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Other: **EPODOC, TXTE, WPI**

(54) Abstract Title: **I.c. engine exhaust system with twin turbochargers**

(57) The i.c. engine 100 has two turbochargers 112,114 coupled to respective sets, eg banks 110, of engine cylinders. The exhaust system has a lower heat loss path 118 coupled between one turbocharger 112 and an emission control device 122 and a lower heat loss path 118 coupled between the other turbocharger 114 and the emission control device 122. The lower heat loss path 118 may be a double walled or insulated pipe while the higher heat loss path 118 is a single-wall pipe having more bends. A valve mechanism 124 may be provided for adjusting the exhaust flow through a crossover pipe 116 joining the two heat loss paths 118, 120. The flow of exhaust gas flowing through the crossover pipe 116 is varied to control the temperature of the gas entering the emission control device 122.

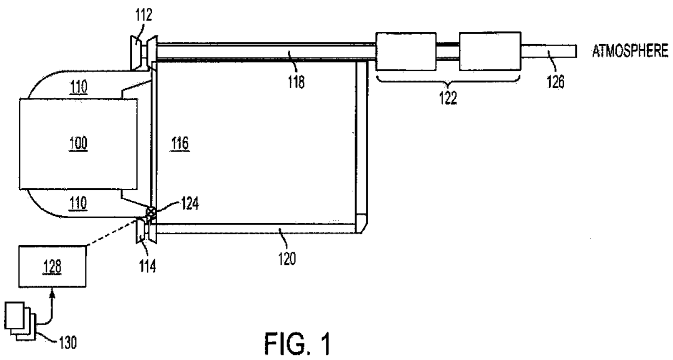

FIG. 1

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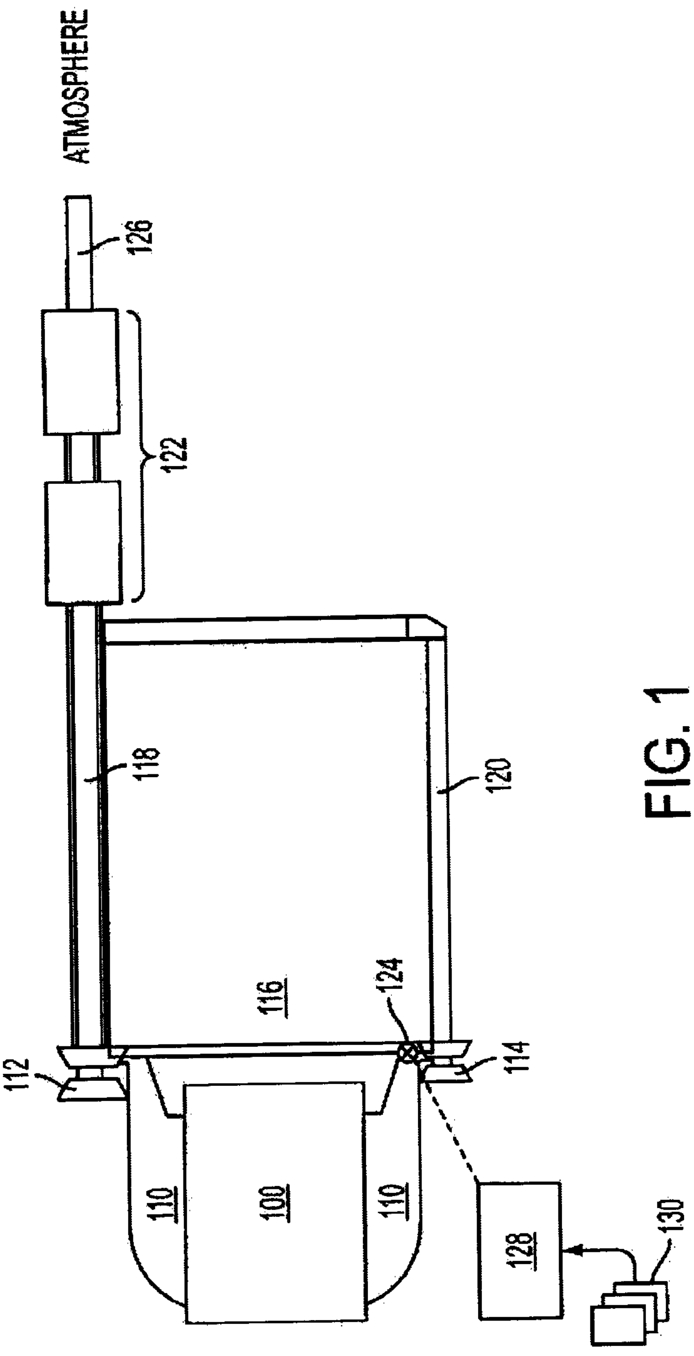

FIG. 1

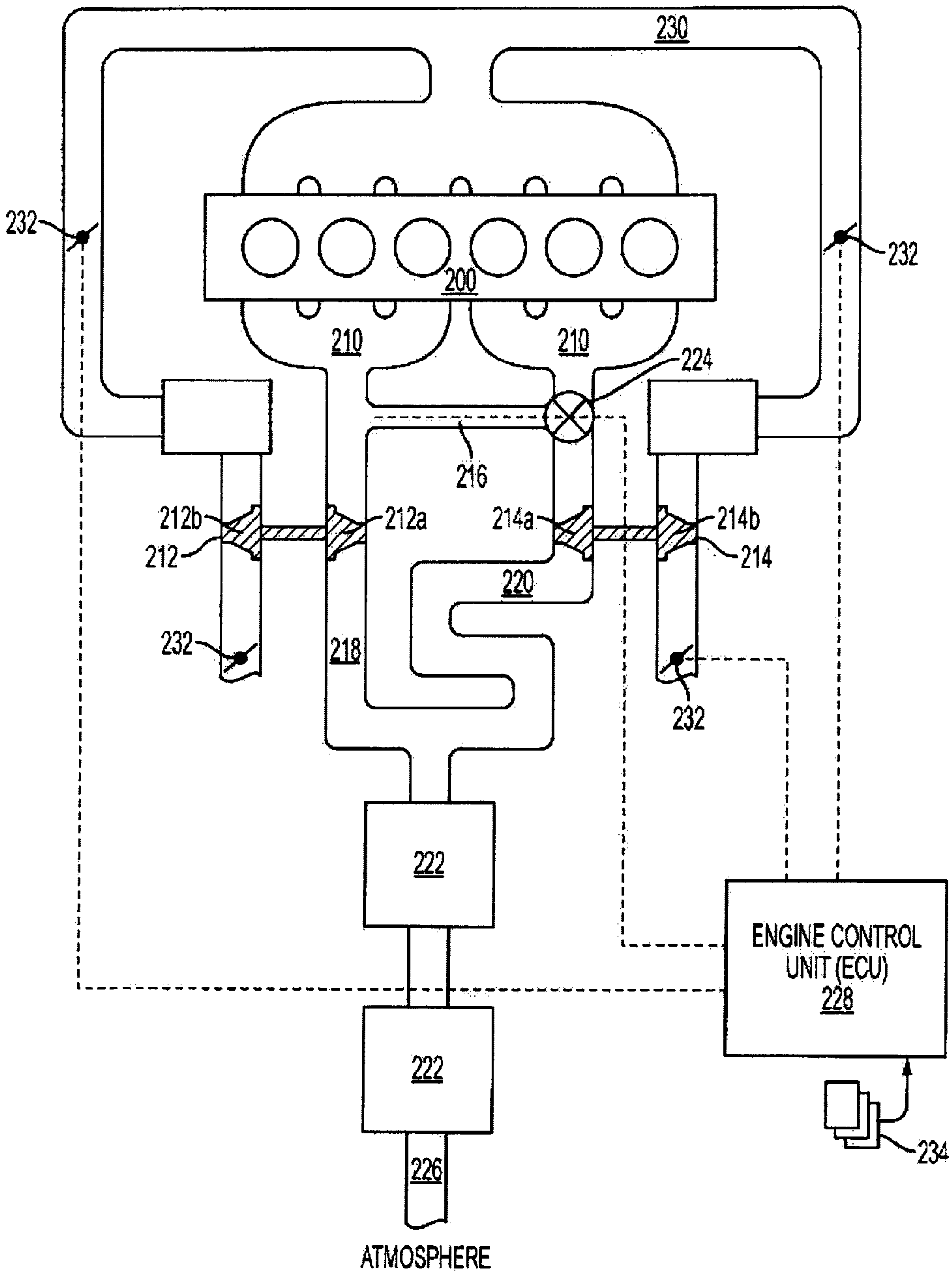
230
232
232
200
210
210
224
216
212b
212a
214a
214b
212
214
220
232
218
232
222
222
ENGINE CONTROL UNIT (ECU) 228
234
226
ATMOSPHERE

FIG. 2

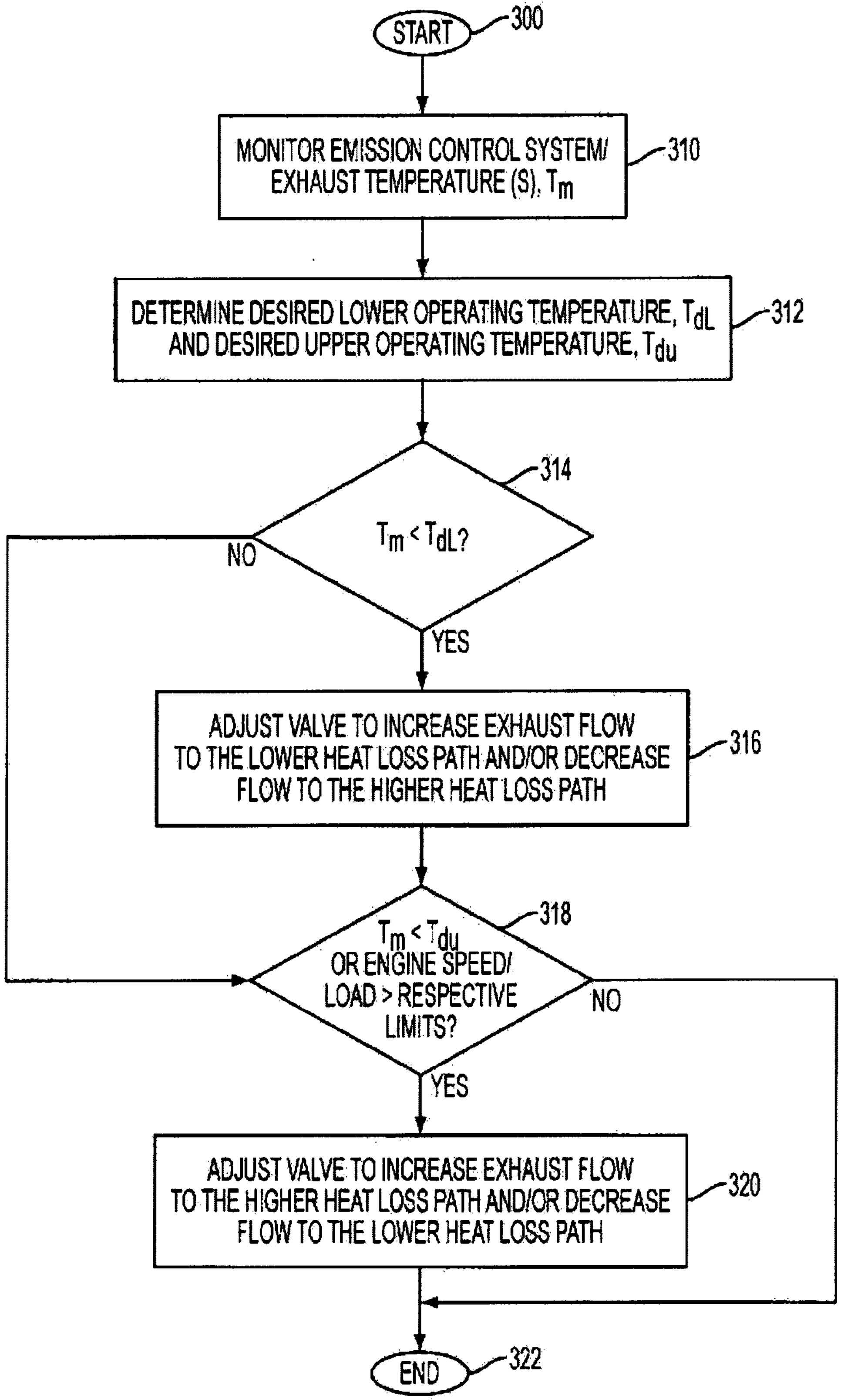
START
300
MONITOR EMISSION CONTROL SYSTEM/ EXHAUST TEMPERATURE (S), T_m
310
DETERMINE DESIRED LOWER OPERATING TEMPERATURE, T_{dL} AND DESIRED UPPER OPERATING TEMPERATURE, T_{du}
312
$T_m < T_{dL}$?
314
NO
YES
ADJUST VALVE TO INCREASE EXHAUST FLOW TO THE LOWER HEAT LOSS PATH AND/OR DECREASE FLOW TO THE HIGHER HEAT LOSS PATH
316
$T_m < T_{du}$ OR ENGINE SPEED/ LOAD > RESPECTIVE LIMITS?
318
NO
YES
ADJUST VALVE TO INCREASE EXHAUST FLOW TO THE HIGHER HEAT LOSS PATH AND/OR DECREASE FLOW TO THE LOWER HEAT LOSS PATH
320
END
322

FIG. 3

4/6

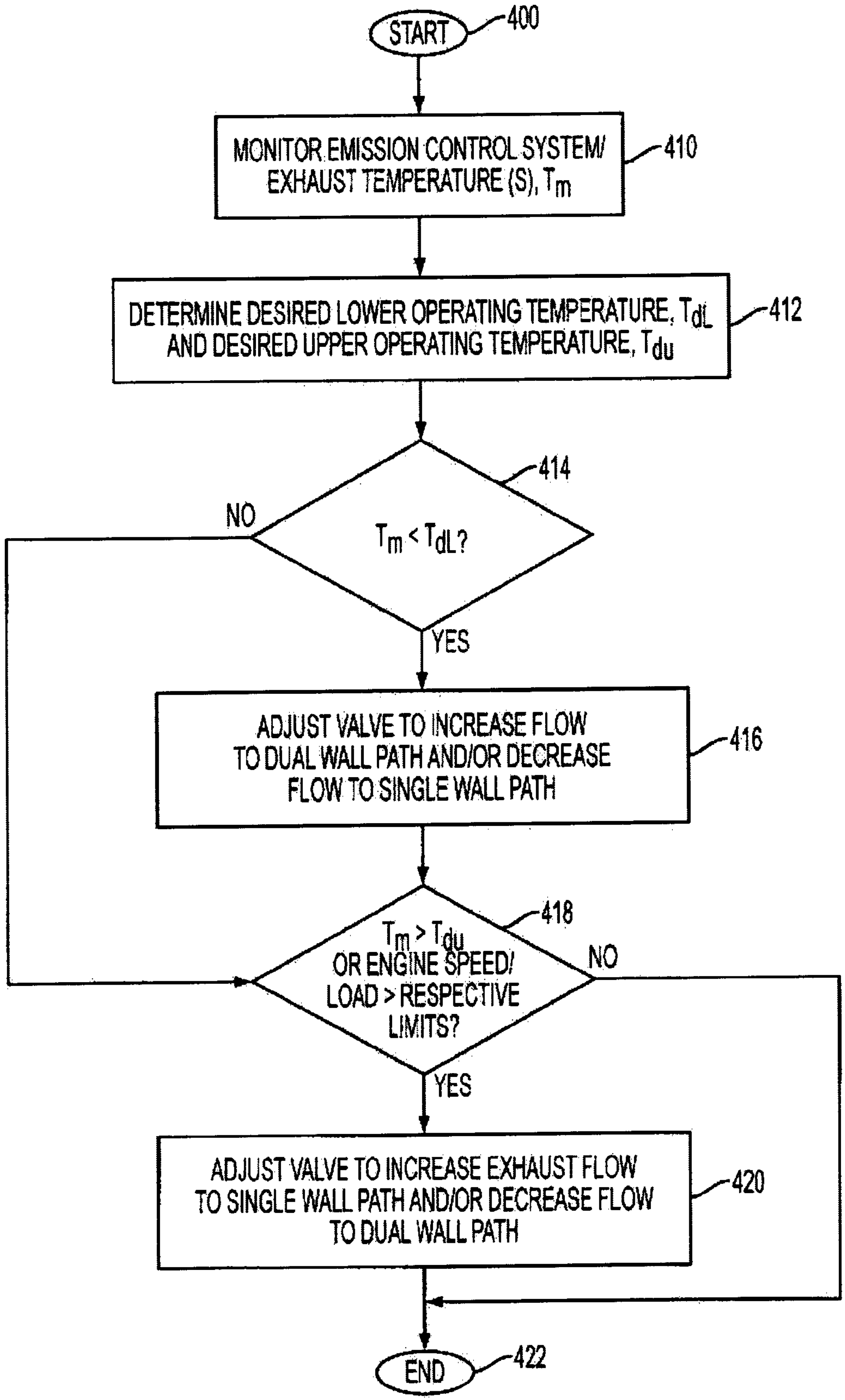
START
400
MONITOR EMISSION CONTROL SYSTEM/ EXHAUST TEMPERATURE (S), T_m
410
DETERMINE DESIRED LOWER OPERATING TEMPERATURE, T_{dL} AND DESIRED UPPER OPERATING TEMPERATURE, T_{du}
412
$T_m < T_{dL}$?
414
NO
YES
ADJUST VALVE TO INCREASE FLOW TO DUAL WALL PATH AND/OR DECREASE FLOW TO SINGLE WALL PATH
416
$T_m > T_{du}$ OR ENGINE SPEED/ LOAD > RESPECTIVE LIMITS?
418
NO
YES
ADJUST VALVE TO INCREASE EXHAUST FLOW TO SINGLE WALL PATH AND/OR DECREASE FLOW TO DUAL WALL PATH
420
END
422

FIG. 4

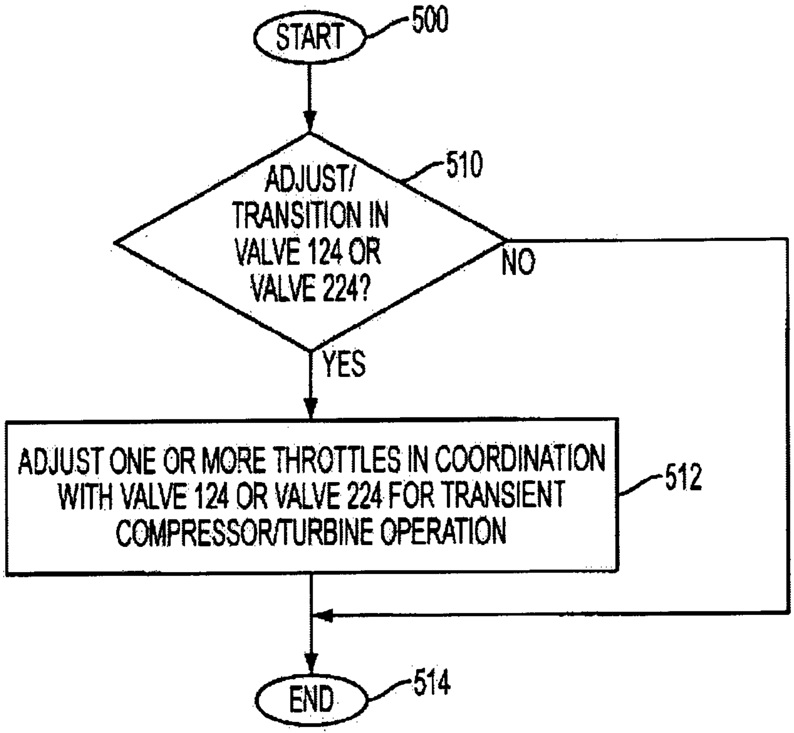
START
500
ADJUST/
TRANSITION IN
VALVE 124 OR
VALVE 224?
510
NO
YES
ADJUST ONE OR MORE THROTTLES IN COORDINATION
WITH VALVE 124 OR VALVE 224 FOR TRANSIENT
COMPRESSOR/TURBINE OPERATION
512
END
514

FIG. 5

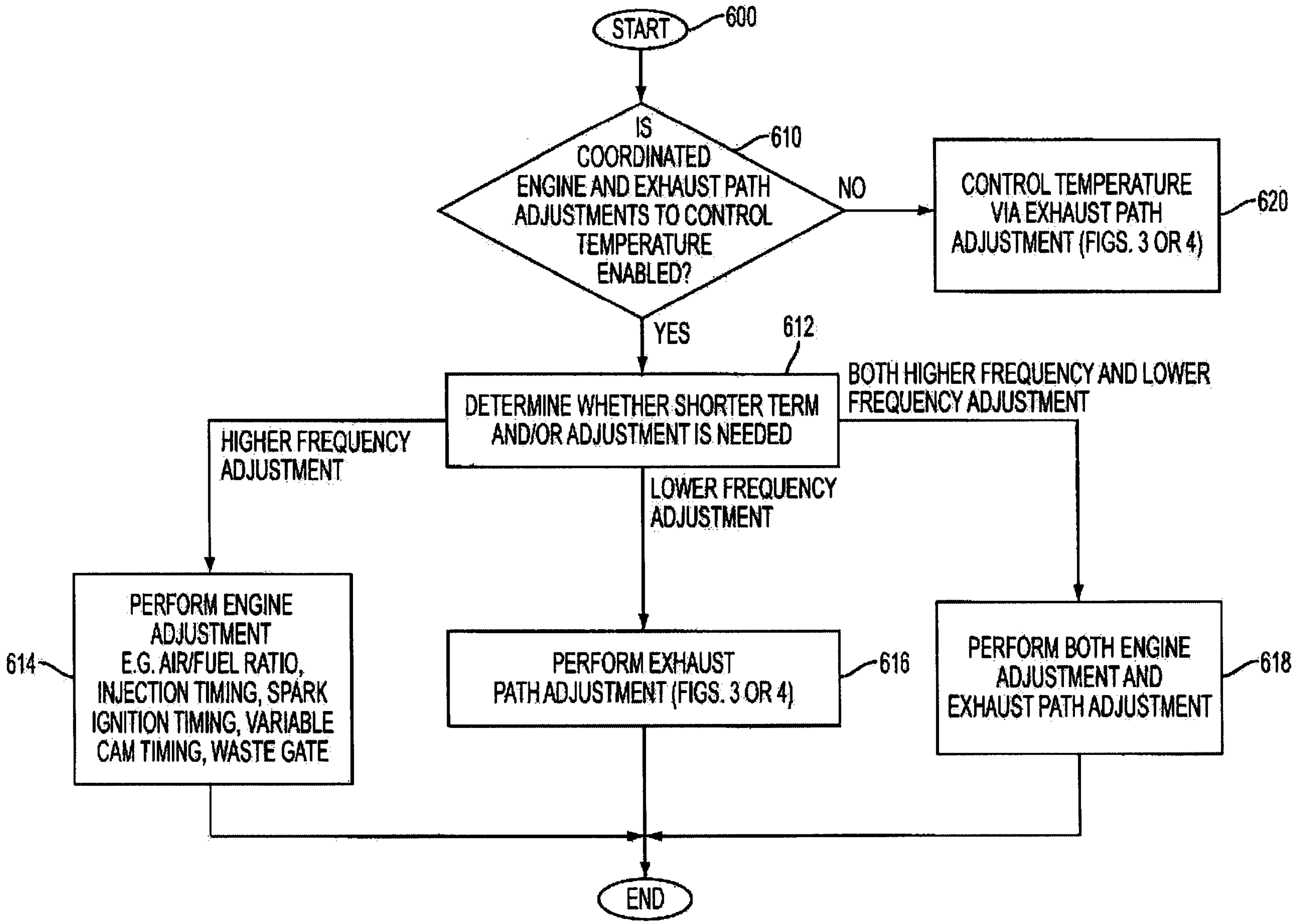
START
600
IS COORDINATED ENGINE AND EXHAUST PATH ADJUSTMENTS TO CONTROL TEMPERATURE ENABLED?
610
NO
CONTROL TEMPERATURE VIA EXHAUST PATH ADJUSTMENT (FIGS. 3 OR 4)
620
YES
612
DETERMINE WHETHER SHORTER TERM AND/OR ADJUSTMENT IS NEEDED
HIGHER FREQUENCY ADJUSTMENT
LOWER FREQUENCY ADJUSTMENT
BOTH HIGHER FREQUENCY AND LOWER FREQUENCY ADJUSTMENT
614
PERFORM ENGINE ADJUSTMENT E.G. AIR/FUEL RATIO, INJECTION TIMING, SPARK IGNITION TIMING, VARIABLE CAM TIMING, WASTE GATE
PERFORM EXHAUST PATH ADJUSTMENT (FIGS. 3 OR 4)
616
PERFORM BOTH ENGINE ADJUSTMENT AND EXHAUST PATH ADJUSTMENT
618
END

FIG. 6

2446916

EXHAUST SYSTEM WITH TWIN TURBOCHARGERS

This invention relates to an exhaust system for an engine and in particular to the use of twin turbochargers.

It is well know to use an internal combustion engine in a motor vehicle such as an automobile. Since inducted air is used to burn fuel and produce power in this type of engine, engine power may be limited by the amount of air that can be inducted into the combustion chamber.

Turbochargers may be used to increase the air inducted to the combustion chamber compared with a naturally aspirated system. Further, some automobiles may employ a dual turbocharger system, which can reduce turbo lag while maintaining peak boosting performance by allowing the operation of a single turbocharger at lower engine speed and the operation of dual turbochargers at higher engine speed.

One type of dual turbocharger system is described in U.S. Patent 5,186,005. In this particular dual turbocharger system, twin turbochargers are arranged in a parallel fashion with respect to the engine, and a crossover pipe connects the twin turbochargers. One turbocharger is operated at low engine load/speed while both turbochargers are operated at high engine load/speed. The switch from the single turbocharger operation to the dual turbocharger operation is based on the intake air quantity. However the switch back to the single turbocharger operation is based on the speed, that is, once a dual turbocharger operation is achieved it is only changed back to a single turbocharger operation when the engine speed is below a certain set value, irrespective of the intake air quantity change.

However, one issue associated with such dual turbocharger systems and possibly other dual turbocharger systems is that it is difficult to maintain the exhaust temperature within a proper range for the optimal operation of a device in the emission control system for reducing emissions in the exhaust. For example, if the exhaust temperature is too cold, the efficiency of the device may be low and if the exhaust temperature is too hot, the device may degrade physically or chemically in the example of a catalytic device. During some conditions, for example when the engine has just been started or when the engine is operated at a low speed, the exhaust temperature may be too low for efficient operation or catalytic conversion. Yet during other conditions, for example when the engine is operated at a high speed or load, the exhaust temperature may be too high, which may cause a catalyst to degrade.

It is an object of the invention to provide an exhaust system having twin turbochargers that eliminates or minimises the problems associated with the prior art.

According to a first aspect of the invention there is provided an exhaust system for an engine having a first set and a second set of cylinders and an emission control device comprising a first turbocharger coupled to the first set of cylinders, a second turbocharger coupled to the second set of cylinders, a crossover pipe coupled between and upstream of the first and second turbochargers, a mechanism for adjusting exhaust flow through the crossover pipe, a higher heat loss path coupled between the first turbocharger and the emission control device and a lower heat loss path coupled between the second turbocharger and the emission control device.

The control mechanism for adjusting exhaust flow through the crossover pipe may be a valve.

The lower heat loss path may be a double-wall pipe.

The higher heat loss path may be a single-wall pipe.

The higher heat loss path may contain more pipe bends compared to the lower heat loss path to increase its cooling effect on the exhaust.

The higher heat loss path may contain a cooling device that cools the exhaust flows through the higher heat loss path.

The higher heat loss path may be a single-wall pipe that contains more pipe bends and a lower number of walls than the lower heat loss path.

The lower heat loss path is a double-wall pipe with less bends than the higher heat loss pipe.

The lower heat loss path may contain a heating mechanism that heats up the exhaust flowing through the lower heat loss path.

The lower heat loss path may contain an insulating layer that insulate the heat loss from the exhaust flowing through the lower heat loss path.

The control mechanism for controlling exhaust flow through the crossover may be immediately upstream of the higher heat loss path.

The emission control device may include a catalytic converter.

The exhaust system may further comprise an engine control unit that controls the control mechanism.

The first set of cylinders may be a first engine bank and the second set of cylinders may be a second engine bank.

According to a second aspect of the invention there is provided a method for controlling the exhaust temperature from an engine for the optimal operation of an emission control device comprising exhausting gas from a first set of cylinders to a first turbocharger and then through a lower heat loss path to the emission control device and exhausting gas from a second set of cylinders to a second turbocharger and then through a higher heat loss path to the emission control device and varying the flow of exhaust gas through the lower and higher heat flow paths to control the temperature of the exhaust gas entering the emission control device.

The method may further comprise passing at least a portion of gas from the second turbocharger and second path to the first turbocharger and the first path during reduced temperature conditions.

The exhaust temperature may be additionally controlled by adjusting various engine parameters including adjusting at least one of air/fuel ratio, injection timing and spark ignition timing.

An engine control unit (ECU) may be operable to vary exhaust path adjustments and engine parameter adjustments to control exhaust temperature as operating conditions vary.

An engine control unit (ECU) may be operable to adjust one or more throttle valves in coordination with a control mechanism for adjusting exhaust flow for transient compressor/turbine operation.

The method may further comprise varying an amount of gas flowing exhaust from the first set of cylinders to the second path as temperature varies during a first condition and adjusting an engine operating parameter to affect exhaust temperature as temperature varies during a second condition.

The method may further comprise adjusting an engine operating parameter in coordination with the varying of exhaust gas flow amounts for transient compressor/turbine operation.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which :-

FIG.1 is a system diagram of an example engine system showing a double wall feature for the lower heat loss path and a single wall feature for the higher heat loss path;

FIG.2 is a system diagram of an alternative engine system showing features such as a longer pipe length and more pipe bends for the lower heat loss path;

FIG.3 is a flowchart illustrating a method for controlling the exhaust temperature for the improved operation of an emission control device by adjusting the amount of exhaust flow through the single-wall path and the double-wall path;

FIG.4 is a flowchart illustrating a method for controlling the exhaust temperature for the improved operation of an emission control device by adjusting the amount of exhaust flow through the higher heat loss path and the lower heat loss path;

FIG.5 is a flowchart illustrating compensation method for transient compressor/turbine operation by adjusting one or more throttles in coordination with the control mechanism for adjusting the exhaust flow path; and

FIG.6 is a flowchart illustrating a method for selecting whether to use engine adjustments, exhaust path adjustments or both engine adjustments and exhaust path adjustments to control exhaust temperature.

As illustrated in FIG.1, an internal combustion engine with a dual turbocharger system in accordance with a first embodiment includes a multi-cylinder engine block 100, an exhaust manifold 110, a first turbocharger 112, a second turbocharger 114, a lower heat loss path 118, a higher heat loss path 120, an emission control device 122, an exhaust tail-pipe 126 that opens into the atmosphere, a crossover 116 that provides a passage between the lower heat loss path 118 and the higher heat loss path 120 and a control mechanism 124 that can control the exhaust flow through the crossover 116.

The control mechanism 124 is in this embodiment coupled to and controlled by an engine control unit (ECU) 128. The ECU 128 may further adjust various other exhaust or engine actuators in response to various feedback mechanisms. For example, ECU 128 may be coupled to various engine throttles, for adjusting various engine parameters, such as air/fuel ratio, ignition timing, firing order, exhaust gas recirculation, and positive crankcase ventilation, to increase engine efficiency and therefore decrease emission. The ECU 128 receives inputs from various engine or exhaust sensors as indicated generally at 130.

The exhaust manifold 110 is connected to the engine exhaust outlets and includes a first portion connected to a first group of engine cylinders and a second portion connected to a second group of engine cylinders. The exhaust manifold 110 is also connected to the turbochargers with the first portion connected to the first turbocharger 112 and the second portion connected to the second turbocharger 114. In this example, exhaust gasses from the first group of cylinders are maintained separate from exhaust gasses from the second group of cylinders, and are later mixed together before entry into the emission control device 122. However, various other configurations may be used, if desired.

The turbochargers 112, 114 are arranged downstream of the engine and the exhaust manifold 110 and are arranged in a parallel configuration, with each turbocharger 112, 114 coupled exclusively to a cylinder group separate from other cylinder groups.

The first turbocharger 112 is coupled to and upstream of the lower heat loss path 118 and the second turbocharger 114 is coupled to and upstream of the higher heat loss path 120. The turbocharger may be of various types of turbochargers, for example, it may be a fixed geometry turbocharger or it may be a variable geometry turbocharger. Further, it may be a variable nozzle turbocharger or include a bypass waste gate. Each turbocharger includes a least a turbine and a compressor. The engine exhaust drives the turbine (not shown), which in turn drives the compressor (not shown), which in turn compresses the engine intake air (not shown).

The lower heat loss path 118 may contain one or more features that contribute to its lower heat loss quality, for example, the path may contain a double wall or a thicker wall, may have a shorter path length compared to the higher heat loss path, it may be lined with insulating materials, and/or it may be heated for example with an electric source.

Conversely, the higher heat loss path 120 may contain one or more features that contribute to its higher heat loss quality, for example, the path may contain a single wall or a thinner wall (as compared to path 118), it may have more pipe bends and/or have a longer pipe length compared to the lower heat loss path, and/or it may be cooled by a cooling device. Further, it may be located further from heat sources as compared to path 118. For example, it may be located further from heat rejected from heat exchangers, or it may be located in a region with reduced airflow generated by vehicle motion.

The crossover 116 provides a passage between the lower heat loss path 118 and the higher heat loss path 120.

The crossover 116 may be placed upstream of both turbochargers, but it may also be placed downstream of one or both of the turbochargers. By placing the crossover 116 upstream of both turbochargers, it is possible to achieve (1) a faster boost response because only one turbocharger has to be spun up and this turbocharger will receive twice as much airflow compared to if both turbochargers have to be spun up, and (2) a faster exhaust warm-up because all exhaust flows through the lower heat loss path and the cooling that may result from air expansion in the second turbocharger is reduced. Further, when combined with control mechanism 124, the crossover 116 may provide a variable flow path that can vary flow depending on operating conditions of the engine or vehicle.

The internal combustion engine may be one or more of a various types of internal combustion engines, for example it may be a rotary-piston engine or a reciprocating piston engine. The internal combustion may burn various types of fuels, for example it may be a gasoline burning or a diesel fuel burning engine. Additionally, the internal combustion engine may use different stroke cycles, for example it may use a two-stroke or a four-stroke cycle. Furthermore, the cylinders of the engine may be laid out in various configurations with at least two groups. For example, the cylinders may be arranged in a line as in in-line engines, arranged in a v configuration as in v engines, arranged in w configuration as in w engines, arranged into two opposing banks of cylinders as in flat engines, or a combination of different engine configurations.

The emission control device 122 may contain one or more of individual components, which may for example be catalytic converters, evaporative emission devices, scrubbing devices for hydrocarbon and/or sulphur, particulate filters, traps, adsorbers and non-thermal plasma reactors. The emission control device may also contain various sensors, such as oxygen sensors and temperature sensors, etc. The catalytic converter in the emission control device may contain one or more types of catalysts, for example oxidation catalysts, such as platinum and rhodium for oxidizing carbon monoxide (CO) and unburned hydrocarbons (HC) and reduction catalysts, such as platinum and palladium for reducing oxides of nitrogen (NOx). Further, it may be a selective catalyst reduction (SCR) catalyst, a lean NOx trap, or combinations of various types of catalysts. The catalytic converter may be of different physical structures, such as ceramic honeycombs, metal plates and ceramic beads, or a combination of different physical structures.

The control mechanism 124 for controlling the amount of exhaust that flows through the crossover 116 may contain one or more suitable valves, such as, needle valves, butterfly valves, ball valves, globe valves, angle globe valves, and/or gate valves; and it may be operated by one or more suitable actuators, such as electric solenoid actuators, pneumatic actuators, hydraulic actuators, and/or electric motor driven actuators.

Still referring to FIG. 1, when the control mechanism 124 is in an open position or in a partially open position, part of the exhaust flows through the higher heat loss path; and when the control mechanism 124 is in a closed position, exhaust that flows through the higher heat loss path is shut off and all the exhaust is directed towards and flows through the lower heat loss path. The engine control unit (ECU) 128 is used to control the operation of the control mechanism 124. For example, when the exhaust temperature is below a desired lower operating temperature, TdL, of the emission control device 122, for example when the engine has just started (e.g. within 5 -10 minutes of engine start) or when the ambient temperature is relatively low (e.g. < -20°C), the engine control unit (ECU) 128 sends out signals to the control mechanism 124 to increase exhaust flow to the lower heat loss path 118 and/or decrease exhaust flow to the higher heat loss path 120. As more exhaust flows through the lower heat loss path 118 and less exhausts flow through the higher heat loss path 120, less cooling of the exhaust and/or warming of the exhaust prior to entering the emission control device 122 results. Conversely, when the exhaust temperature is above a desired upper operating temperature, TdU, of the emission control device 122, for example when the engine has been continuously running at high speed for a long time or when the ambient or exhaust temperatures are relatively high, the engine control unit (ECU) 128 sends out signal to the control mechanism 124 to decrease exhaust flow to the lower heat loss path 118 and/or increase exhaust flow to the higher heat loss path 120. As less exhaust flows through the lower heat loss path 118 and more exhaust flows through the higher heat loss path 120, greater cooling of the exhaust prior to entering the emission control device is achieved. Further details of such control operations are described further with regard to FIGS. 3-6.

If the control mechanism 124 is located upstream of one or both turbochargers, the exhaust that flows through one or both turbochargers may be adjusted in a similar fashion.

Although the above example describes control of exhaust temperature or catalyst temperature for improved operation of the catalytic converter emission control device via adjustment of mechanism 124, in some situations temperature control may be used for efficient operation of other types of emission control devices.

FIG.2 illustrates an engine system with a dual turbocharger system in accordance with a second embodiment includes an in-line engine block 200, an engine intake conduit 230, an exhaust manifold 210, a first turbocharger 212, a second turbocharger 214, a lower heat loss path 218, a higher heat loss path 220, an emission control device 222, an exhaust tail-pipe 226 that opens into the atmosphere, a crossover 216 that provides a passage between the lower heat loss path 218 and the higher heat loss path 220, a control mechanism 224 that can control the exhaust flow through the crossover 216, and an engine control unit (ECU) for controlling the operation of the mechanism 224, sometimes in coordination with various engine throttles 232.

In this particular embodiment, the control mechanism 224 is located immediately upstream of the lower heat loss path and serves to cut off the exhaust flow through the lower heat loss path when it is in a closed position, and to enable various levels of flow to 216 as the valve is opened.

The exhaust manifold 210 is connected to the engine exhaust outlets and includes a first portion connected to a first group of engine cylinders and a second portion connected to a second group of engine cylinders. The exhaust manifold 210 is also connected to the turbochargers with the first portion connected to the first turbocharger 212 and the second portion connected to the second turbocharger 214. In this example, exhaust gasses from the first group of cylinders are maintained separate from exhaust gasses from the second group of cylinders, and are later mixed together prior to entry into the emission control device 222. However, various other configurations may be used, if desired.

The turbochargers 212, 214 are arranged downstream of the engine and the exhaust manifold 210 and are arranged in a parallel configuration, with each turbocharger coupled exclusively to a cylinder group separate from other cylinder groups.

The first turbocharger 212 is coupled to and upstream of the lower heat loss path 218 and the second turbocharger 214 is coupled to and upstream of the higher heat loss path 220. The turbocharger may be of various types of turbochargers, as discussed in reference to FIG.1. The engine exhaust drives the turbine 212a 214a, which in turn drives the compressor 212b 214b, which in turn compresses the engine intake air flowing through the engine intake conduit 230.

In this particular embodiment, the lower heat loss path 218 has a double wall and a shorter path length compared to the higher heat loss path 220; and the higher heat loss path 220 is shown to have more pipe bends and longer path length compared to the lower heat loss path 218.

The lower heat loss path 218 may contain one or more features that contribute to its lower heat loss quality; conversely, the higher heat loss path 220 may contain one or more features that contribute to its higher heat loss quality, as discussed previously in reference to FIG. 1.

The crossover 216 provides a passage between the lower heat loss path 218 and the higher heat loss path 220. In this particular embodiment, the crossover 216 is placed upstream of both turbochargers. In other embodiments the crossover may be placed downstream of one or both of the turbochargers in other embodiments. With similar reasoning as provided for FIG.1, by placing the crossover 216 upstream of both turbochargers, it is possible to achieve (1) a faster boost response and (2) a faster exhaust warm-up. Further, when combined with control mechanism 224, crossover 226 may provide a variable flow path that can vary flow depending on operating conditions of the engine or vehicle.

The internal combustion engine 200 may be one or more of a various types of internal combustion engines, as discussed previously in reference to FIG.1.

The emission control device 226 may contain one or more of individual units/sub-components and may contain various sensors, as discussed previously in reference to FIG. 1. The catalytic converter in the emission control device may contain one or more types of catalysts, as discussed previously in reference to FIG.1. The catalytic converter may be of different physical structures, as discussed previous in reference to FIG.1.

The control mechanism 224 for controlling the amount of exhaust that flows through the crossover 216 may contain one or more suitable valves, as discussed previously in more detail in reference to FIG.1.

In this particular embodiment, when the control mechanism 224 is in an open position or in a partially open position, part of the exhaust flows through the lower heat loss path 218; and when the control mechanism 224 is in a closed position, exhaust flow through the lower heat loss path 218 is shut off and all the exhaust is directed towards and flows through the lower heat loss path 220. Also in this particular embodiment, the control mechanism 224 is located upstream of one or both turbochargers, the exhaust that flows through the one or both turbochargers may be adjusted in a similar fashion.

The mechanism 224 is coupled to and controlled by an engine control unit (ECU) 228 and the engine control unit (ECU) also controls one or more of the throttle 232. As discussed previously in reference to FIG. 1, the engine control unit (ECU) may adjust exhaust flow path and therefore exhaust temperature by controlling the operation of the control mechanism.

Exemplary engine and exhaust system controls to maintain exhaust temperature operation in desired ranges using the example systems of FIGS. 1 and 2 are described herein. In particular, control routines are described below which may be used with various engine and exhaust configurations, such as those described in FIGS. 1 and 2.

The specific routines described below in the flowcharts may represent one or more of any number of processing strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various acts or functions illustrated may be performed in the sequence illustrated, in parallel, or in some cases omitted. Likewise, the order of processing is not necessarily required to achieve the features and advantages of the example embodiments described herein, but is provided for ease of illustration and description. Although not explicitly illustrated, the illustrated acts or functions may be repeatedly performed depending on the particular strategy being used, during engine operation. Further, these figures may graphically represent code to be programmed into the computer readable storage medium in a controller or control system.

FIG.3 shows a high-level flowchart of an example routine that may be implemented in a vehicle control system, such as an engine control unit (ECU). Specifically, the routine illustrates control of the exhaust temperature via adjustments of exhaust flow in a crossover in a parallel turbocharger system such as illustrated in FIGS. 1-2.

First, after starting at 300, the engine control unit (ECU) monitors the exhaust temperature Tm in 310. Then, in 312, the engine control unit (ECU) determines a desired lower operating temperature TdL and a desired upper operating temperature TdU based on various operating parameters, such as vehicle speed, engine speed, engine load, and/or others.

Next, in 314, the engine control unit (ECU) determines whether the exhaust temperature Tm is lower than the desired upper operating temperature TdU (Tm < TdL) and if Tm is less than TdL (Tm < TdL), the method advances to 316 and engine control unit (ECU) adjusts an exhaust valve (e.g., mechanism 214 in FIG.1 or mechanism 224 in FIG.2) to increase exhaust flow to the lower heat loss path and/or decrease exhaust flow to the higher heat loss path. However, if at 314 Tm is not less than TdL (Tm ≥ TdL), the engine control unit (ECU) advances to 318 and then determines if the exhaust temperature Tm is higher than the desired upper operating temperature TdU or engine speed and load are greater than respective limits and, if so, the method advances to 320 and the engine control unit (ECU) adjusts the valve to increase exhaust flow to the higher heat loss path and/or decrease flow to the lower heat loss path. Otherwise, the routine ends at 322.

Note that the exhaust temperature Tm may be based on direct measurements via various sensors; it may be based on or estimated from various parameters, for example from various ambient and/or engine parameters, such as engine temperature, engine speed, engine intake air quantity, ambient temperature, ambient humidity and/or ambient wind level and/or it may also be based on parameters indicative of temperature of the exhaust, such as speed and load.

By controlling the operation of the control mechanism in a way exemplified in FIG.3, it is possible to achieve more accurate control of exhaust temperature within a proper range for the efficient operation of the emission control device. For example, it may be possible to avoid or reduce situations where exhaust temperature is below a desired lower operating temperature TdL and it may be possible to avoid or reduce situations where exhaust temperature is above a desired upper operating temperature TdU to reduce degradation of catalysts in the emission control device.

FIG.4 shows a high-level flowchart of an example routine that may be implemented in a vehicle control system, such as an engine control unit (ECU). Specifically, the routine shows control of exhaust flow through a crossover pipe in a parallel turbocharger system that has a dual wall path and a single wall path, such as illustrated in FIGS.1 and 2.

After starting at 400, the engine control unit (ECU) monitors the exhaust temperature Tm at 410. Then, at 412 the engine control unit (ECU) determines a desired lower operating temperature TdL and a desired upper operating temperature TdU before advancing to 414 where the engine control unit (ECU) determines whether the exhaust temperature Tm is lower than the upper operating temperature TdU ($Tm < TdL$). If Tm is less than TdL ($Tm < TdL$), the method advances to 416 and the engine control unit (ECU) adjusts valve (e.g. control mechanism 124 in FIG.1 and control mechanism 224 in FIG. 2) to increase exhaust flow to the dual wall path and/or decrease exhaust flow to the single wall path but, if Tm is not less than TdL ($Tm \leq TdL$), then the method advances to 418 and the engine control unit (ECU) then determines if the exhaust temperature Tm is higher than the upper operating temperature TdU ($Tm>TdU$). If Tm is higher than TdU ($Tm>TdU$) or Engine Speed/Load > Respective Limits, the method advances from 418 to 420 and the engine control unit (ECU) adjusts valve (e.g., control mechanism 214 in FIG.1 and control mechanism 224 in FIG.2) to increase exhaust flow to the single wall path and/or decrease flow to the dual wall path. If Tm is lower than TdU the method ends at 422.

As discussed in reference to FIG. 3, the exhaust temperature Tm may be based on direct measurements via various sensors; it may be based on or estimated from various parameters, and/or it may also be based on parameters indicative of temperature of the exhaust.

Similarly, by controlling the operation of the control mechanism in a way exemplified in FIG.4, it is possible to achieve more accurate control of exhaust temperature within a proper range for the efficient operation of the emission control device, as discussed in more detail in reference to FIG.3.

The engine control unit (ECU) may also adjust one or more throttles or other engine parameters such as fuel injection, cam timing, etc. in coordination with the control mechanism (e.g., control mechanism 124 in FIG. 1 or control mechanism 224 in FIG. 2), to compensate for transient engine and compressor/turbine operation to reduce transient torque errors, air-fuel errors, etc. In particular, the adjustment of the exhaust flow through the crossover (e.g., crossover 116 in FIG. 1 and crossover 216 in FIG. 2) may affect the turbocharger (and thus compressor) speeds, thereby affecting intake and exhaust pressure. The transient pressures and speeds may further generate transient airflow variations and cylinder charge variations that may cause transient torque disturbances, air-fuel ratio disturbances, etc. To reduce the potential for such transient disturbances, engine operation may be adjusted in coordination with adjustment of the cross-over flow via control mechanism 124/224, such as described in Figure 5.

Specifically, the engine control unit (ECU) determines whether there is any adjustment or transition in the control mechanism (e.g., control mechanism 124 in FIG. 1 and control mechanism 224 in FIG. 2) in 510. If there is an adjustment in the control mechanism, the engine control unit (ECU) then adjusts one or more throttles (e.g., throttle 232 in FIG. 2) in coordination with the control mechanism (e.g., control mechanism 224 in FIG. 2) for transient compressor/turbine operation in 510. Otherwise, the routine ends. For example, the routine may adjust throttle differently and therefore the flow differently to the first and second cylinder groups to compensate for the unequal turbo-charging operation when or as the control mechanism increases the flow diverted from the first group to the second group.

In this way, it may be possible to reduce uneven turbo-charging caused by different exhaust flow through each turbocharger. For example, when the engine control unit (ECU) (e.g., engine control unit 128 in FIG. 1 and engine control unit 228 in FIG. 2) adjusts the control mechanism (e.g., control mechanism 124 in FIG.1 and control mechanism 224 in FIG. 2) to increase exhaust flow to the lower heat loss path (e.g., 118 in FIG.1 and 218 in FIG.2), the first turbocharger may receive more exhaust flow and may spin faster than the second turbocharger (e.g., 112 in FIG.1 and 212 in FIG.2), therefore the intake air will be compressed more on the side of the first turbocharger than on the side of the second turbocharger which consequently may result uneven distribution of compressed air into different engine cylinders.

The compensation mechanism described in FIG.5 may adjust various engine throttles to equalize intake air compression by both turbochargers, for example here by possibly decreasing the flow of intake air passing the compressor of the first turbocharger.

After starting at 500 the method advances to step 510 where it is determined whether to adjust or transition one of the valves 124 or 224 if not the method ends at 514 but if one the valves 124, 224 are to be transitioned or adjusted then the method advances to 512 before ending at 514.

As noted herein, exhaust temperature may be controlled or adjusted by exhaust flow path adjustments, by engine adjustments, or by both exhaust flow path adjustments and engine adjustments. For example, the routine of Fig.6 illustrates the selection of various temperature adjustments based on operating conditions to achieve improved temperature control across engine and vehicle operation.

Specifically, after starting at 600 the engine control unit (ECU) at 610 determines whether coordinated engine and exhaust path adjustments for controlling exhaust temperature is enabled based on various parameters, such as time since engine start, turbocharger status, and/or others.

If coordinated engine and exhaust path adjustments for controlling exhaust temperature is not enabled at 610, then the engine control unit (ECU) controls the exhaust temperature by adjusting the exhaust path in 620.

However, if the coordinated engine and exhaust path adjustments for controlling exhaust temperature is enabled, the method advances to 612 and the engine control unit (ECU) determines whether higher frequency or lower frequency exhaust temperature adjustment is needed based on, for example, a rate of change of temperature control error and/or other operating conditions. If only higher frequency exhaust temperature adjustment is needed, the method advances to 614 and the engine control unit (ECU) determines which one or a combination of engine adjustments may be used and then performs the necessary engine adjustments, for example by adjusting air/fuel ratio, by controlling injection timing, by controlling spark ignition timing, by adjusting the variable cam timing, by adjusting the waste gate operation.

If both higher frequency and lower frequency exhaust temperature adjustments are needed, the method advances to 618 and the engine control unit then controls the exhaust temperature by adjusting the engine parameters and by adjusting the exhaust path.

Finally, if only lower frequency engine adjustment is needed, the method advances to 616 and the engine control unit then adjusts the exhaust flow path.

After any of steps 614, 616, 618 the method ends.

In this way, it may be possible to select appropriate temperature adjustment mechanism for appropriate conditions and to achieve advantages such as reduce transitions in exhaust flow and turbo-charging operation.

Therefore in summary, the inventors herein have recognized the above issues and that such issues may be at least partially addressed by an exhaust system for an engine having a first set and a second set of cylinders, a first turbocharger coupled to the first set of cylinders and a second turbocharger coupled to the second set of cylinders, and an emission control device. Specifically, the exhaust system may include a lower heat loss path that is coupled to and downstream of the first turbocharger, a higher heat loss path that is coupled to and downstream of the second turbocharger, a crossover pipe coupled between and upstream of the first and the second turbocharger that provides a passage between the higher heat loss path and the lower heat loss path, and a control mechanism for adjusting flow in the crossover pipe.

By providing both a higher heat loss and a lower heat loss path with a crossover that allows communication between the two paths, and by providing a mechanism to control the flow through the higher heat loss and the lower heat loss paths, the exhaust temperature may be better controlled to increase the efficiency of the emission control device operation in a dual turbocharger environment. Under certain conditions, for example, when the engine is operating at a lower load/speed, the exhaust flow through the higher heat loss path is reduced and the exhaust flow through the lower heat loss path is increased to reduce heat loss; while under certain other conditions, for example, when the engine is operating at a higher load/speed, the exhaust flow through the higher heat loss path is increased and the exhaust flow through the lower heat loss path is decreased to increase heat loss from the exhaust.

Further, by placing the crossover between the higher heat loss path and the lower heat loss path upstream of both turbochargers, it is possible to achieve (1) a faster boost response because only one turbocharger has to be spun up and this turbocharger will receive twice as much airflow compared to if both turbochargers have to be spun up, and (2) a faster exhaust warm-up because all exhaust flows through the lower heat loss path and the cooling that may result from air expansion in the second turbocharger is reduced.

As such, it is possible to provide an internal combustion engine that has a dual turbocharger system and an emission control device with mechanisms to control the exhaust temperature for improved operation of the emission control device.

While the above example is illustrated with regard to a dual turbocharger system, the concepts may be equally applicable to other turbocharger systems.

CLAIMS

1. An exhaust system for an engine having a first set and a second set of cylinders and an emission control device comprising a first turbocharger coupled to the first set of cylinders, a second turbocharger coupled to the second set of cylinders, a crossover pipe coupled between and upstream of the first and second turbochargers, a mechanism for adjusting exhaust flow through the crossover pipe, a higher heat loss path coupled between the first turbocharger and the emission control device and a lower heat loss path coupled between the second turbocharger and the emission control device.

2. An exhaust system as claimed in claim 1 wherein the control mechanism for adjusting exhaust flow through the crossover pipe is a valve.

3. An exhaust system as claimed in claim 1, wherein the lower heat loss path is a double-wall pipe.

4. An exhaust system as claimed in any preceding claim wherein the higher heat loss path is a single-wall pipe.

5. An exhaust system as claimed in any preceding claim wherein the higher heat loss path contains more pipe bends compared to the lower heat loss path to increase its cooling effect on the exhaust.

6. An exhaust system as claimed in any preceding claim wherein the higher heat loss path contains a cooling device that cools the exhaust flows through the higher heat loss path.

7. An exhaust system as claimed in any preceding claim wherein the higher heat loss path is a single-wall

pipe that contains more pipe bends and a lower number of walls than the lower heat loss path.

8. An exhaust system as claimed in any preceding claim wherein the lower heat loss path is a double-wall pipe with less bends than the higher heat loss pipe.

9. An exhaust system as claimed in any preceding claim wherein the lower heat loss path contains a heating mechanism that heats up the exhaust flowing through the lower heat loss path.

10. An exhaust system as claimed in any preceding claim wherein the lower heat loss path contains an insulating layer that insulate the heat loss from the exhaust flowing through the lower heat loss path.

11. An exhaust system as claimed in any preceding claim wherein the control mechanism for controlling exhaust flow through the crossover is immediately upstream of the higher heat loss path.

12. An exhaust system as claimed in any preceding claim wherein the emission control device includes a catalytic converter.

13. An exhaust system as claimed in any preceding claim further comprising an engine control unit that controls the control mechanism.

14. An exhaust system as claimed in any preceding claim wherein the first set of cylinders is a first engine bank and the second set of cylinders is a second engine bank.

15. A method for controlling the exhaust temperature from an engine for the optimal operation of an emission

control device comprising exhausting gas from a first set of cylinders to a first turbocharger and then through a lower heat loss path to the emission control device and exhausting gas from a second set of cylinders to a second turbocharger and then through a higher heat loss path to the emission control device and varying the flow of exhaust gas through the lower and higher heat flow paths to control the temperature of the exhaust gas entering the emission control device.

16. A method as claimed in claim 15 wherein the method further comprises passing at least a portion of gas from the second turbocharger and second path to the first turbocharger and the first path during reduced temperature conditions.

17. A method as claimed in claim 15 or in claim 16 wherein the exhaust temperature is additionally controlled by adjusting various engine parameters including adjusting at least one of air/fuel ratio, injection timing and spark ignition timing.

18. A method as claimed in any of claims 15 to 17 wherein an engine control unit (ECU) is operable to vary exhaust path adjustments and engine parameter adjustments to control exhaust temperature as operating conditions vary.

19. A method as claimed in any of claims 15 to 18 wherein an engine control unit (ECU) is operable to adjust one or more throttle valves in coordination with a control mechanism for adjusting exhaust flow for transient compressor/turbine operation.

20. A method as claimed in claim 15 wherein the method further comprises varying an amount of gas flowing exhaust from the first set of cylinders to the second path as temperature varies during a first condition and adjusting an

engine operating parameter to affect exhaust temperature as temperature varies during a second condition.

21. A method as claimed in any of claims 15 to 20 wherein the method further comprises adjusting an engine operating parameter in coordination with the varying of exhaust gas flow amounts for transient compressor/turbine operation.

22. An exhaust system for an engine having a first set and a second set of cylinders and an emission control device substantially as described herein with reference to the accompanying drawing.

23. A method for controlling the exhaust temperature from an engine for the optimal operation of an emission control device substantially as described herein with reference to the accompanying drawing.

Application No:	GB0801669.3	**Examiner:**	John Twin
Claims searched:	1 to 23	**Date of search:**	17 April 2008

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
A	-	US 5186005 A (Toyota)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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The following online and other databases have been used in the preparation of this search report

EPODOC, TXTE, WPI

International Classification:

Subclass	Subgroup	Valid From
F02B	0037/007	01/01/2006