



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.07.2008 Bulletin 2008/29

(51) Int Cl.:
F02D 41/04 (2006.01) F02D 41/12 (2006.01)

(21) Application number: **07000428.8**

(22) Date of filing: **10.01.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

- **Wahlberg, Torkel**
186 92 Vallentuna (SE)
- **Wittefeldt, Thomas**
14137 Huddinge (SE)
- **Sunnegårdh, Erik**
12542 Älvsjö (SE)

(71) Applicant: **GM Global Technology Operations, Inc.**
Detroit, MI 48265-3000 (US)

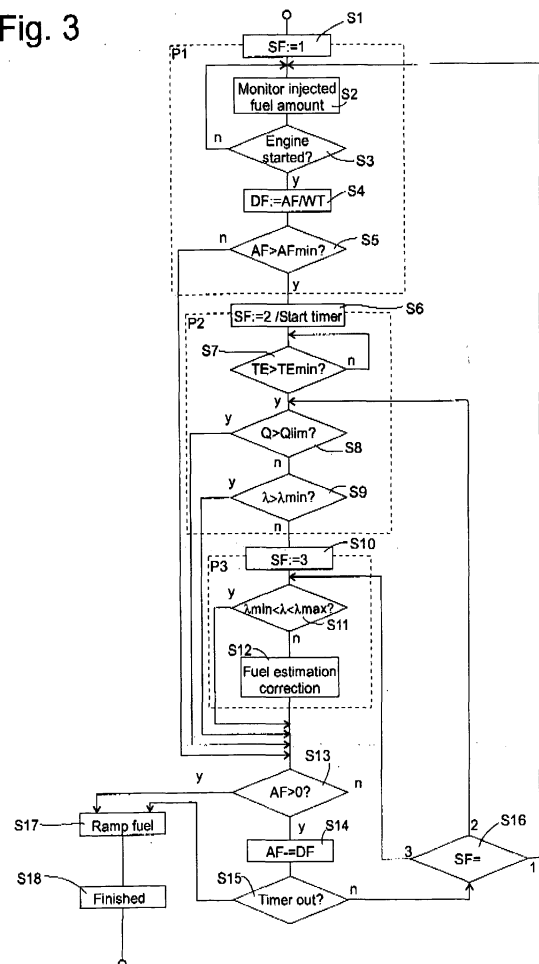
(74) Representative: **Heuer, Wilhelm**
Patentanwalt
Dürrbergstrasse 20
82335 Berg (DE)

(72) Inventors:
• **Gäddevik, Jouko**
64060 Åkers Styckebruk (SE)

(54) **Fuel control method**

(57) A fuel control method for an internal combustion engine having one or more combustion chambers (1) and a crankcase (8) connected to an air intake manifold (3) of the combustion chambers (1), comprising the steps of
a) monitoring (S2, S14) the amount of fuel (AF) in the crankcase (8),
b) estimating (S12) a fuel vapour flow from the crankcase (8) to the combustion chambers (1),
c) setting (S12) a fuel injection amount injected into the combustion chambers (1) so that the injected fuel amount and the fuel vapour flow yield a predetermined air-fuel ratio in the combustion chambers.

Fig. 3



Description

[0001] The present invention relates to a fuel control method for an internal combustion engine, in particular for an engine for a motor vehicle which is capable of running on alcohol-containing fuel.

[0002] Combustion engines of this type have received considerable public interest in recent times in view of the fact that alcohol is a renewable resource, and that worldwide supplies of petrol are dwindling. Due to the limited availability of ethanol fuel, engines have been developed which are capable of running on fuels that contain gasoline and ethanol in varying proportions. In order to ensure stoichiometric combustion, these engines must be able to adjust the air-fuel ratio according to the composition. For example, if an engine operates on pure ethanol, its air-fuel ratio must be set approx. 1.4 times higher than when it operates on gasoline, in order to achieve stoichiometric combustion. Adaptation of the air-fuel ratio to the fuel composition should be automatic, so that a user can refill a tank with a fuel of arbitrary composition, which may be different from that of residual fuel, which may be present in the tank.

[0003] The need for the air-fuel ratio to be tuneable in a wide range can cause serious problems if the parameters on which control of the air-fuel ratio is based exhibit transient fluctuations which are not based on a change in the fuel composition.

[0004] A known source for such transient fluctuations is the tendency of the fuel to wash down into the crankcase of the engine and to mix with oil in the crankcase while the engine is cold, in particular during cranking. When the engine warms up, ethanol in this washed-down fuel will evaporate, and since in most spark-ignited combustion engines the combustion chambers receive part of their intake air from the crankcase, it will cause the air-fuel ratio in the combustion chamber to be richer than expected. The ratio between air from the crankcase and fresh inlet air in the combustion chambers depends on inlet pressure and engine speed, parameters which may fluctuate at a timescale of seconds. Accordingly, the amount of fuel vapour from the crankcase in the combustion chambers may vary widely in a short timescale, making closed-loop control of the injected fuel amount based on the exhaust gas composition extremely difficult.

[0005] The object of the present invention is, therefore, to provide a fuel control method for an internal combustion engine which is compatible with a wide tuning range of the air-fuel ratio, on the one hand, while avoiding fuel metering problems related to a possible presence of fuel vapour in the crankcase.

[0006] This object is achieved by a fuel control method for an internal combustion engine having one or more combustion chambers and a crankcase connected to an air intake manifold of the combustion chambers, which comprises the steps of

a) monitoring the amount of fuel in the crankcase,

b) estimating a fuel vapour flow from the crankcase to the combustion chambers, and

c) setting a fuel injection amount injected into the combustion chambers so that the injected fuel amount and the fuel vapour flow yield a predetermined air-fuel ratio in the combustion chambers.

[0007] The fuel vapour flow from the crankcase can be estimated to be negligible if at least one of the following conditions is met:

a) the monitored fuel amount is below a predetermined threshold. If the amount of fuel in the crankcase is small, the amount of fuel vapour in the crankcase air must be small, too, and its effect on the air-fuel ratio in the combustion chamber may be neglected.

b) the engine temperature is below a predetermined threshold. If the engine is cold, the fuel vapour concentration will be low, even if there is a considerable fuel in the crankcase oil.

c) the intake airflow is above a predetermined threshold. The higher intake airflow is, the smaller is the negative pressure in the intake manifold, and, hence, the airflow from the crankcase to the intake manifold. Accordingly, only a small fraction of the air which enters the combustion chambers comes from the crankcase, and fuel vapour which may be present in the crankcase air is strongly diluted when it reaches the combustion chambers.

d) a predetermined time has elapsed since the start of the engine. After this predetermined time, the engine may be assumed to be warm enough, so that all ethanol which may have entered the crankcase oil can be assumed to have evaporated.

[0008] The monitoring step a) above preferably comprises incrementing an estimated amount of fuel in the crankcase in proportion to an amount of fuel injected into the combustion chambers while cranking. In other words, it may be assumed that a certain fraction of the fuel which is injected during cranking is washed down into the crankcase oil.

[0009] After the engine has started, the monitoring step a) may comprise decrementing an estimated amount of fuel in the crankcase at a constant rate. The inventors found that in spite of the simplicity of this approach, for the purpose of controlling the injection amount, it yields a surprisingly good estimation of the actual amount of fuel in the crankcase.

[0010] On the one hand, one might expect the amount of fuel in the crankcase to decrease exponentially, because the less fuel there is in the crankcase oil, the less can evaporate. However, since the crankcase oil heats up during operation of the engine, the tendency of the

fuel to evaporate increases, so that the rate at which fuel vapour is generated in the crankcase is fairly constant over a substantial portion of the evaporation process.

[0011] Experiments have shown that the time needed for evaporating the fuel in the crankcase is substantially independent of the initial amount of fuel. Therefore, the decrease rate of the estimated amount of fuel may be obtained by dividing the estimated amount of fuel at the start of the engine by the predetermined time mentioned above.

[0012] When the monitored fuel amount in the crankcase is below a predetermined threshold, in particular in a limited time interval after refilling a fuel tank from where the engine receives its fuel, the predetermined air-fuel ratio may be set by closed loop control based on exhaust gas composition. As soon as the monitored fuel amount rises above the predetermined threshold, the closed-loop is preferably disabled, so that fluctuations of the exhaust gas composition caused by the introduction of fuel vapour from the crankcase into the combustion chambers will not have an influence on the predetermined air-fuel ratio.

[0013] In above-mentioned method step b) the vapour flow may be estimated proportional to at least one of the following parameters:

- a) the monitored fuel amount in the crankcase,
- b) the airflow rate from the crankcase to the combustion chambers, and
- c) a proportional factor which is controlled based on exhaust gas oxygen content.

[0014] In particular if closed loop control of the air-fuel ratio is disabled, stoichiometric combustion conditions may be maintained by adapting this proportional factor, instead.

[0015] Further features and advantages of the invention will become apparent the subsequent description of embodiments thereof referring to the appended drawings.

- Fig. 1 is a schematic view of a combustion engine of a vehicle in which the present invention is applicable;
- Fig. 2a is a graph of the crankcase airflow as a function of engine speed and inlet pressure in a sample combustion engine;
- Fig. 2b is a graph of inlet airflow as a function of engine speed and inlet pressure in the same combustion engine; and
- Fig. 3 is flowchart of a fuel control method according to the present invention.

[0016] In the simplified representation of Fig. 1, only a single combustion chamber 1 of an internal combustion engine of a motor vehicle is shown; it being understood

that a plurality of such combustion chambers 1 will conventionally be arranged along a crankshaft 2 extending perpendicular to the plane of the drawing. All combustion chambers 1 are connected to an intake manifold 3 by an intake valve 4, and to an exhaust duct 5 by an exhaust valve 6. A throttle 7 at an upstream end of intake manifold 3 controls the flow of fresh air to the combustion chambers 1.

[0017] An injection valve 12 for injecting fuel is shown at the upper end of combustion chamber 1. Alternatively, it might be located in a downstream portion of intake manifold 3. A fuel controller circuit 15 controls the amount of fuel injected by valve 12 in a closed loop based on e.g. engine speed data from an engine speed sensor, not shown, airflow data from an airflow sensor 16 placed in the intake manifold 3, and data on the composition of the exhaust gas, in particular on their oxygen content, from a lambda sensor 18 provided at a upstream side of a catalytic converter 17 placed in exhaust duct 5. The fuel controller circuit 15 has stored in it a current air-fuel ratio AFR and calculates the amount of fuel to be injected by valve 12 based on the airflow detected by airflow sensor 16 and the air-fuel ratio AFR. Based on data from the lambda sensor 18, it judges whether the injected fuel quantity is appropriate for stoichiometric combustion, or whether it must be increased or reduced. Under predetermined circumstances, in particular if the fuel tank (not shown) of the vehicle has recently been refilled, so that the fuel composition may have changed, an increase or reduction of the injected fuel quantity is controlled by updating the current air-fuel ratio AFR.

[0018] The injection quantity determined by controller 15 may be modified at 19 by a compensation quantity from compensating circuit 20, the operation of which will be explained later referring to Fig. 3. The compensating circuit 20 is connected, among others, to a pressure sensor 14 located at intake manifold 3 between throttle 7 and intake valve 4.

[0019] Oil 9 at the bottom of crankcase 8 is supplied to moving parts of the engine by conventional means, not shown.

[0020] A ventilation duct 10 from crankcase 8 reaches intake manifold 3 at a downstream side of throttle 7, so that when the engine is operating, a negative pressure in the intake manifold 3 generated by throttle 7 will cause a valve 11 between ventilation duct 10 and intake manifold 3 to open and air to flow from crankcase 8 through intake manifold 3 into combustion chambers 1. The valve 11 prevents an airflow in the reverse direction, from intake manifold 3 to crankcase 8, in case that the pressure in the intake manifold 3 should exceed that in crankcase 8. By means of the ventilation duct 10, exhaust fumes and water vapour which escape from combustion chamber 1 into crankcase 8 while the engine is operating, are evacuated. However, not only exhaust gas escapes from combustion chamber 1 into the crankcase 8, but also, in particular while the engine is cranking, unburned fuel.

[0021] At first, this down-washed fuel mixes with the

oil 9 in the crankcase 8. When the engine becomes warm, it will evaporate from the oil, and the evaporated fuel is re-introduced into combustion chamber 1 via ventilation duct 10. If the fuel injected at that time by injection valve 12 is metered so as to achieve stoichiometric combustion, the fuel vapour from the crankcase will cause the engine to run rich. If the fuel contains components which tend to evaporate quickly from the crankcase oil, such as, in particular, ethanol, the contribution of these fuel vapours to the overall fuel quantity in combustion chamber 1 can be significant. This may lead to problems such as engine stalling, the fuel controller appearing to be defective, etc.

[0022] From Figs. 2a and 2b, it can be seen that these problems will be most significant if the engine is running at low speed and low load. While warming up, the ethanol vapour concentration in the crankcase 8 may easily exceed ten percent. When the engine is running slowly and under low load, the opening of throttle 7 is small, and the negative pressure at the downstream side of throttle 7 is most significant. Under these circumstances, a large portion of the overall air intake of the combustion chambers is from the crankcase, so that the total amount of fuel in the combustion chambers may exceed the quantity injected at valve 12 significantly.

[0023] The present invention deals with this problem by controlling the fuel injected by valve 12 according to a method which will be described referring to the flow-chart of Fig. 3.

[0024] The method will be described in the following as being carried out by compensating circuit 20. It is understood, however, that the tasks carried out by control circuit 15 and compensating circuit 20 can easily be implemented in a same piece of hardware.

[0025] The method can be divided into three phases, each of which is symbolized by a dashed box, P1, P2, P3 in Fig. 3. When starting the engine, the method first enters phase P1 by initializing a status flag SF to be 1 in step S1. Phase P1 is a cranking phase, in which fuel is injected into combustion chamber 1, but revolutions of the engine are not yet driven by combustion of the injected fuel. The injected fuel quantity is monitored in step S2 by incrementing a fuel counter AF by an amount proportional to the injected fuel quantity whenever fuel is injected into a combustion chamber 1. The value of the fuel counter AF may be assumed to represent the total amount of fuel injected, or the portion of the injected fuel which is actually washed down from the combustion chambers 1 into the crankcase 8, or the amount of ethanol in this down-washed fuel.

[0026] Step S2 is repeated as long as the engine is not yet started, i.e. as long as its revolutions are not powered by combustion of the fuel. When the engine is started, the process reaches step S4, in which a fuel decrement DF is calculated by dividing the accumulated fuel amount AF by a warmup time WT, or, to be more exact, by a number of iterations of the method which will be carried out during this warmup time. The warmup time

is an empirically determined quantity representing a time in which the washed-down ethanol is expected to have evaporated from the crankcase oil under normal operating conditions.

[0027] Step S5 determines whether the accumulated fuel AF is above a threshold AFmin. The threshold AFmin is predetermined so that if the fuel in crankcase 8 is less than AFmin, evaporation of this fuel will not significantly influence the air-fuel ratio in the combustion chambers 1. If the accumulated fuel amount AF is below this threshold, the method proceeds directly to step S13, described later on.

[0028] If the accumulated fuel amount AF exceeds the threshold, the method proceeds to phase P2 by setting status flag SF=2 and starting a timer in step S6. In step S7, it is checked whether the engine temperature TE exceeds a threshold T_{emin} or not. If the threshold is not exceeded, it is assumed that the engine is still too cold for a significant amount of ethanol to evaporate in the crankcase 8. This threshold temperature T_{emin} is typically in a range from 50 to 70°C, it being understood that depending on the location where this temperature is measured, it may deviate systematically from the average temperature of crankcase oil 9, which determines the propensity of the ethanol to evaporate.

[0029] When it is found in step S7 that the engine is warm enough for ethanol to evaporate in the crankcase 8, the air intake Q of the engine is compared to a threshold Q_{lim} in step S8. If Q exceeds the threshold Q_{lim}, it is assumed that the proportion of crankcase air in the total air intake of the combustion chambers 1 is so low that ethanol vapour contained in the crankcase air has no significant influence on the air-fuel ratio in combustion chambers 1.

[0030] If the air intake Q is found low enough in step S8 for the crankcase air to contribute significantly, the method proceeds to step S9, in which a λ value from lambda sensor 18 is compared to a threshold λ_{min} . As long as λ is above this threshold, there can be no significant enrichment of the air-fuel mixture in the combustion chambers 1 by ethanol vapour from the crankcase 8, so that no compensation of the fuel amount determined by fuel controller 15 to be injected at valve 12 is necessary. In that case, the method proceeds directly to step S13.

[0031] Only if λ drops below the threshold λ_{min} , the third phase P3 of the method is reached. In this phase, at first the status flag is set to 3 in step S10, and, if updating the current air-fuel ratio was enabled in fuel controller circuit 15, it is disabled now. Then it is checked in step S11 whether λ is in a range between the above-mentioned lower limit λ_{min} and an upper limit λ_{max} .

[0032] When step S11 is carried out for the first time, λ will be found to be less than λ_{min} , as in preceding step S9, and a fuel quantity compensation step S12 is carried out for the first time. The first execution of step S12 comprises initialising to a positive value a correction factor or vapour concentration factor CF which is to be representative of the ethanol concentration in the crankcase air.

This correction factor may be selected proportional to the fuel amount AF, or it may simply be a predetermined value. Further, the airflow rate from the crankcase 8 to the combustion chambers 1 is determined based on the engine speed measured by the engine speed sensor, inlet pressure measured by pressure sensor 14, and a pro-stored table representing the crankcase airflow characteristic depicted in Fig. 2a. In a similar way, based on the same data and a second table representing the characteristic of Fig. 2b, the intake airflow is determined. Based on these data, the amount of ethanol vapour from the crankcase which is being introduced into the combustion chambers 1 is calculated, and the fuel amount injected at injection valve 12 is reduced by this amount.

[0033] Step S13 then checks whether the fuel amount is still positive, i.e. whether ethanol is expected to be left in the crankcase. If yes, the fuel amount AF is decremented by DF in step S14.

[0034] Subsequently, it is checked in step S15 whether the timer started in step S6 is out or not. If it is not, the method proceeds to step S16, from where it reverts to step S2, S8 or S11, depending on the value of status flag SF.

[0035] In case of the method reverting to step S2 or S8, the process continues as described above for these steps and need not be described further. In case of SF=3, it is checked again in step S11 whether λ is in the desired range between $\lambda_{\min}$ and $\lambda_{\max}$ or not. If the vapour concentration factor CF was initialized correctly, λ will have returned to the desired range, so that the method proceeds directly to step S13, skipping the fuel estimation correction S12. If λ is outside the desired range in step S11, the fuel estimation correction step S12 is repeated, i.e. the concentration factor CF is incremented or decremented depending on whether combustion conditions are still rich or have turned to lean. In this way, by carrying out step S12 repeatedly, the concentration factor CF will eventually become proportional to the ethanol concentration in the crankcase air, and λ will fall into the desired range.

[0036] The progress of the method is time-controlled so that step S13 is repeated at regular intervals.

[0037] When the ethanol in the crankcase oil is nearly exhausted, its concentration in the crankcase airflow decreases, so that on occasional repetitions of step S11, λ will be found to exceed $\lambda_{\max}$, causing the concentration factor CF to be decremented in step S12.

[0038] When step S14 has been repeated WT times, the fuel amount will be found to be 0 in step S13. In that case, the method branches to step S17. Here, if the concentration factor CF has not yet become zero, it is gradually decreased to zero, and at the same time the air-fuel rate AFR of fuel controller circuit 15 is allowed to adapt. When this adaptation is finished, ethanol boiloff compensation according to the invention ends in step S18, and steady-state control of the injected fuel quantity may be continued by fuel controller circuit 15 alone.

[0039] Similarly, if the timer is found to have expired

in step S15, it is assumed that all ethanol must have evaporated from crankcase oil 9, and the method proceeds to step S17, so that a smooth transition to control by fuel controller circuit 15 alone is achieved.

Reference signs

[0040]

- combustion chamber 1
- crankshaft 2
- intake manifold 3
- intake valve 4
- exhaust duct 5
- exhaust valve 6
- throttle 7
- crankcase 8
- Oil 9
- ventilation duct 10
- valve 11
- injection valve 12
- pressure sensor 14
- fuel controller circuit 15
- airflow sensor 16
- catalytic converter 17
- lambda sensor 18
- compensating circuit 20

Claims

1. A fuel control method for an internal combustion engine having one or more combustion chambers (1) and a crankcase (8) connected to an air intake manifold (3) of the combustion chambers (1), comprising the steps of

- a) monitoring (S2, S14) the amount of fuel (AF) in the crankcase (8),
- b) estimating (S12) a fuel vapour flow from the crankcase (8) to the combustion chambers (1),
- c) setting (S12) a fuel injection amount injected into the combustion chambers (1) so that the injected fuel amount and the fuel vapour flow yield a predetermined air-fuel ratio in the combustion chambers.

2. The fuel control method of claim 1, wherein the fuel vapour flow from the crankcase is estimated to be negligible if at least one of the following conditions is met:

- a) the monitored fuel amount (AF) is below a predetermined threshold (AF_{min}) (S5);
- b) the engine temperature (TE) is below a predetermined threshold (TE_{min}) (S7);
- c) the intake airflow (Q) is above a predetermined threshold (Q_{lim}) (S8);

d) a predetermined time has elapsed since the start of the engine (S16).

3. The fuel control method of any of the preceding claims, wherein the monitoring step a) (S2) comprises incrementing an estimated amount of fuel (AF) in the crankcase (8) in proportion to an amount of fuel injected into the combustion chambers (1) while cranking.

5
10
4. The fuel control method of any of the preceding claims, wherein the monitoring step a) comprises decrementing (S14) an estimated amount of fuel (AF) in the crankcase (8) at a constant rate (DF) after start of the engine.

15
5. The fuel control method of claim 4, wherein the constant rate (DF) is obtained by dividing (S4) the estimated amount of fuel (AF) at the start of the engine by a predetermined time (WT).

20
6. The fuel control method of any of the preceding claims, wherein the predetermined air-fuel ratio (AFR) is set by closed loop control based on exhaust gas composition, preferably based on exhaust gas oxygen content, when the monitored fuel amount (AF) is below a predetermined threshold.

25
7. The fuel control method of claim 6, wherein the closed-loop control is disabled (S10) when the monitored fuel amount rises above the predetermined threshold (λ_{min}).

30
8. The fuel control method of any of the preceding claims, wherein in step b) the vapour flow is estimated proportional to at least one of the following parameters:

35

 - a) the monitored fuel amount (AF) in the crankcase (8),

40
 - b) the airflow rate from the crankcase (8) to the combustion chambers (1),
 - c) a proportional factor (CF) which is controlled based on exhaust gas oxygen content.

45
9. The fuel control method of claim 8, wherein the proportional factor (CF) is controlled only while the monitored fuel amount (AF) is above the predetermined threshold.

50

55

Fig. 1

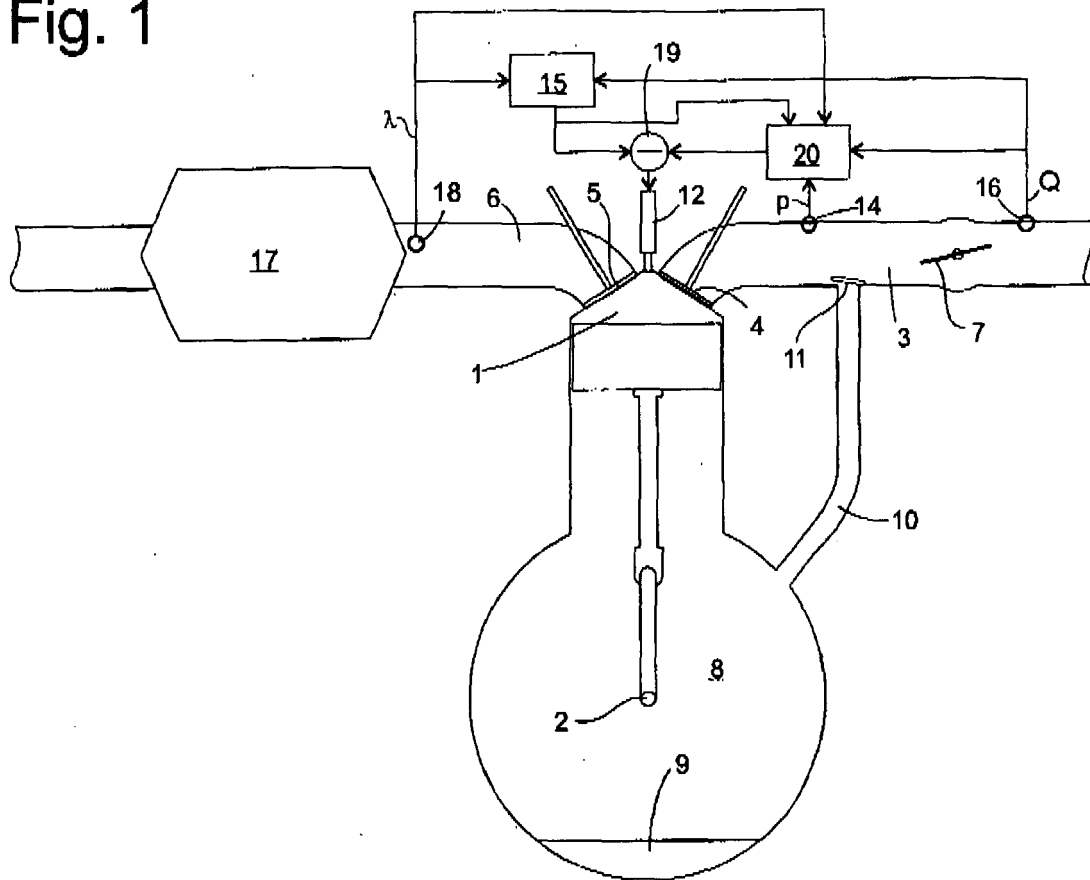


Fig. 2a

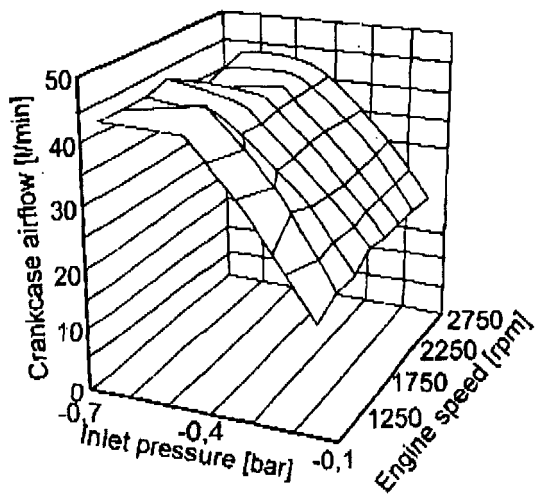


Fig. 2b

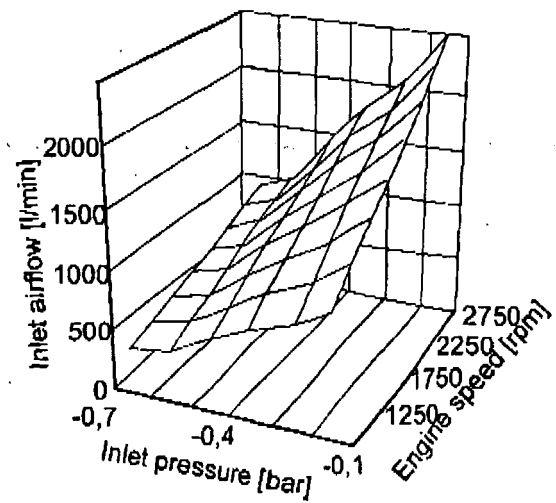
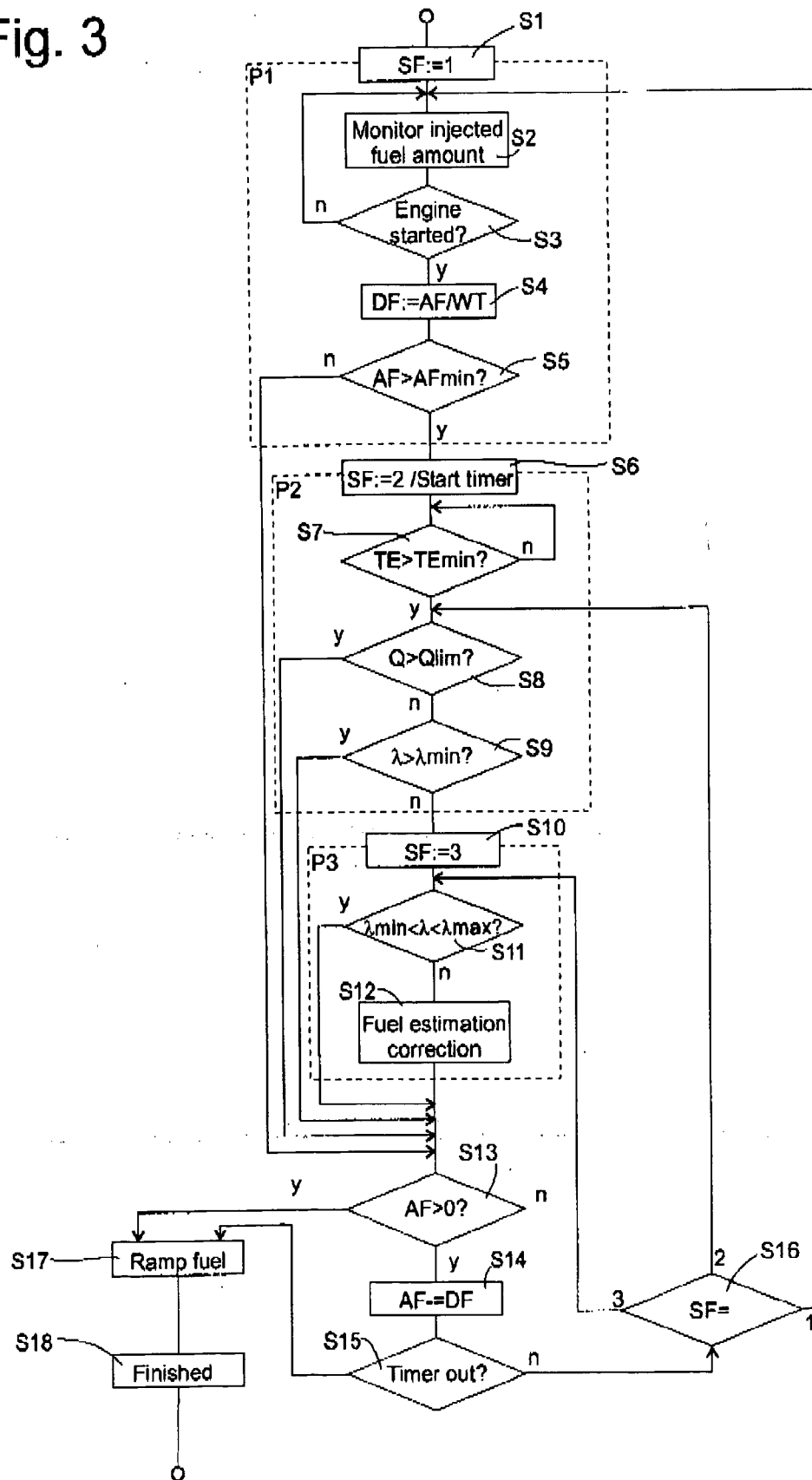


Fig. 3





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 00 0428

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2004 009679 A1 (SIEMENS AG [DE]) 22 September 2005 (2005-09-22) * abstract * * paragraph [0008] - paragraph [0053] * * claims 1-4 * * figures 2-4 *	1-9	INV. F02D41/04 F02D41/12
X	DE 197 27 861 C1 (SIEMENS AG [DE]) 17 December 1998 (1998-12-17) * the whole document *	1-9	
X	DE 102 52 214 A1 (IAV GMBH [DE]) 27 May 2004 (2004-05-27) * the whole document *	1-9	
X	DE 196 04 136 A1 (BOSCH GMBH ROBERT [DE]) 7 August 1997 (1997-08-07) * claim 1 *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 March 2007	Examiner Calabrese, Nunzianta
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			

2
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 07 00 0428

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-03-2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102004009679 A1	22-09-2005	NONE	
DE 19727861 C1	17-12-1998	NONE	
DE 10252214 A1	27-05-2004	NONE	
DE 19604136 A1	07-08-1997	WO 9729276 A1	14-08-1997
		EP 0819210 A1	21-01-1998
		JP 11504099 T	06-04-1999
		US 5839409 A	24-11-1998