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(54) Abstract Title: **An emission control apparatus for an engine**

(57) An emission control apparatus is disclosed in which a three way catalyst 14 and a lean NOx trap 15 are mounted in a single housing 22. An exhaust gas cooler 13 may be positioned upstream from the lean NOx trap 15 to reduce the temperature of the exhaust gases passing through the lean NOx trap 15 and allow it to be positioned close to an outlet 11 from an engine 10.

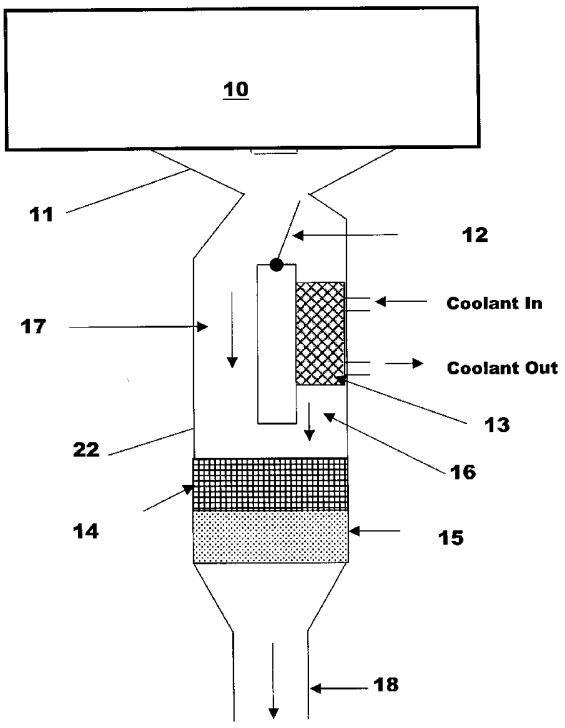

Fig.1

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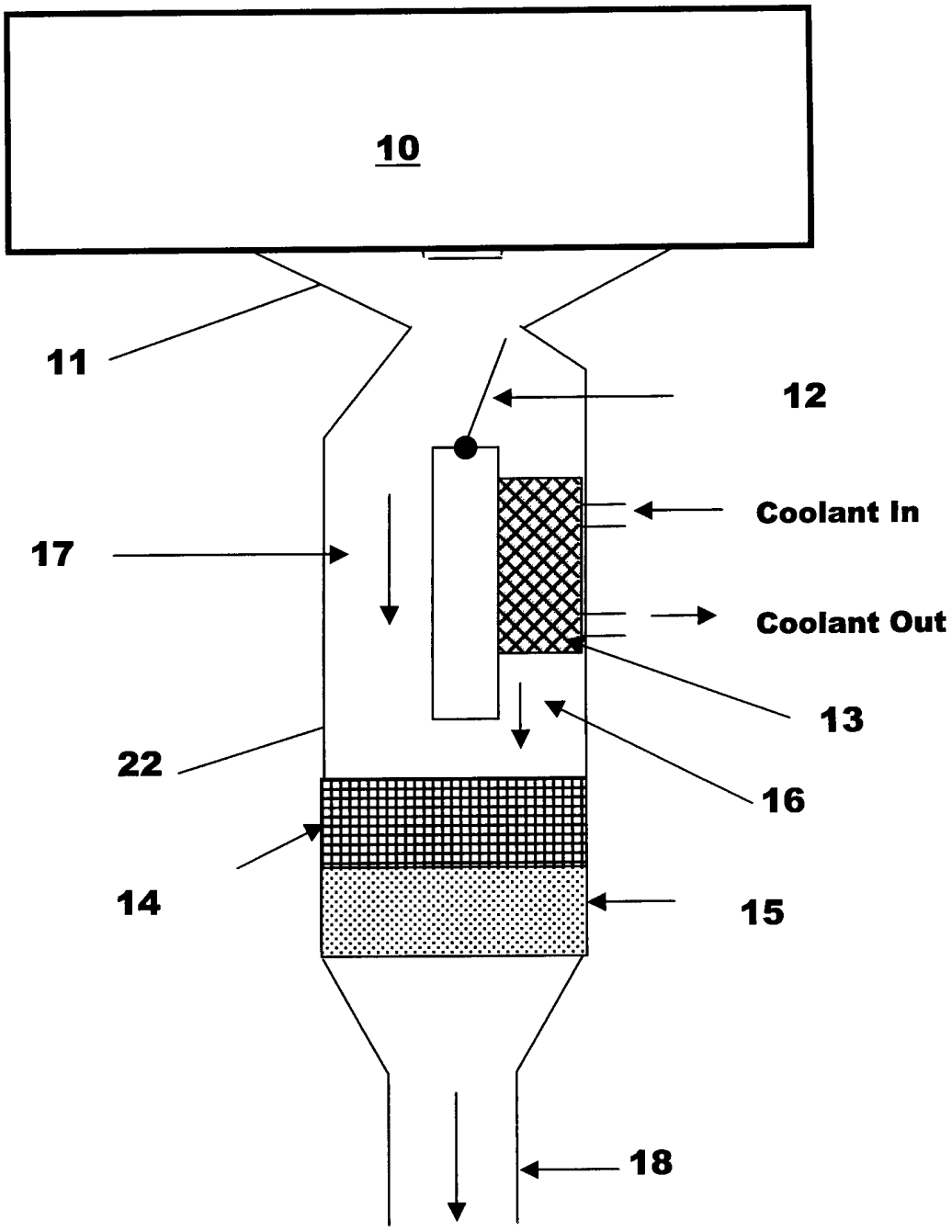

Fig.1

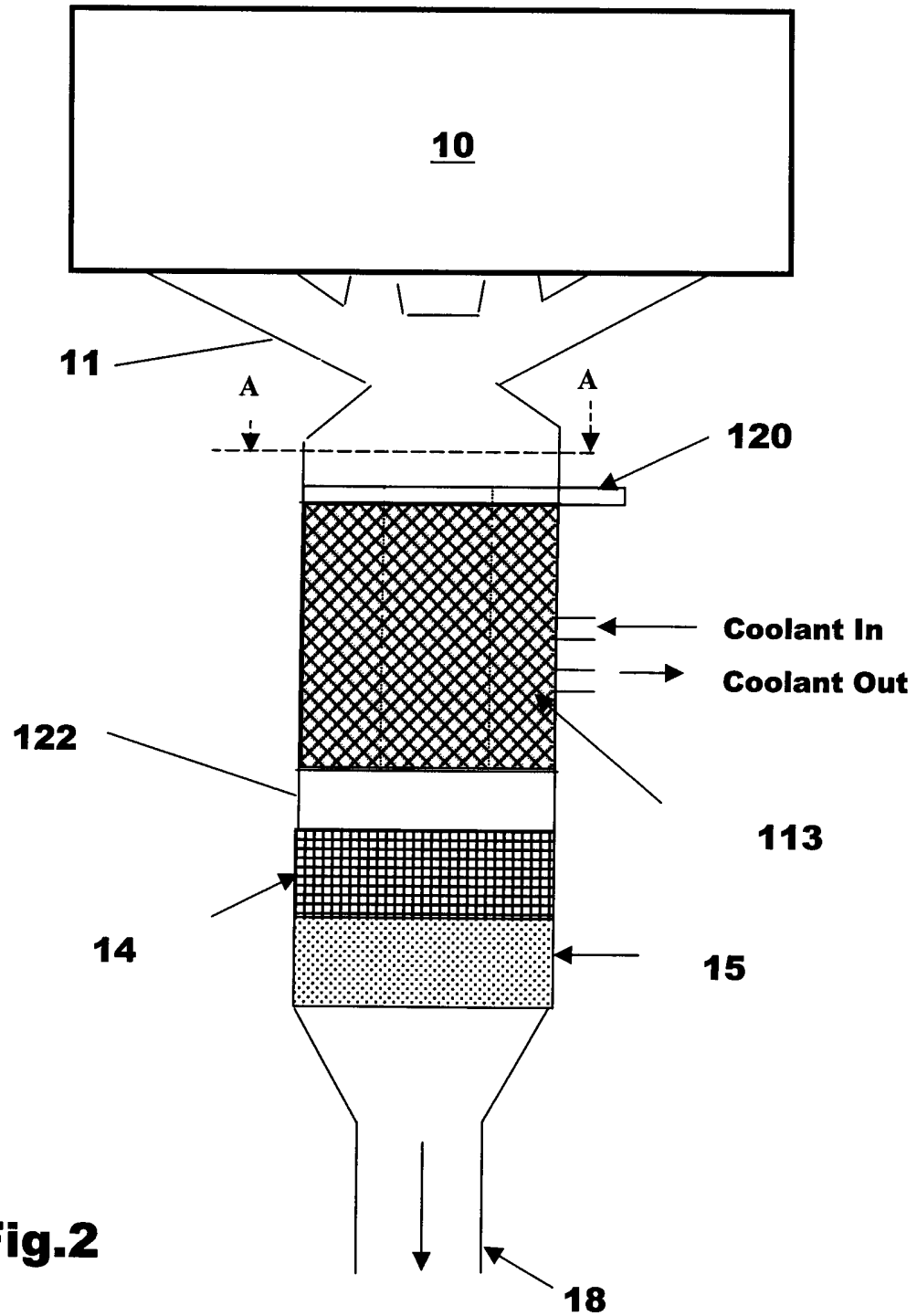

Fig.2

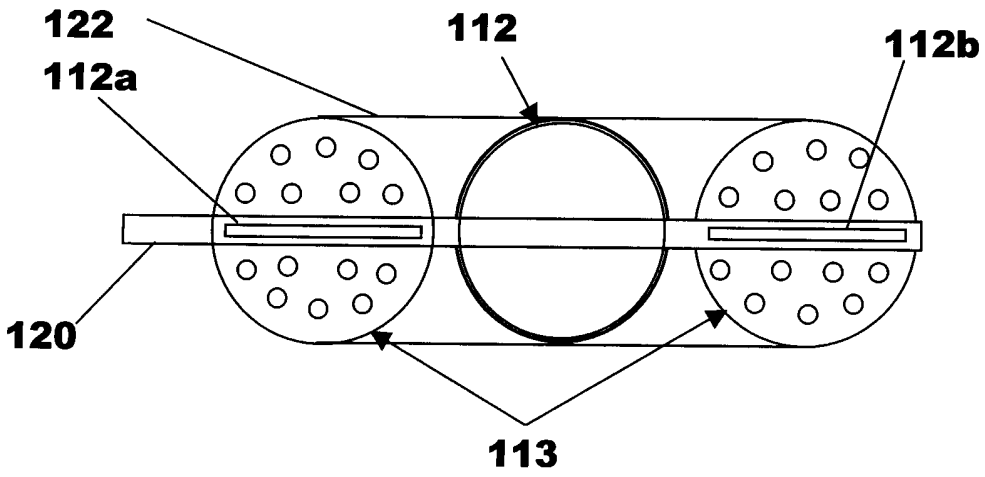

Fig.3

113

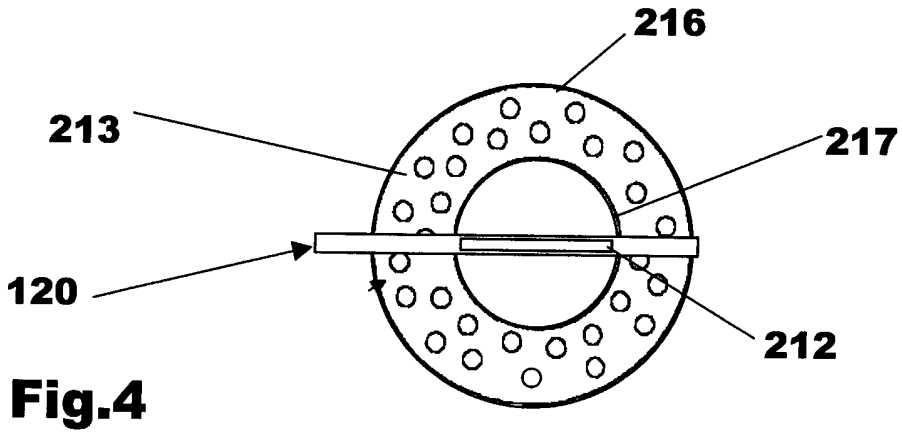

Fig.4

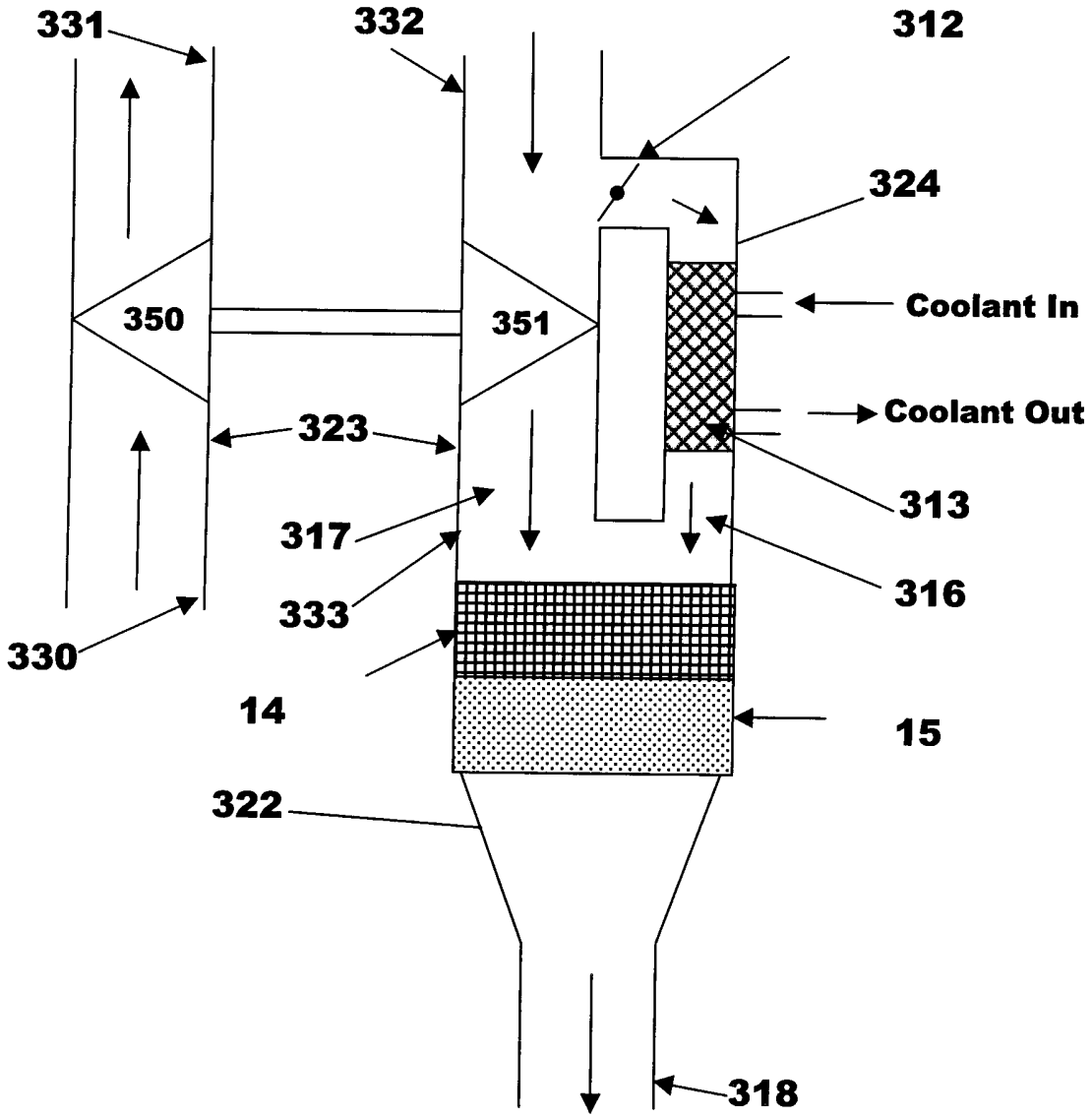
331
332
312
324
350
351
Coolant In
Coolant Out
323
313
317
316
333
330
14
15
322
318

Fig.5

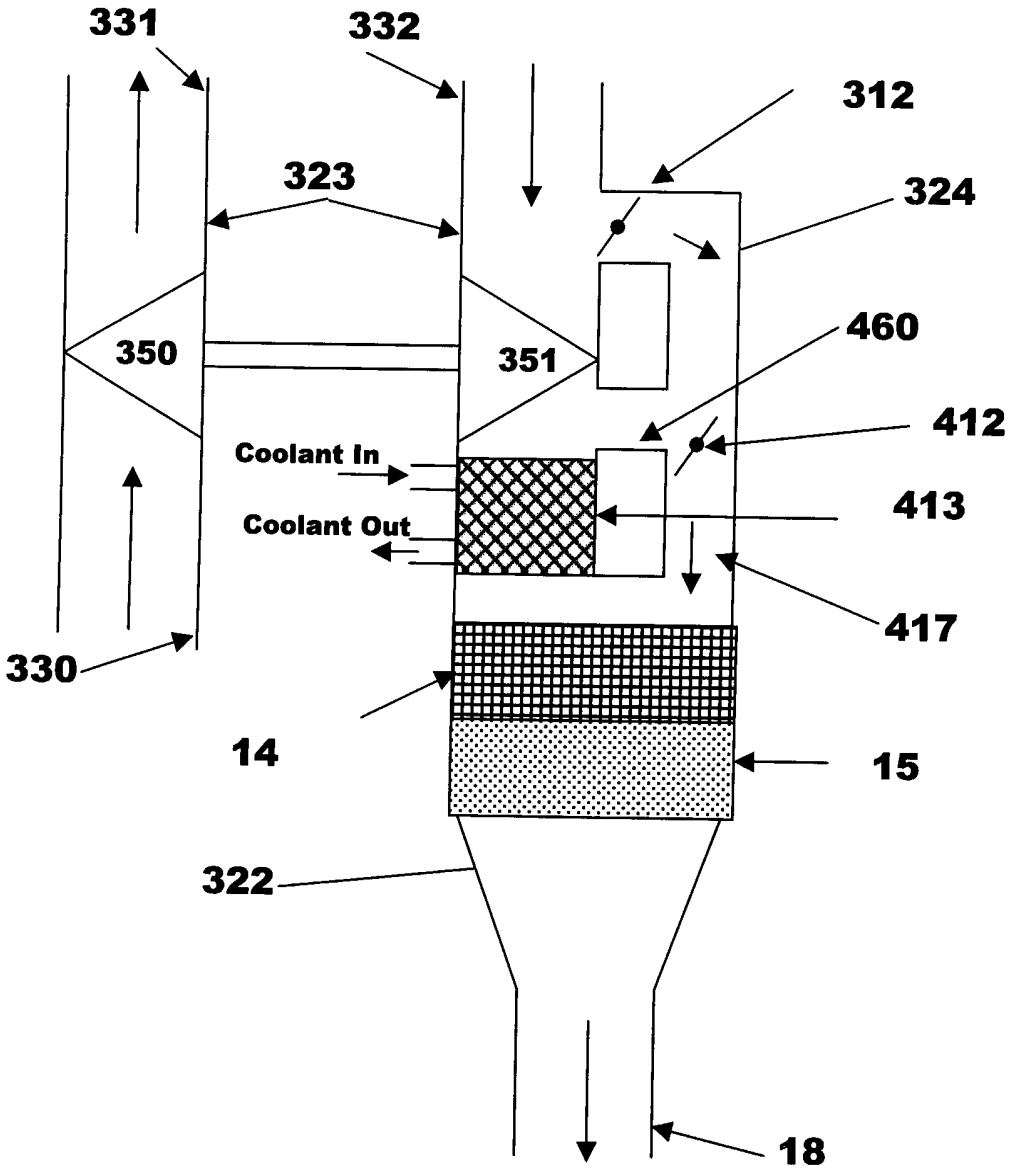
331
332
312
323
324
350
351
460
412
Coolant In
Coolant Out
413
417
330
14
15
322
18

Fig.6

AN EMISSION CONTROL APPARATUS FOR AN ENGINE

This invention relates to internal combustion engines and in particular to the reduction of emissions from a lean burn internal combustion engine.

It is known to provide an internal combustion engine that can be operated in more than one combustion mode such as, a lean combustion mode, a stoichiometric combustion mode and a rich combustion mode.

To reduce emission from such an engine a three way catalyst is used for combustion that is stoichiometric or rich but such a catalyst is not effective when the engine is operating in the lean combustion mode and so a lean NOx trap is normally also used.

It is a problem with a lean NOx trap that it must be operated within a fairly limited range of temperature if it is to perform efficiently and its performance will deteriorate rapidly if the temperature of the exhaust gasses passing through it are too high for too long a period.

It is an object of this invention to provide an emission control apparatus that enables a lean NOx trap to be positioned close to an exhaust gas outlet from an engine and can be manufactured in a more economical manner.

According to a first aspect of the invention there is provided an emission control apparatus for an internal combustion engine operable in several combustion modes of which one is a lean combustion mode, the apparatus comprising a housing having an inlet for receiving in use exhaust gases from the engine and an outlet from which in use treated exhaust gases flow wherein a three way catalyst and a lean NOx trap are located within the housing.

The three way catalyst may be located upstream from the lean NOx trap.

Preferably, the three way catalyst and the lean NOx trap form a single unit within the housing.

The inlet of the housing may be attached to an exhaust manifold directing the exhaust gases from the engine.

An exhaust gas cooler may be mounted in the housing upstream from the lean NOx trap.

The housing may provide a first passageway to direct in use the exhaust gasses through the exhaust gas cooler and a second passageway to direct in use the exhaust gasses so as to bypass the exhaust gas cooler.

At least one valve may be provided to control in use the flow of exhaust gasses through the exhaust gas cooler.

The valve may be operable to control the flow of exhaust gases through the first passageway.

The valve may be operable to control the flow of exhaust gases through the second passage way.

The valve may be operable to control the flow of exhaust gases through the first and second passageways.

There may be two first passageways, one located on each side of a central second passageway.

Preferably, flow through each of the passageways may be controlled by a respective butterfly valve mounted on a common spindle.

The butterfly valves for controlling the exhaust gas flow through the first passageways may be mounted on the spindle at right angles to the butterfly valve for controlling the exhaust gas flow through the second passageway.

Alternatively, the second passageway may be located within the first passageway so that the second passageway passes through the exhaust gas cooler.

The first and second passageways may be concentrically arranged.

The or each valve may be controlled to ensure that substantially all of the exhaust gases flow through the exhaust gas cooler when the engine is operating at high load.

The or each valve may be controlled, at least when the engine is operating in the lean combustion mode, to control the temperature of the exhaust gasses flowing through the lean NOx trap.

The emission control apparatus may further comprise an exhaust gas turbocharger having a casing to house a compressor and a turbine and a valve controlled wastegate passage to selectively bypass the turbine of the turbocharger wherein the housing is arranged to receive exhaust gasses from the turbocharger and the wastegate passage.

The wastegate passage may be formed by a separate conduit having an inlet end operatively connected upstream of the turbine and an outlet end connected downstream from the turbine.

A wastegate valve may be used to permit exhaust gasses in use to flow through the wastegate passage when pre-determined engine operating conditions exist.

The pre-determined engine operating conditions may be when the pressure produced by the compressor reaches a pre-determined limit, when the engine is operating at high load or when the temperature of the lean NOx trap needs to be maintained within pre-determined limits.

An exhaust gas cooler may be mounted in the wastegate passage.

Alternatively, the exhaust gas cooler may be mounted downstream from the turbine of the turbocharger.

At least one bypass valve may be provided to control in use the flow of exhaust gasses through the exhaust gas cooler.

A passage may be provided to selectively bypass in use the exhaust gas cooler.

The bypass valve may be arranged to control the flow of exhaust gases through the bypass passage.

The bypass valve may be arranged to ensure that substantially all of the exhaust gases flow through the exhaust gas cooler when the engine is operating at high load.

The bypass valve may be controlled, at least when the engine is operating in the lean combustion mode, to control the temperature of the exhaust gasses flowing through the lean NOx trap.

According to a second aspect of the invention there is provided an internal combustion engine operable in a least a lean combustion mode wherein the engine has an emission control apparatus in accordance with said first aspect of the invention operatively connected thereto to receive exhaust gases from the engine.

The invention will now be described by way of example with reference to the accompanying drawing of which:-

Fig.1 is a schematic diagram of an engine and emission control apparatus according to a first embodiment of the invention;

Fig.2 is a schematic diagram of an engine and emission control apparatus according to a second embodiment of the invention;

Fig.3 is a cross-section on the line A-A on Fig.2 showing the arrangement of an exhaust gas cooler and bypass passage forming part of the emission control apparatus shown in Fig.2;

Fig.4 is a cross-section on the line A-A on Fig.2 showing an alternative arrangement of an exhaust gas cooler and bypass passage forming part of the emission control apparatus shown in Fig.2;

Fig.5 is a schematic diagram of an engine and emission control apparatus according to a third embodiment of the invention; and

Fig.6 is a schematic diagram of an engine and emission control apparatus according to a fourth embodiment of the invention.

With reference to Fig.1 there is shown an engine 10 having an exhaust manifold 11 connected thereto for directing exhaust gases away from the engine 10. The engine 10 is operable in three separate combustion modes, a lean combustion mode in which the air/fuel ratio is higher than a stoichiometric air/fuel ratio, a stoichiometric mode in which the air/fuel ratio is stoichiometric and a rich combustion mode in which the air/fuel ratio is lower than a stoichiometric air/fuel ratio.

An emission control apparatus has a housing 22 forming an inlet at one end which is operatively connected to the exhaust manifold 11 and an outlet 18 from which exhaust gases flow in use to an exhaust system (not shown).

The housing 22 is used to house a three way catalyst 14 and a lean NOx trap 15 which are formed as a single unit and are arranged in the housing 22 such that the three way catalyst 14 is upstream from the lean NOx trap 15. In the example shown the three way catalyst 14 and the lean NOx trap 15 are held together by a support structure (not shown) but it will be appreciated that they could be simply held in place by the housing 22 and that they then need not be fastened together but could be located close to one another but spaced apart.

The housing 22 also supports an exhaust gas cooler 13 which is connected to a main cooling circuit (not shown) of the engine 10 from which coolant is extracted passed through he exhaust gas cooler 13 and returned.

The housing 22 defines two exhaust gas flow passageways 16, 17, therebeing a first passageway 16 in which is mounted the exhaust gas cooler 13 and a second passageway 17 which bypasses the exhaust gas cooler 13 and through which in use

the exhaust gasses can be diverted when the exhaust gas cooler 13 is not required.

A valve 12 is operable to control the flow of exhaust gasses through the first and second passageways 16 and 17 and in this case the valve 12 is operable to close the entrance to the first passageway 16 at one limit of travel and close off the entrance to the second passageway at an opposite limit of travel. However, it will be appreciated that the valve 12 could be arranged to only open or close the entrance to the second passageway 17 without closing or opening the first passageway 16. This is because, when the entrance to the second passageway 17 is open, virtually all of the exhaust gasses will flow therethrough even if the entrance to the first passageway remains unobstructed due to the resistance to flow through the second passageway 17 being much lower than the resistance to flow through the exhaust gas cooler 13.

The valve 12 can be actuated by any convenient means but in this case a vacuum operated actuator (not shown) is connected to the valve 12. The vacuum operated actuator is controlled by an electronic control unit (not shown) programmed to move the valve 12 between its two limits when certain engine operating conditions exist. In this example the valve 12 is proportionally controlled between its two limits of operation so that the flow through the first passageway 16 can be continuously adjusted during use to maintain the temperature of the exhaust gasses entering the lean NOx trap 15 within predetermined limits. To achieve this one or more temperature sensors (not shown) are used to monitor the temperature of the exhaust gases entering the three way catalyst 14 and leaving the lean NOx trap 15 from which an estimate of the temperature in the lean NOx trap 15 can be deduced by the electronic control unit.

Operation of the emission control apparatus is as follows. From a cold start it is desirable to rapidly heat the three way catalyst 14 and so initially the valve 12 is positioned so as to permit the flow of exhaust gasses through the second passageway 17. When the temperature of the three way catalyst 14 reaches a temperature where light off of the catalyst has occurred then the valve 12 is moved to permit exhaust gasses to begin flowing through the first passageway 16 and hence through the cooler 13. This allows heat from the exhaust gasses to be recuperated and used to heat the coolant flowing through the main cooling circuit of the engine 10.

This has several advantages when the engine 10 is started from cold in a low ambient temperature. Firstly, it improves cabin heater performance by reducing the time for the coolant to reach a useable temperature for cabin heating and secondly it reduces the time taken for the engine 10 to reach its normal operating temperature and so reduces fuel usage and emissions during initial engine operation.

During normal engine operation when the engine is operating in the lean combustion mode under light or part load conditions it is desirable to maintain the temperature of the exhaust gasses flowing through the lean NOx trap 15 within fairly tight limits which in this case are 400 to 450°C but could be other limits depending upon the construction of the lean NOx trap 15. Therefore, when operating under such conditions, the valve 12 is under the control of the electronic control unit and is operable to continuously vary the flow of exhaust gases through the cooler 13 to achieve the desired temperature. This ensures that, when the engine 10 is operating lean, the lean NOx trap 15 is operating at peak efficiency.

When the engine 10 is subject to high or full load conditions the valve 12 is operable under the control of the electronic control unit to close off the second passageway 17 so as to maximise the cooling effect of the cooler 13 so as to keep the lean NOx trap 15 as cool as possible but it is possible that under such high load conditions the temperature of the exhaust gasses may exceed the preferred upper temperature limit of 450°C if the heat extraction capacity of the exhaust gas cooler is not sufficient.

However, even if the upper temperature limit is exceeded the emission performance of the emission control apparatus is not seriously affected. This is because at such loads the engine will be operating outside of the lean operating mode and in most cases in the rich operating mode where the lean NOx trap 15 is ineffective and it is the three way catalyst 14 which is used to remove undesirable pollutants from the exhaust gasses. As the three way catalyst 14 is able to operate efficiently over a wide range of temperatures and in particular at high temperatures the efficiency of the emission control apparatus is therefore not greatly affected. It will however be appreciated that it is desirable to use an exhaust gas cooler with sufficient capacity to maintain the exhaust gas temperature in the lean NOx trap close to the upper limit because it will reduce the degradation of the lean NOx trap which will otherwise occur at high temperatures.

Therefore it can be seen that the invention provides a three way catalyst and lean NOx trap which are packaged in a common can or housing which enables them to be manufactured more economically than if manufactured as separate components. In addition, if combined with an exhaust gas cooler and switchable bypass the combined catalyst/lean NOx trap can be mounted close to the exhaust outlet from an engine improving catalyst light off performance and hence

the emission performance of the engine to which they are connected.

With reference to Figs.2 and 3 there is shown a second embodiment of an emission control apparatus according to the invention for connection to the exhaust manifold 11 of the engine 10 to replace the apparatus previously described.

The emission control apparatus has a housing 122 forming an inlet at one end which is operatively connected to the exhaust manifold 11 and an outlet 18 from which exhaust gases flow in use to an exhaust system (not shown).

The housing 122 is used to house a three way catalyst 14 and a lean NOx trap 15 which, as before, are formed as a single unit and are arranged in the housing 122 such that the three way catalyst 14 is upstream from the lean NOx trap 15. In the example shown the three way catalyst 14 and the lean NOx trap 15 are held in position by the housing 122 and are not separately fastened together.

The housing 122 also supports an exhaust gas cooler 113 which is connected to a main cooling circuit (not shown) of the engine 10 from which coolant is extracted passed through the exhaust gas cooler 13 and returned.

The housing 22 defines three exhaust gas flow passageways therebeing two first passageway in each of which is mounted part of the exhaust gas cooler 13 and a single second passageway which bypasses the exhaust gas cooler 13 mounted in the two first passageways and through which in use the exhaust gasses can be diverted when the exhaust gas cooler 13 is not required.

A butterfly valve 112 is operable to control the flow of exhaust gasses through the second passageway and two

further butterfly valves 112a, 112b are used to control the flow of exhaust gasses through the first passageways. All three of the butterfly valves 112, 112a, 112b are mounted on a common spindle 120 and are arranged such that the butterfly valve 112 for the second passage way is arranged at right angles to the two butterfly valves 112a, 112b for the first passageways. The butterfly valves 112a, 112b are operable to open and close the entrance to the first passageway and the remaining butterfly valve 112 is used to open and close the entrance to the second passageway.

It will be appreciated that the arrangement of the butterfly valves is such that when the entrances to the first passageways are fully open, the entrance to the second passageway is fully closed and vice-versa.

However, it will be appreciated that as an alternative only one butterfly valve could be arranged to open or close the entrance to only the second passageway without closing or opening the first passageways. This is because when the entrance to the second passageway is open virtually all of the exhaust gasses will flow therethrough even if the entrance to the first passageways remains unobstructed. It will be further appreciated that the invention is not limited to the use of butterfly valves and any suitable valve could be used.

The spindle 120 can be rotated by any convenient means but in this case a vacuum operated actuator (not shown) is connected to the spindle 120. The vacuum operated actuator is controlled by an electronic control unit (not shown) programmed to open and close the valves 112, 112a, 112b when certain engine operating conditions exist. In this example the valves 112, 112a and 112b are proportionally controlled between their two limits of operation so that the flow through the first passageways can be continuously adjusted

during use to maintain the temperature of the exhaust gasses entering the lean NOx trap 15 within predetermined limits.

To achieve this one or more temperature sensors (not shown) are used to monitor the temperature of the exhaust gases entering the three way catalyst 14 and leaving the lean NOx trap 15 from which an estimate of the temperature in the lean NOx trap 15 can be deduced by the electronic control unit.

Operation of the emission control apparatus is as follows. From a cold start in cold ambient conditions it is desirable to rapidly heat the three way catalyst 14 and so initially the valve 112 is positioned so as to permit the flow of exhaust gasses through the second passageway and the other two valves 112a, 112b are positioned to close off the entrance to the two first passageways. When the temperature of the three way catalyst 14 reaches a temperature where light off of the catalyst has occurred then the valves 112a, 112b are moved to permit exhaust gasses to begin flowing through the first passageways and hence through the cooler 113 and the valve 112 is consequentially moved to a position where the flow of exhaust gasses through the second passageway is restricted. As previously described, this allows heat from the exhaust gasses to be recuperated and used to heat the coolant flowing through the main cooling circuit of the engine 10 and has the same advantages as previously referred to.

During normal engine operation when the engine is operating in the lean combustion mode under light or part load conditions it is desirable to maintain the temperature of the exhaust gasses flowing through the lean NOx trap 15 within fairly tight limits which as before are 400 to 450°C.

When operating under such conditions the valves 112, 112a and 112b or more precisely the spindle 120 is rotated under the control of the electronic control unit to continuously vary the flow of exhaust gases through the cooler 113 to achieve the desired temperature. This ensures that, when the engine 10 is operating lean, the lean NOx trap 15 is operating at peak efficiency.

When the engine 10 is subject to high or full load conditions the valve 112 is operable under the control of the electronic control unit to close off the second passageway so as to maximise the cooling effect of the cooler 13. This will keep the lean NOx trap 15 as cool as possible but it is possible that under such high load conditions the temperature of the exhaust gasses may exceed the preferred upper temperature limit of 450°C.

However, as previously indicated this will not have a serious effect on the efficiency of the emission control apparatus because it is the performance of the three way catalyst 14 that is important because at such loads the engine will be operating outside of the lean operating mode where the lean NOx trap 15 is required to reduce emissions.

With reference to Fig.4 there is shown an alternative arrangement of first and second passageways 216, 217 to replace that shown in Fig.3. In this case the second passageway 217 is located within the first passageway 216 and, as shown, is concentrically arranged with respect to the first passageway 216.

That is to say, the second passageway 217 passes through the exhaust gas cooler 213. A single valve 212 attached to the spindle 120 is used to control the entrance to the second passageway 217. Operation is as before with the valve 212 being used to divert exhaust gasses past the

cooler 213 during warm up from cold, prevent the flow of exhaust gases through the second passageway when the engine is operating at high load and vary the flow through the first passageway when the engine is operating in a lean combustion mode under light to moderate load conditions to maintain the temperature of the exhaust gases as close as possible to the optimum temperature for lean NOx trap performance/ efficiency. This construction has the advantage that it is relatively compact and is therefore easier to package in a motor vehicle.

With reference to Fig.5 there is shown an emission control apparatus having a three way catalyst 14 and lean NOx trap 15 housed within a common housing 322 which has an outlet 18 leading to an exhaust system (not shown). The three way catalyst 14 is located upstream from the lean NOx trap 15 so that exhaust gasses pass through the three way catalyst 14 before entering the lean NOx trap 15. The housing 322 is operatively connected at an inlet end to a source of exhaust gases from an internal combustion engine (not shown) via an exhaust gas turbocharger and a valve controlled wastegate passage 324 forming other components of the emission control apparatus. The engine is operable in at least a lean combustion mode and in this case is operable in lean, stoichiometric and rich combustion modes.

The turbocharger has a casing 323 defining an exhaust gas inlet passage 332 for supplying exhaust gases from the engine to a turbine 351, an exhaust gas outlet 333 operatively connected to the housing 322, an air inlet 330 for supplying air to a compressor 350 and an air outlet for supplying compressed air to the engine via an intercooler (not shown). In practice, the exhaust gas inlet passage 332 is connected directly to an exhaust manifold (not shown) of the engine.

The compressor 350 and the turbine 351 are mounted on a common shaft such that rotation of the turbine 351 by the passage therethrough of exhaust gasses will cause rotation of the compressor 350.

An exhaust gas cooler 313 is located in the wastegate passage 324 which is formed by a separate conduit extending from a position upstream of the turbine 351 to a position downstream from the turbine 351. The exhaust gas cooler is connected to a main cooling circuit (not shown) of the engine from which coolant is extracted passed through he exhaust gas cooler 313 and returned.

The housing 322 defines two exhaust gas flow passageways 316, 317, therebeing a first passageway 316 in which is mounted the exhaust gas cooler 313 and a second passageway 317 which bypasses the exhaust gas cooler 313 and through which in use the exhaust gasses flow to drive the turbine 351.

A wastegate valve 312 is operable to control the flow of exhaust gasses through the first and second passageways 316 and 317 and in this case the wastegate valve 312 is a butterfly valve operable to close the entrance to the first passageway 316 at one limit of travel and open the entrance to the first passageway 316 at an opposite limit of travel. However, it will be appreciated that other valve arrangements could be used.

The wastegate valve 312 can be actuated by any convenient means but in this case an air operated actuator (not shown) is connected to the wastegate valve 312. The air operated actuator is connected to the air outlet 331 of the turbocharger such that when the pressure in the air outlet 331 exceeds a predetermined pressure the valve 312 is opened to reduce the flow of exhaust gases passing through

the turbine 351. However it will be appreciated that other means can be used to control the movement of the wastegate valve and the valve could be controlled by an electronic control unit (not shown) programmed to open and close the valve 312 when certain engine operating conditions exist.

The exhaust gas cooler 313 is provided to reduce the temperature of the exhaust gasses passing through the lean NOx trap 15 when the engine is operating at high load.

By using the wastegate valve 312 to control the flow of exhaust gases through the first passageway a very simple apparatus is provided in which at low engine load conditions all of the exhaust gasses will flow through the turbine and thereby bypass the exhaust gas cooler 313 but when the engine is under high load the wastegate valve 312 will open thereby allowing the exhaust gasses or at least some of them to flow through the exhaust gas cooler 313. In practice approximately 35 to 40% of the total exhaust gas flow will pass through the exhaust gas cooler 313 when the wastegate valve is fully open and the engine is operating at high load.

In an improvement of this arrangement the wastegate valve 312 is not controlled only by the pressure in the air outlet 332 but also based upon a need to cool the exhaust gases passing through the lean NOx trap 15 or to assist with engine warm up from cold. With such an arrangement an electronic controller is programmed to control the position of the wastegate valve 312 taking into account the need to prevent overpressure in the air outlet 332 but also the need to keep the temperature of the lean NOx trap 15 within a predetermined range of temperature if possible. That is to say, the wastegate valve is controlled by the electronic control unit to open and close when pre-determined engine operating conditions exist.

A ranking system may be used in the programming to ensure that in all cases when the wastegate valve needs to be opened to limit the pressure in the air outlet 332 it is opened.

One advantage of such independent control is that after a cold start from a low ambient temperature exhaust gasses can be bled off to the exhaust gas cooler 313 to speed up warm-up of the engine and also to improve cabin heater performance during engine warm-up.

A further advantage of such an arrangement is that the wastegate valve 312 can be opened and closed during lean operation of the engine to maintain the temperature of the lean NOx trap 15 within or close to the temperature at which its maximum operating performance is achieved irrespective of whether the pressure in the air outlet 332 is high enough to open the valve 312. This will improve the emission performance of the emission control apparatus during combustion in the lean combustion mode.

In both cases it is an advantage that only one control valve is needed to provide excess pressure relief and control of exhaust gas cooling.

With reference to Fig.6 there is shown an emission control apparatus having a three way catalyst 14 and lean NOx trap 15 housed within a common housing 322 which has an outlet 18 leading to an exhaust system (not shown). The three way catalyst 14 is located upstream from the lean NOx trap 15 so that exhaust gasses pass through the three way catalyst 14 before entering the lean NOx trap 15. The housing 322 is operatively connected at an inlet end to a source of exhaust gases from an internal combustion engine (not shown) via an exhaust gas turbocharger and a valve

controlled wastegate passage 324 forming other components of the emission control apparatus. The engine is operable in at least a lean combustion mode and in this case is operable in lean, stoichiometric and rich combustion modes.

The turbocharger has a casing 323 defining an exhaust gas inlet passage 332 for supplying exhaust gases from the engine to a turbine 351, an exhaust gas outlet operatively connected to the housing 322, an air inlet 330 for supplying air to a compressor 350 and an air outlet for supplying compressed air to the engine via an intercooler (not shown). In practice, the exhaust gas inlet passage 332 is connected directly to an exhaust manifold (not shown) of the engine.

The compressor 350 and the turbine 351 are mounted on a common shaft such that rotation of the turbine 351 by the passage therethrough of exhaust gasses will cause rotation of the compressor 350.

A wastegate passage 324 is formed by a conduit extending from a position upstream of the turbine 351 to a position downstream from the turbine 351 where it is connected to an outlet passage from the turbine 351 by a passage 460. A wastegate valve 312 is used to control the flow of exhaust gasses entering the wastegate passage 324.

An exhaust gas cooler 413 is located downstream from the turbine 351 in a first passageway connected to the outlet passage from the turbine 351 and a bypass valve 412 is used to control the flow of exhaust gases through a second passageway 417 arranged to permit exhaust gasses to flow from the turbine 351 to the outlet 18 without passing through the exhaust gas cooler 413.

The exhaust gas cooler 413 is connected to a main cooling circuit (not shown) of the engine from which coolant

is extracted passed through the exhaust gas cooler 413 and returned.

In this example, the wastegate valve 312 and the bypass valve 412 are both formed by a butterfly valve operable to close the entrance to the respective passageway 324,417 in which they are mounted at one limit of travel and open the entrance to the respective passageway 324, 417 at an opposite limit of travel. However, it will be appreciated that other valve arrangements could be used.

The wastegate and bypass valves 312, 412 can be actuated by any convenient means but in this case a vacuum actuator (not shown) controlled by an electronic control unit (not shown) is connected to each valve 312, 412 and the valves 312, 412 are controlled by the electronic control unit to open and close when pre-determined engine operating conditions exist.

The exhaust gas cooler 413 is provided to reduce the temperature of the exhaust gasses passing through the lean NOx trap 15 when the engine is operating at high load and maintain the temperature in the lean NOx trap 15 between predetermined limits when the engine is operating in the lean combustion mode.

Operation is as follows, after start-up from cold the wastegate valve 312 and the bypass valve 412 are both open thereby allowing hot exhaust gases to flow unimpeded to the three way catalyst 14 and lean NOx trap 15. This speeds up warm up of the components and ensures that light-off of the three way catalyst 14 occurs as soon as possible after start-up of the engine to minimise emissions from the engine. After a short initial period sufficient heat will have been transferred to the three way catalyst 14 to ensure that light-off has occurred and at this time the bypass

valve 412 is closed to divert exhaust gases through the passage 460 to the exhaust gas cooler 413. The heat extracted from the exhaust gases is used to reduce the warm-up time of the engine and improve cabin heater performance. It will be appreciated by those skilled in the art that both emissions and fuel economy are adversely affected when an engine is not at or close to its normal operating temperature.

The control of the two valves 312, 412 by the electronic control unit is such that when the engine has reached or approached its normal operating temperature a third control mode is used in which the wastegate valve 312 is controlled to limit the air pressure in the air outlet 331 and the bypass valve 412 is used to control the temperature of the exhaust gasses passing though the lean NOx trap 15 when the engine is operating at light or part load in the lean combustion mode.

However, if the engine is sensed to be operating at high load, then the bypass valve 412 is normally closed and the wastegate valve 312 is normally open ensuring maximum cooling of the exhaust gasses to minimise the degradation of the lean NOx trap 15.

By using two valves to separately and independently control the wastegate passage and the second passageway greater control can be achieved than with the embodiment shown in Fig.5 but the cost of such an arrangement and the system complexity are both higher.

Although in the case of both of the embodiments shown in Figs.5 and 6 the wastegate passage is shown as a separate conduit it will be appreciated that it could be formed as part of the turbocharger casing.

Therefore in summary the invention provides a three way catalyst and lean NOx trap packaged in a single housing that with the use of an upstream exhaust gas cooler can be close coupled to the exhaust outlet from an engine.

It will be appreciated by those skilled in the art that although the invention has been described by way of example with reference to a number of specific embodiments it is not limited to these embodiments and that various alternative embodiments or modifications to the disclosed embodiments could be made without departing from the scope of the invention.

Claims

1. An emission control apparatus for an internal combustion engine operable in several combustion modes of which one is a lean combustion mode, the apparatus comprising a housing having an inlet for receiving in use exhaust gases from the engine and an outlet from which in use treated exhaust gases flow wherein a three way catalyst and a lean NOx trap are located within the housing.

2. An apparatus as claimed in claim 1 wherein the three way catalyst is located upstream from the lean NOx trap.

3. An apparatus as claimed in claim 1 or in claim 2 wherein the three way catalyst and the lean NOx trap form a single unit within the housing.

4. An apparatus as claimed in any of claims 1 to 3 wherein the inlet of the housing is attached to an exhaust manifold directing the exhaust gases from the engine.

5. An apparatus as claimed in any of claims 1 to 4 wherein an exhaust gas cooler is mounted in the housing upstream from the lean NOx trap.

6. An apparatus as claimed in claim 5 wherein the housing provides a first passageway to direct in use the exhaust gasses through the exhaust gas cooler and a second passageway to direct in use the exhaust gasses so as to bypass the exhaust gas cooler.

7. An apparatus as claimed in claim 6 wherein at least one valve is provided to control in use the flow of exhaust gasses through the exhaust gas cooler.

8. An apparatus as claimed in claim 7 wherein the valve is operable to control the flow of exhaust gases through the first passageway.

9. An apparatus as claimed in claim 7 wherein the valve is operable to control the flow of exhaust gases through the second passage way.

10. An apparatus as claimed in claim 7 wherein the valve is operable to control the flow of exhaust gases through the first and second passageways.

11. An apparatus as claimed in any of claims 6 to 10 wherein there are two first passageways one located on each side of a central second passageway.

12. An apparatus as claimed in claim 11 wherein flow through each of the passageways is controlled by a respective butterfly valve mounted on a common spindle.

13. An apparatus as claimed in claim 12 wherein the butterfly valves for controlling the exhaust gas flow through the first passageways are mounted on the spindle at right angles to the butterfly valve for controlling the exhaust gas flow through the second passageway.

14. An apparatus as claimed in any of claims 6 to 10 wherein the second passageway is located within the first passageway so that the second passageway passes through the exhaust gas cooler.

15. An apparatus as claimed in any of claims 6 to 10 or in claim 14 wherein the first and second passageways are concentrically arranged.

16. an apparatus as claimed in claim 7 wherein the or each valve is controlled to ensure that substantially all of the exhaust gases flow through the exhaust gas cooler when the engine is operating at high load.

17. An apparatus as claimed in claim 7 wherein the or each valve is controlled, at least when the engine is operating in the lean combustion mode, to control the temperature of the exhaust gasses flowing through the lean NOx trap.

18. An apparatus as claimed in any of claims 1 to 3 wherein the emission control apparatus further comprises an exhaust gas turbocharger having a casing to house a compressor and a turbine and a valve controlled wastegate passage to selectively bypass the turbine of the turbocharger wherein the housing is arranged to receive exhaust gasses from the turbocharger and the wastegate passage.

19. An apparatus as claimed in claim 18 wherein the wastegate passage is formed by a separate conduit having an inlet end operatively connected upstream of the turbine and an outlet end connected downstream from the turbine.

20. An apparatus as claimed in claim 18 or in claim 19 wherein a wastegate valve is used to permit exhaust gasses in use to flow through the wastegate passage when pre-determined engine operating conditions exist.

21. An apparatus as claimed in any of claims 18 to 20 wherein an exhaust gas cooler is mounted in the wastegate passage.

22. An apparatus as claimed in any of claims 18 to 21 wherein an exhaust gas cooler is mounted downstream from the turbine of the turbocharger.

23. An apparatus as claimed in claim 22 wherein at least one bypass valve is provided to control in use the flow of exhaust gasses through the exhaust gas cooler.

24. An apparatus as claimed in claim 22 or in claim 23 wherein a passage is provided to selectively bypass in use the exhaust gas cooler.

25. An apparatus as claimed in claim 24 when dependent upon claim 23 wherein the bypass valve is arranged to control the flow of exhaust gases through the bypass passage.

26. An apparatus as claimed in claim 23 or in claim 25 wherein the bypass valve is arranged to ensure that substantially all of the exhaust gases flow through the exhaust gas cooler when the engine is operating at high load.

27. An apparatus as claimed in claim 23 or in claim 25 or in claim 26 wherein the bypass valve is controlled, at least when the engine is operating in the lean combustion mode, to control the temperature of the exhaust gasses flowing through the lean NOx trap.

28. An internal combustion engine operable in a least a lean combustion mode wherein the engine has an emission control apparatus as claimed in any of claims 1 to 27 operatively connected thereto to receive exhaust gases from the engine.

29. An emission control apparatus substantially as described herein with reference to the accompanying drawing.

30. An internal combustion engine substantially as described herein with reference to the accompanying drawing.

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Application No: GB0412580.3 **Examiner:** Heather Webber

Claims searched: 1 - 30 **Date of search:** 28 October 2004

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	X = 1 - 4 & 28; Y = 5 - 12 & 14 - 17	EP 1152140 A2 (NISSAN MOTOR) see column 5 [0020] and figure 1 especially
X,Y	X = 1, 2, 4 & 28; Y = 5 - 12 & 14 - 17	EP 0937877 A (FORD GLOBAL TECH INC) see abstract and figure especially
X,Y	X = 1, 2, 4 & 28; Y = 5 - 12 & 14 - 17	JP 2003106141 A (MITSUBISHI) see abstract and figrue
X,Y	X = 1, 3, 4 & 28; Y = 5 - 12 & 14 - 17	JP 2003278529 A (TOYOTA MOTOR CORP) see abstract and figure 3 especially
Y	5 - 12 & 14 - 17	US 2003/0033801 A1 (HINDER et al) see abstract and figure1
Y	5 - 10, 16 & 17	FR 2841595 A (BENTELER AUTOMOBILTECHNIK GMBH) see abstract and figures

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{W} :

B1W; F1B

Worldwide search of patent documents classified in the following areas of the IPC^{07}

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The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, JAPIO