US 20070006576A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2007/0006576 A1**

PERSSON et al. (43) **Pub. Date: Jan. 11, 2007**

(54) **METHOD FOR CLEANING A PARTICLE FILTER AND A VEHICLE FOR UTILIZING SAID METHOD**

(75) Inventors: **Per PERSSON**, Partille (SE); **Bo SVENSSON**, Hisings Backa (SE); **Christer ALM**, Goteborg (SE)

Correspondence Address:
NOVAK DRUCE & QUIGG, LLP
1300 EYE STREET NW
400 EAST TOWER
WASHINGTON, DC 20005 (US)

(73) Assignee: **VOLVO LASTVAGNAR AB**, Goteborg (SE)

(21) Appl. No.: **10/908,265**

(22) Filed: **May 4, 2005**

Related U.S. Application Data

(63) Continuation of application No. PCT/SE03/01621, filed on Oct. 20, 2003.

(30) **Foreign Application Priority Data**

Nov. 5, 2002 (SE) 0203250-6

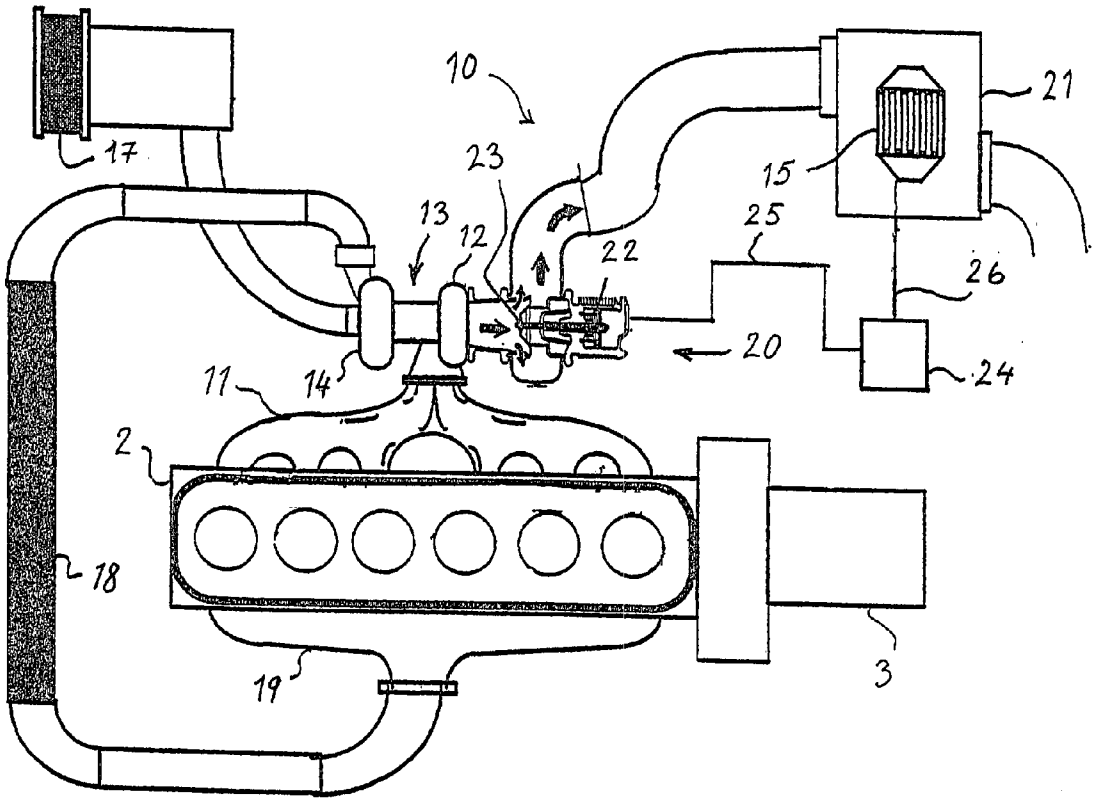
Publication Classification

(51) **Int. Cl.**
F01N 3/00 (2006.01)

(52) **U.S. Cl.** **60/295**; 60/286; 60/297

(57) **ABSTRACT**

Method and arrangement for regenerating a particle filter (**15**) arranged in thermal proximity to a catalyst unit (**16**) in an exhaust duct (**10**) connected to an internal combustion engine (**2**). The particle filter is located downstream of an adjustable exhaust pressure regulator (**20**) for regulating an exhaust flow through the exhaust duct. When the internal combustion engine is driven at low engine load, the exhaust pressure regulator (**20**) is activated with a predetermined regulating pressure. Fuel is then supplied to the exhaust duct (**10**) by means of an injection unit, the catalyst unit (**16**) being exposed to the fuel, which is oxidized, and the particle filter (**15**) being heated to such a temperature that soot particles are converted into carbon dioxide in reaction with oxygen contained in the exhaust flow.



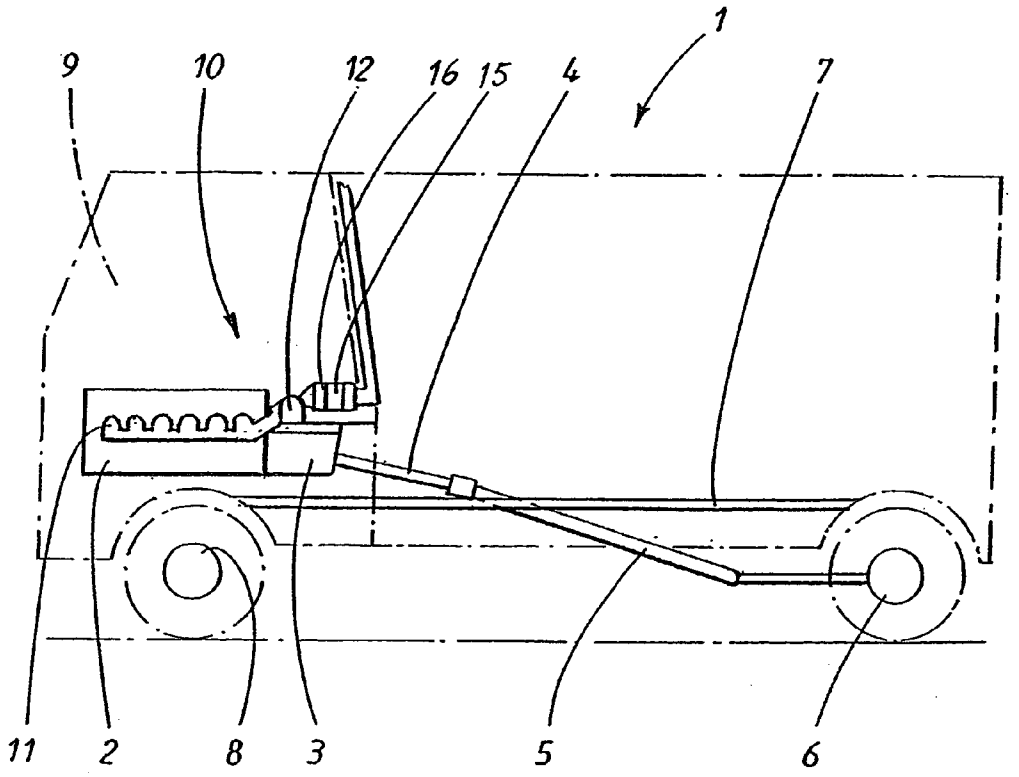
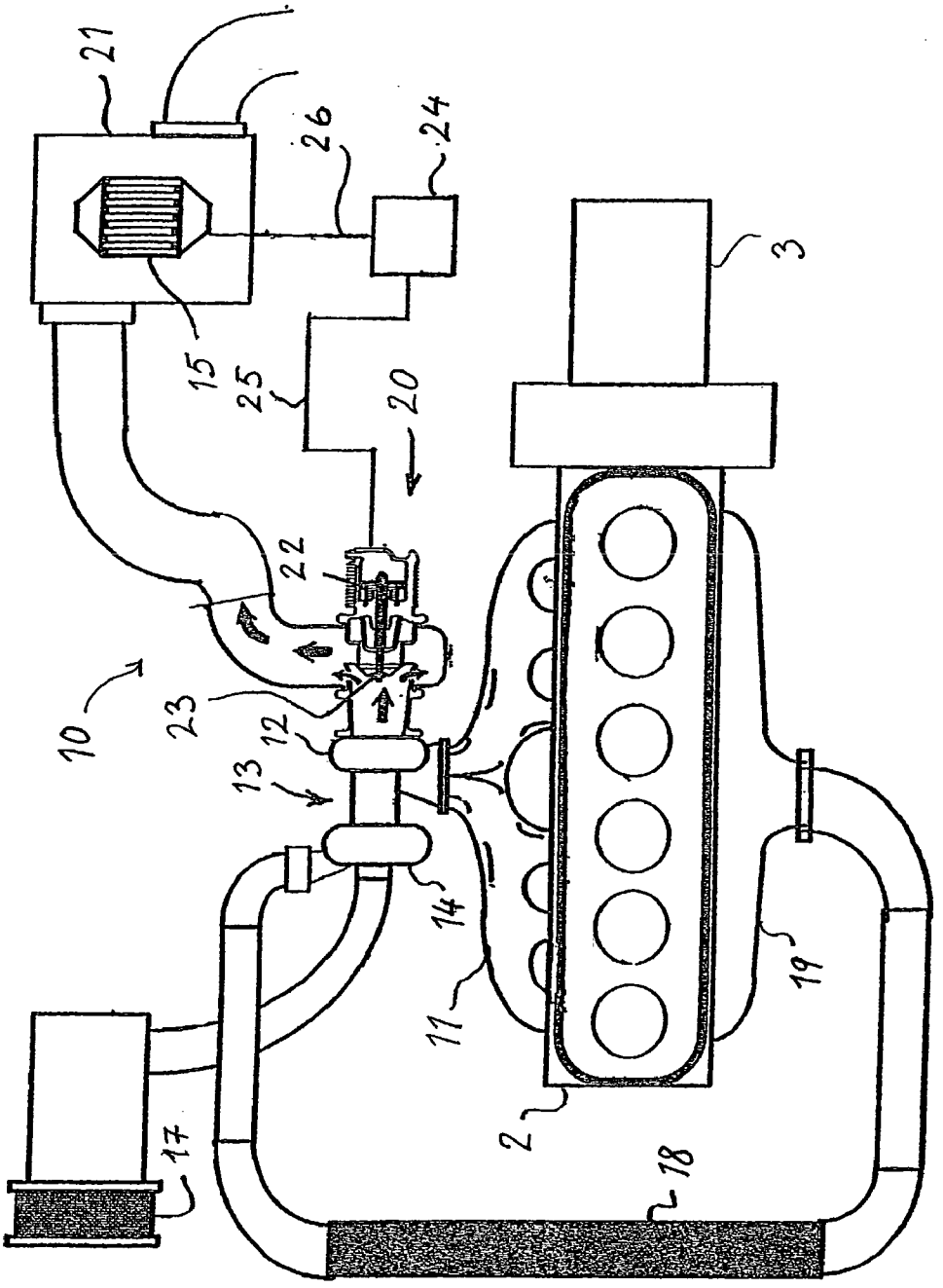


FIG. 1

FIG.2



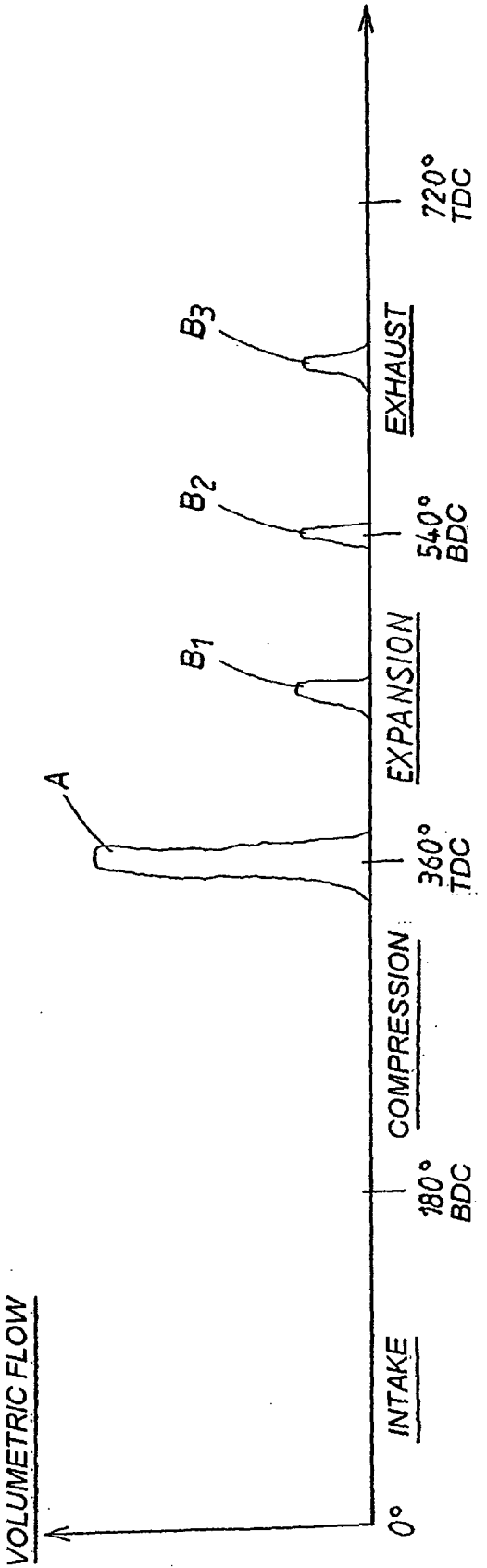

VOLUMETRIC FLOW
0°
INTAKE
180° BDC
COMPRESSION
360° TDC
EXPANSION
540° BDC
EXHAUST
720° TDC
A
B1
B2
B3

FIG. 3

METHOD FOR CLEANING A PARTICLE FILTER AND A VEHICLE FOR UTILIZING SAID METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation patent application of International Application No. PCT/SE2003/001621 filed 20 Oct. 2003 which was published in English pursuant to Article 21(2) of the Patent Cooperation Treaty, and which claims priority to Swedish Application No. 0203250-6 filed 5 Nov. 2002. Said applications are expressly incorporated herein by reference in their entireties.

TECHNICAL FIELD

[0002] The present invention relates to a method for regenerating a particle filter arranged in thermal proximity to a catalyst unit in an exhaust duct connected to an internal combustion engine, such as is often utilized to power a vehicle.

BACKGROUND OF INVENTION

[0003] In the combustion process in diesel engines, soot particles are also formed in addition to water vapor, nitrogen oxides and carbon dioxide. Small quantities of uncombusted hydrocarbons and carbon monoxide also occur. A diesel engine provided with a particle filter greatly reduces particle emissions. However, the particle filter has to be regenerated more or less continuously so that it does not become full and cause high pressure drops across the exhaust system. In order for the particle filter to self-regenerate automatically, an exhaust gas temperature of at least 250° C. and sulfur-poor fuel<30 ppm are necessary. When the diesel engine works at low load levels and/or low ambient temperatures, however, the exhaust gas temperature is usually lower than 250° C., which leads to soot accumulating in the particle filter. If such operating states are allowed to continue for a relatively long time, the soot build-up in the particle filter can reach a detrimental level. In this context, the expression detrimental level shall be taken to mean that if the operating state is subsequently changed and regeneration of the filter begins, there is an imminent risk of overheating with permanent damage to the filter as a consequence. Moreover, there is a risk that the magnitude of the exhaust back-pressure can threaten the functioning of the engine.

[0004] EP 341 832, for example, describes a system comprising a filter in which soot particles are caught. The soot particles are then combusted in a nitrogen dioxide environment. The nitrogen dioxide is formed from within the exhaust gases from nitrogen monoxide in an oxidation catalyst arranged upstream of the filter. One problem with the system described in EP 341 832 is that the capacity for converting the soot particles into carbon dioxide is low in operating conditions with low exhaust gas temperatures. In this connection, the regeneration of the particle filter requires too much time or, as the case may be, is inadequate, then the filter gradually becomes blocked with increased pressure drop as a consequence. This in turn results in the filter having to be serviced frequently.

SUMMARY OF THE INVENTION

[0005] One object of the invention is therefore to provide a method which makes possible effective regeneration of particle filters and is moreover easy to apply to internal combustion engines.

[0006] According to the inventive method, an injection unit assigned to the internal combustion engine supplies fuel to an exhaust system connected to the engine at times when the engine is driven with low engine load, an exhaust pressure regulator arranged in the exhaust system then being activated. A catalyst unit arranged in the exhaust duct in thermal proximity to the particle filter is exposed to the fuel supplied, which is oxidized. In this connection, the particle filter is heated to such a temperature that soot particles are converted into carbon dioxide in reaction with oxygen contained in said exhaust gases. The injection unit can consist of a separate unit which has an injector located in the exhaust duct, or of the existing injection system of the internal combustion engine.

[0007] The invention makes use of the fact that an exhaust pressure regulator can be used at low load in order to build up a back-pressure in the exhaust system which increases the temperature of the exhaust flow.

[0008] In a preferred embodiment, the fuel is supplied by means of injectors assigned to the combustion chambers of the engine. In this case, the fuel is supplied as indicated above, when the engine is driven at low load and the exhaust pressure regulator is activated, and at such a stage that fuel is allowed to pass through the combustion chamber into the exhaust duct in a non-combusted or only partly combusted state. This is achieved by supplying the fuel at a delayed crank angle position in relation to normal injection; that is to say, during the expansion or exhaust stroke.

[0009] The invention also relates to a vehicle in which the method described above is implemented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention will be described in greater detail with reference to accompanying drawing figures, in which:

[0011] FIG. **1** diagrammatically shows a vehicle comprising an internal combustion engine equipped with a particle filter which is regenerated by a method according to the present invention;

[0012] FIG. **2** diagrammatically shows, in greater detail, a turbocharged diesel engine with a particle filter according to the arrangement of FIG. **1**; and

[0013] FIG. **3** graphically shows the volumetric flow of injected fuel quantity during normal operation and at low engine load when regeneration takes place.

DETAILED DESCRIPTION

[0014] FIG. **1** shows a vehicle **1** equipped with an internal combustion engine **2** and a gearbox **3** coupled to the engine. The gearbox has an output driving shaft **4** which, via a propeller shaft **5**, drives at least one pair of driving wheels **6**. In a conventional way, the vehicle **1** is constructed around a frame **7** which is supported by the driving wheels **6**, and preferably a set of steerable wheels **8**. The vehicle preferably comprises (includes, but is not necessarily limited to) a cab **9**.

[0015] In a conventional way, the internal combustion engine is equipped with an exhaust system **10** which comprises an exhaust pipe **11** connected to the outlet ports of the engine. A turbine **12** is preferably arranged in the exhaust system **10** and forms part of a turbo unit **13** and is thus

mechanically coupled to a compressor **14** arranged on the intake side (not shown) of the engine.

[**0016**] There may also be a turbine mechanically coupled back to the driving shaft of the internal combustion engine in a turbo compound system.

[**0017**] The engine is of the diesel type, which means that soot particles are formed during the combustion process. The exhaust system is therefore equipped with a particle filter **15**. An oxidation catalyst **16** is arranged in thermal proximity to the particle filter. In the present context, thermal proximity shall be taken to mean that the reaction which takes place in the oxidation catalyst is capable of heating the particle filter. For this purpose, the oxidation catalyst is usually mounted upstream of and in direct proximity to the particle filter, but it is also conceivable to integrate the particle filter and the oxidation catalyst on a common bearing structure where catalyst material is spread over the filtering body.

[**0018**] The oxidation catalyst and the particle filter can preferably be designed as described in EP 341 832 or EP 835 684. Soot particles are caught in the particle filter **13**. Under favorable conditions, a continuous conversion of nitric oxide NO into nitrogen dioxide NO_2 takes place in the oxidation catalyst. Oxidation of the soot particles then takes place in a nitrogen dioxide environment, the soot particles being oxidized to form carbon dioxide in one, some or all of the processes $NO_2+C=>NO+CO$, $NO_2+C=>½N_2+CO_2$ or $2NO_2+C=>2NO+CO_2$.

[**0019**] On account of the relatively low content of NOx, and in particular NO_2, however, these processes are too slow in order completely to regenerate the filter at low temperatures and/or low load on the engine. Disruption of the NO_2 formation, for example on account of sulfur poisoning, also leads to impaired soot combustion.

[**0020**] The soot particles can also react directly with the excess oxygen O_2 present in diesel exhaust gases, but a prerequisite for this is that the temperature exceeds approximately 600° C. This reaction is several powers of ten faster than the reaction in which NO_2 reacts with the soot because the concentration of oxygen O_2 remaining in diesel exhaust gases is approximately three powers of ten greater than the concentrations of NO_2 are. If this temperature is used for regeneration of the soot filter, the whole regeneration can be limited to a few minutes.

[**0021**] FIG. **2** shows in greater detail the internal combustion engine **2** which is arranged for regeneration of a particle filter according to the invention. The internal combustion engine preferably forms part of a driving unit for a truck or a bus. The engine is advantageously of the directly injected diesel engine type in which a turbo unit **13** with an exhaust-driven turbine **12** and a compressor **14** arranged on the turbine shaft is used for compression and supply of combustion air. Intake air is supplied to the supercharger from an air filter **17** for compression, after which the compressed air is cooled as it passes through an intercooler **18** before it is supplied to the intake manifold **19** of the engine.

[**0022**] The exhaust gases of the engine are collected in a conventional way in an exhaust manifold **11** and are then conducted to the turbine **12** of the supercharger **13** for driving the compressor **14**. The exhaust gases are then conducted onward via an exhaust pressure regulator **20** to a muffler unit **21** with a particle filter **15**.

[**0023**] The exhaust pressure regulator **20** can be of a kind known per se and comprises a piston valve with a pneumatically controlled piston **22** and a valve disk **23** mounted at the opposite end of a rod. A regulating air pressure acts against the piston **22** via a compressed-air line (not shown) which is connected to a compressed-air system contained in the vehicle, which is used for generating power for auxiliary units in the vehicle.

[**0024**] A control unit **24**, suitably a microprocessor, is connected to the exhaust pressure regulator **20** via the compressed-air line **25** for controlling the regulating pressure depending on input data. Such input data is provided via, for example, a line **26** to the particle filter **15**. The exhaust pressure regulator can be activated by, for example, detection of the particle quantity in the particle filter **15** having reached a certain level. Alternatively, activation can take place on detection of the pressure drop in the particle filter having reached a certain level. Another variant is to detect whether the engine has worked at low load for a certain time. By means of the control unit **24**, the valve disk can therefore be set between fully open position and active position, where a given exhaust pressure is defined by the interaction of the valve with the gas flowing through.

[**0025**] The exhaust pressure regulator **20** can be activated to different degrees depending on how hot the exhaust gases are. In this connection, the exhaust gas temperature can be measured and the exhaust pressure regulator can be controlled until its desired temperature is obtained. Alternatively, the control unit of the engine can, with a known ambient temperature in combination with the current operating point, calculate the exhaust gas temperature and then control the exhaust pressure regulator until the desired exhaust gas temperature is obtained.

[**0026**] FIG. **3** shows diagrammatically the volumetric flow of injected fuel quantity during normal operation and at low engine load during regeneration. The regulation of injected fuel quantity and the angle position of the crankshaft when injection takes place are controlled by the control unit **24** in a manner well-known to the expert. An example of a control unit for vehicles is given in SAEJ1939/71,1996. The graph shows the volumetric flow as a function of the crankshaft angle position, which is indicated with the bottom and top dead centers of the piston as reference points. The four strokes of the internal combustion engine are indicated along the x axis, the intake stroke between 0° and 180°, the compression stroke between 180° and 360°, the expansion stroke between 360° and 540°, and the exhaust stroke between 540° and 720°.

[**0027**] Curve A shows the fuel quantity supplied for an operating case when the engine is working under normal load. Fuel is then supplied at the transition between the compression stroke and the expansion stroke with a duration of between 3 and 30 crank angle degrees.

[**0028**] The curves B_1-B_3 show the fuel quantity supplied under low engine load for regeneration of a particle filter arranged downstream of an oxidation catalyst in the exhaust duct. The fuel is preferably supplied during the expansion stroke or the exhaust stroke within a range covering 30° to 90° after top dead center between the compression stroke

and the expansion stroke. A wider range of 0° to 360° after top dead center between the compression stroke and the expansion stroke is possible; that is to say, during the expansion stroke and the exhaust stroke.

[0029] In illustrative embodiments B_1 and B_2, fuel is supplied between 30° and 180° after top dead center between the compression stroke and the expansion stroke.

[0030] In illustrative embodiment B_3, fuel is supplied 270° after top dead center.

[0031] The invention is not to be regarded as being limited to the illustrative embodiments described above, but a number of further variants and modifications are conceivable and that are within the scope of the patent claims below.

What is claimed is:

1. A method for regenerating a particle filter (**15**) arranged in thermal proximity to a catalyst unit (**16**) in an exhaust duct (**10**) connected to an internal combustion engine (**2**), said particle filter being located downstream of an adjustable exhaust pressure regulator (**20**) for regulating an exhaust flow through the exhaust duct, said method comprising:

establishing by means of a control unit (**24**) that the internal combustion engine is being driven at low engine load;

activating the exhaust pressure regulator (**20**) with a predetermined regulating pressure; and

supplying fuel to the exhaust duct (**10**) by means of an injection unit, the catalyst unit (**16**) being exposed to said fuel, which is oxidized, and the particle filter (**15**) being heated to a temperature at which soot particles are converted into carbon dioxide in reaction with oxygen contained in the exhaust flow.

2. The regenerating method as recited in claim 1, wherein said injection unit supplies fuel to a combustion chamber arranged in the internal combustion engine (**2**) at such a stage of the working cycle of the internal combustion engine that fuel is allowed to pass through the combustion chamber into the exhaust duct (**10**) in a non-combusted or partly combusted state, said non-combusted or partly combusted fuel being oxidized on contact with the catalyst unit (**16**) and the particle filter (**15**) being heated to such a temperature that soot particles are converted into carbon monoxide in reaction with oxygen contained in said exhaust flow.

3. The regenerating method as recited in claim 2, wherein said fuel is supplied during one of (**1**) the expansion stroke and (**2**) the exhaust stroke of the internal combustion engine.

4. The regenerating method as recited in claim 1, wherein fuel is supplied directly to the exhaust duct (**10**) via an injection unit assigned to the exhaust duct.

5. The regenerating method as recited in claim 1, wherein fuel is supplied when the exhaust gas temperature at the particle filter (**15**), under low load and with the exhaust pressure regulator activated, is at least 250° C.

6. A vehicle (**1**) comprising:

an internal combustion engine (**2**) and a particle filter (**15**) in thermal proximity to a catalyst unit (**16**) in an exhaust duct (**10**) connected to the internal combustion engine, the particle filter being located downstream of an adjustable exhaust pressure regulator (**20**) for regulating an exhaust flow through the exhaust duct; and

an injection system configured so that when regeneration of the particle filter (**15**) is necessary, fuel is supplied to the exhaust duct (**10**) with simultaneous activation of the exhaust pressure regulator (**20**), the catalyst unit (**16**) is exposed to the fuel which is oxidized, and the particle filter is heated to such a temperature that soot particles are converted into carbon dioxide in reaction with oxygen contained in said exhaust flow.

7. The vehicle as recited in claim 6, wherein the injection system is configured to supply fuel to combustion chambers arranged in the internal combustion engine (**2**) at such a stage of the working cycle of the internal combustion engine that fuel is allowed to pass through the combustion chamber into the exhaust duct (**10**) in a non-combusted or partly combusted state.

8. The vehicle as recited in claim 7, wherein said injection system is configured to supply fuel during one of (**1**) the expansion stroke and (**2**) the exhaust stroke of the internal combustion engine.

9. The vehicle as recited in claim 6, wherein the vehicle further comprises an injection unit assigned to the exhaust duct (**10**), said injection unit being arranged to supply fuel directly to the exhaust duct.

10. The vehicle as recited in claim 6, wherein the exhaust pressure regulator (**20**) comprises a pneumatically operated piston (**22**) that is connected to a valve disk (**23**) which, when moved in the direction of a seat, forms a throttle for the exhaust flow of the engine.

* * * * *