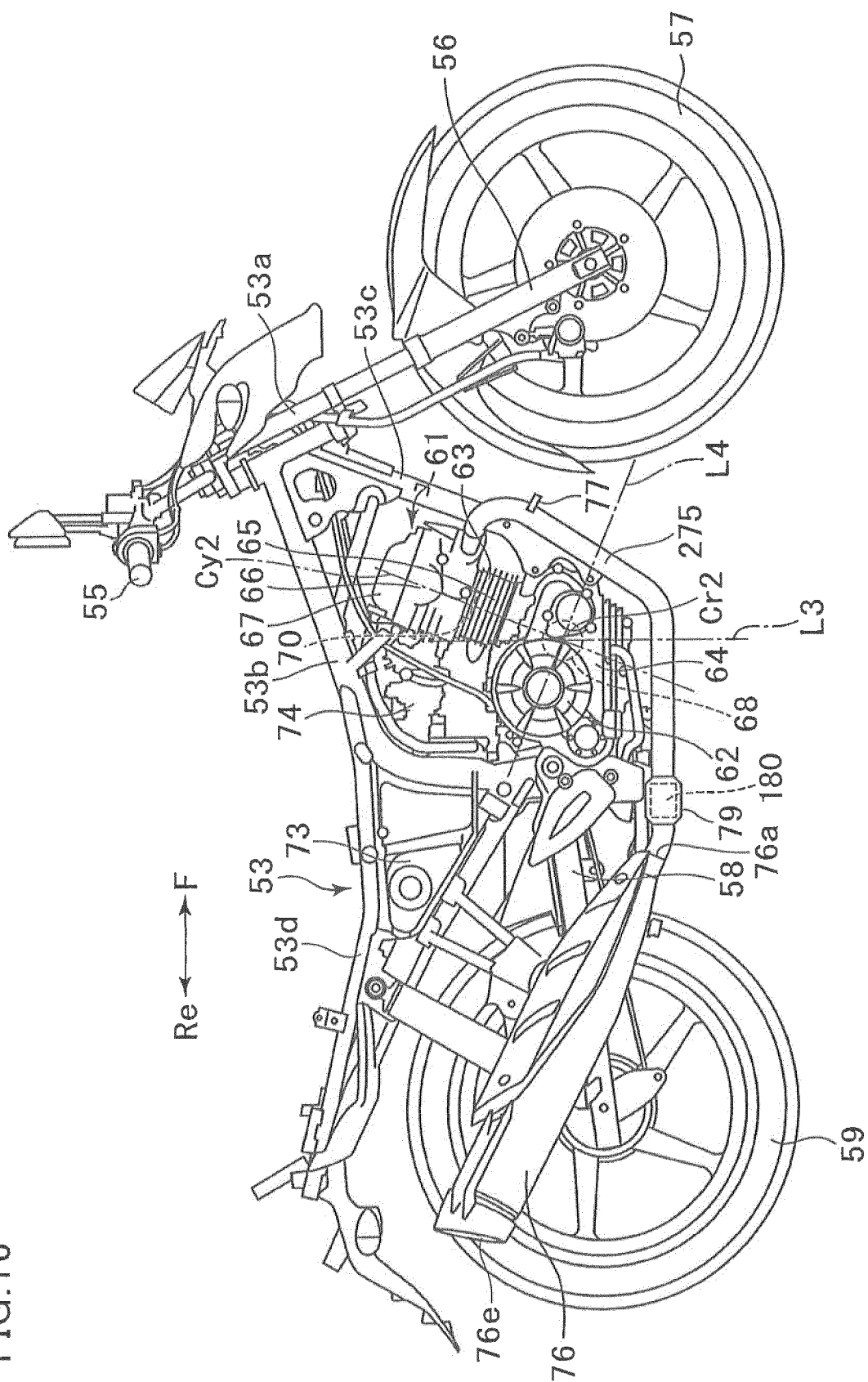


FIG. 16

FIG.17

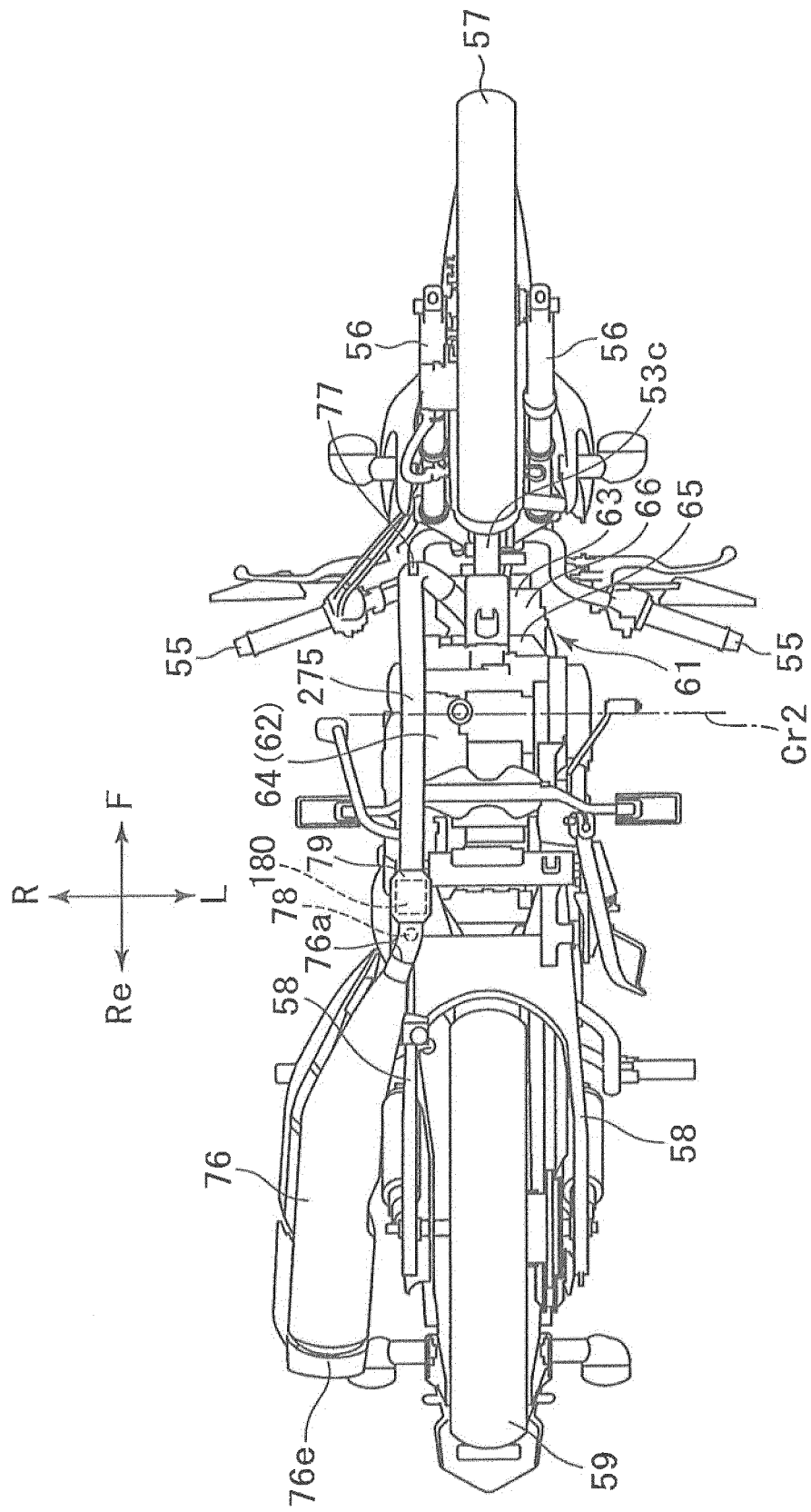
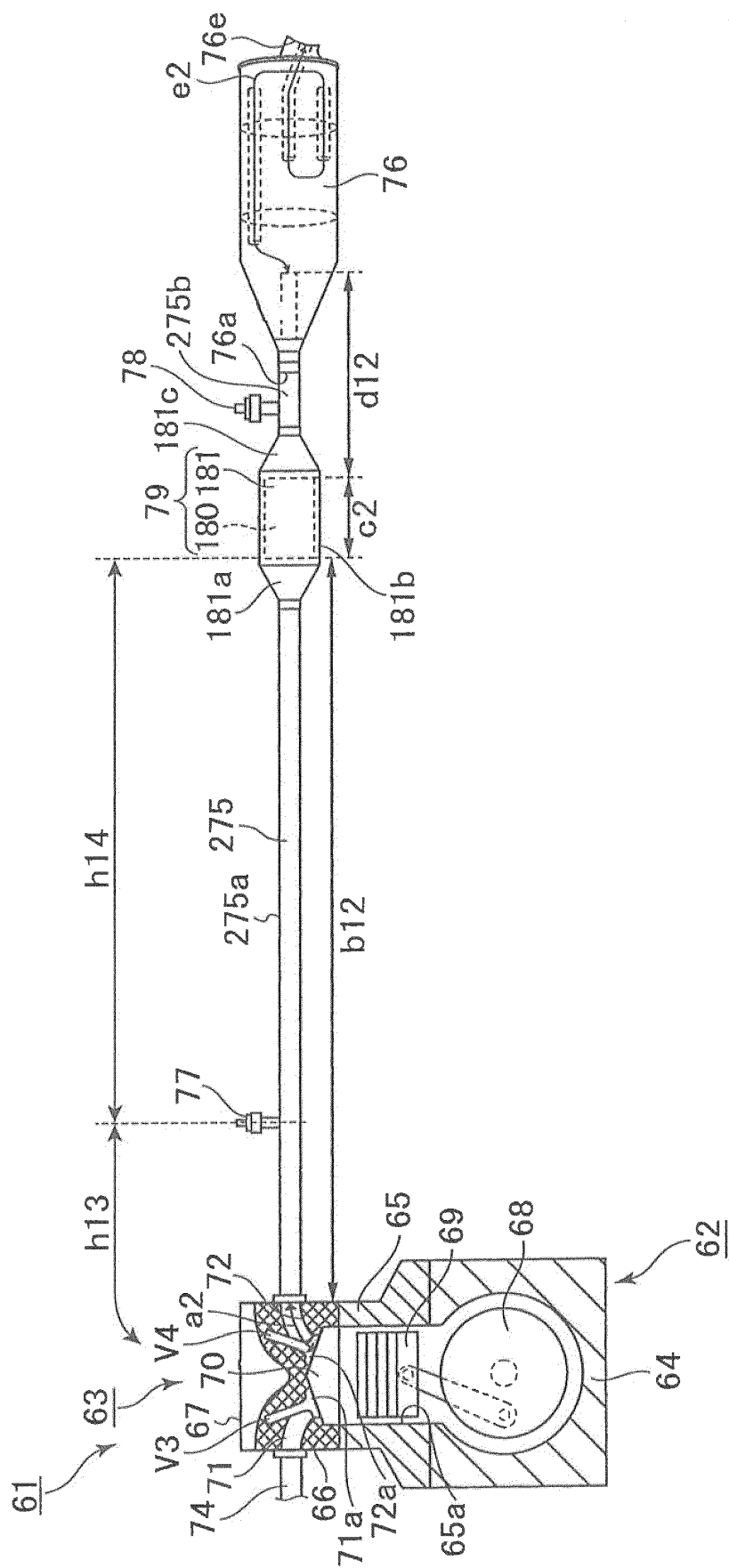
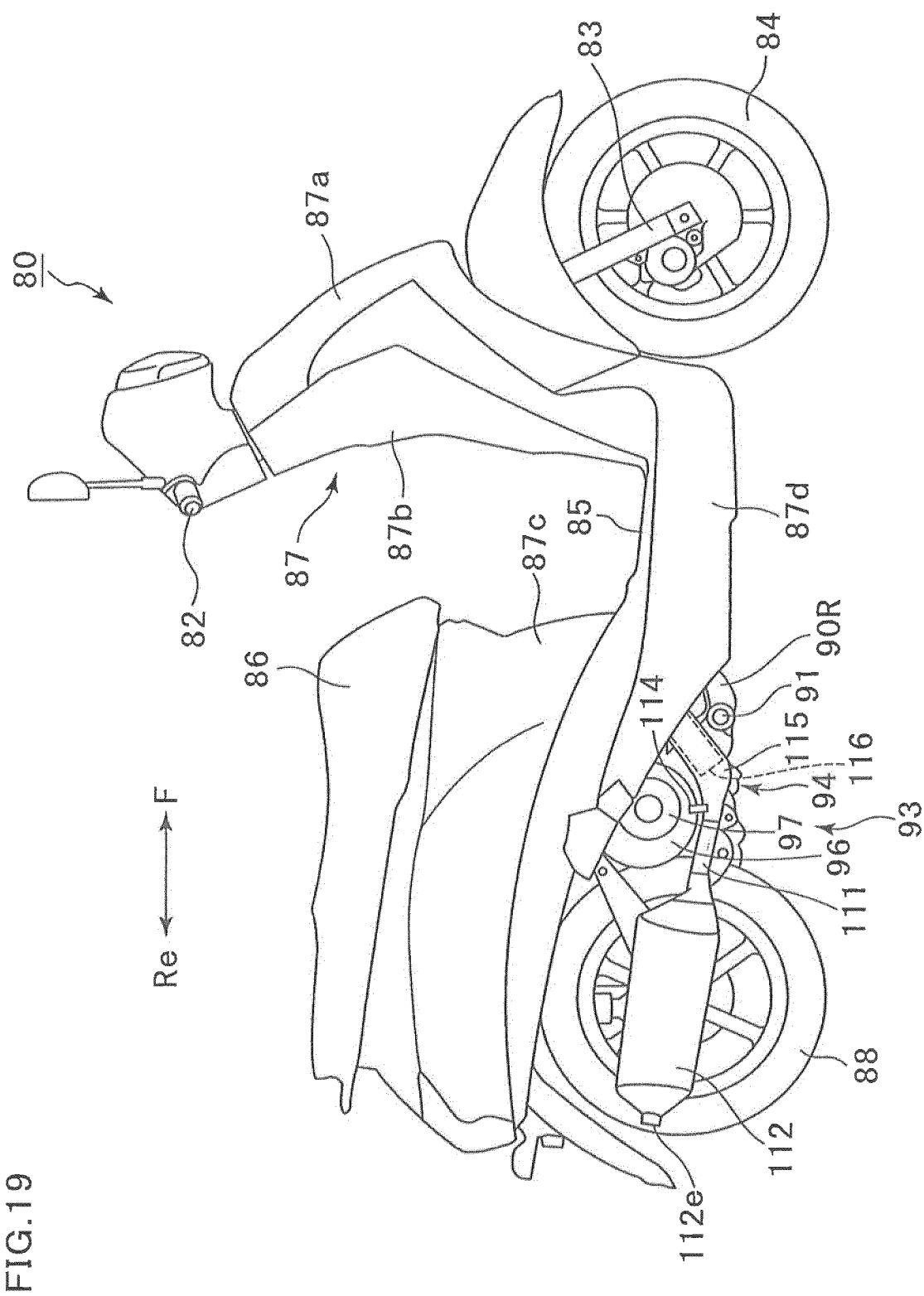


FIG.18





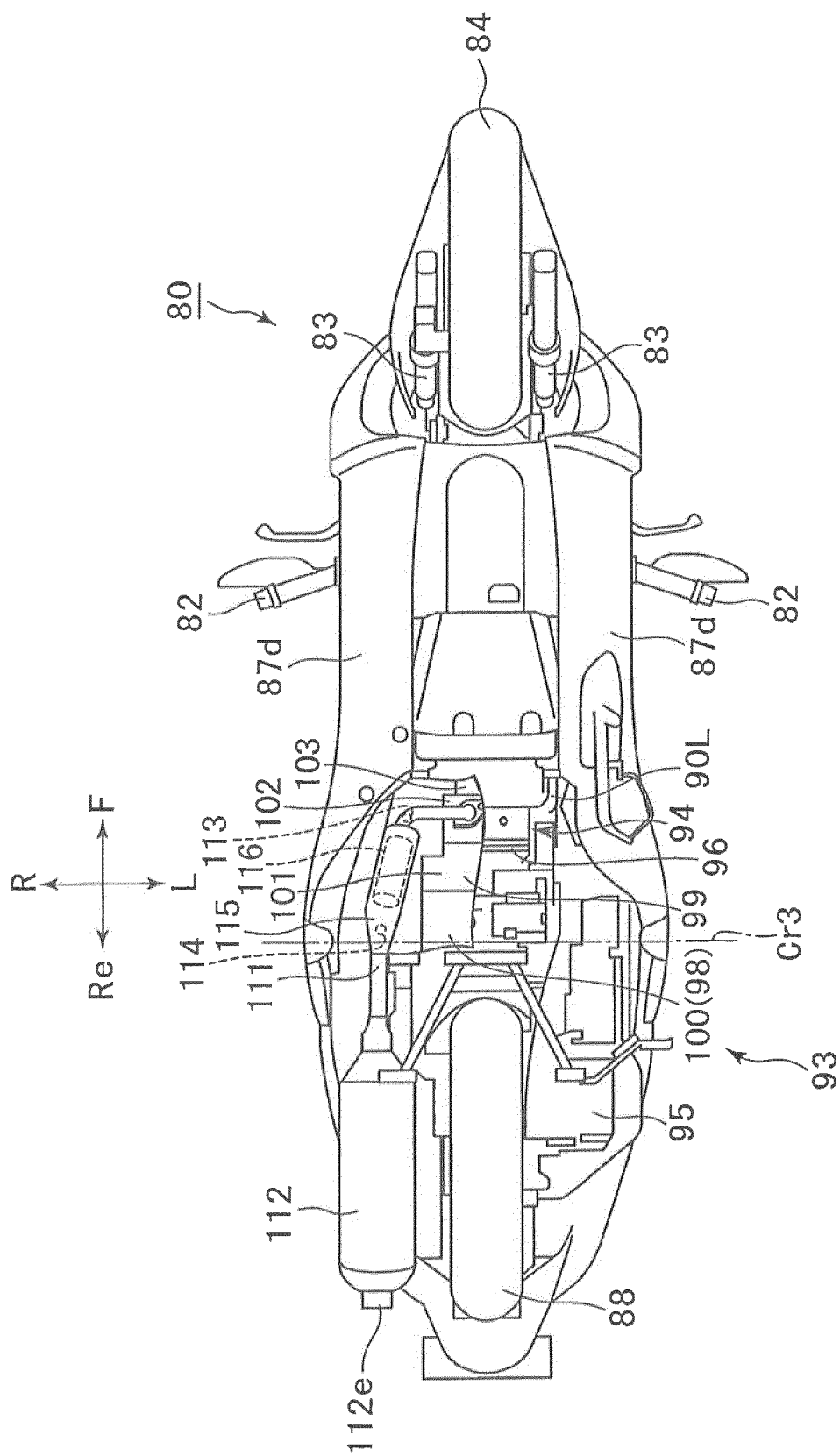


FIG. 20

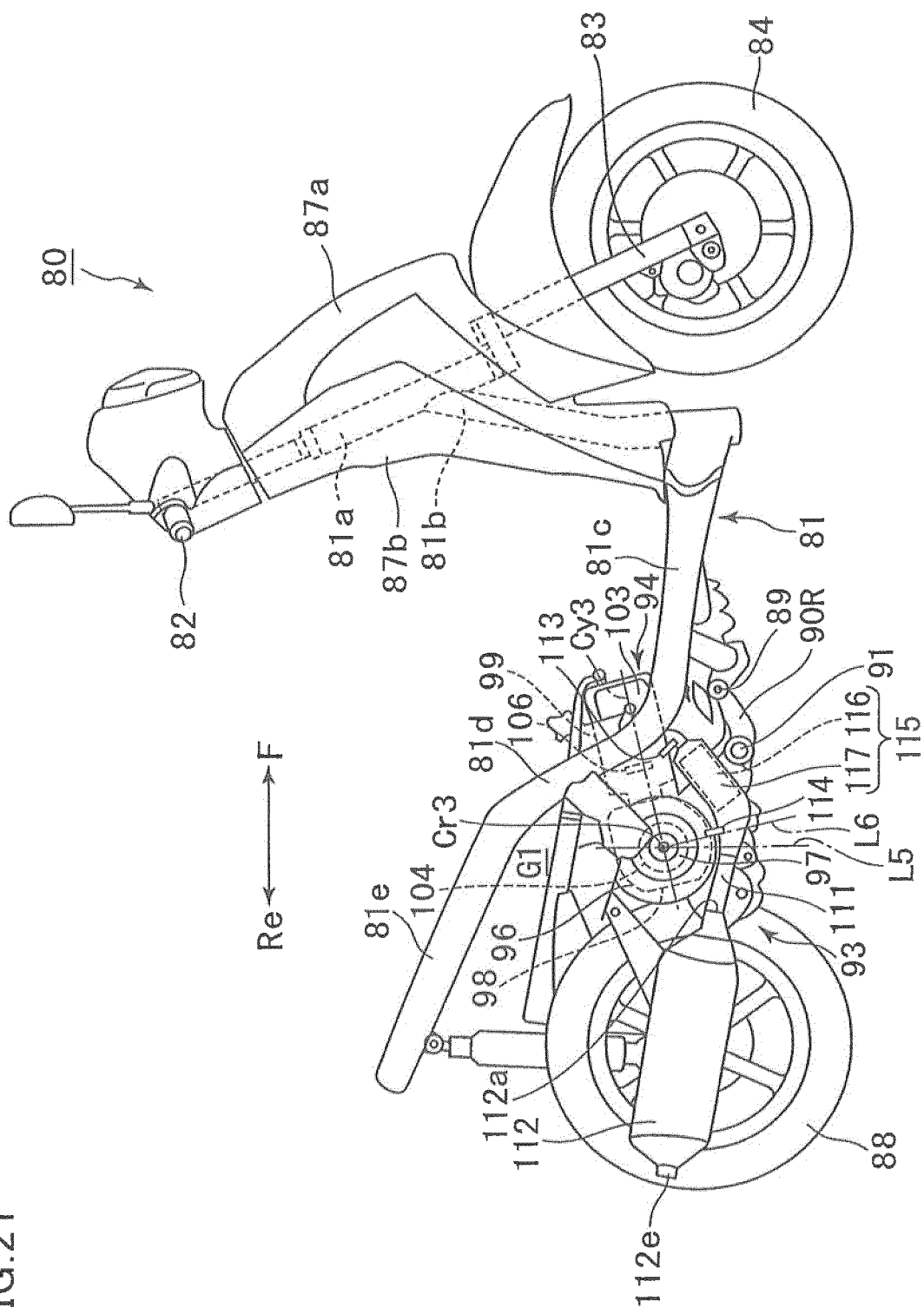


FIG. 21

FIG.22

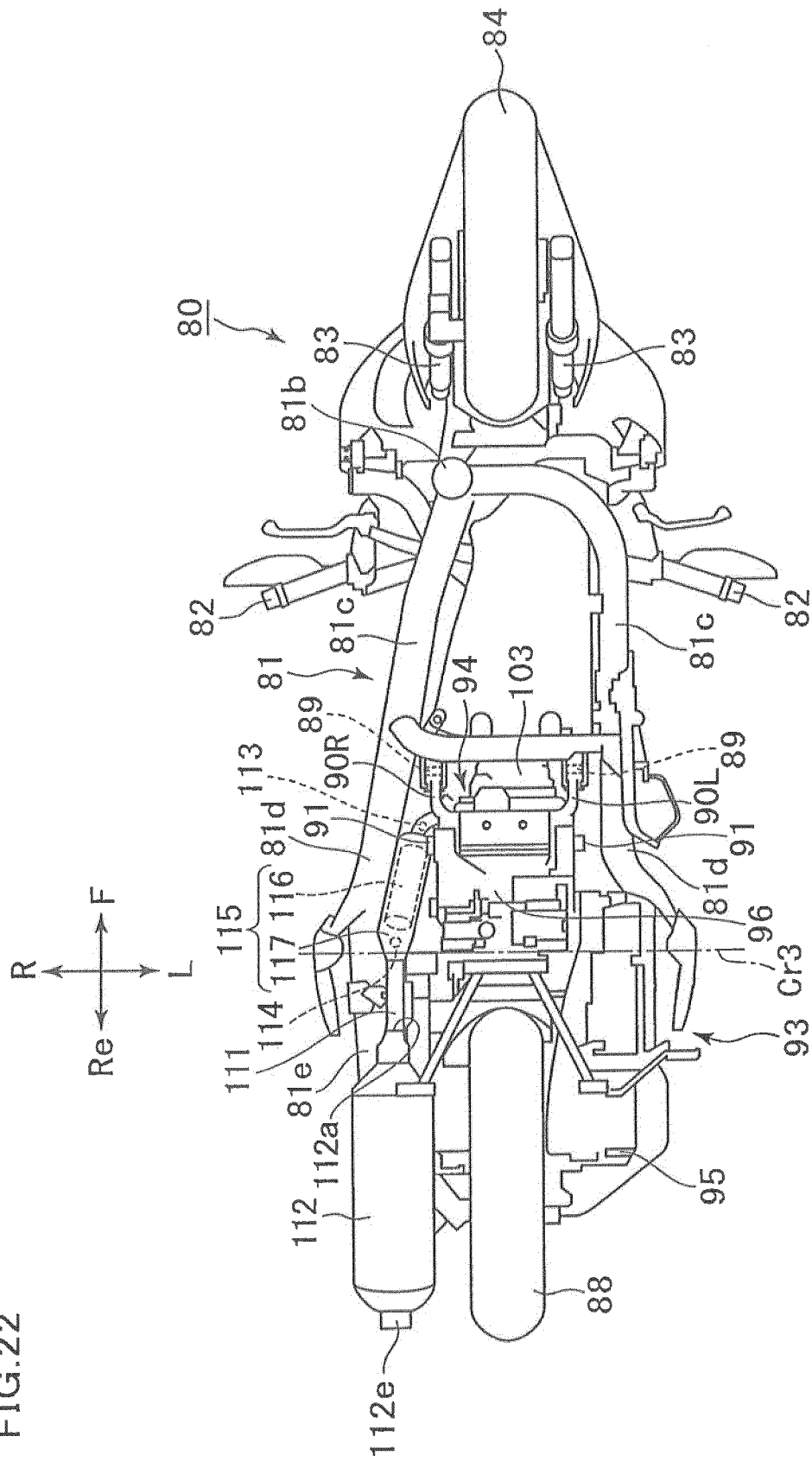


FIG. 23

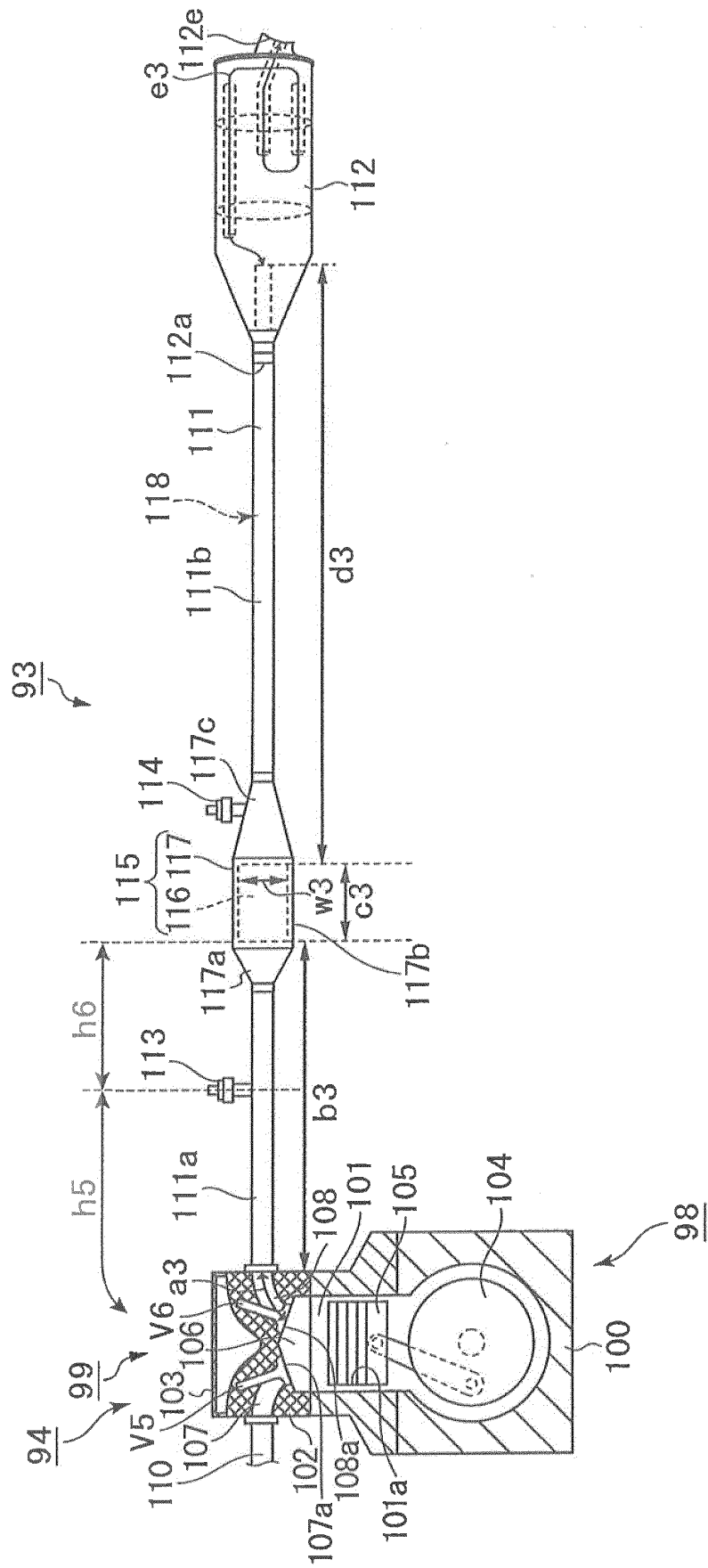


FIG. 24

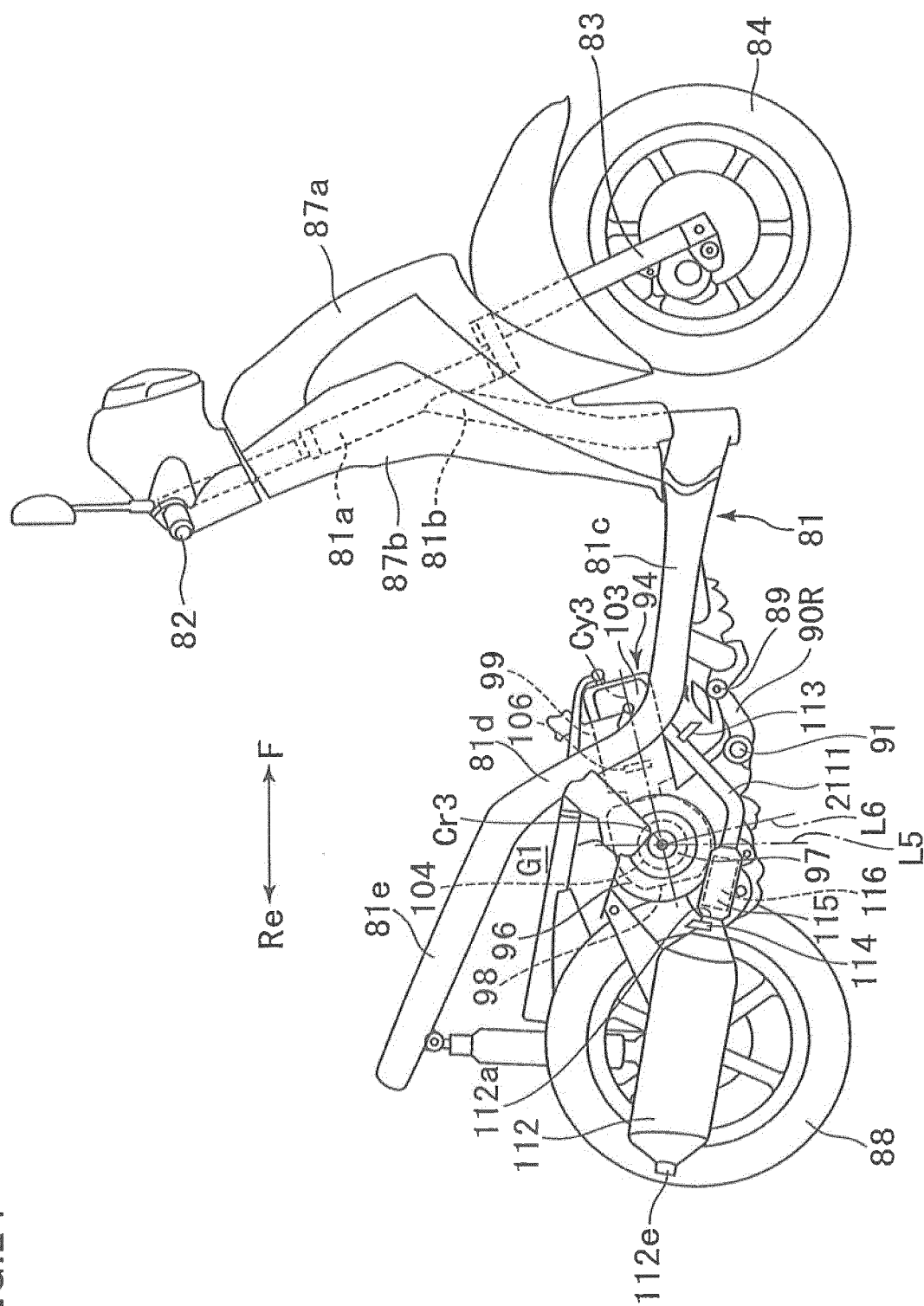
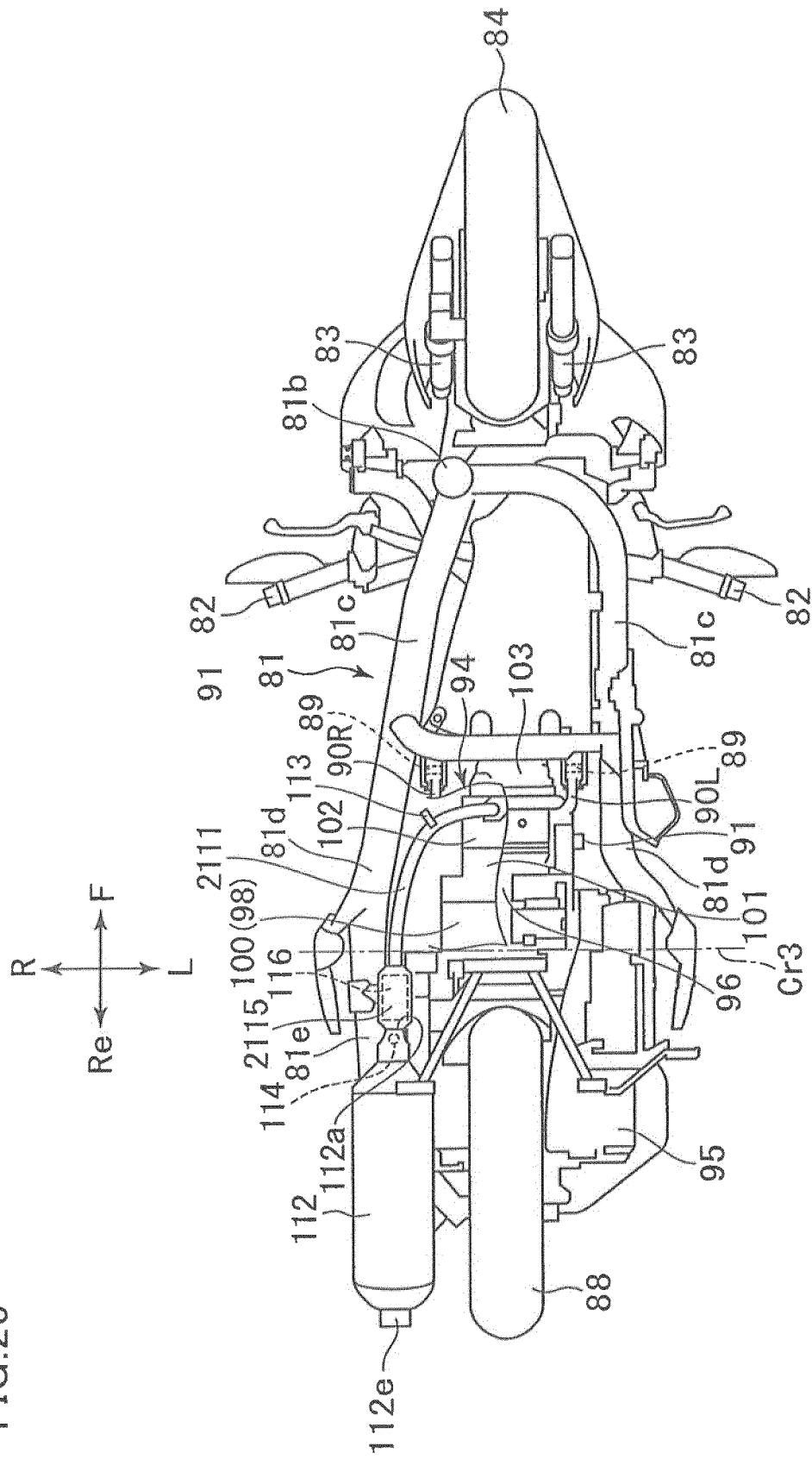


FIG.25



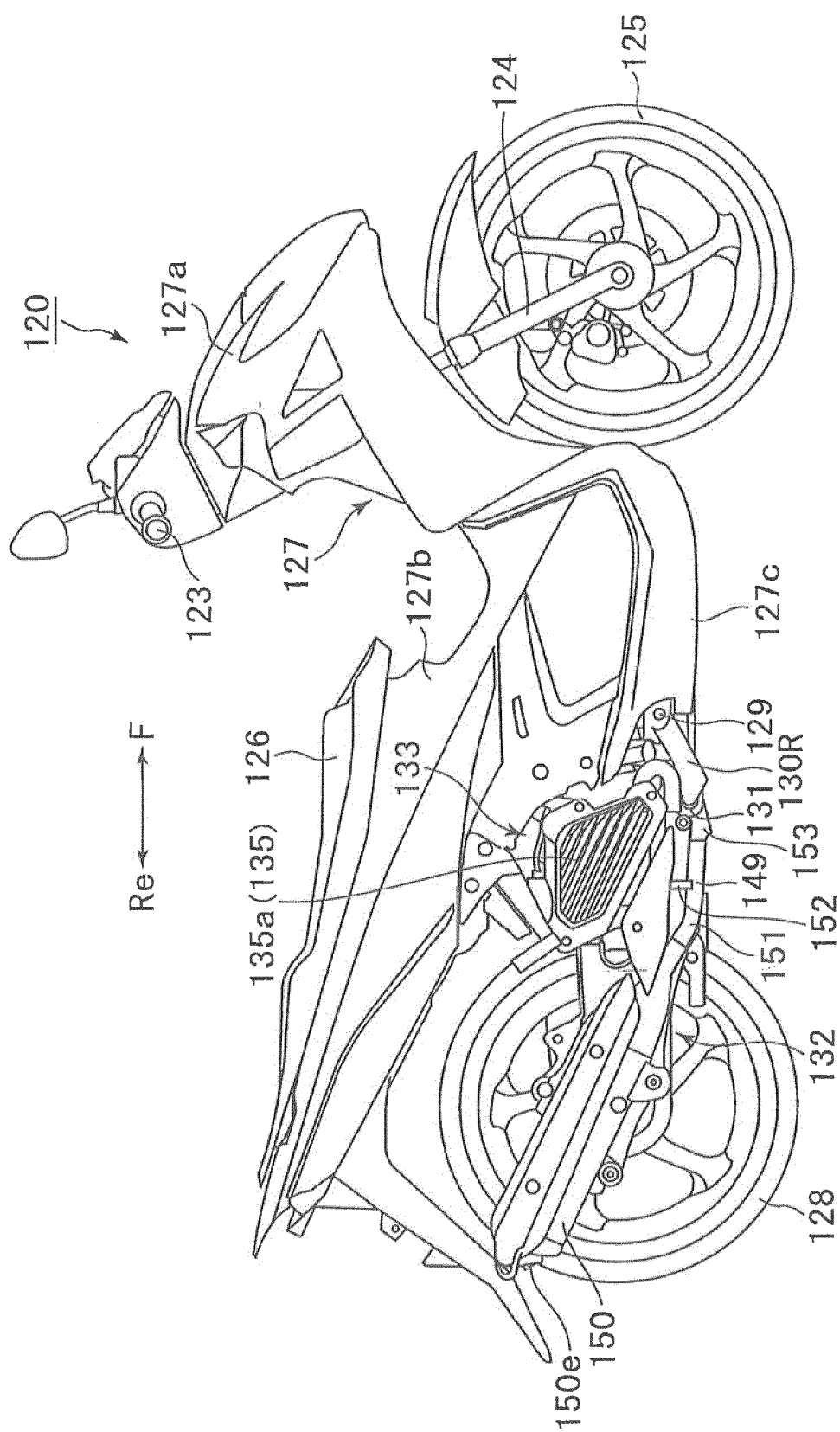


FIG. 27

FIG.28

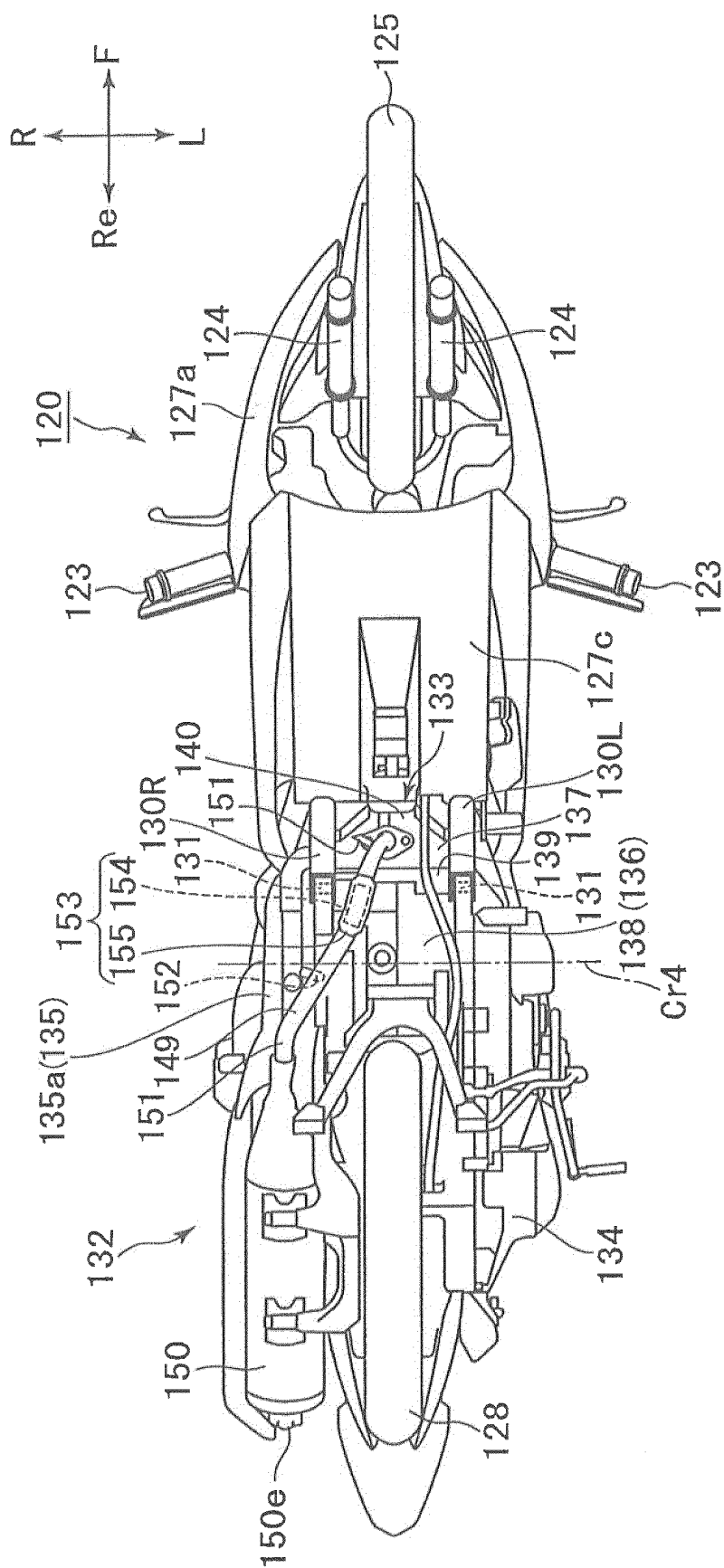


FIG.29

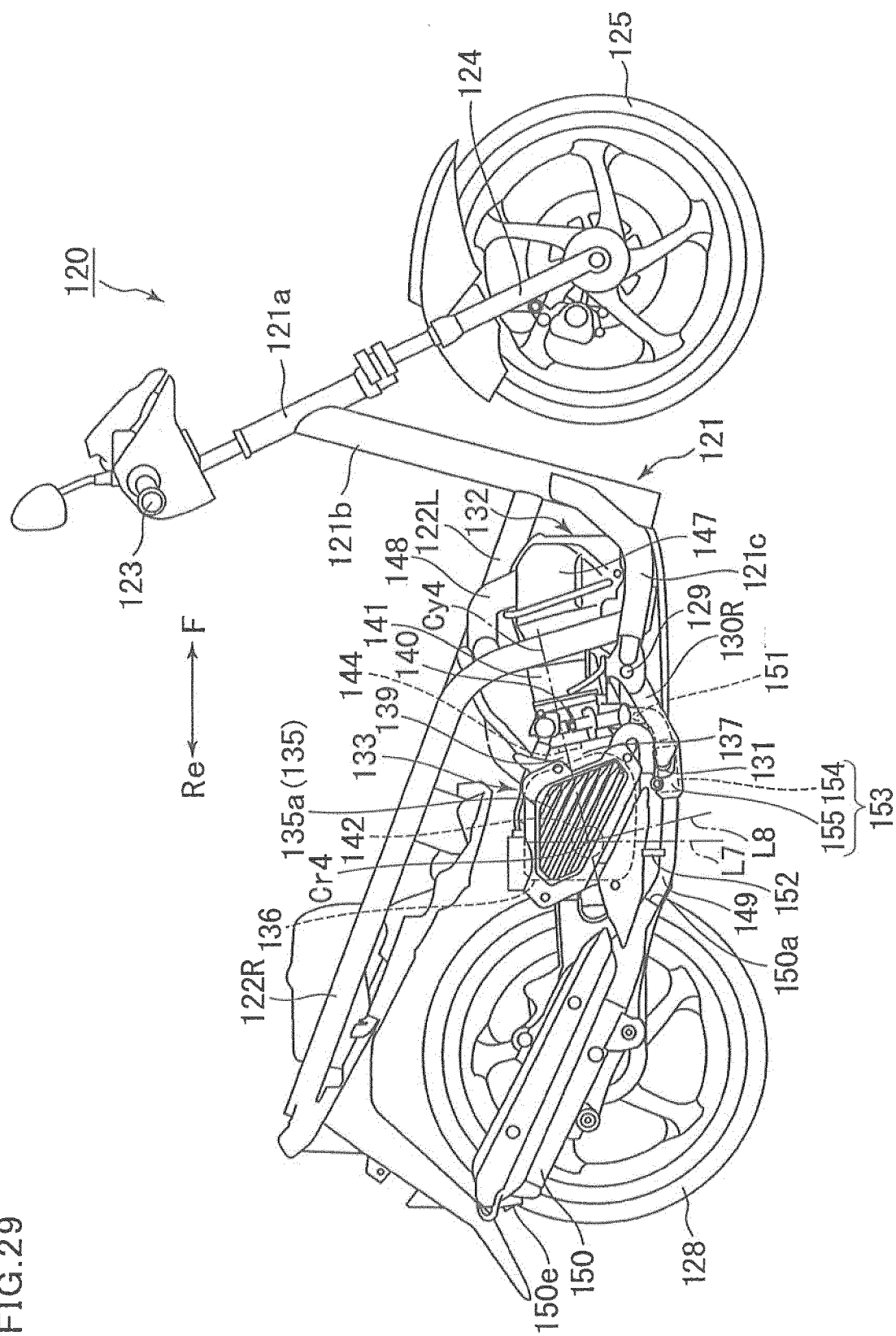
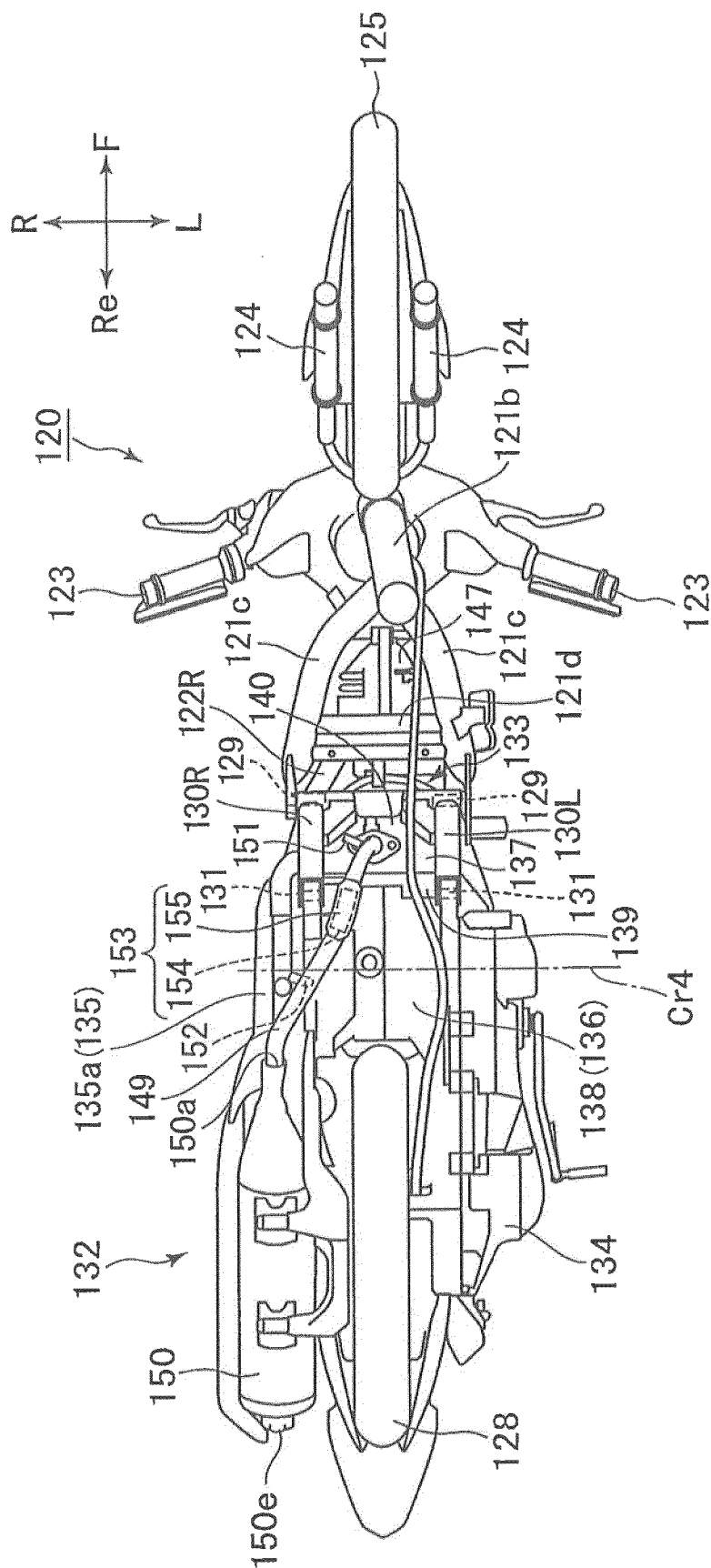


FIG.30



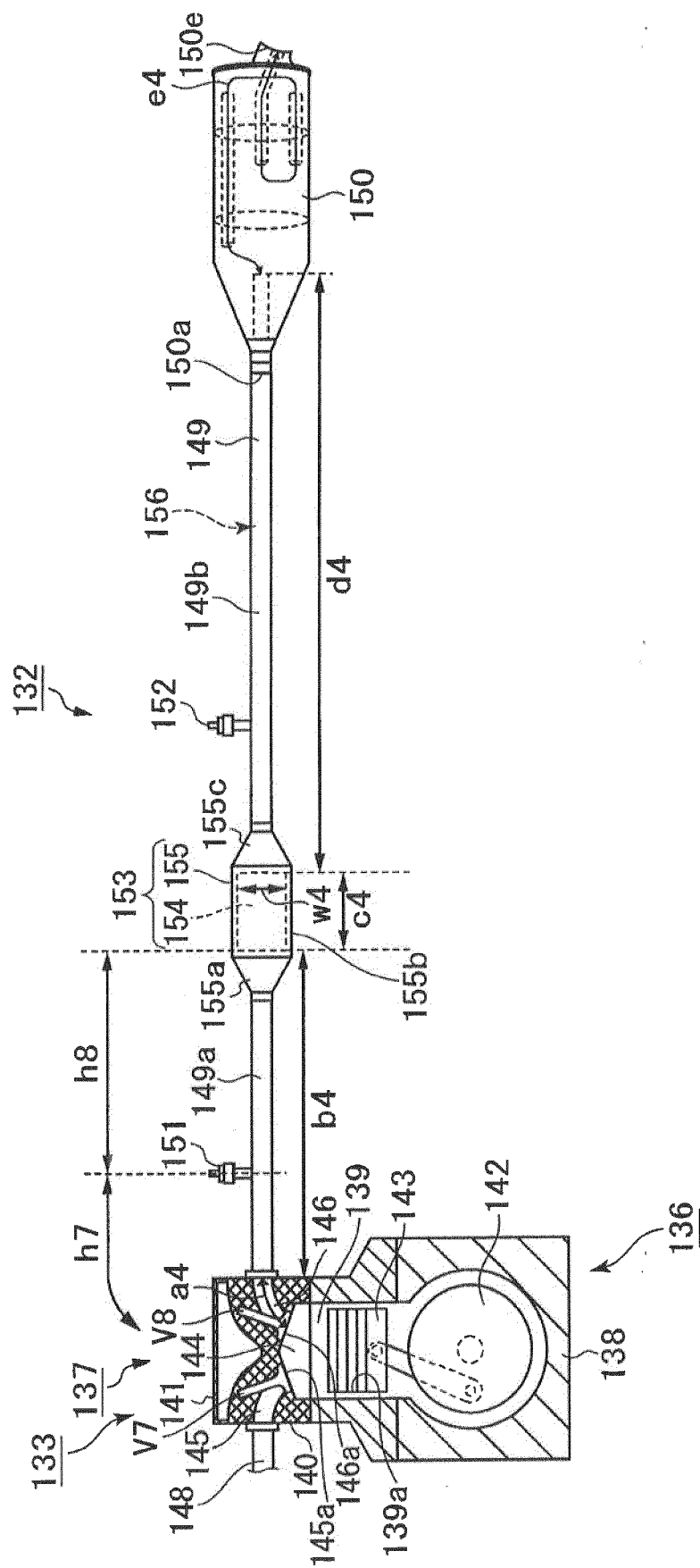


FIG. 31

FIG.32

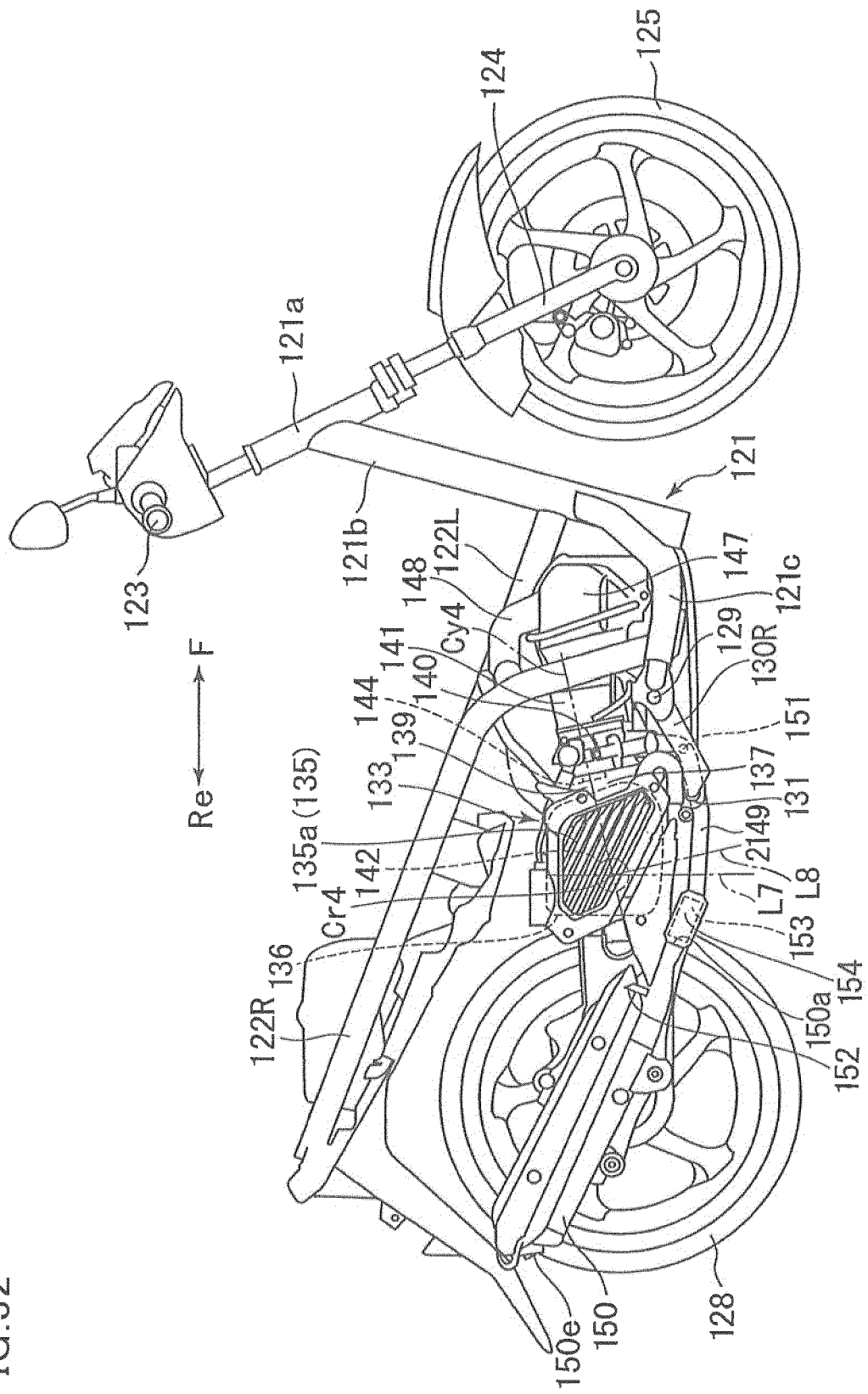


FIG.33

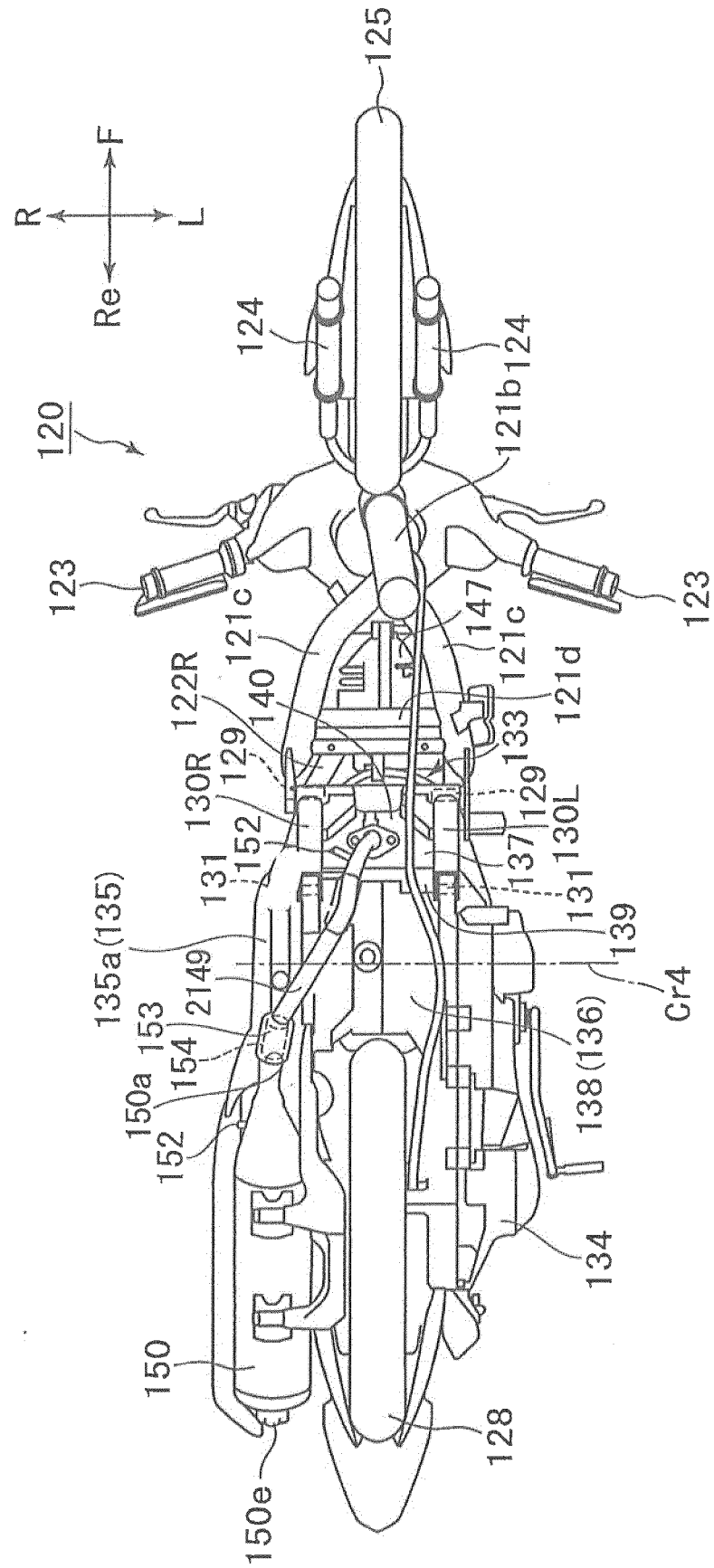


FIG.34

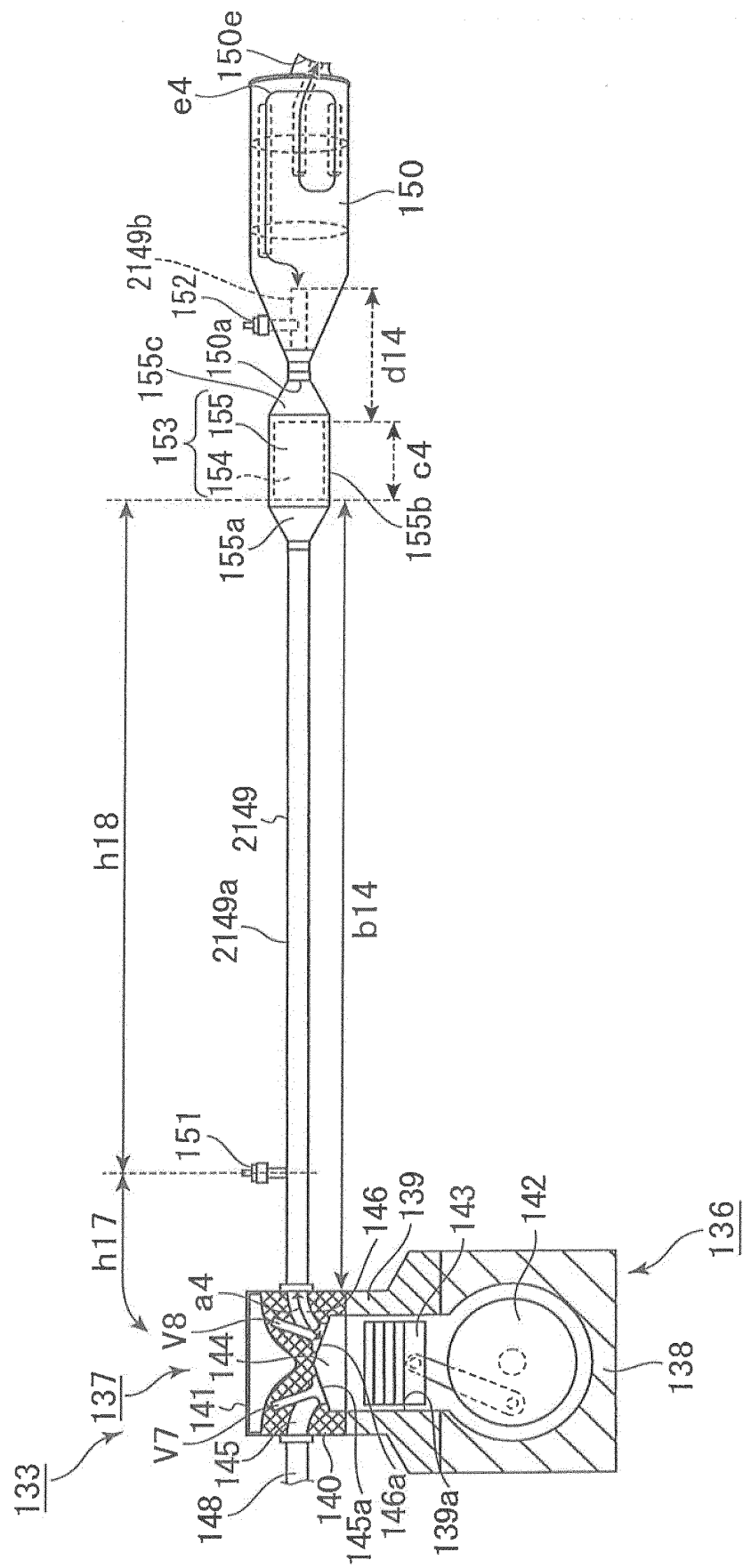


FIG.35

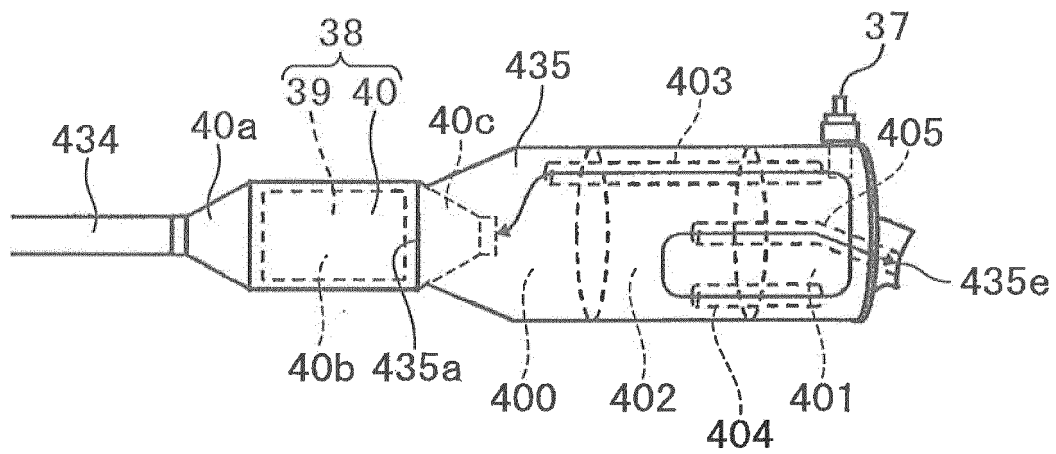


FIG. 36

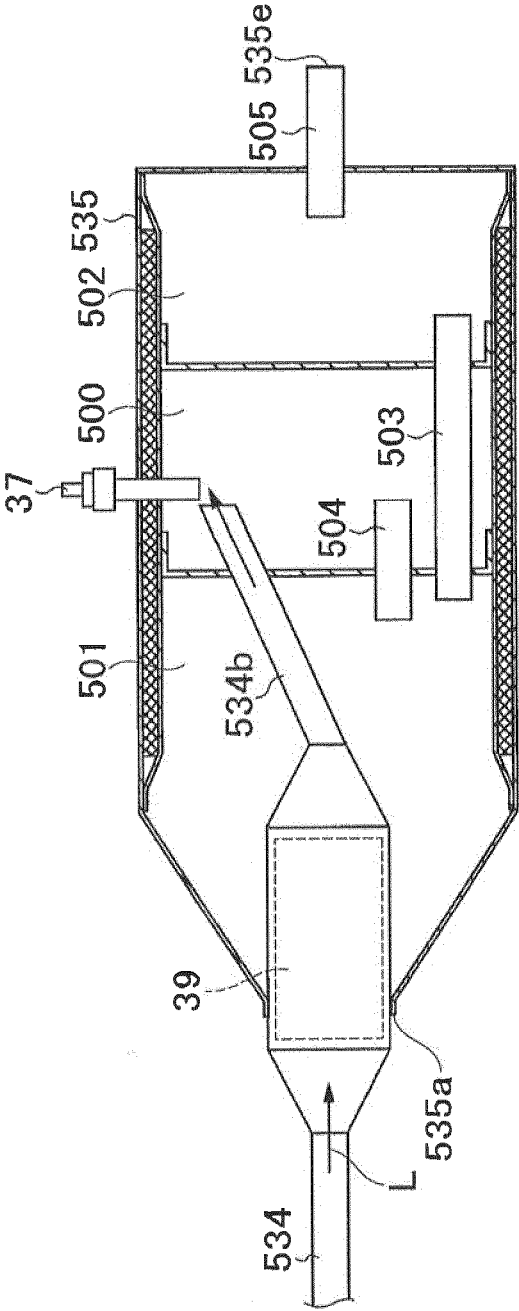


FIG.37

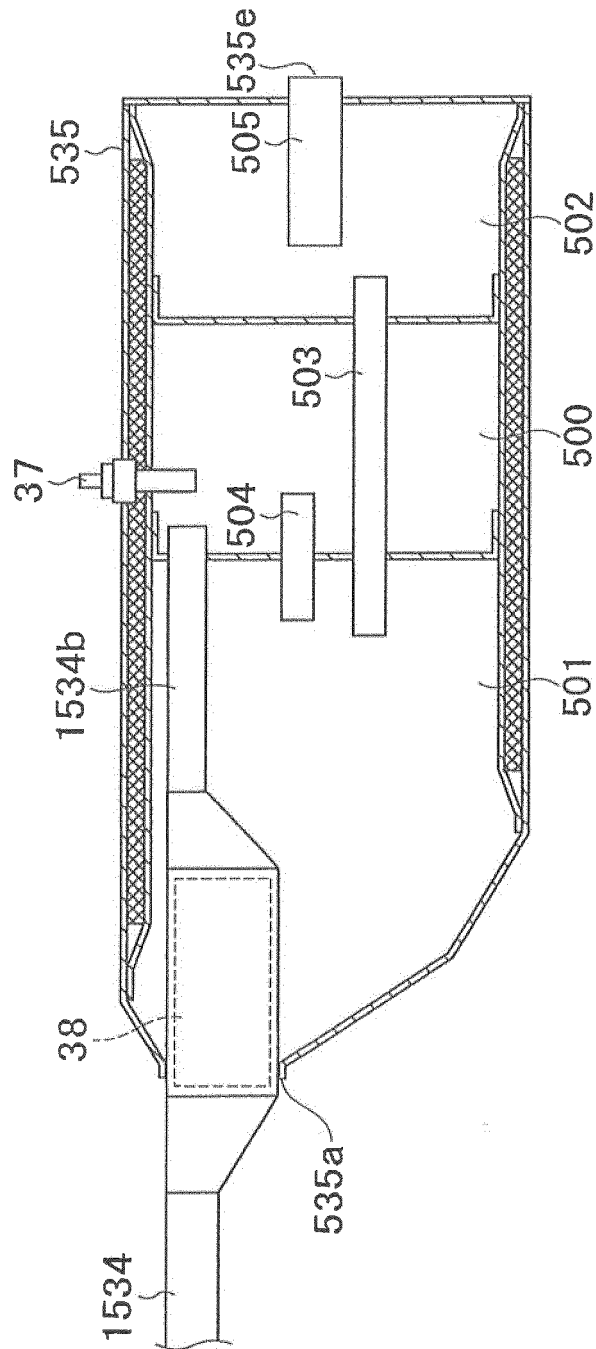


FIG.38

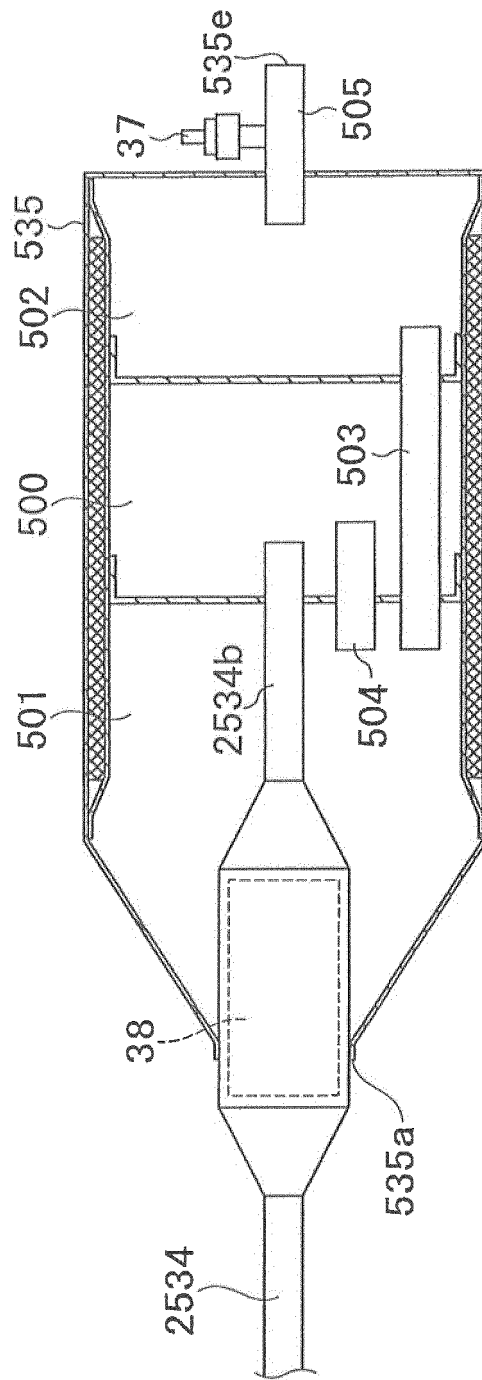


FIG.39

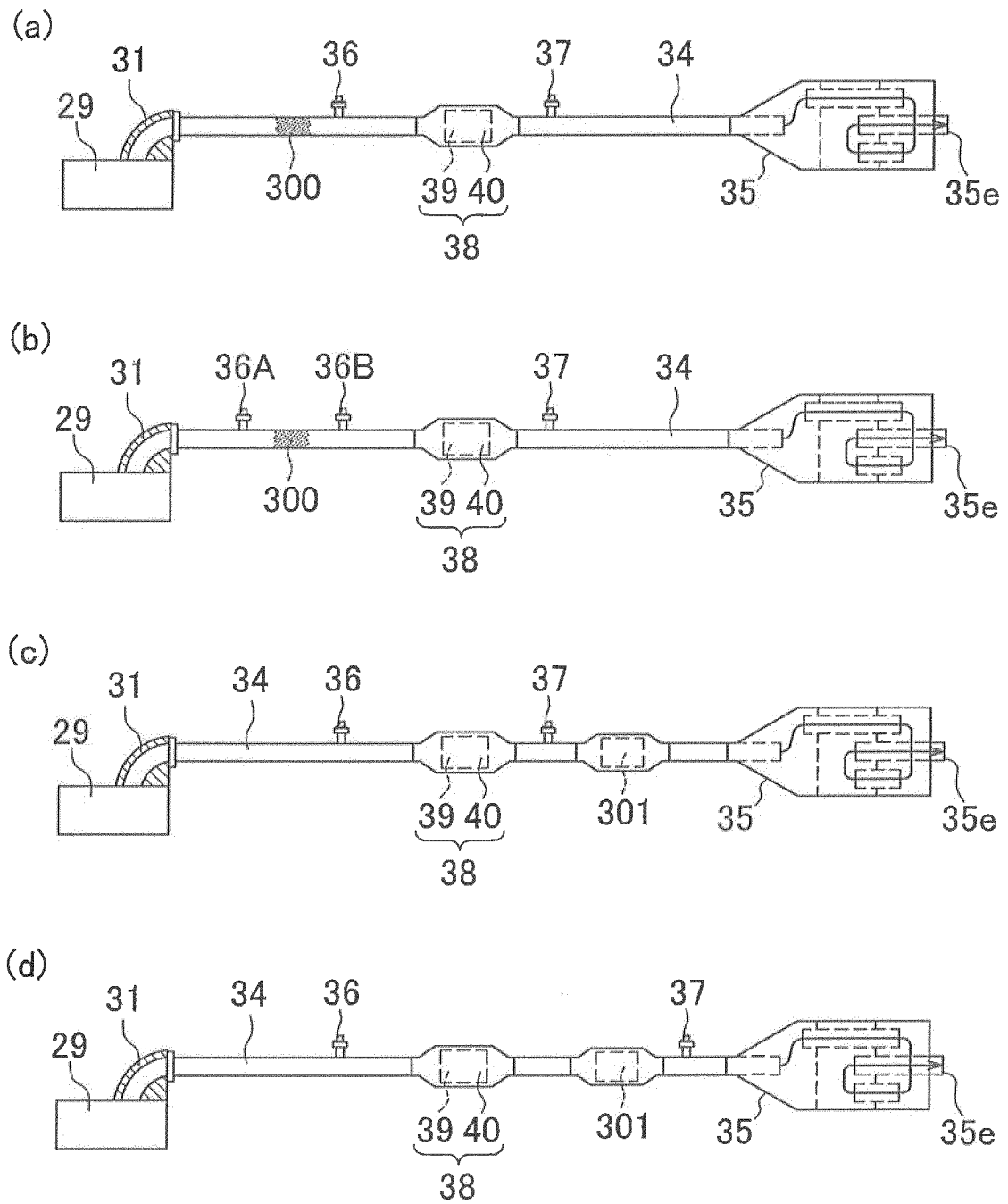
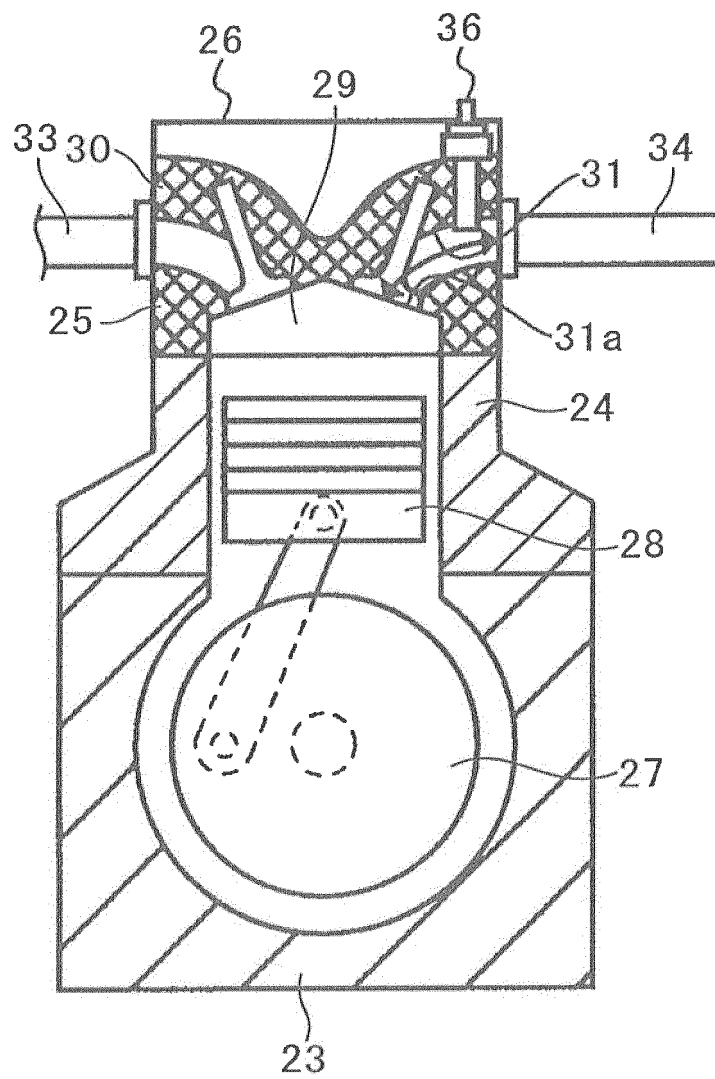


FIG.40



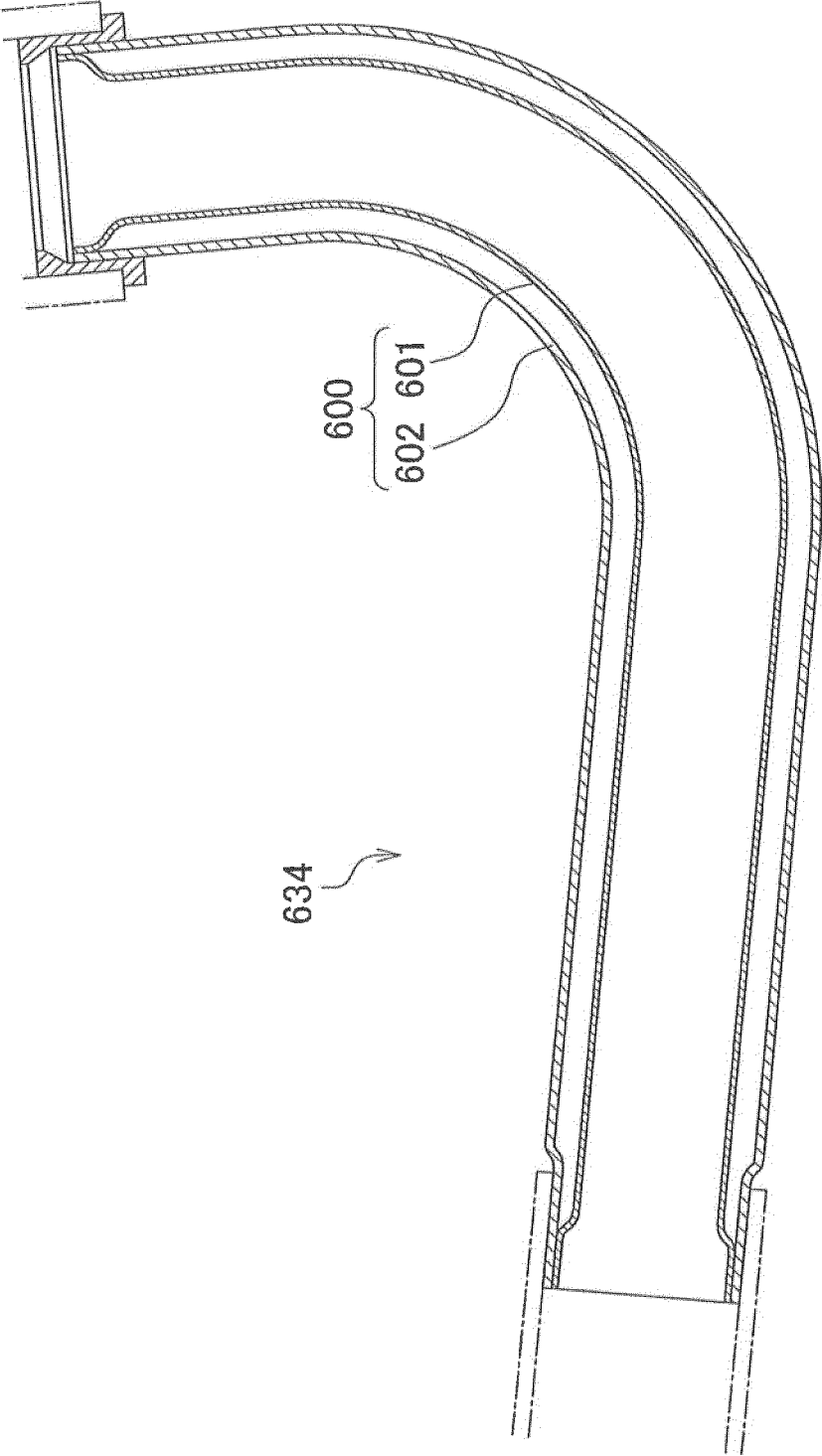
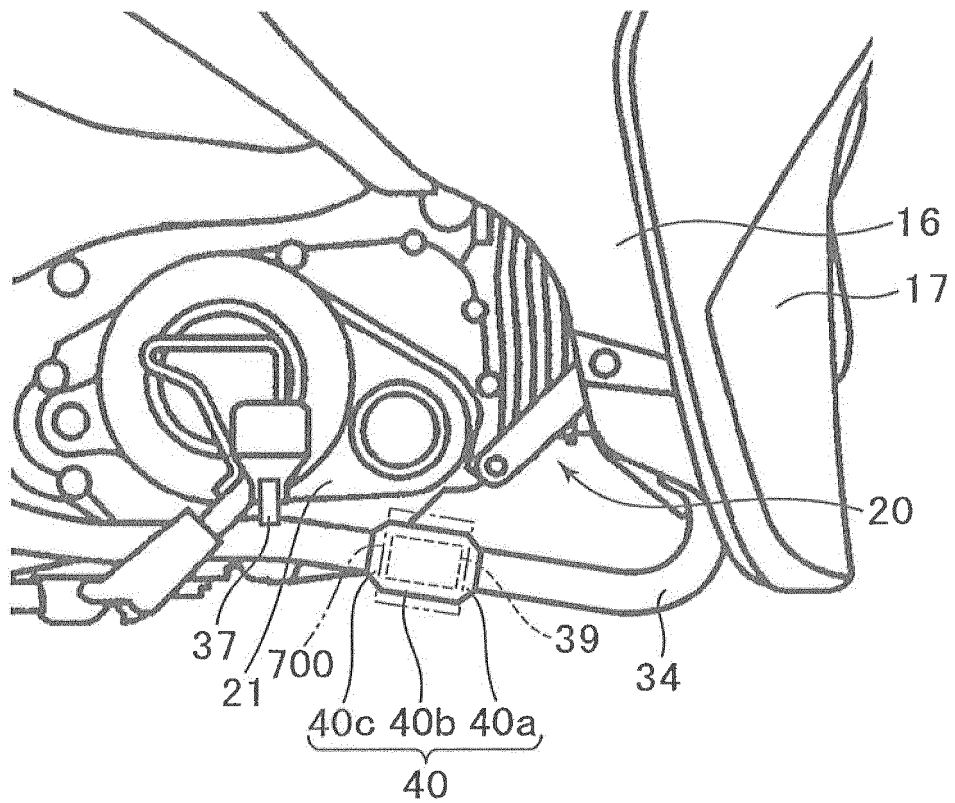


FIG.41

FIG.42



REFERENCES CITED IN THE DESCRIPTION

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