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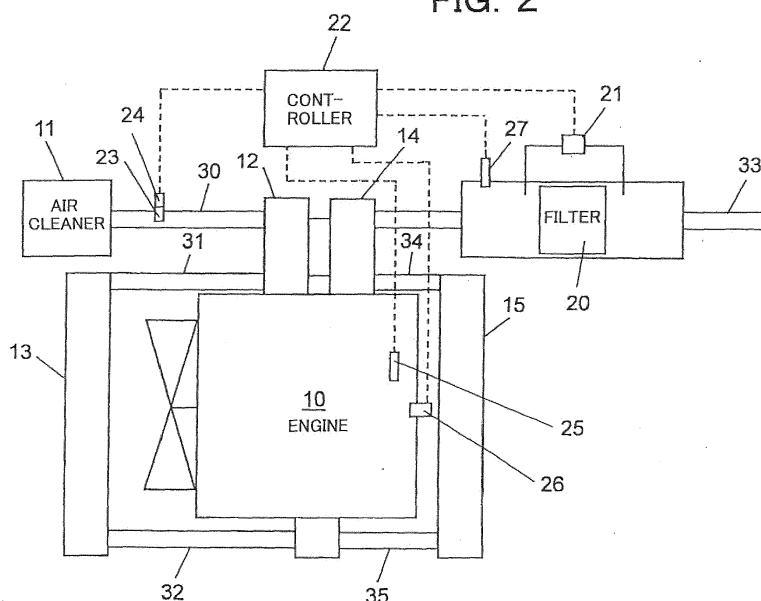
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(54) **Exhaust gas purification system for working machine**

(57) Disclosed is an exhaust gas purification system for a working machine. The system is provided with a filter (20) for capturing particulate matter contained in exhaust gas from an engine, a differential pressure sensor (21) for detecting a differential pressure between an exhaust upstream side and an exhaust downstream side of the filter, and a controller (22) having a regeneration determination unit for determining whether or not a time, at which forced regeneration is needed, has been

reached. The controller includes one that has a variation determination unit for determining whether or not a state quantity relevant to an operation of the engine, for example, an engine speed has varied abruptly and that, when the state quantity is determined to have abruptly varied, performs processing to invalidate the determination by the regeneration determination unit during a predetermined time in which an effect of the state quantity is considered to diminish.

FIG. 2



Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority of Japanese Patent Application 2011-004960 filed January 13, 2011, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to an exhaust gas purification system for a working machine such as a hydraulic excavator, which is provided with a filter for removing particulate matter (hereinafter abbreviated as "PM") contained in exhaust gas from an engine.

2. Description of the Related Art

[0003] As a conventional technology of this type, there is one disclosed in JP-A-2005-307878. This conventional technology is provided with a filter for capturing PM, which is contained in exhaust gas from an engine, on an exhaust downstream side, an exhaust gas temperature sensor, and a differential pressure sensor for detecting a differential pressure between an exhaust upstream side and the exhaust downstream side of the filter. The conventional technology is also provided with a computing unit for computing a flow rate of exhaust gas and a regeneration determination unit for determining, by a comparison between the differential pressure detected at the differential pressure sensor and a determinative differential pressure as a threshold level for determination, whether or not a time, at which forced regeneration is needed to burn PM captured on the filter, has been reached.

[0004] According to the conventional technology having such a constitution as described above, a differential pressure $\Delta P1$ and a determinative differential pressure $\Delta P2$ are compared with each other at the regeneration determination unit of the controller and, when $\Delta P1 > \Delta P2$, forced regeneration is determined to be needed. The differential pressure $\Delta P1$ is determined by converting a detected differential pressure ΔP , which is detected at the differential pressure sensor, to a corresponding value at a standard temperature of exhaust gas from a correlation between a temperature of exhaust gas as detected at the exhaust gas temperature sensor and the standard temperature. The determinative differential pressure $\Delta P2$, on the other hand, is a threshold level at the standard temperature, which corresponds to a flow rate of exhaust gas as computed at the computing unit of the controller.

[0005] Forced regeneration is to inject fuel into exhaust gas from an engine such that using an oxidation reaction by an oxidation catalyst, the temperature of exhaust gas is raised to burn off PM deposited on a filter. Clogging of

the filter can, therefore, be solved by forced regeneration.

[0006] With the above-described conventional exhaust gas purification system, an appropriate value can be calculated as the above-mentioned determinative differential pressure ΔP insofar as it is applied to a vehicle, such as a truck, that does not undergo much abrupt variations in the injection quantity of fuel or abrupt variations in the volume of intake air, because the flow rate of exhaust gas remains stable during an operation. In a working machine, such as a hydraulic excavator, for which the present invention is useful, however, its body undergoes frequent abrupt variations such as variations in load and variations in swing torque so that the flow rates of exhaust gas as calculated at the time of the respective variations also vary significantly. As a consequence, no appropriate determinative differential pressure $\Delta P2$ may be calculated in some instances. When the conventional technology is applied to a working machine and a determination is made at the regeneration determination unit of the controller by using such a determinative differential pressure $\Delta P2$, a problem may hence arise that, even if PM has not deposited much on the filter actually, $\Delta P1 > \Delta P2$ is determined and forced regeneration is performed although it is not needed. Such unnecessary forced regeneration results in a wasteful injection of fuel, and leads to a deterioration in fuel economy.

SUMMARY OF THE INVENTION

[0007] With the foregoing circumstances of the above-described conventional technology in view, the present invention has as an object thereof the provision of an exhaust gas purification system for a working machine, which can realize forced regeneration without being affected by abrupt variations of a body.

[0008] To achieve the above-described object, the present invention provides, in one aspect thereof, an exhaust gas purification system for a working machine provided with working equipment, a main body with the working equipment attached thereto, and an engine arranged on the main body to drive the working equipment, said exhaust gas purification system being provided with a filter for capturing particulate matter, which is contained in exhaust gas from the engine, on an exhaust downstream side, a differential pressure sensor for detecting a differential pressure between an exhaust upstream side and the exhaust downstream side of the filter, and a controller having a regeneration determination unit for determining, by a comparison between the differential pressure detected at the differential pressure sensor and a determinative differential pressure as a threshold level for determination, whether or not a time, at which forced regeneration is needed to burn the particulate matter captured on the filter, has been reached, wherein the controller comprises one that has a variation determination unit for determining whether or not a state quantity relevant to an operation of the engine has varied abruptly and that, when the state quantity is determined to have

abruptly varied by the variation determination unit, performs processing to invalidate the determination by the regeneration determination unit during a predetermined time in which an effect of the state quantity is considered to diminish.

[0009] The present invention has been made with an attention focused on the fact that upon occurrence of an abrupt variation on a body, a state quantity relevant to an operation of an engine, such as the engine speed or the injection quantity of fuel, varies abruptly. According to the present invention, when the state quantity relevant to the operation of the engine is determined by the variation determination unit of the controller to have abruptly varied in response to an abrupt variation of the body, processing is performed by the controller to invalidate the determination by the regeneration determination unit that determines whether or not forced regeneration is to be performed, in other words, to terminate a determination function of the regeneration determination unit during a predetermined time in which an effect of the abrupt variation in the state quantity is considered to diminish. The above-described predetermined time can be set experimentally or empirically in view of load variations which may occur on the associated working machine. As a consequence, the present invention can realize forced regeneration without being affected by abrupt variations of the body.

[0010] The controller may preferably have a first computing unit for computing a flow rate of exhaust gas, and a second computing unit for computing the determinative differential pressure based on the flow rate of exhaust gas as computed at the first computing unit and a map preset in the controller and indicating correlations between flow rates of exhaust gas and determinative differential pressures.

[0011] Preferably, the exhaust gas purification system may be further provided with a fuel control unit for controlling an injection quantity of fuel to be fed to the engine, an intake air volume sensor for detecting a volume of intake air to be fed to the engine and outputting a detection signal to the controller, an intake air temperature sensor for detecting a temperature of intake air and outputting a detection signal to the controller, and an exhaust gas temperature sensor for detecting a temperature of exhaust gas from the engine and outputting a detection signal to the controller; the controller may further comprise a fuel injection quantity instruction unit for outputting an instruction signal to instruct the injection quantity of fuel to the fuel control unit, and an intake air weight computing unit for computing a weight of intake air based on a density of intake air, which is determined according to the temperature of intake air as detected at the intake air temperature sensor and a map preset in the controller and indicating correlations between intake air temperatures and intake air densities, and the volume of intake air as detected at the intake air volume sensor; an exhaust gas weight computing unit for computing a weight of exhaust gas based on the weight of intake air

as computed at the intake air weight computing unit and the injection quantity of fuel as instructed by the fuel injection quantity instruction unit; and the first computing unit of the controller may perform processing to compute a flow rate of exhaust gas based on a density of exhaust gas, which is determined according to the temperature of exhaust gas as detected at the exhaust gas temperature sensor and a map preset in the controller and indicating correlations between exhaust gas temperatures and exhaust gas densities, and the weight of exhaust gas as computed at the exhaust gas weight computing unit.

[0012] The exhaust gas purification system may preferably be further provided with an engine speed sensor for detecting a revolution speed of the engine and outputting a detection signal to the controller; and the state quantity relevant to the operation of the engine may preferably be at least one of the revolution speed of the engine as detected at the engine speed sensor, the injection quantity of fuel as instructed by the fuel injection quantity instruction unit, the volume of intake air as detected at the intake air volume sensor, and the flow rate of exhaust gas as computed at the first computing unit of the controller.

[0013] In the exhaust gas purification system of the present invention for the working machine equipped with the working equipment, the controller is constituted to comprise one that has the variation determination unit for determining whether or not the state quantity relevant to an operation of the engine has varied abruptly and that, when the state quantity is determined to have abruptly varied by the variation determination unit, performs processing to invalidate the determination by the regeneration determination unit during the predetermined time in which the effect of the state quantity is considered to diminish. Owing to this constitution, it is possible to realize forced regeneration without being affected by abrupt variations of the body. Described specifically, it is possible to minimize the performance of unnecessary forced regeneration that would otherwise tend to be performed in response to abrupt variations of the body, thereby making it possible to prevent wasteful injections of fuel and hence to improve the fuel economy of the working machine equipped with the exhaust gas purification system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a side view showing a hydraulic excavator described as an example of a working machine in which an exhaust gas purification system according to one embodiment of the present invention can be arranged.

[0015] FIG. 2 is a diagram illustrating the constitution of the exhaust gas purification system according to the embodiment as arranged in the hydraulic excavator shown in FIG. 1.

[0016] FIG. 3 is a block diagram depicting an essential

constitution of a controller included in the embodiment.

[0017] FIG. 4 is a diagram illustrating characteristics available from the embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] The exhaust gas purification system according to the one embodiment of the present invention for the working machine will hereinafter be described based on the drawings.

[0019] As shown in FIG. 1, the hydraulic excavator which makes up the working machine is provided with a travel base 1 and an upperstructure 2 mounted on the travel base 1. These travel base 1 and upperstructure 2 make up a main body. This hydraulic excavator is also provided with working equipment 3 attached tiltably in up-and-down directions to the upperstructure 2 and including a boom, an arm and so on, an operator's cab 4 arranged on the upperstructure 2, a counterweight 5 for assuring a weight balance, and an engine compartment 6 arranged between the operator's cab 4 and the counterweight 5.

[0020] This hydraulic excavator is also provided, as illustrated in FIG. 2, with an engine 10 accommodated in the engine compartment 6, an air cleaner 11 for removing dust from air to be inducted into the engine 10, that is, from intake air, an air compressor 12 of a turbocharger for compressing the intake air cleaned by the air cleaner 11 and guided through an intake air passage 30, intake air passages 31, 32 for guiding into the engine 10 the intake air compressed by the compressor 12, and an air cooler 13 arranged between the intake air passage 31 and the intake air passage 32 for cooling the intake air to be fed to the engine 10. The hydraulic excavator is further provided with a turbine 14 of the turbocharger and an exhaust gas passage 33, both of which guide exhaust gas from the engine 10, recirculation passages 34, 35 for recirculating a portion of exhaust gas from the engine 10 and feeding it again into the engine 10, and an EGR (Exhaust Gas Recirculation) cooler 15 arranged between these recirculation passages 34 and 35 for cooling the exhaust gas to be fed to the engine 10.

[0021] The exhaust gas purification system of this embodiment for the hydraulic excavator of such a constitution as described above is provided, as also illustrated in FIG. 2, provided with a filter 20 for capturing PM, which is contained in the exhaust gas from the engine 10, at an exhaust downstream side and a differential pressure sensor 21 for detecting a differential pressure between an exhaust upstream side and the exhaust downstream side of the filter 20. This embodiment is also provided with a controller 22 having a regeneration determination unit 22a depicted in FIG. 3. By a comparison between the differential pressure detected at the differential pressure sensor 21, namely the detected differential pressure ΔP and a determinative differential pressure ΔP_0 as a threshold level for determination, the regeneration determina-

tion unit 22a determines whether or not a time, at which forced regeneration is needed to burn PM captured on the filter 20, has been reached. When it is determined at the regeneration determination unit 22a that the time, at which forced regeneration is needed, has been reached, a control signal is outputted from the controller 22 to a fuel injector 28, and by this fuel injector 28, a predetermined quantity of fuel is injected to mix it into exhaust gas from the engine 10.

[0022] Referring back to FIG. 2, this embodiment is also provided with an intake air volume sensor 23, an intake air temperature sensor 24 and an exhaust gas temperature sensor 27. The intake air volume sensor 23 detects a quantity of air guided into the intake air passage 30, that is, a quantity of intake air, and outputs a detection signal to the controller 22. The intake air temperature sensor 24 detects a temperature of the intake air, and outputs a detection signal to the controller 22. The exhaust gas temperature sensor 27 detects a temperature of exhaust gas guided into the exhaust gas passage 33, and outputs a detection signal to the controller 22.

[0023] This embodiment is further provided, as depicted in FIG. 3, with a fuel control unit 25 and an engine speed sensor 26. The fuel control unit 25 controls a quantity of fuel, which is to be fed to the engine 10, response to a control signal outputted from a fuel injection quantity instruction unit 22e included in the controller 22. The engine speed sensor 26 detects a revolution speed of the engine 10, and outputs a detection signal to the controller 22.

[0024] In this embodiment, the controller 22 includes, as depicted in FIG. 3, one that has a variation determination unit 22b for determining whether or not a state quantity relevant to an operation of the engine 10, for example, an engine speed detected at the engine speed sensor 26 has varied abruptly, and that, when the engine speed is determined to have abruptly varied by the variation determination unit 22b, performs processing to invalidate the above-mentioned determination by the regeneration determination unit 22a during a predetermined time in which an effect of the abrupt variation in engine speed is considered to diminish.

[0025] A determinative revolution speed variation ΔN_1 as a threshold level for the determination of an abrupt variation in engine speed is stored in the controller 22. The variation determination unit 22b compares the determinative revolution speed variation ΔN_1 with an actual revolution speed variation ΔN computed based on the detection value by the engine speed sensor 26 and, when $\Delta N > \Delta N_1$, determines that the engine speed has varied abruptly.

[0026] The above-mentioned predetermined time can be set experimentally or empirically in view of variations of the body, such as variations in load and variations in swing torque, which can occur on the hydraulic excavator shown in FIG. 1.

[0027] The controller is also provided, as depicted in FIG. 3, with a first computing unit 22c and a second com-

puting unit 22d. The first computing unit 22c computes an exhaust gas flow rate V_{ex} . The second computing unit 22d computes a determinative differential pressure ΔP_o based on the exhaust gas flow rate V_{ex} computed at the first computing unit 22c and a map preset in the controller 22 and indicating correlations between exhaust gas flow rates and determinative differential pressures.

[0028] The controller is further provided with an intake air weight computing unit 22f, which computes an intake air weight G_{in} ($= f_2 \times V_{in}$) based on a intake air density f_2 , which is determined according to an intake air temperature T_{in} detected at the intake air temperature sensor 24 and a map preset in the controller 22 and indicating correlations between intake air temperatures and intake air densities, and an intake air volume V_{in} detected at the intake air volume sensor 23.

[0029] The controller 22 is still further provided with an exhaust gas weight computing unit 22g for computing an exhaust gas weight G_{ex} ($= G_{in} + q$) based on the intake air weight G_{in} computed at the intake air weight computing unit 22f and a fuel injection quantity q instructed by the fuel injection quantity instruction unit 22e.

[0030] The above-mentioned first computing unit 22c of the controller 22 performs processing to compute an exhaust gas flow rate V_{ex} ($= G_{ex}/f_3$) based on an exhaust gas density f_3 and the exhaust gas weight G_{ex} computed at the exhaust gas weight computing unit 22g. The exhaust gas density f_3 is determined according to an exhaust gas temperature T_{ex} detected at the exhaust gas temperature sensor 27 and a map preset in the controller 22 and indicating correlations between exhaust gas temperatures and exhaust gas densities. Based on the determinative differential pressure ΔP_o computed at the second computing unit 22d in accordance with the exhaust gas flow rate V_{ex} computed at the first computing unit 22c and the detected differential pressure ΔP detected at the differential pressure sensor 21, the above-mentioned regeneration determination unit 22a determines, as mentioned above, whether or not the time, at which forced regeneration is needed, has been reached.

[0031] According to this embodiment constituted as described above, when as indicated by a sensing range S1 in FIG. 4, the load A is relatively stable and the engine speed N is maintained at a constant high revolution speed, the actual revolution speed variation ΔN calculated based on the detection value detected at the engine speed sensor 26 is not higher than the determinative revolution speed variation ΔN_1 , that is, $\Delta N < \Delta N_1$, so that at the variation determination unit 22b of the controller 22, the engine speed is determined to have undergone no abrupt variation. Therefore, the regeneration determination unit 22a functions normally, and performs a determination as to whether or not the time, at which forced regeneration is needed to burn PM captured on the filter 20, has been reached, specifically a determination that compares the detected differential pressure ΔP and the determinative differential pressure ΔP_o with each other.

[0032] When $\Delta P \leq \Delta P_o$ is determined at the regenera-

tion determination unit 22a, it is determined that the time, at which forced regeneration is needed, has not been reached. As a consequence, no control signal is outputted to activate the fuel injector 28. When $\Delta P > \Delta P_o$ is determined at the regeneration determination unit 22a, on the other hand, it is determined that the time, at which forced regeneration is needed, has been reached, and the fuel injector 28 performs an injection to mix fuel in the exhaust gas from the engine 10 as mentioned above. As a result, the temperature of the exhaust gas rises under the action of the oxidation catalyst, the PM captured on the filter 20 burns, and the clogging of the filter 20 is solved.

[0033] When the load A has undergone an abrupt variation and the engine speed has undergone, for example, an abrupt drop, both at the variation determination unit 22b of the controller 22, as indicated by a sensing range S2 in FIG. 4, an actual revolution speed variation ΔN calculated based on a detection value of the engine speed sensor 26 becomes greater than the determinative revolution speed variation ΔN_1 , that is, $\Delta N > \Delta N_1$ is obtained, processing is performed at the controller 22 to invalidate the determination processing by the regeneration determination unit 22a during a predetermined time T in which the effect of the rapid variation in engine speed is considered to diminish.

[0034] According to this embodiment constituted as described above, it is possible to perform forced regeneration without being affected by abrupt variations in the engine speed N , in other words, without being affected by abrupt variations of the upperstructure 2 or travel base 1. As a consequence, it is possible to minimize the practice of unnecessary forced regeneration, which would otherwise tend to be performed in response to abrupt variations of the upperstructure 2 or travel base 1 and to prevent wasteful injections of fuel. Owing to this feature, it is possible to improve the fuel economy of a hydraulic excavator equipped with an exhaust gas purification system.

[0035] In the above-described embodiment, the engine speed N is described as the state quantity relevant to the operation of the engine 10 to be determined at the variation determination unit 22b of the controller 22. It is, however, to be noted that this state quantity can be the fuel injection quantity q instructed by the fuel injection quantity instruction unit 22e of the controller 22, the intake air volume V_{in} detected at the intake air volume sensor 23, the exhaust air flow rate V_{ex} computed at the first computing unit 22c, or the like. It is also to be noted that the exhaust gas purification system may be designed to determine plural ones of these state quantities at the variation determination unit 22b.

Claims

1. An exhaust gas purification system for a working machine provided with working equipment, a main body

with the working equipment attached thereto, and an engine arranged on the main body to drive the working equipment, said exhaust gas purification system being provided with a filter for capturing particulate matter, which is contained in exhaust gas from the engine, on an exhaust downstream side, a differential pressure sensor for detecting a differential pressure between an exhaust upstream side and the exhaust downstream side of the filter, and a controller having a regeneration determination unit for determining, by a comparison between the differential pressure detected at the differential pressure sensor and a determinative differential pressure as a threshold level for determination, whether or not a time, at which forced regeneration is needed to burn the particulate matter captured on the filter, has been reached, wherein:

the controller comprises one that has a variation determination unit for determining whether or not a state quantity relevant to an operation of the engine has varied abruptly and that, when the state quantity is determined to have abruptly varied by the variation determination unit, performs processing to invalidate the determination by the regeneration determination unit during a predetermined time in which an effect of the state quantity is considered to diminish to a negligible extent.

2. The exhaust gas purification system according to claim 1, wherein:

the controller has a first computing unit for computing a flow rate of exhaust gas, and a second computing unit for computing the determinative differential pressure based on the flow rate of exhaust gas as computed at the first computing unit and a map preset in the controller and indicating correlations between flow rates of exhaust gas and determinative differential pressures.

3. The exhaust gas purification system according to claim 2, wherein:

the exhaust gas purification system is further provided with:

a fuel control unit for controlling an injection quantity of fuel to be fed to the engine, an intake air volume sensor for detecting a volume of intake air to be fed to the engine and outputting a detection signal to the controller, an intake air temperature sensor for detecting a temperature of intake air and outputting a detection signal to the controller, and

an exhaust gas temperature sensor for detecting a temperature of exhaust gas from the engine and outputting a detection signal to the controller; the controller further comprises:

a fuel injection quantity instruction unit for outputting an instruction signal to instruct the injection quantity of fuel to the fuel control unit, and an intake air weight computing unit for computing a weight of intake air based on a density of intake air, which is determined according to the temperature of intake air as detected at the intake air temperature sensor and a map preset in the controller and indicating correlations between intake air temperatures and intake air densities, and the volume of intake air as detected at the intake air volume sensor; an exhaust gas weight computing unit for computing a weight of exhaust gas based on the weight of intake air as computed at the intake air weight computing unit and the injection quantity of fuel as instructed by the fuel injection quantity instruction unit; and the first computing unit of the controller performs processing to compute a flow rate of exhaust gas based on a density of exhaust gas, which is determined according to the temperature of exhaust gas as detected at the exhaust gas temperature sensor and a map preset in the controller and indicating correlations between exhaust gas temperatures and exhaust gas densities, and the weight of exhaust gas as computed at the exhaust gas weight computing unit.

4. The exhaust gas purification system according to claim 3, wherein:

the exhaust gas purification system is further provided with:

an engine speed sensor for detecting a revolution speed of the engine and outputting a detection signal to the controller; and the state quantity relevant to the operation of the engine is at least one of the revolution speed of the engine as detected at the engine speed sensor, the injection quantity of fuel as instructed by the fuel injection quantity instruction unit, the volume of intake air as detected at the intake air volume sensor,

and the flow rate of exhaust gas as computed at the first computing unit of the controller.

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FIG. 1

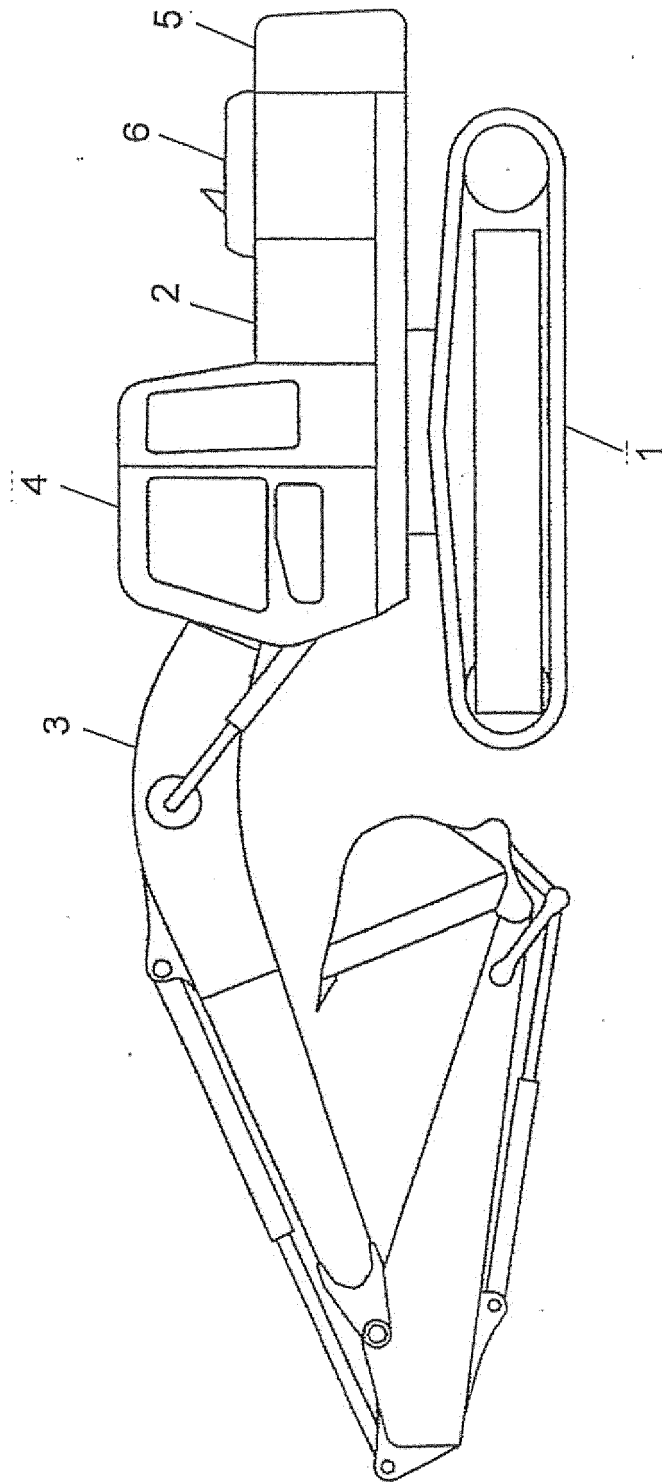


FIG. 2

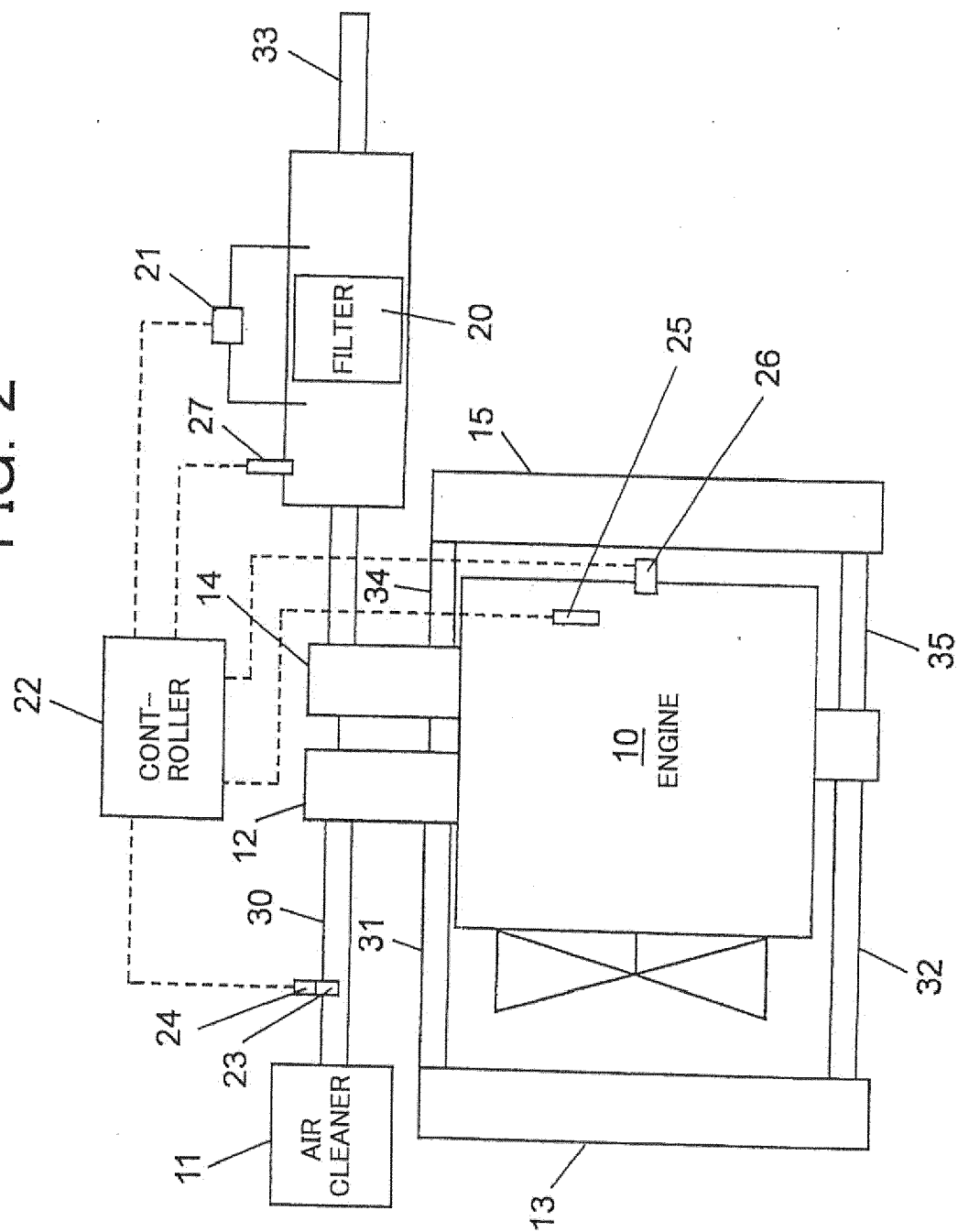


FIG. 3

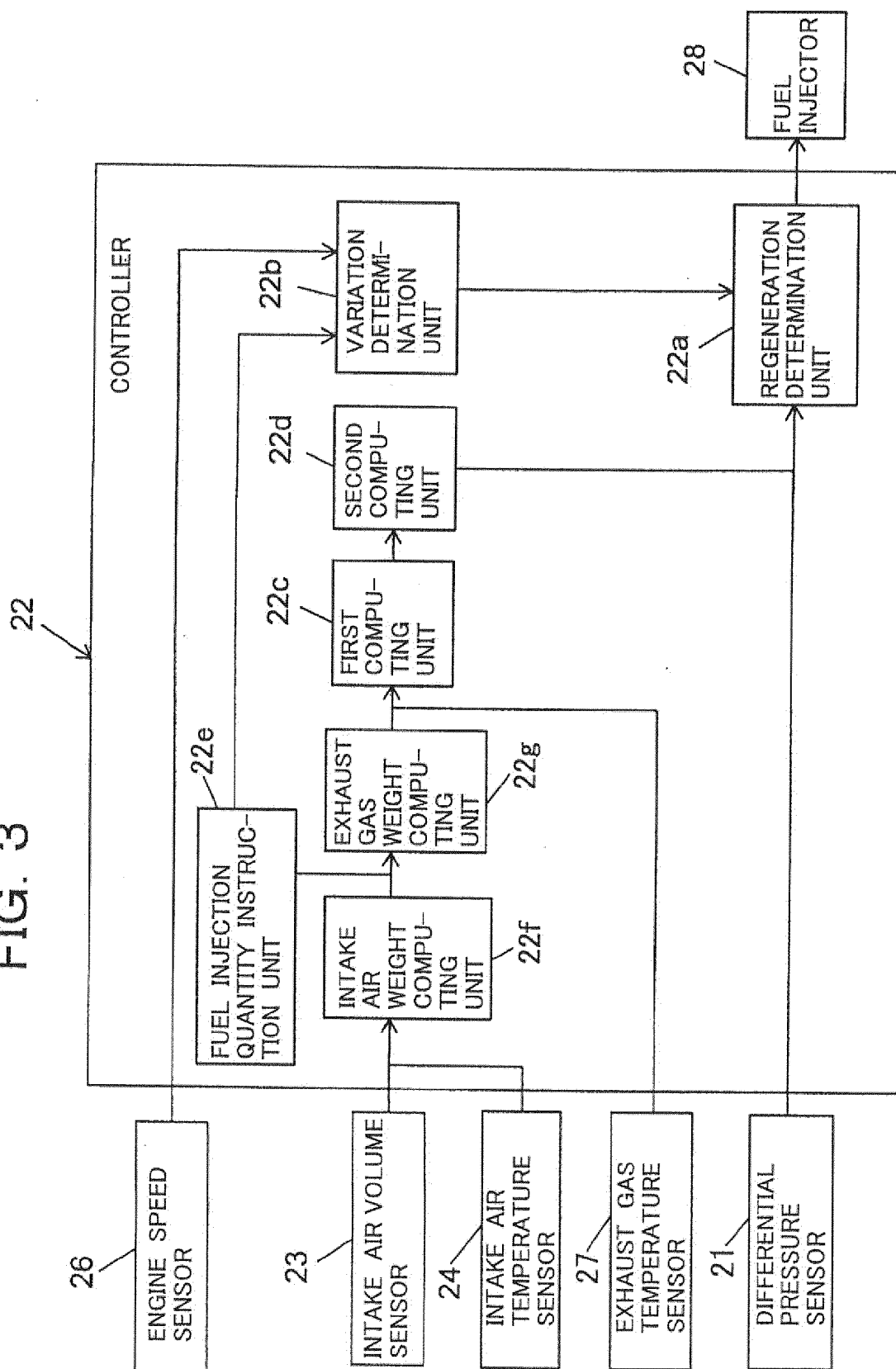
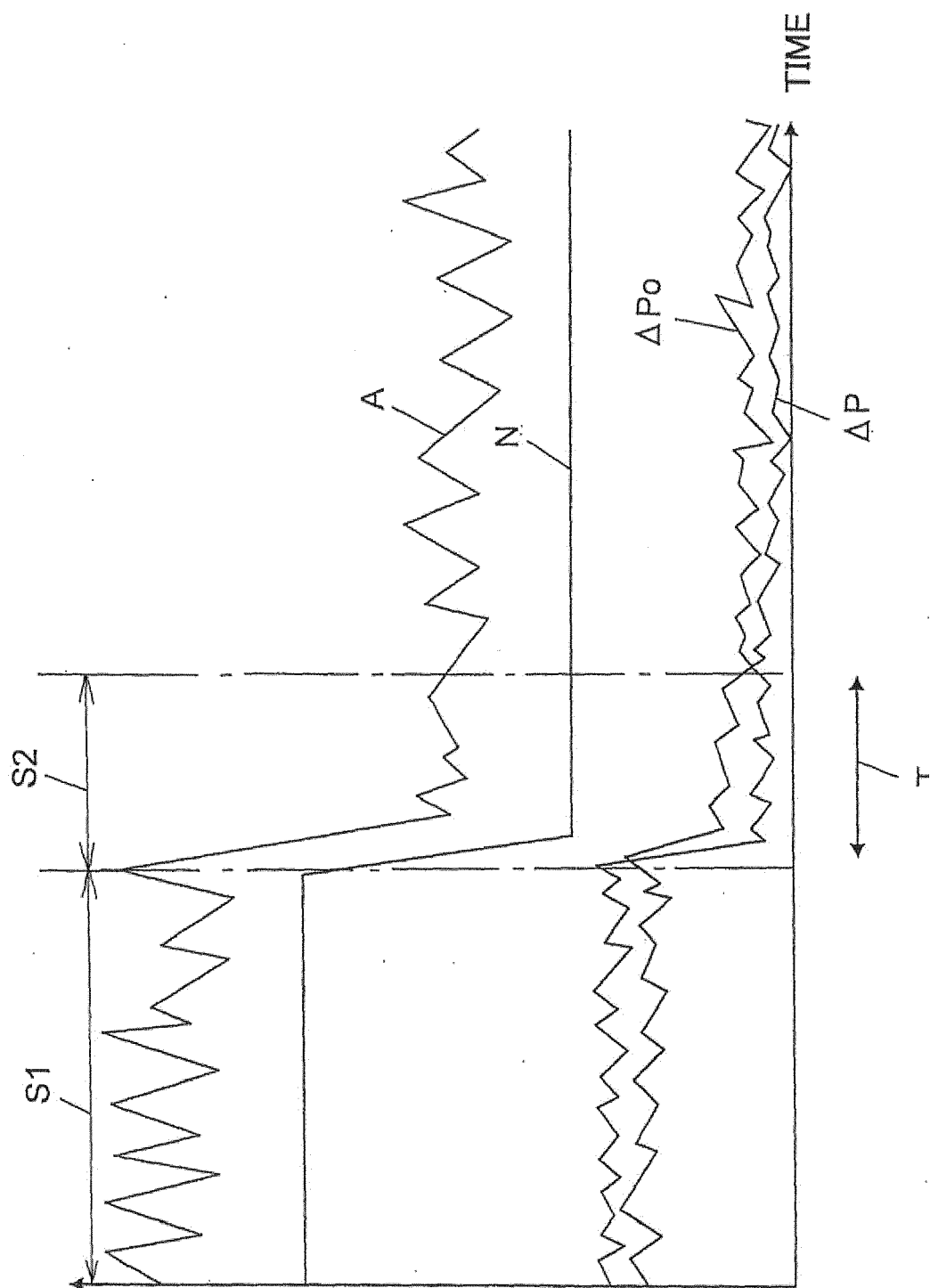


FIG. 4



REFERENCES CITED IN THE DESCRIPTION

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