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(71) Applicant: **Powertrain Engineering Sweden AB**
418 78 Göteborg (SE)

(72) Inventor: **ROLANDSON, Ola**
468 90 Vänersnäs (SE)

(74) Representative: **Zacco Sweden AB**
P.O. Box 5581
Löjtnantsgatan 21
114 85 Stockholm (SE)

(54) **AIR INJECTION SYSTEM**

(57) The present disclosure relates to an air injection system (1) arranged to be connected to an internal combustion engine (100), ICE, of a vehicle, the air injection system (1) comprising an air regulation circuit (2) having a common intake portion (2a) arranged to obtain compressed ambient air. Further, comprising a first and a second branch (3a, 3b), wherein the second branch (3b) is arranged to connect to an exhaust manifold (20) of said internal combustion engine (100), wherein the second branch (3b) comprises a SAI pump (15) integrated therein, and wherein at least one of the branches (3a, 3b) comprises an adjustable valve (11a) integrated therein. The air injection system (1) is configured to, preferably by control circuitry control the adjustable valve (11a) to, based on operating data of said air injection system (1), regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold (10, 20).

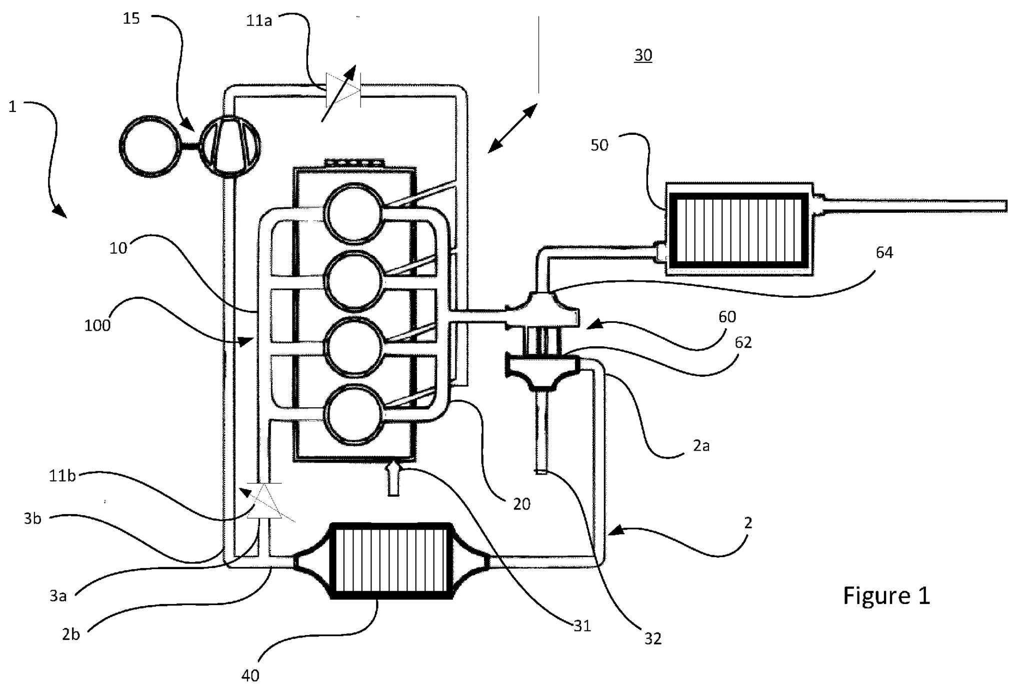

Figure 1

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an air injection system and a method for operating an internal combustion engine comprising such an air injection system.

BACKGROUND

[0002] Air injection systems with means for secondary air injection (SAI) have conventionally been used in internal combustion engines (ICE) as an emission control mechanisms adapted to reduce pollutants in the exhaust gases.

[0003] SAI aim to introduce air into the exhaust manifold or directly into the combustion chamber to aid in the combustion of unburned fuel, thereby enabling a more complete combustion and reducing the emission of harmful substances such as hydrocarbons and carbon monoxide.

[0004] SAI is efficient especially during cold starts as it can facilitate the warming of the catalyst of the ICE to enhance its efficiency in converting pollutants.

[0005] Traditional SAI take air from the ambient environment. Having the SAI active during take-offs puts high demand on the SAI pump. Accordingly, in some cases, the SAI pump is not able to operate in accordance with demand.

[0006] Generally, existing systems are not efficient enough. Existing air injections systems at least fail to provide a SAI which is able to support the catalyst at all engine load points without excessively increasing energy demands thereto.

[0007] Thus, there is room for air injection systems of the present art to explore the domain to provide an air injection system that comprises means for SAI that is increased in efficiency compared to the air injection systems having SAI of the present art. Specifically it would be desirable to provide an air injection system that can provide SAI which is operable and efficient at all engine load points. Moreover, it would be desirable if such a system could accurately determine the amount of air distributed therefrom.

SUMMARY

[0008] It is therefore an object of the present disclosure to alleviate at least some of the mentioned drawbacks to provide a system having secondary air injection means which is more efficient than previous solutions both in terms of operation and in terms of energy consumption.

[0009] The present disclosure relates to an air injection system (hereinafter referred to as the "system") arranged to be connected to an internal combustion engine/ICE system (ICE) of a vehicle. The system comprising an air regulation circuit having a common intake portion arranged to obtain compressed ambient air. The air regulation circuit is, at a first portion, branched into a first and a second branch, thereby enabling distribution of said compressed air to said first and second branch. Accordingly, the compressed air may be dividedly distributed between the first and the second branch, e.g., half of it may go into the first branch and the other half into the second.

[0010] The first branch is arranged to connect to an air intake manifold of said internal combustion engine and the second branch is arranged to connect to an exhaust manifold of said internal combustion engine. The first branch may in some aspects be regarded as a part of a primary air injection arrangement of said air injection system. Accordingly, the second branch may be regarded as the secondary air injection arrangement of the air injection system. The second branch comprising a secondary air injection (SAI) pump integrated therein and wherein at least one of the branches comprises an adjustable valve integrated therein. Moreover, the system preferably comprises control circuitry (in some aspects a mechanical linkage may be used) configured to control the adjustable valve to, based on operating data of said system, regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold. The term "exhaust manifold" may also encompass combustion chambers connected to the exhaust manifold. The ratio may vary according to secondary air injection needs, but e.g. during a cold start 1/3 of the compressed air may be provided to the exhaust manifold such that the rest is provided to the intake manifold. In some aspects, the system is configured to control the adjustable valve to at least regulate an amount of said compressed air being distributed to said exhaust manifold.

[0011] An advantage of the system herein is that as the common intake portion distributes air both to the first and the second branch, i.e. a single air intake point can provide air to two branches, thereby air intaken from a single intake point can be distributed to both the intake manifold and the exhaust manifold, thereby providing primary air injection to the intake manifold and secondary air injection to the exhaust manifold from a common intake point. Hence, the air may be solely received from/exclusively obtained from one point/intake in the system (i.e. the common intake portion). Accordingly, efficiency is increased in terms of at least power consumption and space. Moreover, as compressed air of a flow is readily supplied to the SAI pump, this increases pressure capacity and reduces the burden on the SAI pump compared to SAI pumps of conventional systems which directly receive air from the ambient environment.

[0012] The control circuitry is further configured to control the adjustable valve to, based on said operating data of said system, achieve a pre-defined lambda while regulating said ratio of said compressed air distributed between the exhaust manifold and intake manifold.

[0013] Accordingly, the system may be operable to achieve a pre-defined air-fuel ratio while regulating the ratio between the exhaust manifold and intake manifold. The system may be operable to achieve said pre-defined air-fuel ratio based on a fuel mass flow inputted into the ICE.

[0014] Further, the control circuitry may further be configured to control/regulate/affect a flow of said compressed air through said SAI pump based on said operating data. The SAI pump may work in conjunction with said valve. The control circuitry may control the flow by e.g. activating the SAI pump and/or controlling duration and intensity (power) of the SAI pump.

[0015] The adjustable valve may be a throttle valve which is controlled by said control circuitry. The throttle valve may comprise a throttle valve plate which can be electrically adjusted between different positions (such as a closed position and one or more open positions) to define an amount of compressed air that is to flow therethrough. This is beneficial in comparison with e.g. a binary valve which only have two positions.

[0016] The adjustable valve may be a first valve integrated in said second branch upstreams/after of said SAI pump, such that compressed air reaches/travels to the adjustable valve via the SAI pump. Further, the system may comprise a second adjustable valve integrated in said first branch, wherein the control circuitry is configured to control at least the first (but in some aspects also the second, i.e. each of the first and the second valves may be controlled) adjustable valve to, based on said operating data, regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold. Accordingly, the term "the adjustable valve" herein may be interchanged with "the at least first adjustable valve". In some aspects, the first valve may be controlled by the control circuitry and the second valve may be at least partially controlled based on an air injection demand of the ICE. The air injection demand may be decided/determined by input to an accelerator pedal of a vehicle connectable to said SAI system. Thus, the second valve may be controlled by the control circuitry/a mechanical connection based on regulation of said air injection demand/accelerator pedal input and/or based on a fuel injection into a fuel inlet port of the ICE and/or based on said operating data. The second valve may be referred to as an ICE valve operable in conjunction with a fuel mass flow entering the ICE.

[0017] In some aspects, the first valve may be controlled subject to said second valve. I.e. the position of said second valve may be utilized as operating data for controlling said first valve. Accordingly, e.g. during acceleration, the first valve may controlled to a closed position during the acceleration phase (e.g. when user is pressing pedal) so to maximize an amount of air supplied to the intake manifold.

[0018] An advantage of this is that the control circuitry can provide a variable lambda and a variable amount of air provided to the exhaust manifolds from the second branch.

[0019] Further, the system further comprises a cooling device integrated in the air regulation circuit for cooling the compressed air to a defined temperature.

[0020] An advantage of this is that it can increase the density of the air to provide more oxygen for combustion. The cooling device may be a water-cooled air-cooler.

[0021] The second branch may comprise a bypass circuit arranged to, at a pre-defined condition, route the compressed air to bypass the SAI pump. Accordingly, in situations in which the SAI pump does not need to affect the flow of air therethrough, the SAI pump may be bypassed. This situation may occur in instances where the catalyst of the ICE is already at a sufficient temperature. In other words, if the SAI pump is a restriction for air flow at any load point a bypass valve may be positioned parallel to the SAI pump to enable air injection without SAI pump active using the compressed air only.

[0022] The operating data may be at least one of a thermal condition of a catalyst connected to said exhaust manifold, an engine operating point, lambda, a fuel mass flow, and an air mass flow at said intake portion, a current position of each valve of the at least one valve. The thermal condition may be the temperature of the catalyst. The engine operating point may be the rotational speed of the engines crankshaft or engine load or torque. The air mass flow may be the quantity or mass of air that moves through the intake portion. A fuel mass flow refers to the quantity or mass of fuel inputted to the ICE.

[0023] The intake portion may be arranged to be connected to a compressor-part of a turbocharger of said ICE. The turbocharger may further comprise a turbine part which is connected to the exhaust manifold. Accordingly, the compressed air may be compressed and/or heated by the turbocharger such that turbocharger compressed air is fed to the SAI pump. Accordingly, as mentioned herein, the system is able to function with high efficiency while reducing burden on the SAI pump. In other aspects, the first portion 2a may be comprise a compressor which compresses the air.

[0024] The ratio may be regulated based on an input of said operating data into a pre-determined catalyst heating model which has a purpose of/is adapted to enable the control circuitry to, by regulating said ratio thermally controlling a catalyst of the ICE. Accordingly, the control circuitry may regulate the ratio based on an output of catalyst heating model provided by input of said operating data therein. Hence, the control circuitry may be configured to continuously utilize the catalyst heating model to determine and regulate said ratio. The catalyst heating model may indicate said ratio subject to said operating data. The catalyst heating model may be a pre-defined model that outputs control data based on inputted operating data. In some aspects, the catalyst heating model may be in the form of a look-up table. The catalyst heating model may also enable the control circuitry to control the SAI pump. Accordingly, the ratio and/or the flow of air through said SAI pump is regulated based on an input of said operating data into said pre-determined catalyst heating model.

[0025] An advantage of regulating the ratio based on a pre-determined model is that it enables the ratio to be continuously adjusted with minimum delay in real-time.

[0026] The present disclosure further relates to an ICE (may also be referred to as an ICE system or ICE arrangement) comprising the system according to any aspect herein. Further, the disclosure relates to a vehicle comprising the ICE according to any aspect herein. The ICE may comprise a plurality of cylinders, a fuel inlet port, an intake manifold and an exhaust manifold. Further, the exhaust manifold may comprise a conduit (which may also be referred to as an exhaust pipe portion) connected to a catalyst such as a three-way catalyst via a turbocharger. A turbine part of said turbocharger may be connected to said catalyst and a compressor part thereof may be connected to said first portion for inputting ambient air thereto. After the catalyst, the gases are outputted to the environment.

[0027] The ICE system may comprise any other suitable component as will be appreciated by a skilled person in the art, such as pistons and connecting rods, a crankshaft, a valvetrain, cooling system and lubrication system.

[0028] The present disclosure further relates to a method for operating the ICE according to any aspect herein. The method comprising the steps of monitoring said operating data of said system and controlling the (at least one) adjustable valve based on said operating data.

[0029] The method may further comprise the step of controlling a flow of said compressed air through said SAI pump based on said operating data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] These and other features and advantages of the present disclosure will now be further clarified and described in more detail, with reference to the appended drawings;

Figure 1 illustrates an air injection system according to some aspects of the present disclosure;

Figure 2 illustrates control circuitry of the air injection system in accordance with some aspects of the present disclosure;

Figure 3 illustrates an air injection system according to some aspects of the present disclosure;

Figure 4 illustrates a vehicle comprising the air injection system according to some aspects of the present disclosure; and

Figure 5 illustrates a method for operating an ICE according to some aspects of the present disclosure;

DETAILED DESCRIPTION

[0031] In the following detailed description, some embodiments of the present disclosure will be described. However, it is to be understood that features of the different embodiments are exchangeable between the embodiments and may be combined in different ways, unless anything else is specifically indicated. Even though in the following description, numerous specific details are set forth to provide a more thorough understanding of the present disclosure, it will be apparent to one skilled in the art that the present disclosure may be practiced without these specific details. In other instances, well known constructions or functions are not described in detail, so as not to obscure the present disclosure.

[0032] It is also to be understood that the terminology used herein is for purpose of describing particular aspects only, and is not intended to be limiting. It should be noted that, as used in the specification and the appended claim, the articles "a", "an", "the", and "said" are intended to mean that there are one or more of the elements unless the context clearly dictates otherwise. Thus, for example, reference to "a unit" or "the unit" may refer to more than one unit in some contexts, and the like. Furthermore, the words "comprising", "including", "containing" do not exclude other elements or steps. It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps, or components. It does not preclude the presence or addition of one or more other features, integers, steps, components, or groups thereof. The term "and/or" is to be interpreted as meaning "both" as well and each as an alternative. More specifically, the wording "one or more" of a set of elements (as in "one or more of A, Band C" or "at least one of A, B and C") is to be interpreted as either a conjunctive or disjunctive logic. Put differently, it may refer either to all elements, one element or combination of two or more elements of a set of elements. For example, the wording "A, B and C" may be interpreted as A or B or C, A and B and C, A and B, B and C, or A and C.

[0033] It will also be understood that, although the term first, second, etc. may be used herein to describe various elements or features, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of the embodiments. The first element and the second element are both elements, but they are not the same element.

[0034] Figure 1 schematically illustrates an air injection system 1 (hereinafter referred to as a "system") arranged to be connected to an ICE 100 of a vehicle. In Figure 1, it is connected to the ICE 100. The system 1 comprises an air regulation circuit 2 having a common intake portion 2a arranged to obtain compressed ambient air. In Figure 1, the compressed air is obtained via a turbocharger 60. Further, the air regulation circuit 2 is, at a first portion 2b, branched into a first and a second branch 3a, 3b, thereby enabling distribution of said compressed air to said first and second branch 3a, 3b. The first branch 3a is arranged to connect to an air intake manifold 10 of said internal combustion engine 100 to provide primary air injection to the intake manifold 10 for reacting with fuel received at fuel inlet 31. Further, the second branch 3b is arranged to connect to an exhaust manifold 20 of said internal combustion engine 100 to provide secondary air injection, wherein the second branch 3b comprises a SAI pump 15 integrated therein. The SAI pump being configured to affect a flow of air transferred via the SAI pump 15. At least one of the branches 3a, 3b comprises an adjustable valve 11a, 11b integrated therein. In Figure 1, the system 1 comprises two adjustable valves 11a, 11b. The second adjustable valve 11b may be referred to as an ICE valve and may be arranged to be adjusted based on external input (such as from a user). The second adjustable valve 11b may be adjusted by a mechanical linkage. Figure 1 illustrates that the air distributed between the first and the second branch 3a, 3b is obtained from a common inlet 32, thereby air received from a common inlet can be used both to feed the SAI pump and as air injection to the intake manifold. The second branch may be referred to as a secondary air injection branch. The amount of air obtained from the common inlet 32 may be determined based on said operating data.

[0035] Figure 1 illustrates that the system 1 comprises control circuitry configured 30 to control the adjustable valve 11a to, based on operating data of said system 1, regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold 10, 20.

[0036] The operating data may be obtained by one or more sensors. Accordingly, there may be one or more sensor dedicated to monitor, SAI pump intensity (e.g. rotation per minute, RPM of SAI pump 15), positions of each valve 11a, 11b, a lambda value adjacent to said catalyst, mass air flow at first portion 2a, fuel mass flow at/into a fuel inlet 31, SAI mass flow upstreams/after of said SAI pump 15. All data obtained by the sensors may be said operating data. The one or more sensors are not shown in Figure 1.

[0037] The control circuitry 30 may be configured to control at least one of the adjustable valves 11a-b to, based on said operating data of said air injection system 1, achieve a pre-defined lambda while regulating said ratio of said compressed air distributed between the exhaust manifold and intake manifold. In other words, the control circuitry 30 may be configured to achieve a pre-defined lambda while regulating a secondary air injection to said exhaust manifold, the secondary air injection may be defined by the amount of compressed air that is supplied to the exhaust manifold and the amount of which the SAI pump affects/affected the flow of said compressed air (which flowed via the SAI pump). In the system 1 of Figure 1, the control circuitry 30 is configured to control the first adjustable valve 11a to achieve said pre-defined lambda (which may be lambda 1) while regulating said ratio of compressed air distributed between the exhaust manifold and intake manifold, or in other words, the amount of air which is supplied to the exhaust manifold. In some aspects, the system 1 may comprise one or more sensors that may monitor a delta pressure across the first adjustable valve 11a, this may form part as operating data. Accordingly, the control circuitry 30 may be configured to, in response to said delta pressure is below a threshold, close the adjustable valve. The threshold may be that the pressure is negative such that the flow of compressed air/exhaust flow returns to the SAI pump.

[0038] In some aspects the second valve 11b in said first portion 3a may be arranged to be controlled based on user input to an accelerator pedal of a vehicle. The first valve 3a in the first portion 3a may be controlled by the control circuitry 30 based on said operating data to regulate the ratio. In other words, the first valve 3a may be arranged to, based on said operating data, regulate an amount of compressed air that is inputted/supplied to the exhaust manifold. Advantagously, having a respective valve in each branch 3a, 3b enables a convenient balancing of the compressed air between the branches and an efficient lambda regulation and secondary air injection (i.e. air injected into the exhaust manifold 20).

[0039] The control circuitry 30 may further be configured to (simultaneously as operating the valve) control/affect a flow of said compressed air through said SAI pump 15 based on said operating data.

[0040] At least the first adjustable valve 11a may be a throttle valve such as an electronically controlled throttle valve which is controlled by the control circuitry 30.

[0041] In Figure 1, the adjustable valve is a first valve 11a integrated in said second branch upsteams of said SAI pump 1, wherein the air injection system 1 further comprises a second adjustable valve 11b integrated in said first branch 3a. Accordingly, the control circuitry 30 is configured to control at least the first adjustable valve 11a to, based on said operating data, regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold 10, 20.

[0042] Figure 1 further illustrates that the air injection system 1 further comprises a cooling device 40 integrated in the air regulation circuit 2 for cooling the compressed air to a defined temperature. During a cold-start the cooling device 40 may not be needed. However, when the ICE 100 is hot. The cooling device 40 may be utilized to e.g. cool the temperature of the compressed air to e.g. 50 degrees Celsius from e.g. 150 degrees Celsius. Advantageously, this increases the density of the compressed air which in turn can increase the amount of air that can be used in the combustion.

[0043] Figure 1 further illustrates that the intake portion 2a may be arranged to be connected to a compressor-part 62 of a turbocharger 60 of said ICE 100 thereby enabling the intaken air to be compressed and heated. The turbocharger 60 may further comprise a turbine part 64.

[0044] To describe an example operation of the air injection system. In one instance in which the ICE 100 is cold started and the catalyst 50 is at a temperature of e.g. 35 degrees. The temperature of the catalyst 50 need to be increased to approximately 350 degrees in order to enable the catalyst to be operable to convert harmful gases (such as NO_x) to prevent these to be released into the environment. The control circuitry 30 may then receive operating data that defines e.g. temperature of the catalyst and positions of the adjustable valves 11a, 11b.

[0045] Subsequently, based on the operating data, the control circuitry 30 may activate the SAI pump 15 and control, e.g. by fully opening, the first adjustable valve 11a. Thereby, as the compressed air is supplied will full force to the exhaust manifold 20, the air will react with the gas flowing in the exhaust manifold to heat the catalyst 50 more rapidly. For example, the catalyst may be heated in 12 seconds instead of 25 seconds which is the case for conventional air injection systems. As the system 1 herein is enabled to feed the SAI pump 15 with the compressed air directly, this allows the SAI pump 15 to more efficiently provide air to the exhaust manifold 20. Also, the first adjustable valve 11a may work in conjunction with the SAI pump 15 to variably regulate the amount of air to the exhaust manifold in accordance with requirements. Further, this also allows for variable regulation of the air-fuel ratio (lambda). The second valve 11b may be controlled based on user input. Accordingly, exhaust gas may burn rich in the cylinders of the internal combustion engine which can create NOx, HC and CO which will transform, by the catalyst, in the exhaust pipe facilitated by the air injection to the exhaust manifold. This may, within the context herein be automatically performed and always to a correct lambda.

[0046] The operating data may be at least one of a thermal condition (e.g. temperature) of a catalyst 50 connected to said exhaust manifold 20, an engine operating point, lambda, a fuel mass flow, and an air mass flow at said intake portion 2a, a current/present position of each valve of the at least one valve 11a, 11b.

[0047] Figure 2 further illustrates that the control circuitry 30 may comprise one or more memory devices 33. The memory devices 33 may comprise any form of volatile or non-volatile computer readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by each associated control circuitry 30. Each memory device 33 may store any suitable instructions, data or information, including a computer program, software, an application including one or more of logic, rules, code, tables, etc. and/or other instructions capable of being executed by a first module 35 of control circuitry 30 and, utilized. Memory device 33 may be used to store any calculations made by first module 35 and/or any data received via output and input interfaces 34, 36. The input and output interfaces 34, 36 may communicate with sensor devices of the system 1 to obtain sensor data which may form part of the operating data, and also communicate/send control signals to the valves 11a, 11b and the SAI pump based on said operating data. The communication may be performed by wired or wireless connection.

[0048] Each memory device 33 may also store data that can be retrieved, manipulated, created, or stored by the first module 35 of the control circuitry 30. The data may include, for instance, local updates, parameters and models such as a catalyst heating model. Hence, the catalyst heating model may be stored by the memory device 33 and used by the first module 33 to provide control signals to control the adjustable valves 11a, 11b and the SAI pump 15. Accordingly, the operating data may be synergized/inputted to the catalyst heating model and the catalyst heating model may indicate control signals required for controlling at least the first adjustable valve 11a and the SAI pump. Accordingly, the ratio and/or a flow of said compressed air through said SAI pump 15 may be regulated based on an input of said operating data into the pre-determined catalyst heating model. Accordingly, the catalyst heating model may indicates/-determines said ratio and/or flow subject to said operating data.

[0049] The control circuitry 30 and each component/-module therein may include, for example, one or more central processing units (CPUs), graphics processing units (GPUs) dedicated to performing calculations, and/or other processing devices. The memory device 33 may comprise one or more computer-readable media and can store information accessible by the components of the control circuitry 30.

[0050] Figure 3 illustrates the air injection system 1 in accordance with some aspects herein in which the system 1 comprises at the second branch 3b a bypass circuit 11b' arranged to, at a pre-defined condition, route the compressed air to bypass the SAI pump 15. The pre-defined condition may be e.g. when the temperature of the catalyst 50 is at a defined level (i.e. not too cold) or at specific operating points of the engine (i.e. when there is no cold start).

[0051] The bypass-circuit 11b' may comprises a bypass valve. Accordingly, If the SAI pump is a restriction for air flow at any load point the bypass circuit can enable secondary air injection to the exhaust manifold 20 without SAI pump 15 active by using the compressed air directly (unaffected by the SAI pump) to supply air.

[0052] Figure 4 schematically illustrates a vehicle 200 comprising the air injection system 1 according to any aspect herein. The system 1 is coupled to the ICE of the vehicle operable to provide air injection into the intake manifold and exhaust manifold 10, 20 of the vehicle 200.

[0053] Figure 5 illustrates in the form of a schematic flowchart a method 300 for operating the ICE according to any aspect herein, the method 300 comprising monitoring 310 said operating data of said air injection system and controlling 320 the adjustable valve (at least the first adjustable valve shown in Figure 1) based on said operating data. The monitoring may be performed continuously in real-time or at specific operating points. Further, the method comprises controlling 330 a flow of said compressed air through said SAI pump based on said operating data.

[0054] In aspects in which the adjustable valve is a first valve integrated in said second branch upstream of said SAI pump and the system also comprises a second adjustable valve integrated in said first branch, the method comprises controlling at least the first valve to, based on said operating data, regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold.

Claims

1. An air injection system (1) arranged to be connected to an internal combustion engine (100), ICE, of a vehicle, the air injection system (1) comprising:

   - an air regulation circuit (2) having a common intake portion (2a) arranged to obtain compressed ambient air,
   wherein the air regulation circuit (2) is, at a first portion (2b), branched into a first and a second branch (3a, 3b), thereby enabling distribution of said compressed air to said first and second branch (3a, 3b),
   wherein the first branch (3a) is arranged to connect to an air intake manifold (10) of said internal combustion engine (100);
   wherein the second branch (3b) is arranged to connect to an exhaust manifold (20) of said internal combustion engine (100), wherein the second branch (3b) comprises a SAI pump (15) integrated therein, and wherein at least one of the branches (3a, 3b) comprises an adjustable valve (11a) integrated therein,
   wherein the air injection system (1) is configured to, preferably by control circuitry:

     - control the adjustable valve (11a) to, based on operating data of said air injection system (1), regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold (10, 20).

2. The air injection system (1) according to claim 1, wherein the control circuitry (30) is configured to:

   - control the adjustable valve (11a) to, based on said operating data of said air injection system (1), achieve a pre-defined lambda while regulating said ratio of said compressed air distributed between the exhaust manifold and intake manifold.

3. The air injection system (1) according to claim 1 or 2, wherein the control circuitry (30) is further configured to:

   - control a flow of said compressed air through said SAI pump (15) based on said operating data.

4. The air injection system (1) according to any one of the preceding claims, wherein the adjustable valve (11a) is a throttle valve, preferably an electronically controlled throttle valve.

5. The air injection system (1) according to any one of the preceding claims, wherein the adjustable valve is a first valve (11a) integrated in said second branch upstream of said SAI pump (1), wherein the air injection system (1) further comprises a second adjustable valve (11b) integrated in said first branch, wherein the control circuitry (30) is configured to:

   - control at least the first adjustable valve (11a) to, based on said operating data, regulate a ratio of said compressed air distributed between the exhaust manifold and the intake manifold (10, 20).

6. The air injection system (1) according to any one of the preceding claims, wherein the air injection system further comprises a cooling device (40) integrated in the air regulation circuit (2) for cooling the compressed air to a defined temperature.

7. The air injection system (1) according to any one of the preceding claims, wherein the second branch (3b) comprises a bypass circuit (11b') arranged to, at a pre-defined condition, route the compressed air to bypass the SAI pump (15).

8. The air injection system (1) according to any one of the preceding claims, wherein the operating data is at least one of a thermal condition of a catalyst (50) connected to said exhaust manifold (20), an engine operating point, lambda, a fuel mass flow, and an air mass flow at said intake portion (2a), a current position of each valve of the at least one valve (11a, 11b).

9. The air injection system (1) according to any one of the preceding claims, wherein the intake portion (2a)

is arranged to be connected to a compressor-part (62) of a turbocharger (60) of said ICE (100).

10. The air injection system (1) according to any one of the preceding claims, wherein the ratio and/or a flow of said compressed air through said SAI pump (15) is regulated based on an input of said operating data into a pre-determined catalyst heating model.

11. The air injection system (1) according to claim 10, wherein the catalyst heating model indicates said ratio and/or flow subject to said operating data.

12. An internal combustion engine, ICE, (100) comprising the air injection system (1) according to any one of the preceding claims.

13. A vehicle (200) comprising the ICE (100) according to claim 12.

14. A method (300) for operating the ICE according to claim 13, the method (300) comprising:

- monitoring (310) said operating data of said air injection system;
- controlling (320) the adjustable valve based on said operating data.

15. The method (300) according to claim 14, wherein the method (300) further comprises the step of:

- controlling (330) a flow of said compressed air through said SAI pump based on said operating data.

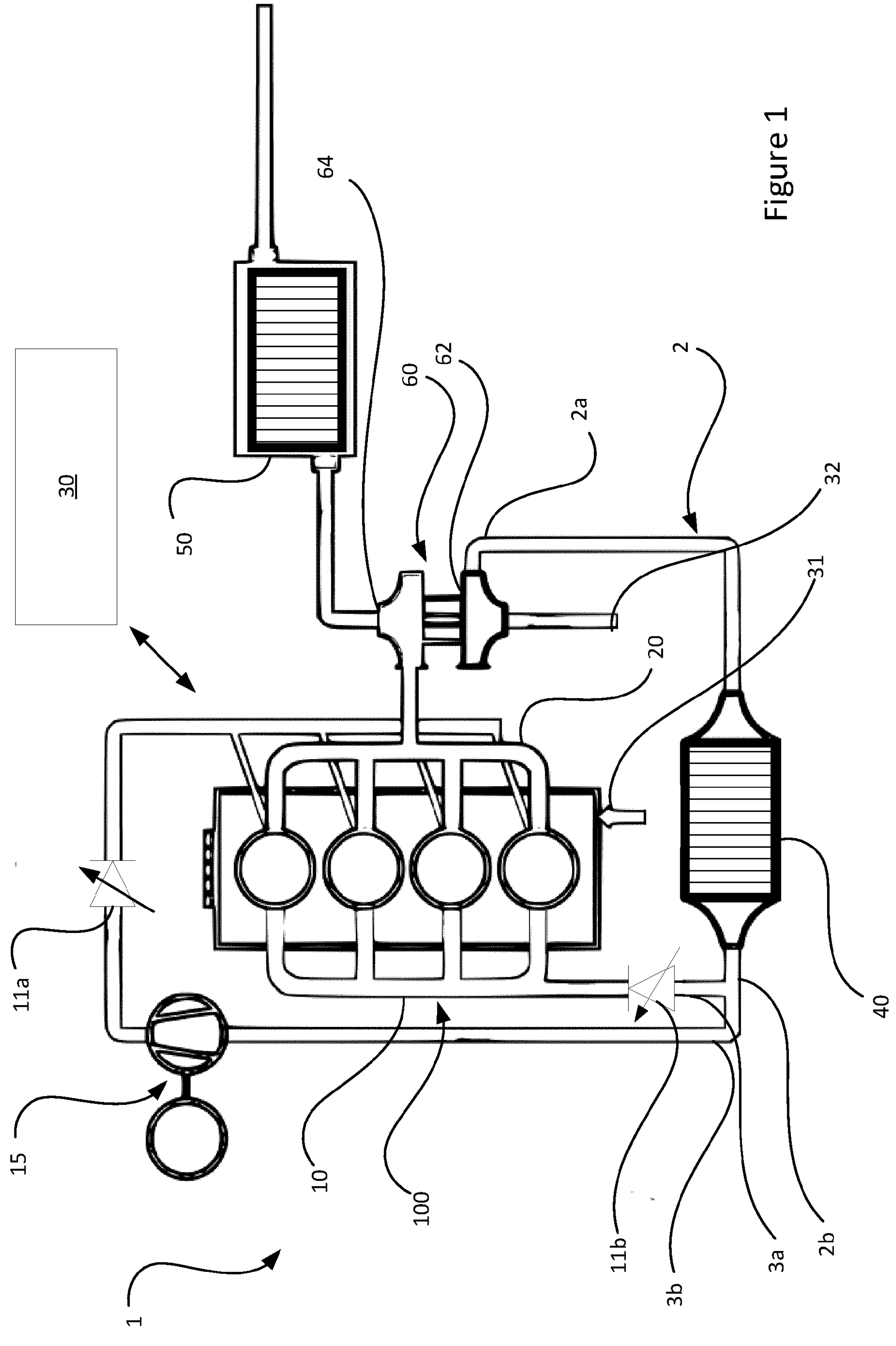

Figure 1

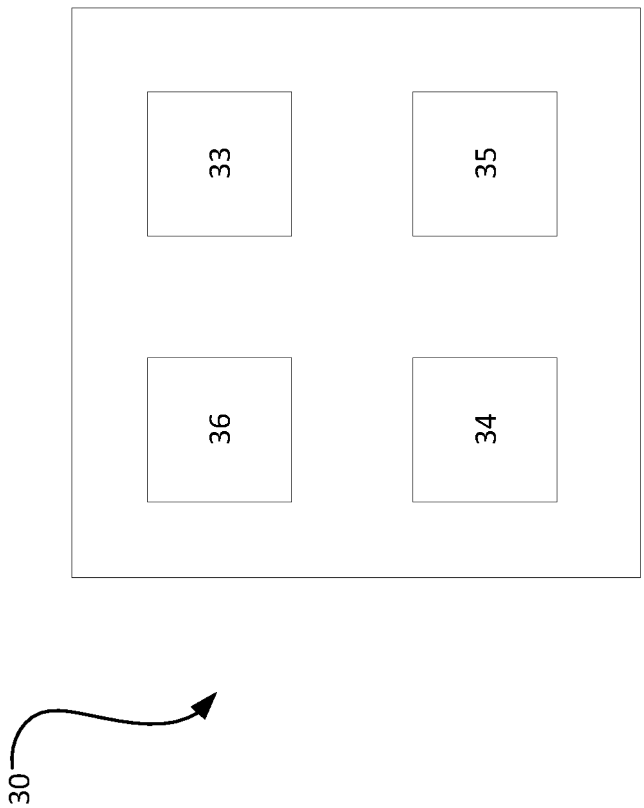

Figure 2

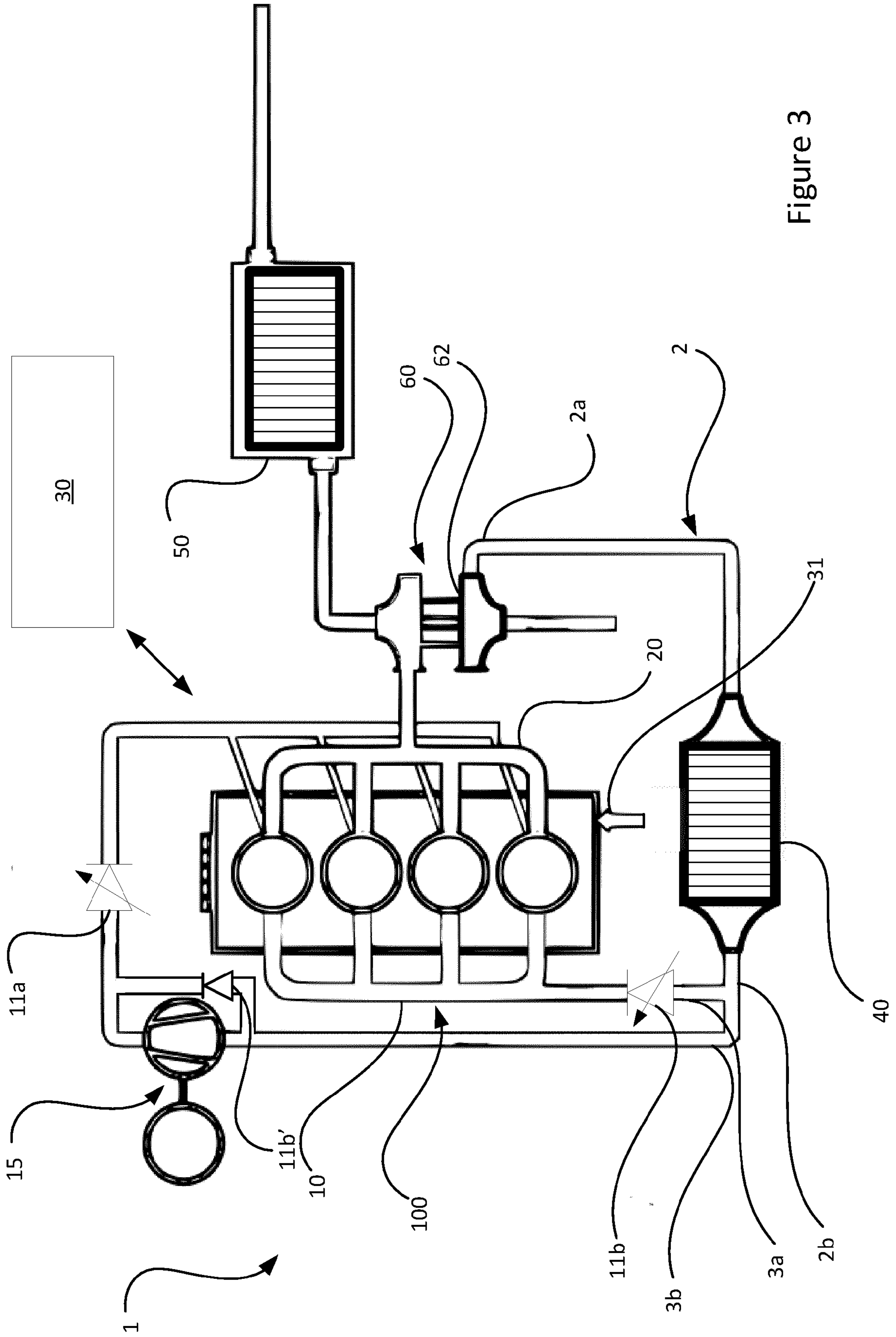

Figure 3

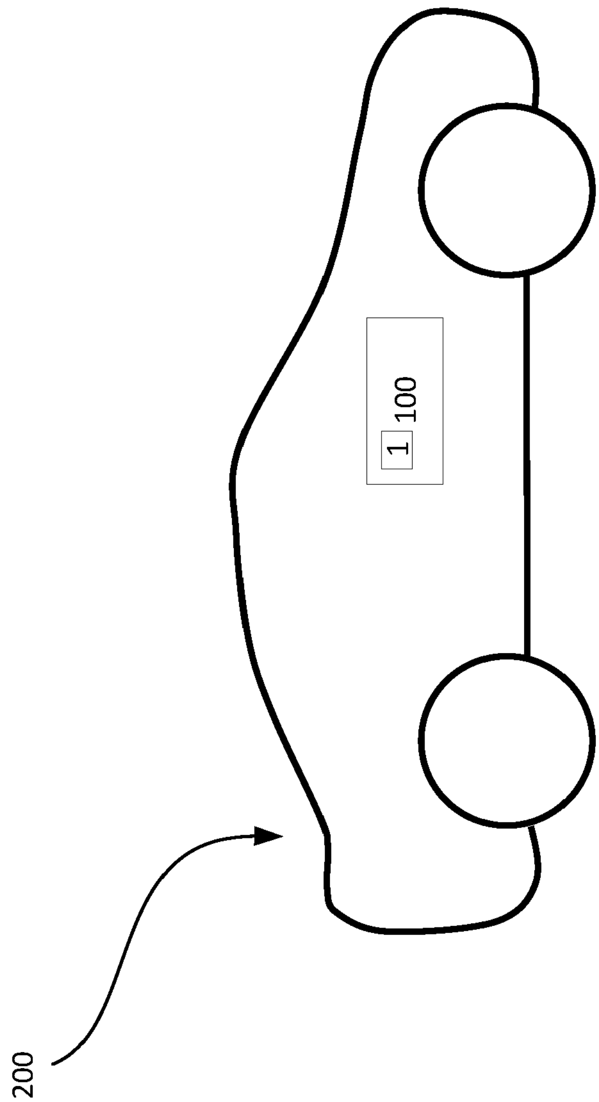

Figure 4

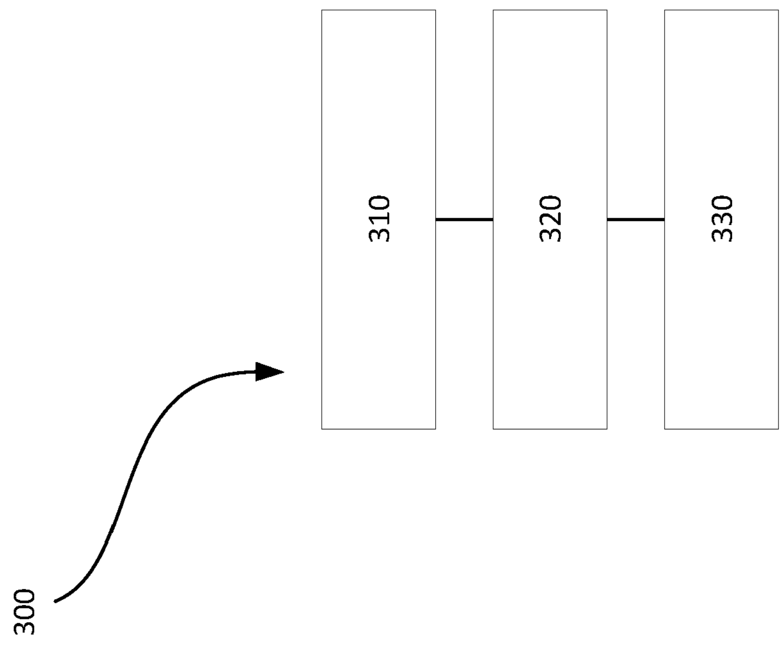

Figure 5

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EUROPEAN SEARCH REPORT

Application Number
EP 23 21 2496

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	16 April 2024	Buecker, Christian

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