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(54) **EXHAUST VALVE ACTUATION SYSTEM FOR DIESEL PARTICULATE FILTER REGENERATION**

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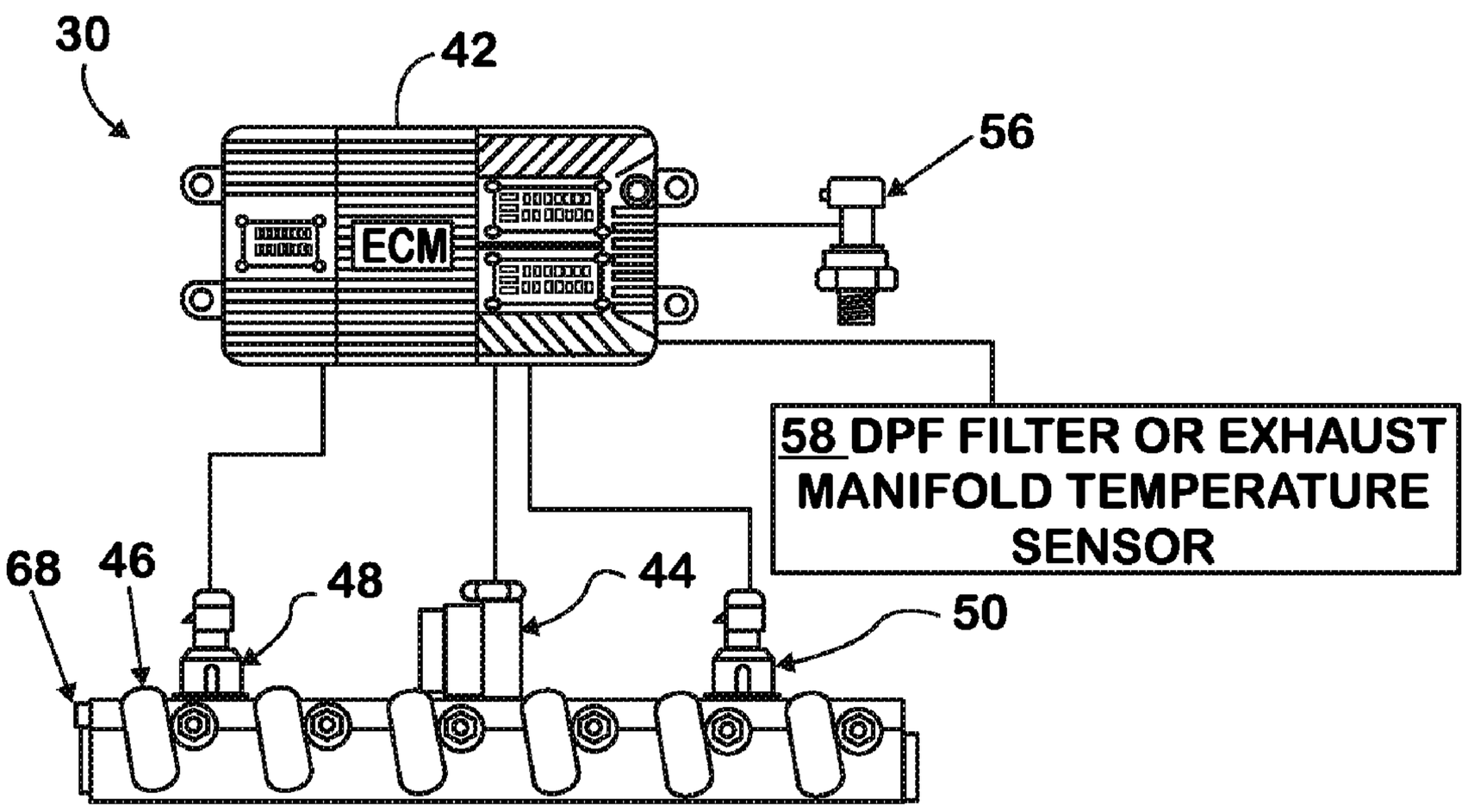
(57) **ABSTRACT**

An exhaust valve actuation system (**30**) for initiating a regeneration event at a diesel particulate filter (**24**) includes an engine control module (**42**) associated with an engine (**14**). A plurality of exhaust valves (**32**) correspond to a plurality of engine cylinders (C**1**-C**6**). When either a predetermined amount of back pressure or a predetermined temperature, or both, are communicated to the engine control module (**42**), the engine control module actuates at least one exhaust valve (**32**) to open. Gas or gas-fuel mixture is compressed and heated inside of the cylinder (C**1**) corresponding to the opened exhaust valve (**32**). At least one exhaust valve (**32**) is not opened by the engine control module (**42**), which permits combustion inside the corresponding cylinder (C**2**).



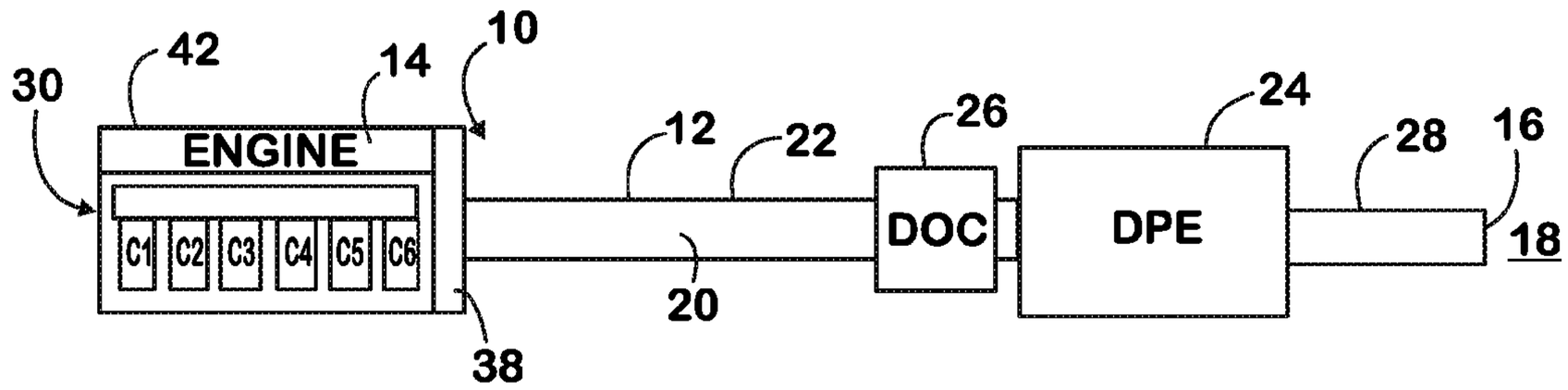

30
42
14
10
ENGINE
C1
C2
C3
C4
C5
C6
12
22
26
24
28
16
DOC
DPE
18
20
38

FIG. 1

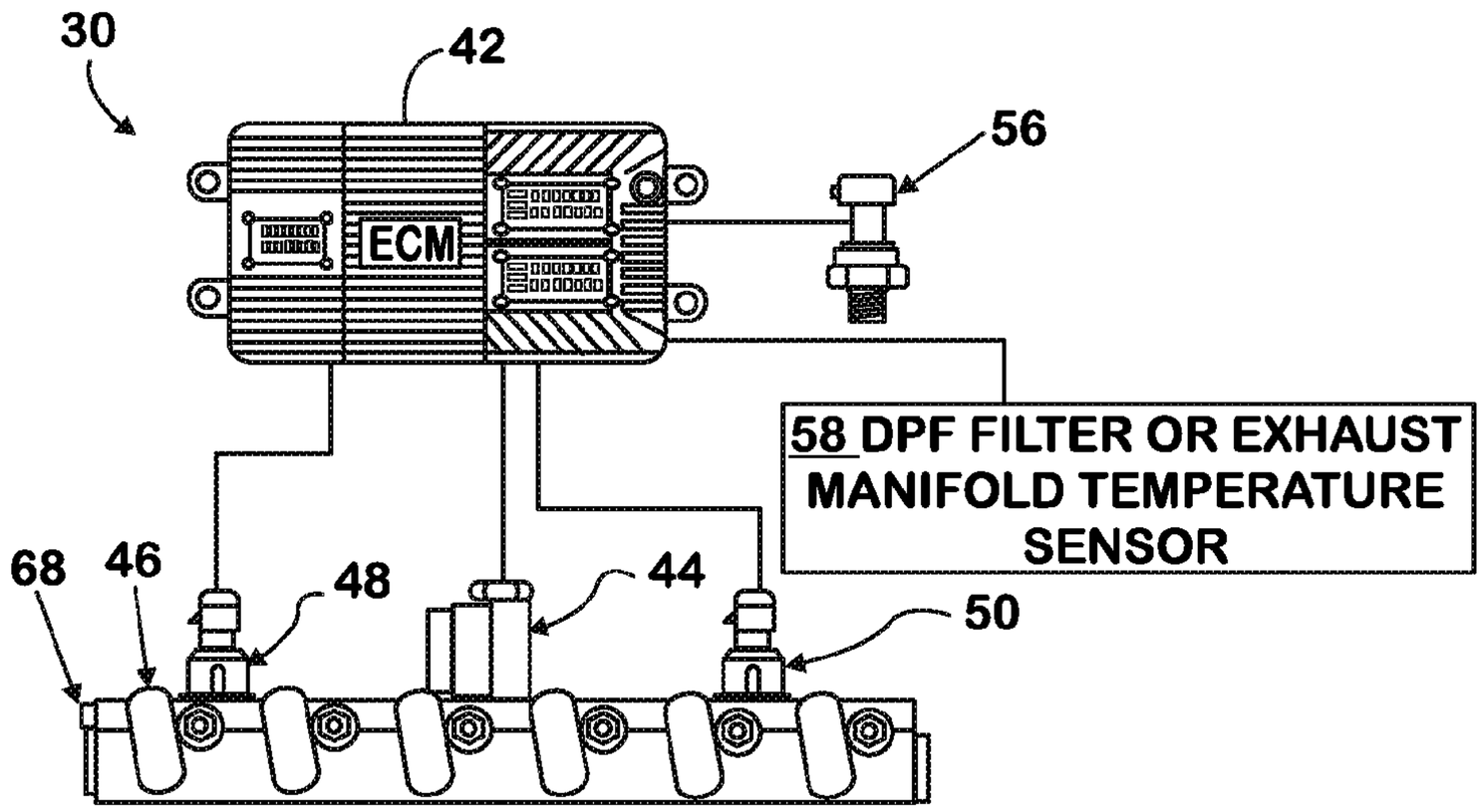

30
42
56
ECM
58 DPF FILTER OR EXHAUST MANIFOLD TEMPERATURE SENSOR
68
46
48
44
50

FIG. 2

FIG. 3A

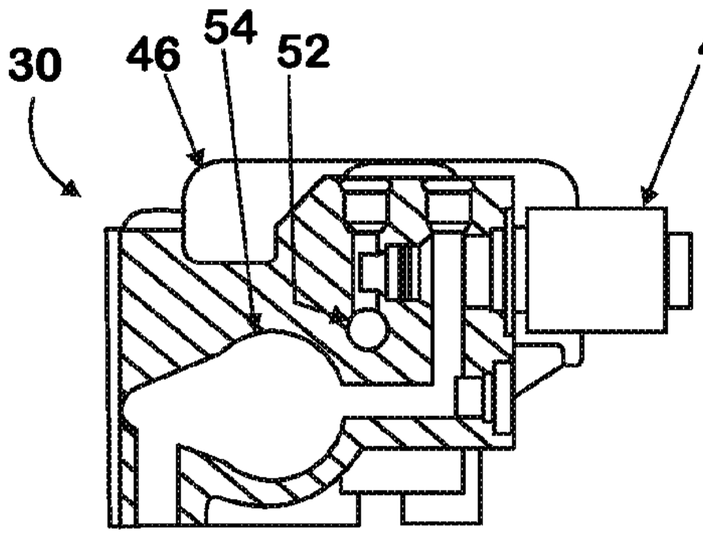


FIG. 3B

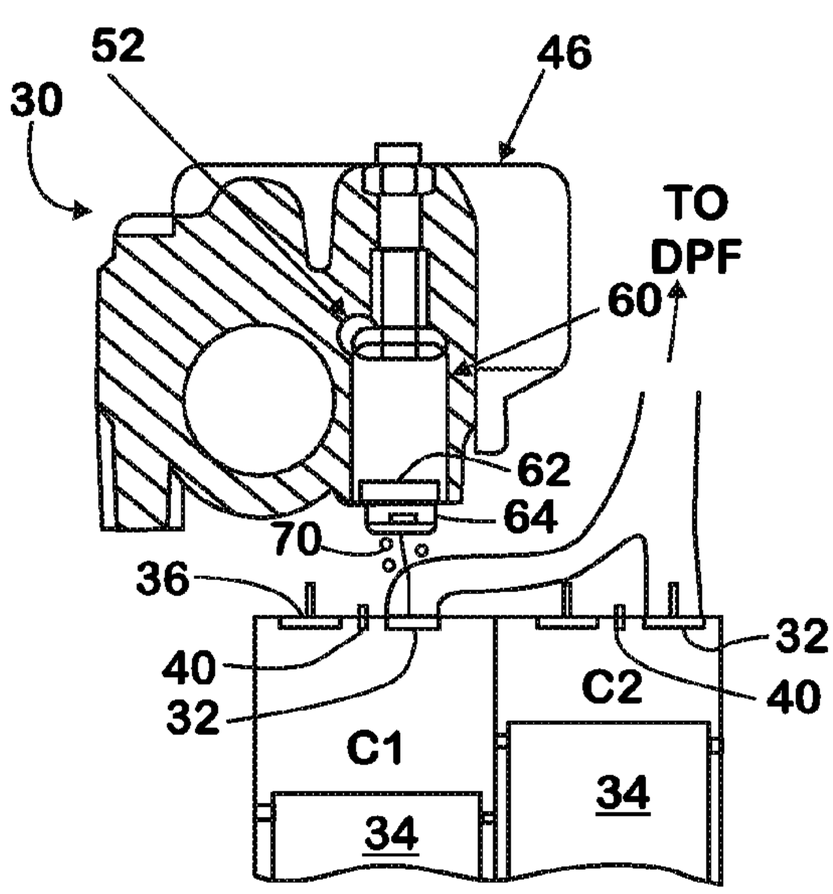


FIG. 4A

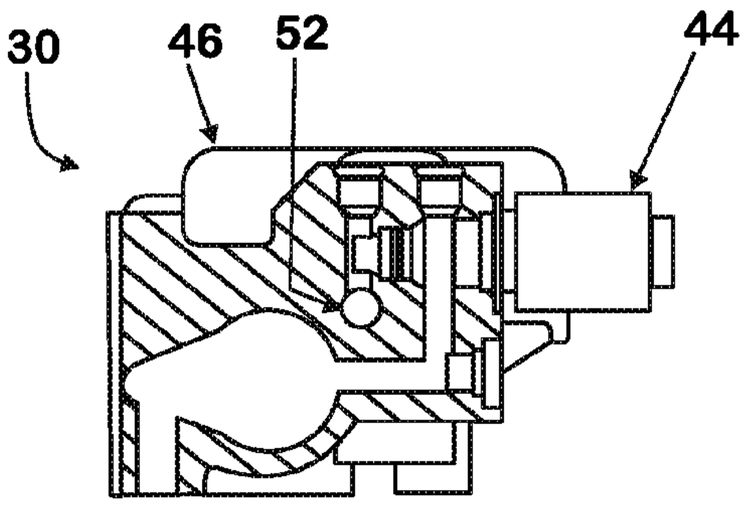
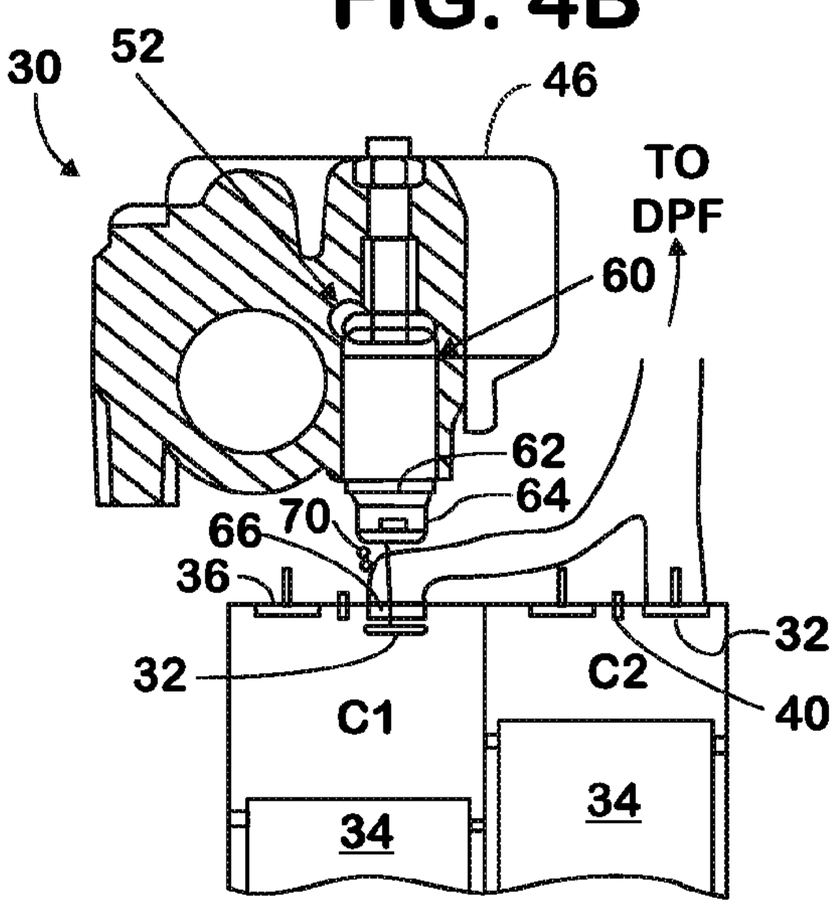


FIG. 4B



EXHAUST VALVE ACTUATION SYSTEM FOR DIESEL PARTICULATE FILTER REGENERATION

BACKGROUND

[0001] Embodiments described herein relate to a system and method for heating exhaust gas. More specifically, embodiments described herein relate to a system and method for heating exhaust gas to create a regeneration event at a diesel particulate filter.

[0002] Exhaust gas aftertreatment systems in diesel vehicles are located downstream of the engine for treating exhaust gases emitted from the engine. The aftertreatment systems typically include a diesel oxidation catalyst (DOC), and a diesel particulate filter (DPF). Particulate matter from the exhaust gas accumulates on the diesel particulate filter, and if left unchecked, can create a back pressure in the aftertreatment system and the diesel engine. Without a regeneration event, the DPF can become plugged with soot and the engine may not operate properly.

[0003] The regeneration event is the periodic oxidation of the collected particulate matter in the aftertreatment system during routine diesel engine operation. When the diesel particulate filter of the exhaust system experiences a build-up of particulate matter, the particulate matter is oxidized to "regenerate" the filter. Regeneration is typically initiated by increasing engine load and activating a post-injection of diesel fuel into the exhaust stream. The combination of the increased engine load and the post-injection provides sufficient heat to oxidize the trapped particulate matter within the diesel particulate filter.

[0004] During idling or part load operation conditions, fuel injected into the combustion cycle is not enough to maintain exhaust gas temperature sufficient to start the DPF regeneration cycle. As such, the loading of the engine must be increased to provide a sufficiently heated exhaust gas to initiate the regeneration downstream at the diesel particulate filter. However many vehicles operate on a "stop and drive" or frequent idling basis, and the resulting exhaust gas may not have a sufficiently high temperature to initiate the regeneration.

SUMMARY

[0005] An exhaust valve actuation system for initiating a regeneration event at a diesel particulate filter includes an engine control module associated with an engine. A plurality of exhaust valves correspond to a plurality of engine cylinders. When either a predetermined amount of back pressure or a predetermined temperature, or both, are communicated to the engine control module, the engine control module actuates at least one exhaust valve to open. Gas is compressed and heated inside of the cylinder corresponding to the opened exhaust valve. At least one exhaust valve is not opened by the engine control module, which permits combustion inside the corresponding cylinder.

[0006] A method of regenerating an exhaust aftertreatment system of an engine includes the steps of providing a fluid passageway from the engine to a diesel particulate filter. The method also includes the steps of sensing and communicating a back pressure of the aftertreatment system or a temperature of the aftertreatment system, or both, to an engine control module. The engine control module compares the back pressure or the temperature, or both, to a predetermined back pressure or temperature, or both. On the basis of the comparison, the engine control module actuates at least one exhaust valve of a cylinder, and the exhaust valve is opened to compress gas inside of the cylinder. The heated compressed gas from the cylinder is fluidly communicated to the diesel particulate filter. Not all of the exhaust valves are opened by the engine control module so that combustion can continue to occur at the remaining cylinders. The heated exhaust gas from the remaining cylinders is also fluidly communicated to the diesel particulate filter.

[0007] An exhaust valve actuation system for initiating a regeneration event at a diesel particulate filter includes an engine control module associated with an engine. The system also includes either a temperature sensor for sensing the temperature at the aftertreatment system, or a back pressure sensor for sensing the pressure at the aftertreatment system, or both. The temperature or the back pressure, or both, are communicated to the engine control module. A plurality of exhaust valves correspond to a plurality of cylinders in the engine. A high pressure oil manifold is associated with the engine and has a shut-off valve that selectively prevents oil from an injector oil gallery from flowing to an exhaust valve gallery. When either a predetermined amount of back pressure or a predetermined temperature, or both, are communicated to the engine control module, the engine control module deactivates the shut-off valve. Deactivation of the shut-off valve permits oil from the injector oil gallery to flow to the exhaust valve gallery to open an exhaust valve. At least one of the exhaust valves is not opened by the engine control module to permit combustion inside the corresponding cylinder.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic of an engine having an exhaust aftertreatment system with a diesel particulate filter located downstream of the engine.

[0009] FIG. **2** is a schematic of an exhaust valve actuation system for providing heated gases from the engine.

[0010] FIG. **3**A is a section view of a high pressure oil manifold of the exhaust valve actuation system when the system is not actuated.

[0011] FIG. **3**B is a transverse section view of the high pressure oil manifold of the exhaust valve actuation system when the system is not actuated.

[0012] FIG. **4**A is a section view of the high pressure oil manifold of the exhaust valve actuation system when the system is actuated.

[0013] FIG. **4**B is a transverse section view of the high pressure oil manifold of the exhaust valve actuation system when the system is actuated.

DETAILED DESCRIPTION

[0014] Referring to FIG. **1**, an exhaust gas aftertreatment system for a vehicle is indicated generally at **10**, and has an exhaust pipe assembly **12** extending from an engine **14** to an outlet **16**, such as the outlet to an ambient **18**. The exhaust pipe assembly **12** forms a fluid passageway **20** for the flow of exhaust gas F from the engine **14** to the ambient **18**.

[0015] A first portion **22** of the exhaust pipe assembly **12** extends from the engine **14** to a diesel particulate filter (DPF) **24**. The DPF **24** is a filter constructed from a very high temperature resistant material. The DPF **24** catches and holds particulate matter entrained within the exhaust gases discharged into the exhaust aftertreatment system **10**. The DPF

24 is periodically regenerated to limit increases in exhaust aftertreatment system **10** back pressure and to maintain engine **14** efficiency. A diesel oxidation catalyst (DOC) **26** may be located upstream of the DPF **24**. A second portion **28** of the exhaust pipe **12** assembly extends from the DPF **24** to the outlet **16**. Other components may be disposed on the on the aftertreatment system **10**.

[0016] Referring now to FIGS. **1**-**4**B, an exhaust valve actuation system **30** deactivates at least one cylinder C**1** of the engine **14** from fuel injection and combustion. The cylinder C**1** is deactivated by opening an exhaust valve **32** corresponding to the deactivated cylinder, and using compressive forces to heat up the gas in the deactivated cylinder.

[0017] In the deactivated cylinder C**1**, a cylinder piston **34** compresses the air received by an air intake **36**, which increases the temperature of the air. The heated air is released or bled from the cylinder C**1** through the partially opened exhaust valve **32** to an exhaust manifold **38** and on to the DPF **24**. The high pressure formed by compression in the cylinder C**1** is also a braking force that tends to resist the rotation of the crankshaft (not shown) of the engine **14**.

[0018] While the engine **14** of FIG. **1** has six cylinders C**1**-C**6**, it is possible that the exhaust valve actuation system **30** can be used on any engine with at least two cylinders. Further, while the exhaust valve actuation system **30** deactivates at least one cylinder C**1**, the system may deactivate an equal number of cylinders as the number of activated cylinders, or alternately, an unequal number of cylinders. The exhaust valve actuation system **30** described below opens the exhaust valves **32** on a plurality of the cylinders C**1**, C**3**, C**5** in the engine **14**.

[0019] At least one cylinder C**2** is not deactivated by the exhaust valve actuation system **30**. The remaining cylinders C**2**, C**4**, C**6** that remain activated continue to receive injected fuel at a fuel injector **40** and combust the fuel to maintain the engine speed. To compensate for the deactivated cylinders C**1**, C**3**, C**5** that are not combusting fuel, and to overcome the resistance of the deactivated cylinders on the crankshaft of the engine **14**, the activated cylinders C**2**, C**4**, C**6** may receive an increased amount of fuel at the fuel injector **40**. The resulting exhaust gas from the activated cylinders C**2**, C**4**, C**6** has an increased temperature.

[0020] The combination of the heated, compressed gas from the deactivated cylinders C**1**, C**3**, C**5**, and the heated exhaust gas from the activated cylinders C**2**, C**4**, C**6**, provides sufficient heat to the exhaust gas to initiate regeneration at the DPF **24**. With the exhaust valve actuation system **30**, the engine **14** provides the heated, compressed gas from the deactivated cylinders C**1**, C**3**, C**5**, and the heated exhaust gas from the activated cylinders C**2**, C**4**, C**6** while the engine **14** operates at a low idling and low engine load condition.

[0021] The exhaust valve actuation system **30** includes an engine control module (ECM) **42** that controls an exhaust shut-off valve **44** mounted on a high pressure manifold **46**. A brake control pressure sensor **48** and an injection pressure sensor **50** may be disposed on the high pressure manifold **38** to monitor and communicate the oil pressure in an exhaust valve gallery **52**, and the oil pressure in an injector oil gallery **54** of the high pressure manifold, respectively, to the ECM **42**.

[0022] An exhaust back pressure sensor **56** monitors and communicates the back pressure in the aftertreatment system **10**, such as at the exhaust manifold **38** or the DPF **24**, and communicates the back pressure to the ECM **42**. It is possible that the back pressure can be a change in pressure between two locations on the aftertreatment system **10**, such as upstream and downstream of the DPF **24**.

[0023] A temperature sensor **58** senses the temperature at the DPF **24**, the exhaust manifold **38**, or anywhere between the cylinders C**1**-C**6** and the DPF, and communicates the temperature to the ECM **42**. It is possible that the temperature can be a change in temperature between two locations on the aftertreatment system **10**, such as upstream and downstream of the DPF **24**.

[0024] The ECM **42** has predetermined back pressure values, exhaust valve gallery pressure values, injector oil gallery pressure values, and temperature values that are compared with the values communicated to the ECM by the sensors **48**, **50**, **56**, **58**. Below the predetermined temperature value of aftertreatment system **10** at the sensor **58**, or above the predetermined pressure value of back pressure in the aftertreatment system **10** at the sensor **56**, the DPF **24** may be clogged with soot or other particulate matter, and the exhaust valve actuation system **30** may be actuated.

[0025] Referring to FIGS. **2** and **3**A-**3**B, during normal operation of the engine **14**, oil in the high pressure manifold **46** flows to the fuel injector oil gallery **54**, but the exhaust shut-off valve **44** selectively prevents the oil from entering the exhaust valve gallery **52**. During normal operation, all cylinders C**1**-C**6** receive fuel from the fuel injector **40** and are actuated for combustion.

[0026] When a predetermined amount of exhaust back pressure is monitored by the exhaust back pressure sensor **56**, or when a predetermined temperature is monitored by the temperature sensor **58**, the values are communicated to the ECM **42** and the ECM **42** commands the actuation of the exhaust valve system **30**. The ECM **42** actuates the exhaust valve system **30** by deactivating the shut-off valve **44**, which permits the flow of oil to the exhaust valve gallery **52**.

[0027] Referring now to FIG. **4**A-**4**B, when the exhaust valve actuation system **30** is actuated, at least one of the cylinders C**1** is deactivated using high pressure oil to force the exhaust valve **32** at least partially open. The shut-off valve **44** is deactivated, which permits oil from the injector oil gallery **54** to flow to the exhaust valve gallery **52**, which in turn, permits oil to be distributed to a piston assembly **60** that corresponds to the cylinder C**1** (or cylinders C**1**, C**3**, C**5**) to be deactivated. The oil in the piston assembly **60** causes a piston **62** to displace from a retracted position (FIG. **3**B) to a deployed position (FIG. **4**B), which displaces an exhaust valve bridge **64**. Displacement of the exhaust valve bridge **64** forms an opening **66** between the exhaust valve seat and an exhaust valve **32** of the engine cylinder C**1**.

[0028] With the exhaust valve **32** opened, the heated compressed air flows out of the opening **66**, to the exhaust manifold **38** and is fluidly communicated to the DPF **24**. At the exhaust manifold **38**, the heated compressed air from the deactivated cylinders C**1**, C**3**, C**5** is combined with the heated exhaust gas from the activated cylinders C**2**, C**4**, C**6**, and gases from both sources are fluidly communicated to the DPF **24**.

[0029] Simultaneously or in quick succession with opening of the exhaust valve **32**, the ECM **42** de-activates the injectors **40** of the de-activated cylinders to prevent fuel injection in the de-activated cylinders C**1**, C**3**, C**5**. However, the injectors **40** in the activated cylinders C**2**, C**4**, C**6** remain activated.

[0030] It is possible that in the deactivated cylinders C**1**, C**3**, C**5**, even though there is no combustion at these cylinders during exhaust valve system actuation, that the fuel injectors

40 can inject fuel to be fluidly communicated downstream through the exhaust manifold **38** and to the DPF **24**. The fuel may be combusted at the DOC **26** or upstream of the DOC, resulting in additional heat at the DPF for regeneration.

[0031] After regeneration occurs, as indicated by the exhaust back pressure sensor **56** to the ECM **42** that the back pressure is below the predetermined value, the ECM turns off the exhaust valve actuation system **30**. When the exhaust valve actuation system **30** is turned off, a pressure relief valve **68** (FIG. **2**) is opened and the shut-off valve **44** is activated, preventing the oil from the injector oil gallery **54** from entering the exhaust valve gallery **52**. Oil in the exhaust valve gallery **52** drains to a sump (not shown), and the exhaust valve **32** is retracted to the retracted position (FIG. **3**B) under force of at least one spring **70**. Normal fuel injection resumes in the formerly deactivated cylinder C**1**, which again becomes an activated cylinder for combustion.

[0032] The aftertreatment system **10** allows the regeneration of the DPF **24** without significantly increasing the engine speed or loading. With the aftertreatment system **10**, the vehicle can run on a "stop and drive" basis, where the engine **14** can be run at a lower speed and lower loading, while at the same time, providing exhaust gas flow F with a sufficiently high temperature to initiate the regeneration at the DPF **24**.

What is claimed is:

1) An exhaust valve actuation system of an engine having a plurality of cylinders for initiating a regeneration event at a diesel particulate filter of an exhaust aftertreatment system, the exhaust valve actuation system comprising:

an engine control module associated with the engine;

a plurality of exhaust valves corresponding to the plurality of engine cylinders;

wherein when at least one of a predetermined amount of back pressure and a predetermined temperature is communicated to the engine control module, the engine control module actuates at least one of the plurality of exhaust valves to open to permit the compression of gas or gas-fuel mixture inside the corresponding cylinder, and wherein at least one of the plurality of exhaust valves is not actuated to open to permit combustion inside the corresponding cylinder.

2) The exhaust valve actuation system of claim **1** wherein the exhaust valves are opened using high pressure oil from a high pressure oil manifold associated with the engine.

3) The exhaust valve actuation system of claim **2** wherein the high pressure oil manifold has an injection oil gallery and an exhaust valve gallery.

4) The exhaust valve actuation system of claim **3** further comprising a shut-off valve operable to selectively prevent and allow the fluid communication of oil from the injection oil gallery to the exhaust valve gallery.

5) The exhaust valve actuation system of claim **4** wherein when oil is communicated to the exhaust valve gallery, a piston is displaced from a retracted position to an extended position.

6) The exhaust valve actuation system of claim **5** wherein displacement of the piston to the extended position opens the exhaust valve.

7) The exhaust valve actuation system of claim **1** wherein the cylinder corresponding to the at least one open exhaust valve compresses gas or gas-fuel mixture resulting in heated, compressed gas or gas-fuel mixture, and the heated, compressed gas or gas-fuel mixture is fluidly communicated out of the exhaust valve to the diesel particulate filter.

8) The exhaust valve actuation system of claim **1** wherein the cylinder corresponding to the at least one of the plurality of exhaust valves that is not open receives an increased amount of fuel resulting in heated exhaust gas, and the heated exhaust gas is fluidly communicated out of the exhaust valve to the diesel particulate filter.

9) The exhaust valve actuation system of claim **1** wherein when the engine control module does not open the at least one exhaust valve, the corresponding cylinder is used for combustion.

10) The exhaust valve actuation system of claim **1** further comprising at least one of a temperature sensor for sensing the temperature at the aftertreatment system and a back pressure sensor for sensing the pressure at the aftertreatment system, wherein at least one of the temperature sensor and the back pressure sensor communicate at least one of the temperature and the back pressure to the engine control module.

11) A method of regenerating an exhaust aftertreatment system of an engine having a diesel particulate filter, the method comprising:

providing a fluid passageway from the engine to the diesel particulate filter;

sensing and communicating at least one of a back pressure of the aftertreatment system and a temperature of the aftertreatment system to an engine control module, and comparing at least one of the back pressure and the temperature to a predetermined back pressure and a predetermined temperature, wherein on the basis of the comparison, the engine control module actuates at least one exhaust valve of a cylinder;

opening the at least one exhaust valve to compress gas or gas-fuel mixture inside of the cylinder in response to the command of the engine control module, wherein not all exhaust valves are opened by the engine control module so that combustion can continue to occur at the remaining cylinders;

fluidly communicating the compressed, heated gas or gas-fuel mixture from the cylinder corresponding to the opened exhaust valve to the diesel particulate filter to initiate regeneration; and

fluidly communicating the combusted exhaust gases from the remaining cylinders to the diesel particulate filter to initiate regeneration.

12) The method of claim **11** further comprising the step of the engine control module deactivating a shut-off valve and permitting oil from an injector oil gallery to flow to the exhaust valve gallery.

13) The method of claim **12** further comprising the step of permitting oil to be distributed to a piston assembly that corresponds to the cylinder having the exhaust valve to be opened.

14) The method of claim **13** further comprising the step of displacing a piston of the piston assembly from a retracted position to a deployed position under oil pressure.

15) The method of claim **11** further comprising the step of injecting an increased amount of fuel into the remaining cylinders for combustion.

16) The method of claim **11** further comprising the step of opening the exhaust valve on three cylinders, and not opening the exhaust valve on three cylinders.

17) The method of claim **11** further comprising the step of injecting fuel into the cylinder corresponding to opened exhaust valve, and fluidly communicating the injected fuel to the aftertreatment system.

18) An exhaust valve actuation system of an engine having a plurality of cylinders for initiating a regeneration event at a diesel particulate filter of an exhaust aftertreatment system, the exhaust valve actuation system comprising:

an engine control module associated with the engine;

at least one of a temperature sensor for sensing the temperature at the aftertreatment system and a back pressure sensor for sensing the pressure at the aftertreatment system, wherein at least one of the temperature sensor and the back pressure sensor communicate at least one of the temperature and the back pressure to the engine control module;

a plurality of exhaust valves corresponding to the plurality of cylinders in the engine;

a high pressure oil manifold associated with the engine and having a shut-off valve selectively preventing oil from an injector oil gallery from flowing to an exhaust valve gallery;

wherein when at least one of a predetermined amount of back pressure and a predetermined temperature is communicated to the engine control module, the engine control module deactivates the shut-off valve, permitting oil from the injector oil gallery to flow to the exhaust valve gallery to open at least one exhaust valve, wherein at least one of the plurality of exhaust valves is not actuated to open by the engine control module to permit combustion inside the corresponding cylinder.

19) The exhaust valve actuation system of claim **18** wherein the oil in the exhaust valve gallery displaces a piston from a retracted position to an extended position.

20) The exhaust valve actuation system of claim **19** wherein the displacement of the piston to the extended position opens the exhaust valve.

* * * * *