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(54) **Method and apparatus for activating a diesel particulate filter with engine heat**

(57) An apparatus, including a diesel particulate filter, at least one sensor for sensing information associated with operation of an engine, an engine brake configured to brake the engine, and a controller electrically coupled to the at least one sensor and the engine brake, to determine if the engine is operating in a manner that does

not generate enough engine heat to activate the diesel particulate filter, and if the engine is so operating, operate the engine brake so as to brake the engine to cause the engine to generate enough engine heat to activate the diesel particulate filter. An associated method is disclosed.

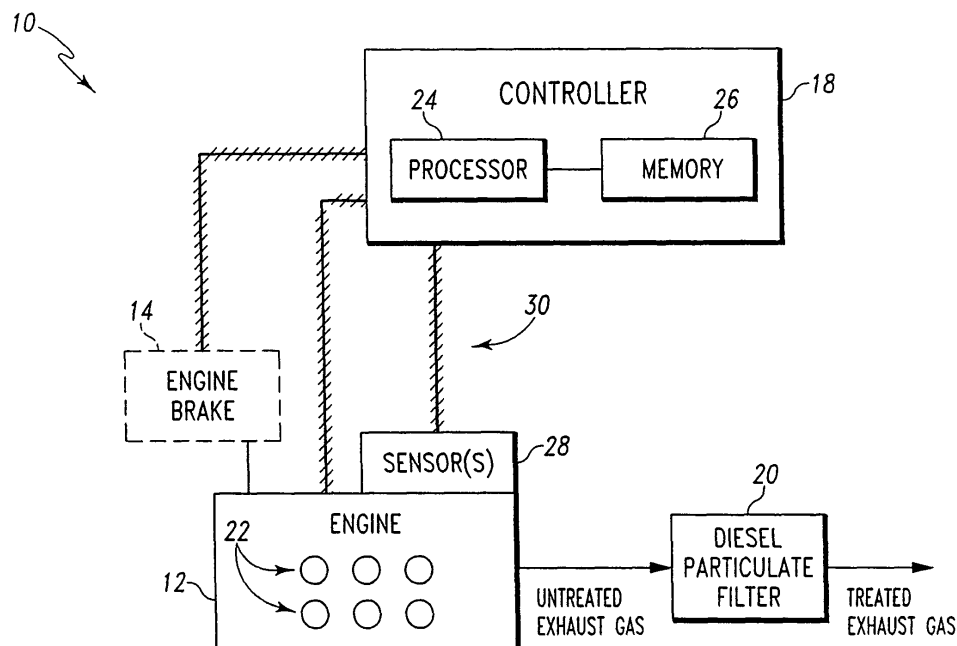


Fig. 1

Description

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates generally to diesel particulate filters.

BACKGROUND

[0002] Untreated internal combustion engine emissions (e.g., diesel emissions) include various effluents such as NO_x, hydrocarbons, and carbon monoxide, for example. Moreover, the untreated emissions from certain types of internal combustion engines, such as diesel engines, also include particulate carbon-based matter or "soot". Federal regulations relating to soot emission standards are becoming more and more rigid thereby furthering the need for devices and/or methods which remove soot from engine emissions.

[0003] The amount of soot released by an engine system can be reduced by the use of a diesel particulate filter. Such a filter or trap is periodically regenerated in order to remove the soot therefrom. The filter or trap may be regenerated by increasing the temperature of exhaust gas from the engine.

[0004] Engine brakes are used to retard the speed of vehicles. Engine brakes may be retrofitted on diesel engines such as a controller-integrated design or may be an original equipment manufacturer-supplied apparatus. An engine brake may be any device that opens the exhaust valves of a cylinder when a piston is at or near a top dead center position of a compression stroke for slowing the vehicle manually or automatically, for example, through a dedicated controller.

SUMMARY

[0005] According to one aspect of the present disclosure, an apparatus, includes an engine brake and a diesel particulate filter. The engine brake may be selectively operated to regenerate the diesel particulate filter.

[0006] According to another aspect of the disclosure, a controller for operating the engine brake is disclosed. In one exemplary embodiment, the controller receives temperature data from the sensor to determine when to activate the engine brake to brake one or more engine cylinders to increase the temperature of exhaust gas flowing from the engine while allowing at least one cylinder to combust fuel.

[0007] According to another aspect of the disclosure, a method of operating an engine brake to regenerate a diesel particulate filter is disclosed. The method includes braking one or more cylinders so that the braking cylinder(s) consumes power. Such a selective braking may continue for an as-required time period after which the selective braking is discontinued and normal power production and operation is resumed. Exemplarily, an increased exhaust gas temperature is generated by selectively

braking one or more engine cylinders while increasing the load on at least one cylinder that is allowed to combust fuel. After a period of time, the activation temperature required by the diesel particulate filter to regenerate the filter is attained.

[0008] According to another aspect of the disclosure, a method of monitoring an engine brake during diesel particulate filter regeneration includes determining the temperature of the diesel particulate filter and selectively braking one or more engine cylinders while increasing the load on at least one cylinder allowed to combust fuel to increase engine exhaust gas temperature based thereon. A controller configured to control the engine brake in such a manner is also disclosed. Temperature measurements may be obtained by use of a sensor.

[0009] The above and other features of the present disclosure will become apparent from the following description and the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The detailed description particularly refers to the accompanying figures in which:

FIG. 1 is a diagrammatic view showing an apparatus for activating a diesel particulate filter by use of engine heat; and

FIG. 2 is a flowchart of a control routine for monitoring operation of the diesel particulate filter during a filter regeneration cycle.

DETAILED DESCRIPTION OF THE DRAWINGS

[0011] While the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific exemplary embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure.

[0012] Referring to FIG. 1, there is shown an apparatus 10 for activating a diesel particulate filter 20 by use of an internal combustion engine 12, such as a diesel engine of an on-highway truck. The apparatus 10 includes an engine brake 14 under the control of a controller 18 and one or more sensors 28 sensing information associated with operation of the engine 12. During operation of the engine 12, untreated exhaust gas flows through the diesel particulate filter 20 which removes emissions from the exhaust gas. The treated exhaust gas may subsequently be released into the atmosphere. From time to time during operation of the engine, the controller 18 selectively operates the engine brake on one or more of the engine cylinders 22 while increasing the load on at least one cylinder allowed to combust fuel to generate

sufficient engine heat to regenerate or otherwise activate the diesel particulate filter 20.

[0013] The engine brake 14 may be any type of commercially available engine brake. For example, the engine brake 14 may be embodied as any known diesel engine brake such as a "compression" brake or any other device that can convert an engine into a power absorbing device. The engine brake 14 may be a combination of a retrofitted application or an original equipment manufacturer-installed device where the term is meant to contemplate other devices, dedicated or integrated for the purpose of retarding the speed of a vehicle.

[0014] In normal operation, the engine 12 produces power through compression of air by a piston in the cylinders 22 into which fuel is then injected and ignited, for example, by the high-pressure, high-temperature air in a diesel engine or a spark generated in a spark ignition engine. When the injection of fuel is stopped by, for example, releasing a throttle, the engine produces little or no power. The engine 12 does however continue to compress air during a compression stroke of the cylinders 22. The "work" required to compress the air during the compression stroke is obtained from the inertia of the vehicle. At the end of the compression stroke of the piston in each cylinder 22, the compressed air forces the piston to move in a downward direction canceling the work performed on the upward stroke. The engine brake 14 modifies the power production of the diesel engine 12 in the compression stroke by opening exhaust valves just prior to the cylinder reaching top dead center to allow compressed air to exhaust from the cylinder into the exhaust gas flow. Because there is no combusted gas to force the braking cylinder away from the top dead center position, the braking cylinder becomes a "consumer" of power.

[0015] As shown in FIG. 1, the diesel particulate filter 20 is positioned downstream from the engine (relative to exhaust gas flow). The diesel particulate filter 20 may be any type of commercially available exhaust gas diesel particulate filter such as a diesel oxidation catalyst alone or in combination with another diesel particulate filter such as a particulate filter downstream therefrom, a catalyzed diesel particulate filter, a NO_x trap, a hydrocarbon trap, a selective catalytic reduction catalyst, or any other diesel particulate filter that is impregnated with a catalytic material such as, for example, a precious metal catalytic material. The catalytic material may be, for example, embodied as platinum, rhodium, palladium, including combinations thereof, along with any other similar catalytic materials. As such, the filter 20 is a catalytic diesel particulate filter.

[0016] In cases where the diesel particulate filter 20 has catalyst material, the engine heat generated by increased engine loading is useful to elevate the temperature of the catalyst material to at least its activation "light-off" temperature to activate the device 20 (e.g., 350°C for at least 5 minutes if a diesel oxidation catalyst is used, or 250°C for 40% or more of the engine duty cycle if a

catalyzed diesel particulate filter is used). Engine braking is particularly useful at engine idle or other low-speed or low-load conditions when the engine duty cycle may seldom generate sufficient exhaust gas temperatures for light-off of the device 20.

[0017] Referring again to FIG. 1, the controller 18 includes a processor 24 and a memory unit 26. The controller 18 is, in essence, the master computer responsible for interpreting electric signals sent by sensor(s) 28 and for activating electronically-controlled components associated with the diesel particulate filter 20. For example, the controller 18 is operable to, amongst many other things, to determine if the engine 12 is operating in a manner that does not generate enough engine heat in order to activate the device 20, and if the engine 12 is so operating, operate the engine brake 14 so as to brake the engine 12 to cause the engine to generate enough engine heat to activate the device 20. In cases where the device 20 has one or more particulate filters, the controller 18 is operable to determine when one of the particulate filters of the diesel particulate filter 20 is in need of regeneration, calculate and control the number of engine cylinders to brake, determine the temperature in various locations within the diesel particulate filter 20, and communicate with the engine brake 14 associated with the engine 12.

[0018] The controller 18 includes a number of electronic components commonly associated with electronic units utilized in the control of electromechanical systems. For example, the controller 18 may include, amongst other components customarily included in such devices, the processor 24 such as a microprocessor and the memory device 26 such as a programmable read-only memory device ("PROM") including erasable PROM's (EPROM's or EEPROM's). The memory device 26 is provided to store, amongst other things, instructions in the form of, for example, a software routine (or routines) which, when executed by the processor 24, allows the controller 18 to control operation of the apparatus 10.

[0019] One illustrative embodiment of the engine brake 14 will herein be described in greater detail. However, it should be appreciated that such a description is exemplary in nature and that the engine brake 14 may be embodied in numerous different configurations.

[0020] The engine brake 14 is able to selectively brake individual cylinders 22, combinations of cylinders, or brake all cylinders collectively. Upon braking one or more cylinders 22 when the engine is at an idle or low-load conditions, the non-braking cylinders 22 will continue to operate "normally" and continue the generation of power by combustion therein. The braking cylinder(s) 22 will be consuming power resulting in an increased load on the non-braking cylinders 22. As a result of this increased load on the non-braking engine cylinders 22, a rise in the exhaust gas temperature will occur.

[0021] The selective braking process is not generally continuous. For example, the process may only be used often enough to activate the device 20. In cases where

the device 20 has a regenerable emissions trap (e.g., particulate filter, NOx trap), the process may be used often enough to meet the minimum regeneration cycles for the particulate filter within the diesel particulate filter 20. The controller 18 monitors the internal temperature of the diesel particulate filter 20 to determine if the activation temperature has been reached. An error signal is generated if the temperature sensor does not meet a predetermined criteria.

[0022] The controller 18 also monitors exhaust gas output from an engine exhaust gas temperature sensor to adjust the braking of cylinders 22 to maintain the temperature of the diesel particulate filter 20 within a predetermined temperature range. For example, a temperature control range may be designed that allows for sufficient heat to adequately regenerate or otherwise activate the diesel particulate filter 20, while also preventing the filter 20 from being exposed to excessive temperatures that may damage the internal filters. It should be appreciated that a temperature control range may be designed to meet many other objectives.

[0023] An exemplary control routine 100 for controlling the engine brake 14 for regeneration or, more generally, activation of the diesel particulate filter 20 regeneration is shown in FIG. 2. The control routine 100 begins with step 102 in which the controller 18 determines the temperature of the diesel particulate filter 20. In particular, the controller 18 scans or otherwise monitors the signal line 30 for the output from the sensor 28. Once the controller 18 has determined the temperature of the diesel particulate filter 20, routine 100 advances to either step 104 or step 106. If the temperature of the device 20 is above the activation temperature, the routine 100 advances to step 104. If the temperature of the device 20 is below the activation temperature, the routine 100 advances to step 106.

[0024] In step 102, the controller 18 determines if the sensed temperature is within a predetermined temperature control range. In particular, as described herein, a predetermined temperature control range may be established. In the exemplary embodiment described herein, an activation temperature (e.g., 350°C if the filter is catalyzed) may be utilized in conjunction with a predetermined upper and lower control limit. As such, in step 102, the controller 18 determines if the sensed temperature is within the predetermined temperature control range (i.e., less than the upper limit and greater than the lower limit). If the temperature of the heat generated by the engine 12 is within the predetermined temperature control range, the control routine 100 advances to step 104 to continue monitoring the output from the sensor 28. However, if the temperature of the heat generated by the engine 12 is not within the predetermined temperature control range, a control signal is generated and the control routine 100 advances to step 104.

[0025] In step 106, the controller 18 determines if the engine brake is required to be activated in at least one cylinder 22. To do so, the controller 18 activates the en-

gine brake 14 by decreasing the fuel being supplied to the braking cylinder 22. The controller also causes the exhaust valve in the braking cylinder to open when the piston is at or near the top dead center position. Typically, this is done just prior to the piston reaching the top dead center position. Once the need for engine braking has been determined, the control routine advances to step 108 or step 110.

[0026] In step 108, the controller 18 continues normal engine 12 operation because of acceleration or load conditions that, if continued, will result in exhaust gas temperatures above the lower control limit temperature of catalytic material within the diesel particulate filter 20.

[0027] In step 110, the controller 18 continues braking at least one cylinder 22 until the exhaust gas temperature is sufficient to achieve the activation temperature of the catalytic material of the diesel particulate filter 20. To do so, the controller 18 activates the engine brake 14 by ceasing the fuel being supplied to the braking cylinder 22. The controller also causes the exhaust valve in the braking cylinder to open just prior to the piston reaching the top dead center position. Once the activation temperature has been attained, the control routine advances to step 112.

[0028] In step 112, the controller 18 determines if the activation temperature has been attained. Once the attainment of the activation temperature has been determined, the control routine advances to step 114 or step 116.

[0029] In step 114, the controller 18 continues braking at least one cylinder 22 because the catalytic material has not reached the activation temperature which will result in exhaust gas temperatures above the lower control limit temperature of catalytic material within the diesel particulate filter 20. Once the activation temperature has been attained, the control routine advances to step 116.

[0030] In step 116, the controller 18 determines if the diesel particulate filter 20 has been purged (cleaned) based on the amount of time the device 20 has been at or above the activation temperature. Once the diesel particulate filter 20 has been purged, the control routine advances to step 118.

[0031] In step 118, the controller 18 discontinues selective engine braking and continues to monitor both engine 12 and diesel particulate filter 20 conditions. If required, the control routine will return to step 102.

Claims

1. A method of regenerating a diesel particulate filter, the method comprising the steps of:

determining if the diesel particulate filter is in need of regeneration,
determining if an engine is operating in a manner that produces insufficient engine heat to regenerate the diesel particulate filter, and

- if the engine is so operating, braking one or more cylinders of the engine while allowing at least one cylinder to combust fuel.
2. The method of claim 1, wherein the determining step comprises determining if the engine is operating below a predetermined engine speed, preferably wherein the determining step comprises monitoring output from an engine speed sensor. 5
 3. The method of claim 1, wherein the determining step comprises determining if the engine is operating below a predetermined engine load, preferably wherein the determining step comprises querying an engine load map. 10
 4. The method of claim 1, wherein the braking step comprises elevating the temperature of the diesel particulate filter to at least an activation temperature of the diesel particulate filter with the engine heat. 20
 5. The method of claim 4, comprising regenerating the diesel particulate filter by use of the engine heat.
 6. The method of claim 5, wherein the regenerating step comprises (i) activating an oxidation catalyst by use of the engine heat, and (ii) regenerating a diesel particulate filter with heat generated by the activated oxidation catalyst. 25
 7. The method of claim 5, wherein the regenerating step comprises regenerating a catalyzed particulate filter by use of the engine heat, or wherein the regenerating step comprises regenerating a NOx trap by use of the engine heat. 30
 8. The method of claim 1, wherein the braking step comprises braking at least one engine cylinder of the engine while operating at least one engine cylinder of the engine so as to generate power by combustion therein. 35
 9. An apparatus, comprising: 40
 - a diesel particulate filter, 45
 - at least one sensor for sensing information associated with operation of an engine,
 - an engine brake configured to brake the engine, and
 - a controller electrically coupled to the at least one sensor and the engine brake, the controller comprising (i) a processor, and (ii) a memory device electrically coupled to the processor, the memory device having stored therein a plurality of instructions which, when executed by the processor, cause the processor to: 50

determine if the diesel particulate filter is in
 - need of regeneration, determine if the engine is operating in a manner that produces insufficient engine heat to regenerate the diesel particulate filter, and if the engine is so operating, operate the engine brake so as to brake one or more cylinders of the engine while allowing at least one cylinder to combust fuel to cause the engine to generate enough engine heat to regenerate the diesel particulate filter.
 10. The apparatus of claim 9, wherein the plurality of instructions, when executed by the processor, further cause the processor to:
 - determine if the engine speed of the engine is within a predetermined engine speed range, and operate the engine brake if the engine speed is within the predetermined engine speed range.
 11. The apparatus of claim 10, wherein the at least one sensor comprises an engine speed sensor, and the plurality of instructions, when executed by the processor, further cause the processor to monitor output from the engine speed sensor.
 12. The apparatus of claim 9, wherein the plurality of instructions, when executed by the processor, further cause the processor to:
 - determine if engine load of the engine is within a predetermined engine load range, and operate the engine brake if the engine load of the engine is within the predetermined engine load range, or wherein the plurality of instructions, when executed by the processor, further cause the processor to query an engine load map.
 13. The apparatus of claim 9, wherein the plurality of instructions, when executed by the processor, further cause the processor to:
 - determine if the temperature of exhaust gas from the engine is within a predetermined temperature range, and operating the engine brake if the temperature of the exhaust gas from the engine is within the predetermined temperature range.
 14. The apparatus of claim 13, wherein the at least one sensor comprises an exhaust gas temperature sensor, and the plurality of instructions, when executed by the processor, further cause the processor to monitor output from the exhaust gas temperature sensor.

15. The apparatus of claim 9, wherein the plurality of instructions, when executed by the processor, further cause the processor to operate the engine brake so as to brake a first engine cylinder of the engine and to operate the engine such that a second engine cylinder of the engine remains active while the engine brake brakes the first engine cylinder. 5
16. The apparatus of claim 9, wherein the diesel particulate filter comprises a NOx trap. 10

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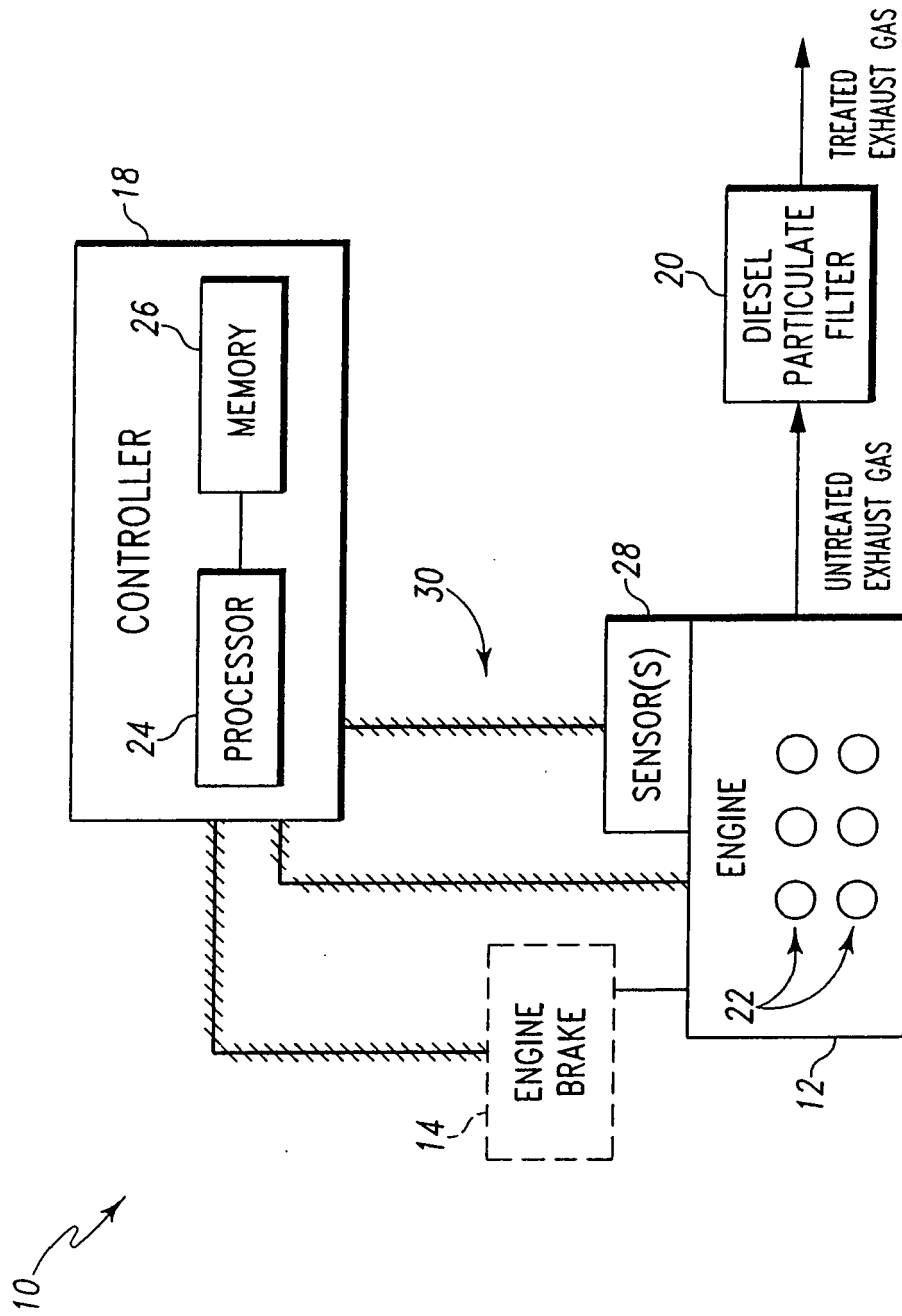


Fig. 1

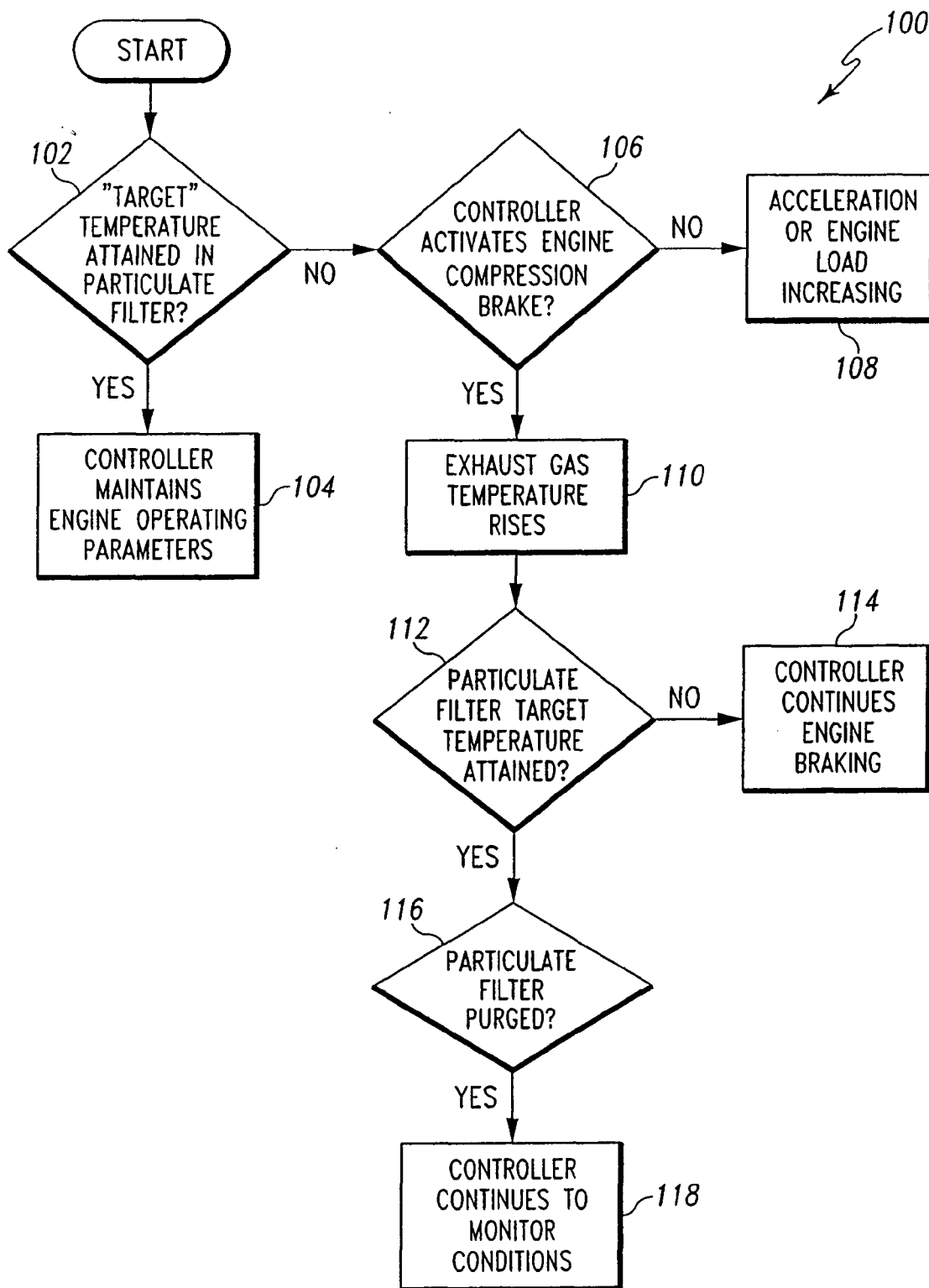


Fig. 2



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 08 25 0370

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Place of search Munich		Date of completion of the search 29 May 2008	Examiner Pileri, Pierluigi
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 08 25 0370

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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