ABSTRACT

In an exhaust gas cleaning device for cleaning the exhaust gases of an engine mounted on a vehicle, of the type in which the exhaust gases are re-burned in an exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine or combined with the exhaust manifold, with secondary fuel and secondary air supplied into said chamber, there are provided valve means for controlling the supply of said secondary fuel and secondary air to said combustion chamber according to the temperature of said combustion chamber, the suction vacuum of the engine and the vehicle speed, in the respective phases of the engine operation, and means for controlling the operations of said valve means.

10 Claims, 3 Drawing Figures
FIG. 2

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ATTORNEYS
EXHAUST GAS CLEANING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the invention

This invention relates to a device for cleaning the exhaust gases of vehicles, particularly automotive vehicles, by burning the exhaust gases in an exhaust gas combustion chamber provided intermediary of the exhaust pipe or combined with the exhaust manifold from the engine by supplying secondary fuel and secondary air into said chamber.

2. Description of the Prior Art

For cleaning the exhaust gases from an engine to a high degree by oxidizing the exhaust gases at a point downstream of the exhaust valve, there have been used manifold reactors, after-burners and catalytic converters. However, with the manifold reactor or the after-burner in which the exhaust gases are burned with only secondary air supplied thereto, it is generally difficult to continuously burn the exhaust gases stably under varying operational conditions of the engine. In addition, the temperature of the combustion chamber tends to rise readily to a level higher than 1,000°C when the combustion takes place therein. Therefore, for cleaning the exhaust gases to an acceptable degree, it becomes necessary to form the combustion chamber with heat-resisting materials sufficiently durable with temperatures of 1,000°C-1,100°C or more even when the temperature of said combustion chamber is controlled by bypassing the exhaust gases, cutting the secondary air or other means. However, such heat-resisting materials are commercially not available and must be newly developed, making the practical use of such devices difficult. On the other hand, the catalytic converter has the advantage that a highly efficient cleaning performance can be obtained even when the reaction temperature of a catalyst layer is as high as about 500°C-600°C, but has the disadvantage that the catalyst is subjected to heavy deterioration by lead present in the gasoline and the catalytic activity thereof is degraded by soot or the like attaching to its surface during the low speed operation of the engine as in the case when the automotive vehicle travel in the urban area. Thus, a catalytic converter having a useful life of 50,000 miles as at the present time required in the United States of America for this type of device can hardly be obtained.

In recent years, there have been proposed devices (secondary fuel feeding type after-burners) in which the exhaust gases are cleaned by being burned in an exhaust gas combustion chamber with secondary fuel and secondary air supplied thereto, which combustion chamber is provided intermediate of the exhaust pipe. These after-burners, particularly those of a volute combustion chamber type, are excellent in durability of combustion of the exhaust gases in the combustion chamber, free of the problem of inducing a deflagration which is called after-burning and liable to occur in after-burners and has the advantage that the outer peripheral surface or the outer wall surface of the combustion chamber can be maintained at a temperature of 700°C-800°C even when the temperature of the central portion thereof has reached a temperature as high as about 1,000°C, so that the material of which the device is made is not required to be so resistive to heat as the materials of the other after-burners or manifold reactors and the commercially available materials can be used, without the necessity of developing new heat-resisting materials. Therefore, these devices have high practicability.

However, in the above-described secondary fuel feeding type after-burners, not speaking of the conventional after-burners and manifold reactors, the structures of the combustion chamber is cold and hence the internal temperature of said combustion chamber is low for a period of several minutes after the engine is placed in operation, and this poses the problem that the exhaust gas oxidizing reaction does not proceed completely and therefore, the cleaning effect is low.

Furthermore, the manifold reactors and the after-burners, whether the secondary fuel is supplied or not, generally have the problem that when the engine is operated continuously at a high speed, the combustion chamber-forming member is overheated to 1,000°C or higher by the elevating temperature of the exhaust gases, and subjected to thermal breakage. The same problem is possessed also by the secondary fuel feeding type after-burners of the volute combustion chamber type.

The present inventors found through numerous experiments and studies that complete cleaning of the exhaust gases immediately after the start of the engine can be achieved by detecting the temperature of the exhaust gas combustion chamber and regulating the flow rate of the secondary fuel or the flow rates of the secondary fuel and the secondary air supplied to said combustion chamber, according to the detected temperature of the combustion chamber so that more secondary fuel and/or more secondary air may be supplied before the combustion chamber temperature reaches the normal reaction temperature from immediately after the start of the engine than after said combustion chamber temperature has reached said normal reaction temperature; and that the overheating of the combustion chamber-forming member can be avoided by decreasing or shutting down the supply of the secondary fuel or the secondary fuel and the secondary air when said combustion chamber temperature rises to an excessively high level.

However, the concentrations of the harmful unburned components in the exhaust gases of gasoline engines and the quantity of the exhaust gases are largely variable depending upon the operating phase of the vehicle. For instance, during idling or deceleration of the engine after the combustion temperature has reached the normal reaction temperature, the concentrations of the harmful unburned components in the exhaust gases become particularly high and, therefore, the combustion of the exhaust gases can be continued without supplying the secondary fuel, but the continuation of combustion during deceleration occasionally becomes difficult unless the quantity of the secondary air is decreased, because otherwise the exhaust gases would be cooled. On the contrary, during acceleration, particularly quick acceleration, of the engine, including the case when the engine is accelerated while shifting the transmission gears, the concentrations of the unburned components are low and in addition the quantity of the exhaust gases is extremely large, so that with about the same quantity of the secondary fuel as required during cruising of the engine, it is impossible to sufficiently oxidize the unburned components. It will, therefore, be understood that the above-described countermeasure only is insufficient and a problem arises in which un-
necessary secondary fuel is supplied and complete cleaning of the exhaust gases cannot be attained during acceleration of the engine.

SUMMARY OF THE INVENTION

In order to solve the above problem, the present invention has for its object the provision of a highly efficient, highly economical secondary fuel feeding type exhaust gas cleaning device for cleaning the exhaust gases of an engine by burning them in an exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine or combined with the exhaust manifold, with secondary fuel and secondary air supplied therein; wherein the flow rate of the secondary fuel and/or the secondary air supplied to the combustion chamber are regulated, upon detecting the temperature of said exhaust gas combustion chamber, the suction vacuum of the engine and the vehicle speed, in at least five stages, i.e. the stage in which the temperature of said combustion chamber rises to the normal reaction temperature and the engine is quickly accelerated after the start of the engine, the stage in which the engine is in the idling phase after the temperature of said combustion chamber has reached the normal reaction temperature, the stage in which the engine is decelerated, the stage in which the temperature of said combustion chamber rises to an excessively high level; and the stage in which the engine is in the other operating phases; whereby complete combustion oxidation of the exhaust gases can be achieved and the secondary fuel consumption can be saved. Other objects, advantages and features of the present invention will become apparent from the following description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a view diagrammatically showing the construction of an embodiment of the exhaust gas cleaning device according to the present invention;

FIG. 2 is a sectional view of the secondary air regulating electromagnetic valve used in the exhaust gas cleaning device shown in FIG. 1; and

FIG. 3 is a sectional view of the secondary fuel regulating electromagnetic valve used in the exhaust gas cleaning device shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, reference numeral 1 designates an engine mounted on a vehicle, 2 a suction manifold and 2 an exhaust manifold. An exhaust pipe 4 having one end connected with the exhaust manifold 3 has the other end open in the upstream side of a cylindrical exhaust gas combustion chamber 5 in the tangential direction, while an exhaust pipe 4' is open in the downstream side of said exhaust gas combustion chamber 5, so that the exhaust gases swirl within said combustion chamber 5 in the direction of the arrow A. On the top of the combustion chamber 5 is formed a cylindrical small chamber 6 into which secondary air necessary for the combustion of secondary fuel and the exhaust gases is supplied through a pipe 8 and a secondary air regulating electromagnetic valve 9, said air pump being driven from the engine 1. The pipe 8 is open in the inner wall of the chamber 6 in a tangential direction and the secondary air supplied from said pipe 8 swirls within said chamber 6 as indicated by the arrow.

B. A fuel injection nozzle 10 is provided substantially centrally of the upper wall of the chamber 6, through which the fuel supplied from a fuel pump through a secondary fuel regulating electromagnetic valve 11 and a fuel pipe 12 is injected into the chamber 6. The fuel injected from the nozzle 10 is finely atomized by the air supplied from an air pipe 8a. Further, porous body 13 is provided surrounding the fuel injection nozzle 10, which serves as an evaporative burner and receives fuel from the secondary fuel regulating electromagnetic valve 11 through a fuel pipe 14. Ignition plugs 15, 15' are fixedly mounted adjacent the nozzle 10 and the porous body 13 and extended into the chamber 6. These ignition plugs 15, 15' respectively have electrodes 15a, 15a' at the center thereof. The nozzle 10 and the porous body 13 are made of an electrode material and grounded so as to serve simultaneously as ground electrodes respectively. Reference numeral 16 designates a power source, 17 an ignition switch of the engine 1, 18 an interrupter and 19 an ignition coil having two ignition coils electrically connected with the ignition plugs 15, 15' respectively. The arrangement is such that while the ignition switch 17 is in its closed position, the interrupter 18 intermittently interrupts the primary current of the ignition coil 19 and sparks are generated across the central electrodes 15a, 15a' of the ignition plugs 15, 15' and the nozzle 10 and the porous body 13 by the high voltage induced in the two secondary coils, to ignite the fuel supplied into the chamber 6 from said nozzle 10 and said porous body 13.

The secondary air regulating electromagnetic valve 9, as shown in FIG. 2, has cooperating first and second valves 9a, 9b and an independent third valve 9c. The first valve 9a opens and closes an air passage between an inlet port 9d, communicating with the pipe 8, and a communication passage 9e and the second valve 9b opens and closes an air passage between the inlet port 9d and a port 9 open into the atmosphere. The third valve 9c opens and closes an air passage between the communication passage 9e and an outlet port 9g communicating with the pipe 8. When the secondary coil 9i is deenergized and the primary coil 9h is energized, the electromagnetic valve 9 takes the position shown in FIG. 2, i.e. the first and third valves 9a, 9c are opened establishing the communication between the inlet port 9d and the outlet port 9g, and the second valve 9b is closed breaking the communication between the inlet port 9d and port 9f. When the primary coil 9h is energized, the first valve 9a breaks the communication between the inlet port 9d and the outlet port 9g, and the second valve 9b establishes the communication between the inlet port 9d and the port 9f. Further, when the secondary coil 9i is energized, the third valve 9c is closed but a small quantity of air from the communication passage 9e into the outlet port 9g through small apertures 9c' formed in said valve 9c. Springs 9j, 9k are provided to return the first and third valves 9a, 9c to their original position upon deenergization of the primary and secondary coils 9h, 9i, and a spring 9l is provided to maintain the first and second valves 9a, 9b in predetermined spaced relation to each other.

The secondary fuel regulating electromagnetic valve 11, as shown in FIG. 3, has main regulating first valve 11a and auxiliary second and third valves 11b, 11c. The first valve 11a opens and closes a main passage 11e upon energization and deenergization of the primary
the second valve 11b opens and closes an auxiliary passage 11g upon energization and deenergization of the secondary coil 11f; and the third valve 11c opens and closes an auxiliary passage 11i upon energization and deenergization of the tertiary coil 11h. Diaphragms 11j, 11k, 11l are provided to prevent fuel from intruding into the coil portions. The main passage 11e communicates with the pipe 12, and the auxiliary passages 11g, 11i communicate with the pipe 14. A temperature detector 21 is provided at the portion of the combustion chamber 5 where the temperature becomes highest and a suction vacuum detector 22 is mounted in the suction manifold. Further, a vehicle speed detector 23 is mounted on the driving shaft 1' of the engine.

A control relay 20 is controlled to the electromagnetic valves 9, 11 in response to signals from the respective detectors 21, 22, 23 in such a manner that, when the temperature detected by the temperature detector 21 is below the normal reaction temperature, the first, second and third valves 11a, 11b, 11c of the electromagnetic valve 9 will be opened independently of the signals from the other detectors 22, 23 so that a large quantity of fuel is supplied to the nozzle 10 and a small quantity of fuel is supplied to the porous body 13, and the corresponding quantity of the secondary air is supplied from the pipes 8, 8a into the chamber 6; when the temperature detected by the temperature detector 21 is in the range from the normal reaction temperature to a set overheated temperature, the electromagnetic valve 9 will in principle be maintained in the above-described operative position and the electromagnetic valve 11 will close only the first valve 11a so that a small quantity of the secondary fuel for the normal combustion is supplied to the nozzle 10; when the engine is in the idling phase, the electromagnetic valve 11 will open only the third valve 11c in response to the signal from the suction vacuum detector 22 representing a large suction vacuum pressure in the suction manifold and the signal from the vehicle speed detector 23 representing the vehicle speed being zero; when the engine is decelerated, the electromagnetic valve 11 will be maintained in the position when the engine is in the idling phase and the electromagnetic valve 9 will open only the first valve 9a in response to the signal from the vehicle speed detector 23 representing the vehicle speed; when the engine is quickly accelerated, the electromagnetic valve 9 will maintain the first and third valves 9a, 9c in their open positions and the second valve 9b in its closed position and the electromagnetic valves 11 will open all of the first, second and third valves 11a, 11b, 11c in response to the signal from the suction vacuum detector 22 representing a small suction vacuum pressure in the suction manifold; and further when the temperature detected by the temperature detector 21 becomes higher than said set overheated temperature, the electromagnetic valve 11 closes all of the first, second and third valves 11a, 11b, 11c independently of the signal from the other detectors 22, 23 to interrupt the supply of fuel to the nozzle 10, and the electromagnetic valve 9 will close the first valve 9a and open the second valve 9b so that the secondary air from the air pump 7 is released into the atmosphere without being supplied into the chamber 6.

Now, the operation of the subject device constructed as described above will be described. Before going into the description, the concentrations of CO (carbon monoxide) and HC (hydrocarbons) in the exhaust gases and the quantity of the exhaust gases in various phases of the engine operation will be shown in Table 1 below:

<table>
<thead>
<tr>
<th>Operation phase of engine</th>
<th>Concentration of CO</th>
<th>Concentration of HC</th>
<th>Quantity of Exhaust gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the engine is cold:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idling</td>
<td>very high</td>
<td>high</td>
<td>small</td>
</tr>
<tr>
<td>Quick acceleration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cruising to medium speed</td>
<td>medium</td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>Deceleration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After the engine is warmed up:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idling</td>
<td>high</td>
<td>medium</td>
<td>small</td>
</tr>
<tr>
<td>Quick acceleration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cruising to medium speed</td>
<td>low</td>
<td>low</td>
<td>large</td>
</tr>
<tr>
<td>Deceleration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the engine 1 is started (the ignition switch is in its closed position), since the engine and the combustion chamber 5 are cold immediately after start of the engine, the first and third valves 9a, 9c of the electromagnetic valve 9 are opened by the signals from the temperature detector 21 and the control relay 20, whereby the secondary air is supplied into the pipes 8, 8a, and at the same time, the first, second and third valves 11a, 11b, 11c of the electromagnetic valve 11 are opened, whereby a large quantity of the secondary fuel is supplied to the nozzle 10 to be sprayed into the chamber 6 and also supplied to the porous body 13. On the other hand, upon closure of the ignition switch 17, sparks are generated across the central electrodes 15a, 15b of the ignition plugs 15, 15", and the nozzle 10 and the porous body 13, by the functions of the interrupter 18 and the ignition coil 19, and the secondary fuel injected into the chamber 6 in an atomized state from the nozzle 10 and gasified on the surface of the porous body 13 is ignited by said sparks. The fuel from the nozzle 10 forms flames jetting into the combustion chamber 5 and burns the swirling flows A of the exhaust gases within said chamber. At the same time, the gasified fuel from the porous body 13 is caused to swirl within the chamber 6 as indicated by the arrow B by the secondary air supplied into said chamber from the pipe 8 and mixed with the exhaust gas flows within the combustion chamber 5 while burning, thereby to promote the combustion oxidation of the exhaust gases. Therefore, the exhaust gases are completely oxidized before reaching the exhaust pipe 4'. The supply of the secondary fuel and the secondary air continues independently of the operating condition of the engine 1, until the temperature within the combustion chamber 5 (the temperature detected by the temperature detector 21) reaches the normal reaction temperature.

During cruising of the vehicle after the temperature detected by the temperature detector 21 has reached the normal reaction temperature, the current supply to the primary coil 11d of the electromagnetic valve 11 is interrupted by the action of the control relay 20 and the first valve 11a only is closed, so that the fuel supply to the nozzle 10 is interrupted and the fuel evaporating
from the porous body 13 only is burned. However, the exhaust gases are completely burned and oxidized as the temperatures of said exhaust gases and the combustion chamber are high. When the engine speed is accelerated quickly, the vacuum pressure in the suction manifold 2 becomes extremely low (e.g. below 200 mmHg), so that the control relay 20 again conducts the current to the first coil 11d of the electromagnetic valve 11 in response to the signal from the temperature detector 22. Therefore, the first valve 11 is opened and a large quantity of the secondary fuel is injected from the nozzle 10 and strong flames are jetted into the combustion chamber 5. Thus, it is possible to completely burn and oxidize the exhaust gases even when the concentrations of CO and HC are low and the quantity of the exhaust gases is large. On the contrary, when the engine speed is decelerated, the suction vacuum pressure is extremely high (e.g. higher than 450 mmHg), so that the control relay 20 again start to conduct the current to the secondary coil 91 of the electromagnetic valve 9 in response to the signal from the suction vacuum detector 23 representing said high vacuum pressure and the signal from the speed detector 24 representing the speed of the vehicle, and thus the third valve 9c is closed. Therefore, a small quantity of the secondary air is supplied through the small apertures 9c' formed in the third valve 9c; the current supply to the secondary coil 11f of the electromagnetic valve 11 is interrupted; the second valve 11b is also closed and the quantity of the secondary fuel supply through the third valve 11c is only supplied to the porous body 13. During acceleration, as will be apparent from Table 1, the quantity of the exhaust gases is small containing a high concentration of HC and is self-combustible. Therefore, the small quantity of the secondary fuel supplied from the porous body 13 serves to heat suitably the aforesaid small quantity of secondary air and stabilize the self-combustion of the exhaust gas upon combustion. Now, when the vehicle is brought to a halt and the engine is placed in the idling phase, the suction vacuum pressure becomes high (e.g. higher than 450 mmHg), so that the electromagnetic valve 11 remains in the same position as in the case of deceleration. However, since the vehicle speed is zero, the current supply to the secondary coil 9i of the electromagnetic valve 9 is interrupted in response to the signal sent from the vehicle speed detector 23 to the control relay 20 representing the vehicle speed being zero, and the third valve 9e is opened. During the idling phase of the engine, as will be apparent from Table 1, the quantity of the exhaust gases is small containing a high concentration of CO and hence the exhaust gases are self-combustible and generate a large amount of heat when burned. In addition, the quantity of the air discharged from the air pump 7 is also small since the rotating speed of the engine 1 is low. Therefore, a continuous stable combustion of the exhaust gases can be obtained by mixing the suitably heated secondary air into the exhaust gases along with a very small quantity of the secondary fuel as in the case of deceleration.

When the temperature detector 21 detects a temperature (e.g. higher than 850°-900° C) predicting overheating of the combustion chamber 5, for instance, during continuous operation of the engine 1 at high speeds under large loads, the current supply to all coils 11a, 11d, 11f, 11h of the electromagnetic valve 11 is interrupted and all of the first, second and third valves 11a, 11b, 11c thereof are closed by the function of the control relay 20, whereby the supply of the secondary fuel is interrupted and the current supply to the primary coil 9h of the electromagnetic valve 9 is also interrupted to close the first valve 9a. Thus, the secondary air from the air pump 7 is released into the atmosphere through the second valve 9b. Therefore, the combustion chamber 5 constitutes merely a part of the exhaust pipe and the combustion of the exhaust gases therein ceases and hence the internal temperature of said combustion chamber drops to the level of the exhaust gas temperature, avoiding the thermal breakage of the structural members of the combustion chamber. When the temperature detected by the temperature detector 21 has lowered to the normal reaction temperature, the supply of the secondary fuel and the secondary air is commenced again by the control relay 20 according to the operating phase of the engine 1, and the combustion and oxidation of the exhaust gases take place.

It will be obvious that the operations of the control relay 20 in response to the signals from the detectors 21, 22, 23, i.e. the operation for commencing and the operation for interrupting the current supply to the electromagnetic valves 9, 11, have hysteresis so as to avoid the so-called hunting.

The relationship between the signals from the respective detectors and the operations of the secondary fuel and secondary air regulating electromagnetic valves, in the embodiment described above, are summarized in Table 2 below:

<table>
<thead>
<tr>
<th>Operating phase of engine</th>
<th>Detected temperature, °C</th>
<th>Detected suction vacuum, mmHg</th>
<th>Detected vehicle speed</th>
<th>Secondary fuel</th>
<th>Secondary air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overheating of the combustion chamber:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idling</td>
<td>650-850</td>
<td>&lt;450</td>
<td>First and third valves are opened.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deceleration</td>
<td>650-850</td>
<td>&lt;450</td>
<td>First and third valves are opened.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td>650-850</td>
<td>200-450</td>
<td>First and third valves are opened.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overheating of the combustion chamber:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idling</td>
<td>&lt;800-900</td>
<td></td>
<td>First and third valves are opened.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deceleration</td>
<td></td>
<td></td>
<td></td>
<td>Second valve is opened and first valve is closed.</td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the embodiment described above, when a heat accumulator 24 made of a heat-resisting material, such as ceramics, is provided within the combustion chamber 5 as indicated by the phantom lines, so as to be heated by the combustion flames, said heat accumulator 24 is at least partially red-heated and provides an ignition source for the exhaust gases even when the secondary fuel cannot be adjusted following the varying state of the exhaust gases due to an abrupt change in operating phase of the engine, thereby greatly contributing the stabilized cleaning of the exhaust gases and making it possible to limit the quantity supplied of the secondary fuel to a level necessary for preventing the heat accumulator 24 from cooling so as to save the secondary fuel.

Although in the embodiment described above overheating of the combustion chamber 5 is prevented by stopping the supply of the secondary fuel and secondary air, it will be obvious that, if an arrangement is possible wherein the overheating of the combustion chamber 5 can be prevented even with small quantities of the secondary fuel and secondary air being continuously supplied thereto, such an arrangement is quite effective for the cleaning of the exhaust gases.

Further, although in the embodiment described above the quantity supplied of the secondary fuel is regulated by three valves, it will be understood that the regulation of the secondary fuel can also be achieved by employing an on-and-off control type valve and varying the width or cycle of the open or closed duration of the valve. In this case, the second and third valves can be substituted by a single valve and in addition, minute regulations of the secondary fuel becomes possible.

The porous body 13 is made of a heat-resisting metal as an electrode material, but it is to be understood that it may be made of electric insulating materials such as ceramics, asbestos fiber and glass fiber. In this case, metallic wires must of course be exposed on the surface of the porous body, with one ends thereof grounded to the wall of the chamber 6, so that sparks may be generated across the exposed ends of said wires and the central electrode 15' of the ignition plug 15'.

As described above, in the exhaust gas cleaning device of the invention for cleaning the exhaust gases of an engine mounted on a vehicle by burning the exhaust gases in a exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine, with secondary fuel and secondary air supplied to said combustion chamber, the quantity of the secondary fuel or the quantities of the secondary fuel and the secondary air are regulated, upon detecting the temperature of said exhaust gas combustion chamber, the suction vacuum of the engine and the vehicle speed, in at least five different stages, i.e. the stage in which the temperature of the combustion chamber reaches the normal reaction temperature and the engine is quickly accelerated after the engine is started, the stage in which the engine is in the building phase after the temperature of the combustion chamber has reached the normal reaction temperature, the stage in which the engine is decelerated, the stage in which the temperature of the combustion chamber rises to an excessively high level and the stage in which the engine is in the other operating phases. Therefore, there can be achieved the following advantages:

1. During the period in which the temperature of the combustion chamber rises to the normal reaction temperature after start of the engine and during quick acceleration of the engine, a large quantity of the secondary fuel is injected into the combustion chamber from the fuel injection nozzle and burned therein, whereby the exhaust gases can be completely burned which would otherwise be hardly burned.

2. a. During idling and during deceleration of the engine after the temperature of the combustion chamber has reached the normal reaction temperature, the secondary fuel is supplied in a small quantity sufficient for heating the secondary air and maintaining the combustion of the exhaust gases,

b. when the temperature of the combustion chamber rises to an excessively high level, the quantities supplied of the secondary fuel and the secondary air are decreased so as to inhibit the temperature rise of said combustion chamber, and

c. when the engine is in the other operating phases, the secondary fuel and the secondary air are supplied in quantities necessary for assisting in combustion of the exhaust gases, whereby it becomes possible to completely clean the exhaust gases throughout the various operating phases of the engine after the engine has been warmed up and to save the consumption of the secondary fuel. It is also possible to prevent a breakage of the exhaust gas combustion chamber by overheating.

Thus, the exhaust gas cleaning device of the invention is highly efficient, highly economical and is of great practical value.

Whereas the invention has been described and illustrated with reference to one specific embodiment thereof, it should be recognized that the invention can be modified in a variety of ways without departing from the scope of the attached claims. What is most important is to match the exhaust gas cleaning device with the engine such that by controlling the secondary air and fuel the detrimental components finally contained in the exhaust gas be minimized.

Further, although the device of the invention has been shown and described as being attached to a reciprocating engine, it should also be understood that it can be attached to rotary engines similarly.

We claim:

1. An exhaust gas cleaning device for cleaning the exhaust gases of an engine mounted on a vehicle by burning said exhaust gases in an exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine, with secondary fuel and secondary air supplied to said combustion chamber, the quantity of the secondary fuel or the quantities of the secondary fuel and the secondary air are regulated, upon detecting the temperature of said exhaust gas combustion chamber, the suction vacuum of the engine and the vehicle speed, in at least five different stages, i.e. the stage in which the temperature of the combustion chamber reaches the normal reaction temperature and the engine is quickly accelerated after the engine is started, the stage in which the engine is in the building phase after the temperature of the combustion chamber has reached the normal reaction temperature, the stage in which the engine is decelerated, the stage in which the temperature of the combustion chamber rises to an excessively high level and the stage in which the engine is in the other operating phases. Therefore, there can be achieved the following advantages:

   a. During the period in which the temperature of the combustion chamber rises to the normal reaction temperature after start of the engine and during quick acceleration of the engine, a large quantity of the secondary fuel is injected into the combustion chamber from the fuel injection nozzle and burned therein, whereby the exhaust gases can be completely burned which would otherwise be hardly burned.

   b. When the temperature of the combustion chamber rises to an excessively high level, the quantities supplied of the secondary fuel and the secondary air are decreased so as to inhibit the temperature rise of said combustion chamber, and

   c. When the engine is in the other operating phases, the secondary fuel and the secondary air are supplied in quantities necessary for assisting in combustion of the exhaust gases, whereby it becomes possible to completely clean the exhaust gases throughout the various operating phases of the engine after the engine has been warmed up and to save the consumption of the secondary fuel. It is also possible to prevent a breakage of the exhaust gas combustion chamber by overheating.

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Further, although the device of the invention has been shown and described as being attached to a reciprocating engine, it should also be understood that it can be attached to rotary engines similarly.

We claim:

1. An exhaust gas cleaning device for cleaning the exhaust gases of an engine mounted on a vehicle by burning said exhaust gases in an exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine, with secondary fuel and secondary air supplied to said combustion chamber, said device comprising:

   a. Said combustion chamber for re-burning the exhaust gases being led into the exhaust pipe of the engine, means for supplying the secondary air into said combustion chamber for re-burning the exhaust gases, first valve means for regulating the quantity of the secondary air supplied to the combustion chamber,

means for supplying the secondary fuel into the combustion chamber for re-burning the exhaust gases, second valve means for regulating the quantity of the secondary fuel and means for operating said first and second valve means according to the temperature of said exhaust gas combustion chamber, the suction vacu-
uum of the engine and the vehicle speed, whereby the quantities of the secondary fuel and the secondary air are regulated in at least five stages, i.e. the stage in which the temperature of the combustion chamber rises to the normal reaction temperature and the engine is quickly accelerated after the engine has been started, the stage in which the engine is in the idling phase after the temperature of the combustion chamber has reached the normal reaction temperature, the stage in which the engine is decelerated, the stage in which the temperature of the combustion chamber rises to an excessively high level and the stage in which the engine is in other operating phases,

wherein said combustion chamber has a head chamber and said secondary air and secondary fuel introduced into said head chamber are ignited therein with the resulting combustion gases jetting into the combustion chamber, whereby the unburned components in the exhaust gases of the engine led into said combustion chamber are completely burned and cleaned, and wherein said second valve is for closing said passage to release the air into said secondary fuel is supplied into said head chamber through said central opening and said porous body.

2. An exhaust gas cleaning device for cleaning the exhaust gases of an engine mounted on a vehicle by burning said exhaust gases in an exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine, with secondary fuel and secondary air supplied to said combustion chamber, said device comprising said combustion chamber for re-burning the exhaust gases being led into the exhaust pipe of the engine, means for supplying the secondary air into said combustion chamber for re-burning the exhaust gases, first valve means for regulating the quantity of the secondary air supplied to the combustion chamber, means for supplying the secondary fuel into the combustion chamber for re-burning the exhaust gases, second valve means for regulating the quantity of the secondary fuel and means for operating said first and second valve means according to the temperature of said exhaust gas combustion chamber, the suction vacuum of the engine and the vehicle speed, whereby the quantities of the secondary fuel and the secondary air are regulated in at least five stages, i.e. the stage in which the temperature of the combustion chamber rises to the normal reaction temperature and the engine is quickly accelerated after the engine has been started, the stage in which the engine is in the idling phase after the temperature of the combustion chamber has reached the normal reaction temperature, the stage in which the engine is decelerated, the stage in which the temperature of the combustion chamber rises to an excessively high level and the stage in which the engine is in other operating phases,

wherein said first valve means for regulating the quantity of the secondary air includes a first valve for opening and closing a passage leading from air supply means to said combustion chamber, a second valve for closing said passage to release the air into the atmosphere and a third valve having apertures formed therein and located downstream of said first valve, and operations of said valves are controlled by said controlling means according to the temperature of the combustion chamber, the suction vacuum of the engine and the vehicle speed, whereby while the temperature of the combustion chamber rises to the normal reaction temperature and the engine is quickly accelerated and while the engine is idling, cruising and quickly accelerated after the engine has been warmed up, said first and third valves are opened and said second valve is closed to supply a large quantity of air into said combustion chamber, and said first valve is opened and said second and third valves are closed to supply a small quantity of air into said combustion chamber through the apertures formed in said third valve, respectively, whereas when the combustion chamber is overheated, said first valve is closed and said second valve is opened to release the air into the atmosphere.

3. An exhaust gas cleaning device as defined in claim 1, wherein the secondary air supplied to said head chamber and exhaust gases supplied to said combustion chamber are introduced into the respective chambers in such a manner as to form swirling flows in said chambers.

4. An exhaust gas cleaning device as defined in claim 1, characterized in that, said exhaust gas and said secondary air are respectively introduced into said combustion chamber in a tangential direction of said chamber so as to form swirling flows in said chambers.

5. An exhaust gas cleaning device for cleaning the exhaust gases of an engine mounted on a vehicle by burning said exhaust gases in an exhaust gas combustion chamber, provided intermediate of the exhaust pipe of the engine with secondary fuel and secondary air supplied to said combustion chamber, said device comprising said combustion chamber for re-burning the exhaust gases being led into the exhaust pipe of the engine, means for supplying the secondary air into said combustion chamber for re-burning the exhaust gases, first valve means for regulating the quantity of the secondary air supplied to the combustion chamber, means for supplying the secondary fuel into the combustion chamber for re-burning the exhaust gases, second valve means for regulating the quantity of the secondary fuel and means for operating said first and second valve means according to the temperature of said exhaust gas combustion chamber, the suction vacuum of the engine and the vehicle speed, whereby the quantities of the secondary fuel and the secondary air are regulated in at least five stages, i.e. the stage in which the temperature of the combustion chamber rises to the normal reaction temperature and the engine is quickly accelerated after the engine has been started, the stage in which the engine is in the idling phase after the temperature of the combustion chamber has reached the normal reaction temperature, the stage in which the engine is in other operating phases,
decelerated, the stage in which the temperature of
the combustion chamber rises to an excessively high
level and the stage in which the engine is in
other operating phases.

characterized in that, said combustion chamber com-
prises a head chamber having a central opening
around which a porous body is provided, said cen-
tral opening is adapted for letting the secondary
fuel and a portion of the secondary air go through
into said head chamber enhancing the atomization
of said fuel by said portion of air, said porous body
is adapted for evaporation secondary fuel from
the surface thereof being supplied with secondary
fuel independently of said secondary fuel to be at-
omized, the remaining portion of said secondary
air is blown into said head chamber in a tangential di-
rection thereof, said exhaust gases are introduced
into a portion of said combustion chamber other
than the portion of said head chamber in a tangen-
tial direction of said combustion chamber.

6. An exhaust gas cleaning device as claimed in claim
5, wherein a heat accumulator is disposed in said com-
bustion chamber, which when red heated provides an
ignition source for the exhaust gas.

7. An exhaust gas cleaning device as defined in claim
5, characterized in that said first valve means for regu-
lating the quantity of the secondary air includes a first
valve for opening and closing a passage leading from
said air supply means to said central opening and a tan-
gentially orientated port provided at said head cham-
ber, a second valve for closing said passage to release
the air into the atmosphere, and a third valve having
apertures formed therein and located at the down-
stream of said first valve, and operation of said valves
are controlled by said controlling means according to
the temperature of said combustion chamber, the suc-
tion vacuum in the intake pipe and the vehicle speed,
whereby while the temperature of the combustion
chamber rises to the normal reaction temperature
while the engine is idling, cruising and quickly accele-
rated, said first and third valves are opened with said
second valves being closed to supply a large quantity
of air into said head chamber, and while the engine is
decelerated said first valve is opened with said third
valve being capable of closing a small quantity of air
into said head chamber through the apertures formed
in said third valve, whereas when the combustion
chamber is overheated, said first valve is closed and
said second valve is opened to release the air into atmo-
sphere; and characterized in that said second valve
means for regulating the quantity of the secondary
fuel includes a first valve for opening and closing a passage
leading from said means for supplying the secondary
fuel to said central aperture, a second valve for opening
and closing a passage leading from said means for sup-
plying the secondary fuel to said porous body and a
third valve which is adapted for opening and closing an-
other passage leading from said means for supplying the
secondary fuel to said porous body, and the opera-
tion of said valves of the second valve means are con-
trolled by said controlling means according to the tem-
perature of the combustion chamber, the suction vac-
uum of the engine and the vehicle speed, whereby while
the temperature of the combustion chamber rises to
the normal reaction temperature and while the en-
gine is quickly accelerated said first and second and
third valves are opened to supply a large quantity of
the secondary fuel into said combustion chamber, while the
engine is idling and decelerated said first and second
valves are closed with said third valve being opened to
supply minimum quantity of the secondary fuel only to
said porous body, while the engine is in cruising condi-
tion said first valve is closed with said second and third
valves being opened to supply a proper quantity of sec-
ond fuel only to said porous body, whereas then the
combustion chamber is overheated said three valves are
all closed to shut the second fuel off.

8. An exhaust gas cleaning device as claimed in claim
7, wherein a heat accumulator is disposed in said com-
bustion chamber, which when red heated provides an
ignition source for the exhaust gas.

9. An exhaust gas cleaning device for cleaning the ex-
hau st gases of an engine mounted on a vehicle by burn-
ning said exhaust gases in an exhaust gas combustion
chamber, provided intermediate of the exhaust pipe of
the engine with secondary fuel and secondary air sup-
plied to said combustion chamber, said device compris-
ing said combustion chamber for re-burning the exhaust
gases being led into the exhaust pipe of the engine,
means for supplying the secondary air into said com-
bustion chamber for re-burning the exhaust gases,
first valve means for regulating the quantity of the
secondary air supplied to the combustion chamber,
means for supplying the secondary fuel into the com-
bustion chamber for re-burning the exhaust gases,
second valve means for regulating the quantity of the
secondary fuel and
means for operating said first and second valve
means according to the temperature of said ex-
hau st gas combustion chamber, the suction vac-
uum of the engine and vehicle speed, whereby the
quantities of the secondary fuel and the secondary
air are regulated in at least five stages, i.e. the stage
in which the temperature of the combustion cham-
ber rises to the normal reaction temperature and
the engine is quickly accelerated after the engine
has been started, the stage in which the engine is in
the idling phase after the temperature of the com-
bustion chamber has reached the normal reaction
temperature, the stage in which the engine is decel-
erated, the stage in which the temperature of the com-
bustion chamber rises to an excessively high
level and the stage in which the engine is in other
operating phases,

characterized in that said first valve means for regu-
lating the quantity of the secondary air includes a first
valve for opening and closing a passage leading from
said means for supplying the secondary air supply means to said combustion
chamber, a second valve for closing said passage to
release the air into the atmosphere and a third valve
having apertures formed therein and located at the
downstream of said first valve, and the opera-
tions of said valves are controlled by said control-
ling means according to the temperature of the com-
bustion chamber, the suction vacuum in the
intake pipe and the vehicle speed, whereby while
the temperature of the combustion chamber rises to
the normal reaction temperature and while the
engine is idling, cruising and quickly accelerated
after the engine has been warmed up, said first and
third valves are opened and said second valve is
closed to supply a large quantity of air into said combustion chamber, and while the engine is decelerated said first valve is opened and said second and third valve are closed to supply a small quantity of air into said combustion chamber through the apertures formed in said third valve, whereas when the combustion chamber is overheated, said first valve is closed and said second valve is opened to release the air into the atmosphere.

10. An exhaust gas cleaning device as defined in claim 9, characterized in that said second valve means for regulating the quantity of the secondary fuel includes a first valve for opening and closing a passage leading from said means for supplying the secondary fuel to said combustion chamber, a second valve for opening and closing a passage leading from said means for supplying the secondary fuel to a porous body provided within said combustion chamber, and a third valve which is adapted for opening and closing another passage communicating said means for supplying the secondary fuel to said porous body, and the operations of said valves of the second valve means are controlled by said controlling means according to the temperature of the combustion chamber, the suction vacuum of the engine and the vehicle speed, whereby while the temperature of the combustion chamber rises to the normal reaction temperature and the engine is quickly accelerated, said first and second and the third valves are opened to supply a large quantity of the second fuel into said combustion chamber, while the engine is idling and decelerated said first and second valves are closed with said third valve being opened to supply minimum quantity of the second fuel only to said porous body, while the engine is in cruising condition said first valve is closed with said second and said third valves being opened to supply a proper quantity of second fuel only to said porous body, whereas when the combustion chamber is overheated said three valves are all closed to shut the second fuel off.

* * * * *
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,802,194 Dated April 9, 1974

Inventor(s) Yasushi Tanasawa et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading:
Item [73], "Toyota Jidosha Kogyo Kabushiki Kaisha" should read -- Toyota Jidosha Kogyo Kabushiki Kaisha --; "all of Aichiken," should read -- both of Aichiken, --.

Signed and sealed this 8th day of October 1974.

(SEAL)
Attest:
McCoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents