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I-10121 Torino (IT)(54) **System for reducing detonation phenomena in a combustion chamber of an endothermic engine.**

(57) The system (31) is used to reduce the possibility of the recurrence of the conditions which trigger the phenomenon of detonation in a combustion chamber (21) of an endothermic engine (2) of an engine assembly (1) which comprises an air intake manifold (5), a multiplicity of cylinders (4), a pipe (14) for conveying exhaust gases from the cylinders, and a system (20, 19) for electronic injection and ignition. The system (31) comprises :

means (34) which detect the detonation phenomenon;

means (32 and 33) for conveying the exhaust gases from the pipe (14) to the combustion chamber (21); and

means (35) connected to the means for detecting (34) and controlling the means for conveying (32 and 33) the exhaust gases to determine the inflow of exhaust gas in the combustion chamber (21).

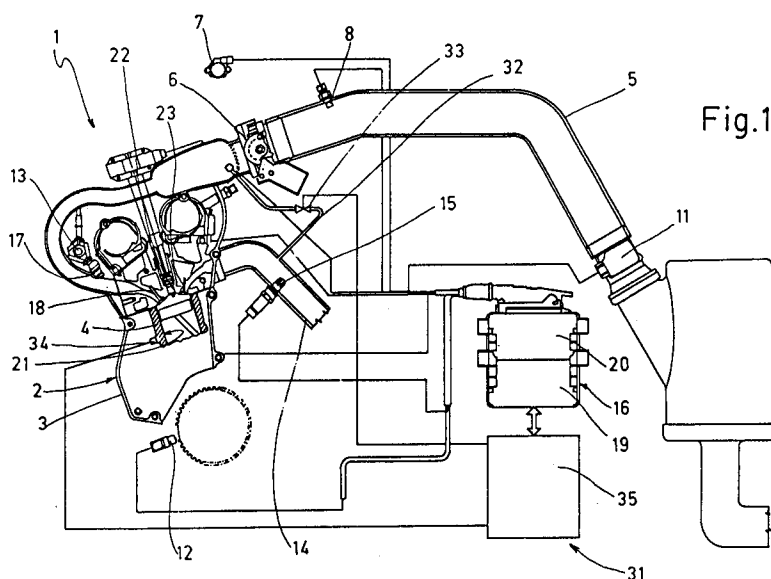


Fig.1

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The invention relates to a system for reducing detonation phenomena in a combustion chamber of an endothermic engine.

As is known, a detonation, i.e. an explosion due to anomalous combustion of the air/fuel mixture, takes place in a combustion chamber in the presence of elevated temperatures at particular hot spots in the chamber and in the presence of high internal pressure levels. The detonation is particularly damaging in that it leads to high thermal and metallurgical fatigue of the material of which the chamber is made and the components (such as the valves) installed in the combustion chamber.

The object of the invention is to produce a system which permits the detonation phenomena to be reduced so as to prevent the above-mentioned disadvantages.

On the basis of the invention a system is produced for reducing detonation phenomena in a combustion chamber of an endothermic engine of an engine assembly which comprises an air intake manifold, a multiplicity of cylinders, a first pipe for conveying exhaust gases from the said cylinders, a system for electronic ignition and a system for electronic injection, characterized in that it comprises :

means for detecting the detonation phenomenon;
means for conveying exhaust gases from the said first pipe to the said combustion chamber; and
means connected to the said means for detecting and controlling the said means for conveying exhaust gases to determine the inflow of exhaust gases in the said combustion chamber in order to reduce the possibility of a recurrence of the conditions which trigger the detonation phenomenon.

A preferred embodiment will now be described in order to provide a better understanding of the invention, purely by way of non-exhaustive example and with reference to the accompanying drawings, in which :

Fig. 1 is a diagrammatic view of the system to which the invention relates; and

Fig. 2 shows a functional flow chart of the system of Fig. 1.

Fig. 1 partially illustrates an engine assembly denoted in its entirety by 1 and comprising :

an endothermic engine 2 having a block 3 and a multiplicity of cylinders 4, only one of which is partially illustrated;

an air intake manifold 5 provided with a throttle-valved body 6 for controlling the amount of air conveyed towards the cylinders 4;

a sensor 7 capable of detecting the angular position of the throttle valve with which the body 6 is provided;

a sensor 8 capable of detecting the temperature of the air taken in along the manifold 5;

a sensor 11 capable of detecting the flowrate of the

air taken in along the manifold 5;

a sensor 12 capable of detecting the number of engine revolutions;

a fuel manifold 13;

5 a pipe 14 for conveying exhaust gases from the cylinders 4;

a lambda probe 15 capable of detecting the amount of oxygen present in the exhaust gases; and

10 an electronic unit 16 to which the sensors 7, 8, 11 and 12 and the lambda probe 15 lead.

The unit 16 is provided with an electronic injection system 19 capable of controlling electronic injectors 17, only one of which is shown, which from the manifold 13 inject fuel into the final section of the manifold 5 where the air/fuel mixture is produced. Via an intake valve 18 this final section of the manifold 5 opens into the combustion chamber 21 defined in the cylinder 4. The unit 16 is also provided with an electronic ignition system 20 capable of controlling the sparking of the arc between the plug electrodes 22, electrodes located inside the combustion chamber 21 between the valve 18 and an exhaust valve 23 from which the exhaust gases are introduced into the pipe 14.

With reference to Fig. 1, in its entirety 31 denotes a system which permits the reduction of the detonation phenomena which may occur in the chamber 21 as a result of anomalous combustion.

As will be seen more clearly below, the system 31 prevents the recurrence of the conditions which trigger the detonation phenomenon; conditions which chiefly consist of the elevated temperature at particular points of the chamber 21 and of the high internal pressure. To prevent the succession of detonation phenomena, once the presence of detonation phenomena has been ascertained the system 31 controls the introduction into the manifold 5 of an amount of exhaust gas taken from the pipe 14. As a result the combustion chamber 21 will be supplied with an amount of air/fuel mixture and an amount of exhaust gas which is, as we will recall, an inert gas which takes no part in the combustion process taking place in the chamber 21. The exhaust gases introduced into the chamber 21 reduce the pressure values inside the chamber 21 and remove energy derived from the combustion insofar as these exhaust gases perform the function of a "thermal sponge" which absorbs some of the calories derived from the combustion. This function of the exhaust gases determines the reduction of the maximum peak of the combustion temperature and hence discourages the creation of particularly hot spots inside the chamber 21. In short, the presence in the chamber 21 of exhaust gases prevents the recurrence of the conditions which trigger the detonation phenomenon; conditions which, we will recall, chiefly consist of the high

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temperature at particular spots in the chamber 21 and of the high internal pressure.

The system 31 comprises :

a pipe 32 which originates from the pipe 14 and which opens into the manifold 5 downstream of the throttle-valved body 6;
a solenoid valve 33 installed along the pipe 32;
a sensor 34 capable of detecting the detonation; and
an electronic device 35 to which the sensor 34 leads and which is capable of controlling the solenoid valve 33.

The device 35 may form part of the unit 16 or it may be a separate device which nonetheless "talks" to the unit 16. In a preferred embodiment shown in Fig. 1, the sensor 34 is fitted to a wall of the cylinder 4 and is constituted by an accelerometer capable of detecting the vibrations to which this wall of the cylinder 4 is subjected in the course of the operation of the engine 2. The intensity of the vibrations to which the cylinder 4 is subjected is regarded as an indicator of the detonation phenomenon insofar as experimental trials have shown that in the presence of detonations, peak values of the intensity of the vibrations are detected at certain frequencies.

The device 35 manages the functioning of the system 31 according to a functional flow illustrated in Fig. 2 and comprising a starting block 51 from which one passes to a block 52 in which the signals received from the sensor 34 are filtered. This filtering consists of eliminating the signals corresponding to the vibrations which are regarded as typical of a correct operation of the engine 2 and therefore a correct combustion of the air/fuel mixture. Essentially the signals which are outside a frequency band of predetermined width are eliminated and the only signals considered valid are the +Vfilt and -Vfilt signals which occur inside that band on the positive and negative side. From the block 52 we reach a block 53 in which the absolute value |Vfilt| of the +Vfilt and -Vfilt signals considered valid in the block 52 is calculated. From block 53 we pass to a block 54 in which the integral of the absolute values processed in the block 53 is calculated between two angular positions of the drive shaft using the equation $\int |V_{filt}| d\sigma$, where σ is the engine angle. Preferably the integral is calculated for a 90° rotation of the drive shaft from a pre-determined point such as the top dead centre for example. From the block 54 we reach a block 55 in which the value produced by the integration calculated in the block 54 is converted into a digital value Vdet.

From the block 55 we pass to a block 56 in which the value Vdet and a threshold value Vsol are compared. If the engine 2 is operating for the first time a pre-determined magnitude set on the

basis of laboratory experiments is allocated to the value Vsol. If the value Vdet is greater than the value Vsol it is assumed that there is a detonation phenomenon, for which reason we pass from the block 56 to a block 57, whereas if the value Vdet is not greater than the value Vsol it is assumed that there is no detonation phenomenon, for which reason we pass from the block 56 to a block 58.

In the block 58 an assessment is made as to whether the engine 2 is in the first operating cycle and thus whether a value Vmed is stored in a memory block of the device 35 which is not illustrated. If the engine 2 is in the first operating cycle we pass from the block 58 to a block 61 whereas otherwise we reach a block 62 from the block 58. Vmed = T is fixed in the block 61, where T is a pre-determined magnitude set on the basis of laboratory experiments. From the block 61 we pass to the block 62 in which a new value Vmed is calculated, which we can call Vmedn using the equation $V_{medn} = V_{med} + K \cdot V_{det} / V_{med}$ where Vmed relates to the preceding cycle and K is a pre-determined constant. In the case of first operation, of course, the value set in the block 61 is taken as the value Vmed. Still in the block 62 but following the calculation of Vmedn, Vmed = Vmedn is assumed in order to use the new value Vmed in the next operating cycle.

From the block 62 we pass to the block 63 in which the value Ks is calculated on the basis of an equation which takes account of the number of engine revolutions and the engine load and essentially the engine conditions. These data are taken from the unit 16 which, as is known, carries out a whole series of processing operations of the findings of the above-mentioned sensors and is capable of supplying all the data available in it on request. From the block 63 we reach a block 64 in which a new threshold value Vsol is calculated using the equation $V_{sol} = V_{med} \cdot K_s$. From the block 64 we pass to a block 65 in which the value Vsol calculated in the block 63 is stored and this value Vsol replaces the previous threshold value in the block 56.

From the block 65 we pass to a block 66 in which a check is made as to whether there is a correction phase of the fluid conveyed towards the chamber 21 and thus whether a pre-determined amount of exhaust gas is currently being conveyed into the chamber 21, through the pipe 32 and the manifold 5, in addition to the air/fuel mixture. Essentially, in the block 66 a check is made as to whether the solenoid valve 33 is in the opening phase. If there is a correction phase we pass from the block 66 to a block 67 whereas if there is not, we return to the block 52 from the block 66.

According to the equation $C_{orn} = C_{or} - K_{zn}\%$, in the block 67 a calculation is made of the amount

of exhaust gas to be introduced into the chamber 21. The value Cor relates to the amount of exhaust gas currently being introduced into the chamber 21 whereas the value $Kzn\%$ is a percentage value, deduced on the basis of laboratory experiments, which is subtracted from the value Cor so as to define a new value Cor denoted by $Corn$ and relating to a lower amount of exhaust gas than the amount of exhaust gas currently being introduced into the chamber 21 and calculated in a preceding cycle of the operational flow. Essentially, once it has been ascertained in the block 56 that there is no detonation phenomenon and ascertained in the block 66 that a correction phase still exists, the amount of exhaust gas to be introduced into the chamber 21 will reduce, cycle by cycle and gradually ($-Kzn\%$). From the block 67 we pass to a block 68 in which the value $Corn$ just calculated is assumed and stored as the new value $Vcor$ so that in the next cycle the value $Kzn\%$ is subtracted from the new value $Vcor$.

From the block 68 we then reach a block 71 in which the new value $Vcor$ is compared with zero. If the new value $Vcor$ is not greater than zero we pass from the block 71 to a block 72 whereas otherwise we move to a block 73 from the block 71. Essentially, in the block 71 a check is made as to whether, following a series of cycles in each of which the amount of exhaust gas introduced into the chamber 21 has gradually decreased because of the persistent absence of detonation phenomena, a new value $Vcor$ equal to zero or negative has been calculated, a new value $Vcor$ corresponding to the closure position of the solenoid valve 33. In the block 72 the value $Vcor = 0$ is fixed insofar as the correction phase has been concluded. From the block 72 we now pass to the block 73 in which the control of the solenoid valve 33 is actuated to determine the passage of exhaust gas according to an amount corresponding to the new value $Vcor$ set in the block 67, in the block 72 or in other blocks which will be described below. Finally, from the block 73 we pass to the block 52.

As already indicated, from the block 56 we pass to the block 57 if detonation phenomena are present or persist. The amount of exhaust gas to be introduced into the chamber 21 is calculated in the block 57 according to the equation $Corn = Cor + Kz\%$. The value Cor relates to the amount of exhaust gas currently being introduced into the chamber 21 whereas the value $Kz\%$ is a percentage value, deduced on the basis of laboratory experiments, which is added to the value Cor in order to define a new value Cor indicated as $Corn$ and relating to a larger amount of exhaust gas than the amount of exhaust gas currently being introduced into the chamber 21 and calculated in a preceding cycle of the operational flow. Essentially,

once it has been ascertained in the block 56 that there is a succession of the detonation phenomenon, the amount of exhaust gas to be introduced into the chamber 21 will increase, cycle by cycle, and gradually ($+Kz\%$). Following the calculation of the value $Vcorn$, still in the block 57 the value $Vcorn$ just calculated is assumed and stored as a new value $Vcor$ so that the value $Kz\%$ is added to the new value $Vcor$ in the next cycle.

From the block 57 we pass to a block 74 in which the new value $Vcor$ is compared with a pre-determined and stored value $Vcormax$ relating to a maximum value of the amount of exhaust gas that it is possible to introduce into the chamber 21. This maximum value may depend, for example, on the maximum quantity that it is possible to convey along the pipe 32 when the solenoid valve 33 is in the position of maximum opening. If the new value $Vcor$ is not less than the value $Vcormax$ we pass from the block 74 to a block 75 and from there to the block 73, whereas otherwise we move directly to the block 73 from the block 74. Essentially in the block 74 a check is made as to whether, following a series of cycles in each of which the amount of exhaust gas introduced into the chamber 21 has increased gradually because of the persistent presence of detonation phenomena, a new value $Vcor$ has been calculated which is not less than the value $Vcormax$ corresponding to the maximum amount of exhaust gases which it is possible to introduce into the chamber 21. In the block 75 the value $Vcor = Vcormax$ is fixed insofar as beyond this limit it is not possible to increase the amount of the exhaust gases which it is possible to introduce into the chamber 21.

The advantages achieved with the implementation of the invention will be evident from the above description.

In particular a system has been produced which, in the event of detonation phenomena being ascertained, introduces exhaust gases into the combustion chamber according to a pre-determined law and which then, in the event of a persistent absence of detonation phenomena being ascertained, reduces the amount of exhaust gases to be introduced into the combustion chamber according to a pre-determined law. As will be apparent the reduction of the possibility of the recurrence of the conditions which trigger the detonation phenomenon relieves the material of which the combustion chamber is made and the components installed inside it of excessive thermal and metallurgical fatigue. Finally the structural simplicity of the system according to the invention should be stressed; a structural simplicity which promotes a reduced production cost.

Finally it will be evident that modifications and variants may be made to the system 31 described

and illustrated without departing from the scope of the invention.

In particular, the law which determines the amount and/or the variation in that amount of exhaust gases to be introduced into the air intake manifold may be different from that described with reference to Fig. 2. For example, the first occasion that a detonation is detected, independently of the possible succession of detonations, an amount of exhaust gas to be introduced for a pre-determined time or an amount of exhaust gas which decreases in a pre-determined time according to a pre-determined method may be pre-determined. The amount of exhaust gas may be equal for all the cylinders in the engine or an amount of gas which is different for each cylinder may be introduced; in this case a respective detonation detection sensor may be applied to each cylinder. The duration of the correction phase may be correlated to the persistence of the detonation and/or the engine conditions of the engine assembly such as number of engine revolutions, engine load, temperature of air taken in, etc. It is then possible to provide the engine assembly with an element by means of which the user can control the correction and with a device capable of recording a series of engine parameters recorded before, during and after the correction phase so that these parameters can be processed to produce a diagnosis of the engine assembly.

In place of the solenoid valve 33 a different fluid interception device may be used such as, for example, an on/off choking device or a choking device with proportional control. Furthermore, in place of the solenoid valve 33, a battery of interception devices, each strictly dedicated to a corresponding cylinder, may be installed. Finally an interception device with pneumatic, mechanical, magnetic or optical control may be installed in place of the solenoid valve 33.

The means of detecting the detonation may comprise a single sensor 34 installed in correspondence with a cylinder or on the engine block, or they may comprise a multiplicity of sensors 34 each installed in correspondence with a respective cylinder. The detection means may comprise one or more sensors of a type different from that described. For example, the sensor 34 may comprise a pressure sensor installed in one or in several combustion chambers, an acoustic sensor which detects the acoustic waves generated by the engine assembly, an element which analyzes the composition of the combustion products, an element which analyzes the thermal and/or kinematic state of the combustion products, or elements such as load cells installed on components of the engine assembly which record the vibrations of the engine structure.

Claims

1. System for reducing detonation phenomena in a combustion chamber (21) of an endothermic engine (2) of an engine assembly (1) which comprises an air intake manifold (5), a multiplicity of cylinders (4), a first pipe (14) for conveying exhaust gases from the said cylinders (4), a system for electronic ignition (20) and a system for electronic injection (19), characterized in that it comprises :
means (34) for detecting the detonation phenomenon;
means (32 and 33) for conveying exhaust gases from the said first pipe (14) to the said combustion chamber (21); and
means (35) connected to the said means for detecting (34) and controlling the said means for conveying (32 and 33) exhaust gases to determine the inflow of exhaust gases in the said combustion chamber (21) in order to reduce the possibility of a recurrence of the conditions which trigger the detonation phenomenon.
2. System according to Claim 1, characterized in that the said detection means comprise at least one sensor (34) for detecting the vibrations to which a said cylinder (4) is subjected.
3. System according to Claim 1, characterized in that the said detection means comprise at least one sensor (34) for detecting the vibrations to which a structure of the said engine (2) such as the engine block (3) is subjected.
4. System according to Claim 1, characterized in that the said detection means comprise at least one sensor for detecting the pressure inside the said combustion chamber (21).
5. System according to Claim 1, characterized in that the said detection means comprise at least one acoustic sensor for detecting the acoustic waves generated by the said engine assembly (2).
6. System according to Claim 1, characterized in that the said detection means comprise at least one element which analyzes the composition of the combustion products.
7. System according to Claim 1, characterized in that the said detection means comprise at least one element which analyzes the thermal and/or kinematic state of the combustion products.

8. System according to any one of the preceding Claims, characterized in that the said means (32 and 33) for conveying exhaust gas from the said first pipe (14) to the said combustion chamber (21) comprise a second pipe (32) which originates from the said first pipe (14) and which opens into the said manifold (5) and a flow interception device (33) installed along the said second pipe (32) and controlled by said control means (35). 5 10
9. System according to Claim 8, characterized in that the said interception device comprises a solenoid valve (33). 15
10. System according to Claim 8, characterized in that the said interception device comprises an on/off choking device. 20
11. System according to Claim 8, characterized in that the said interception device comprises a choking device with proportional control. 25
12. System according to Claim 8, characterized in that the said interception device comprises a choking device with pneumatic control. 30
13. System according to Claim 8, characterized in that the said interception device comprises a choking device with mechanical control. 35
14. System according to Claim 8, characterized in that the said interception device comprises a choking device with magnetic control. 40
15. System according to Claim 8, characterized in that the said interception device comprises a choking device with optical control. 45
16. System according to any one of the preceding Claims, characterized in that the said control means (35) comprise :
 means for recognizing signals generated by the said detection means and relating to the detonations;
 means for processing the signals relating to the detonation;
 means which on the basis of the result of the processing of the signals relating to the detonations calculate the amount of exhaust gas to be introduced into the said combustion chamber (21);
 means for managing the said conveying means (32 and 33) to allow the passage of the calculated amount of exhaust gas. 50 55
17. System according to Claim 16, characterized in that the said control means (35) comprise means for comparing the result of the processing of the signals relating to the detonations with a pre-determined threshold value above which the passage of the calculated amount of exhaust gas towards the said pipework is controlled.
18. System according to Claims 16 and 17, characterized in that the said control means (35) comprise means which, in the absence of a succession of detonations, control the gradual reduction of the amount of exhaust gases to be introduced into the said chamber (21) up to the closure of the passage of such gases along the said conveying means (32 and 33).
19. System according to Claims 16 to 18, characterized in that the said control means (35) comprise means which, in the event of a succession of detonations, control the gradual increase in the amount of exhaust gases to be introduced into the said chamber (21) up to a maximum quantity.

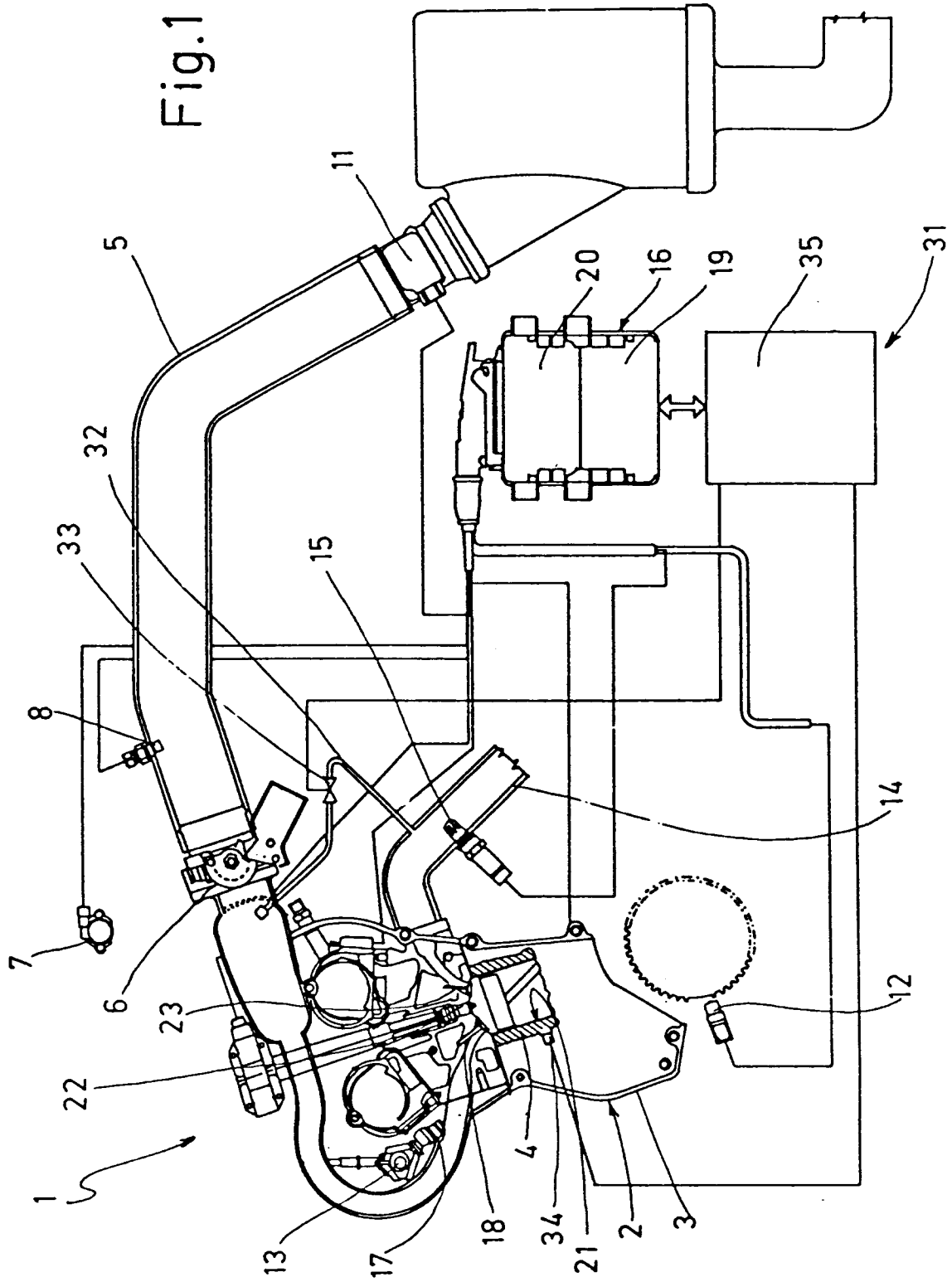
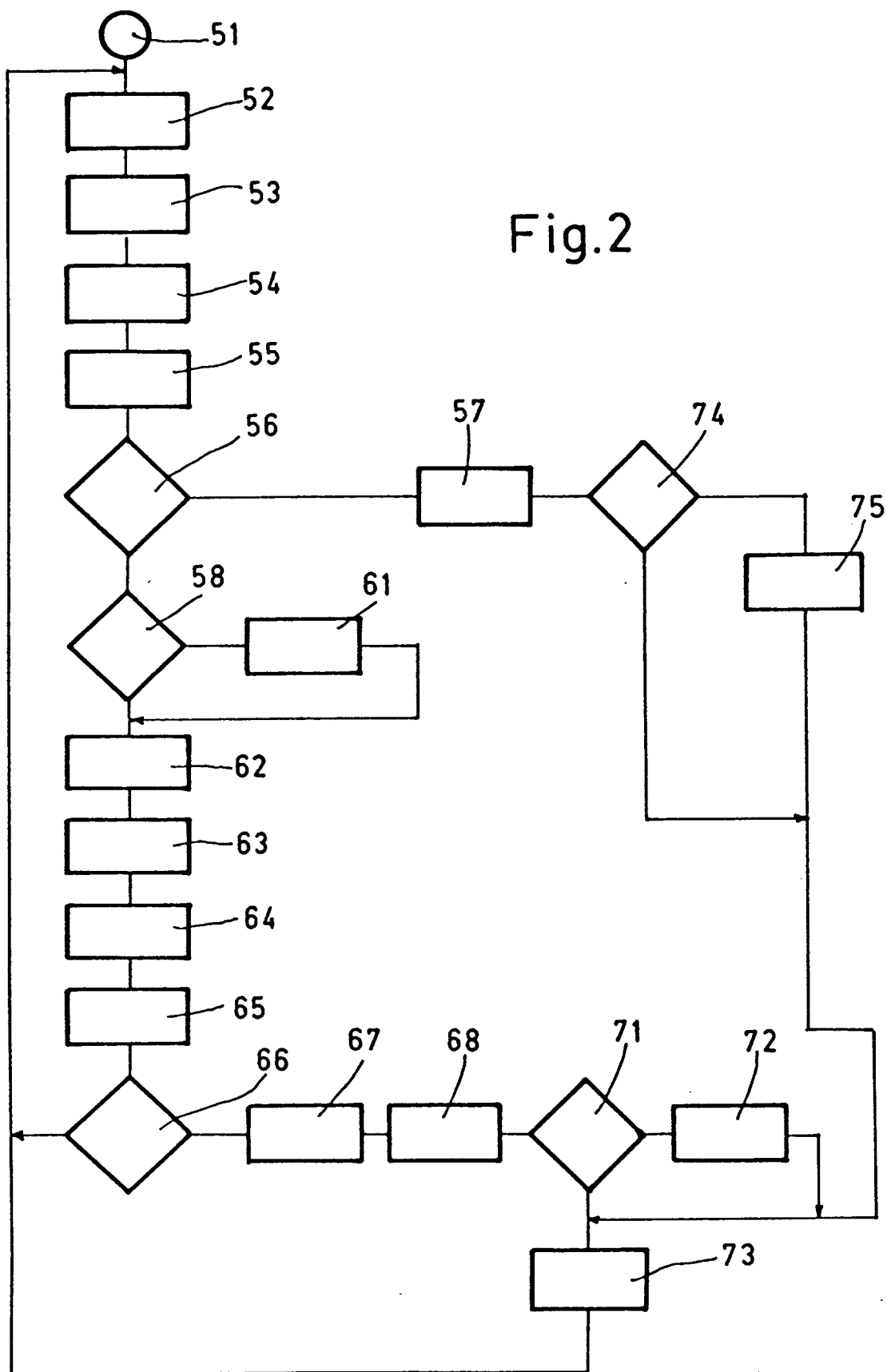


Fig.2





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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	GB-A-2 054 037 (NISSAN MOTOR CO. LTD.) * the whole document * ---	1-3, 8-14, 16-19	F02D21/08
X	PATENT ABSTRACTS OF JAPAN vol. 8 no. 140 (M-305) ,29 June 1984 & JP-A-59 037254 (TOYOTA JIDOSHA KOGYO KK) 29 February 1984, * abstract * ---	1,4,8,16	
X	PATENT ABSTRACTS OF JAPAN vol. 5 no. 83 (M-071) ,30 May 1981 & JP-A-56 032053 (NISSAN MOTOR CO LTD) 1 April 1981, * abstract * ---	1-3	
X	PATENT ABSTRACTS OF JAPAN vol. 17 no. 159 (M-1389) ,29 March 1993 & JP-A-04 325752 (NISSAN MOTOR CO LTD) 16 November 1992, * abstract * ---	1,16-18	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 16 May 1995	Examiner Alconchel y Ungria,J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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X	PATENT ABSTRACTS OF JAPAN vol. 4 no. 120 (M-028) ,26 August 1980 & JP-A-55 078155 (NIPPON DENSO CO LTD) 12 June 1980, * abstract *	1	

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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 16 May 1995	Examiner Alconchel y Ungria,J
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			