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(54) **Method for diagnosting evaporative losses from a fuel tank of an internal combastion engine**

(57) Method for diagnosing evaporative losses from a fuel tank (3) of an internal combustion engine (1); the method of diagnosis consisting of: isolating the tank (3); pressurizing/depressurizing the tank (3) by means of a pneumatic machine (12) driven by an electric motor (13); measuring the time profile of at least one characteristic value of the electric motor (13); calculating the frequency range of the characteristic value of the electric motor (13); and diagnosing the rate of evaporative loss from the tank (3) as a function of the frequency range of the characteristic value of the electric motor (13).

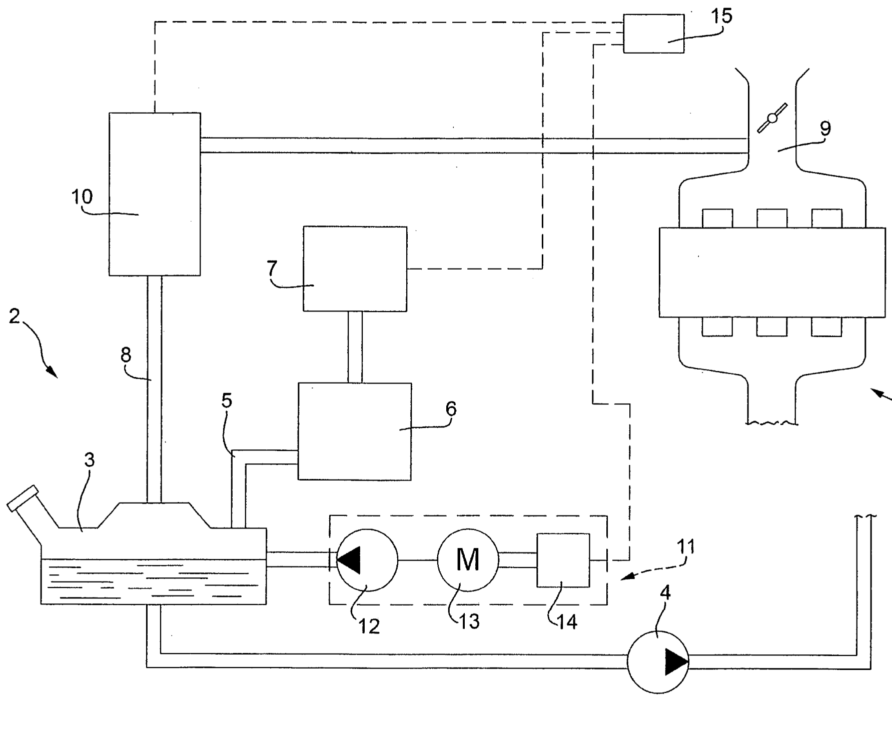


FIG.1

EP 2 108 808 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a method for diagnosing evaporative losses from a fuel tank of an internal combustion engine.

BACKGROUND ART

[0002] A liquid fuel delivery system in an internal combustion engine comprises a tank containing a certain amount of fuel and a fuel pump that draws the fuel from the tank and delivers the fuel under pressure to the injection system.

[0003] In some countries (for example in the United States), type-approval laws require the fuel tank to be tested cyclically (typically each time the internal combustion engine is started) to verify its vapour tightness (i.e. the rate of evaporative loss from the tank). The amount of fuel vapour released into the atmosphere from the tank must not exceed a prescribed threshold value. If the vapour tightness test reveals that the fuel vapour released into the atmosphere from the tank (and the pipes connected to said tank) exceeds the prescribed threshold value, a fuel delivery system fault signal must be generated and technical assistance must be requested.

[0004] The use of a vapour tightness testing unit, which is connected to the tank and comprises a compressor driven by an electric motor to pressurize the tank (i.e. to increase the pressure in the tank) has been proposed to verify the vapour tightness of the tank (and of the pipes connected to said tank); moreover, the vapour tightness testing unit may comprise a spool valve that is operated to connect the delivery pipe of the compressor alternately to the tank or to the atmosphere through a gauged hole with a cross-section that, if made to pass through the tank, would enable the fuel vapour to flow towards the atmosphere at a rate slightly lower than the threshold value prescribed by law. The spool valve isolates the delivery pipe of the compressor from the gauged hole and only connects the compressor delivery pipe to the gauged hole now and then and for short periods of time when the tank is tested for vapour tightness as described more fully below.

[0005] In use, to test the tank for vapour tightness said tank is isolated by closing the CCV solenoid, which connects the tank to the atmosphere via the canister, and closing the PCV solenoid, which connects the tank to the intake duct of the internal combustion engine. Once the tank has been isolated, the spool valve is operated to connect the delivery pipe of the compressor to the atmosphere via the gauged hole and the electric motor is operated to drive the compressor; at this point the electrical characteristics of the electric motor are measured (typically the electric current absorbed) to obtain a term of comparison in the event of a known loss through the gauged hole. The spool valve is then operated again to isolate the delivery pipe of the compressor from the gauged hole and at the same time to connect the delivery pipe of the compressor to the tank and the electric motor is operated again to drive the compressor and pressurize the tank; at this stage the electrical characteristics of the electric motor are measured and said electrical characteristics of the electric motor are compared with the electrical characteristics obtained previously with the delivery pipe of the compressor connected to the gauged hole (i.e. in the presence of a known loss). From the result of this comparison it is possible to determine with precision whether the actual loss from the tank is less than the known loss through the gauged hole and is thus acceptable in that the cross-section of the gauged hole, if made to pass through the tank, would allow the fuel vapour to flow towards the atmosphere at a slightly lower rate than the threshold value prescribed by law, or whether the actual loss from the tank is greater than the known loss through the gauged hole and thus not acceptable.

[0006] In the method for diagnosing evaporative losses described above, the electrical characteristic of the electric motor that is analysed is the electric current absorbed; however, the analysis in time of the electric current absorbed has been found to have some drawbacks as it is influenced by various accidental disturbances which may introduce a relatively high error in judgment as regards the vapour tightness of the tank. This error is irrelevant if the actual loss from the tank is far from the threshold value prescribed by law (whether lower or higher), while it is extremely important when the actual loss from the tank is close to the threshold value prescribed by law.

[0007] Moreover, the presence of the controllable spool valve to connect the delivery pipe of the compressor alternately to the atmosphere through the gauged hole or to the tank is useful for self-tuning of the system each time testing is performed to compensate for construction tolerance and changes over time; however, the presence of the spool valve and the presence of the gauged hole (which requires high-precision machining) significantly increase the overall cost of the vapour tightness testing unit.

DISCLOSURE OF INVENTION

[0008] The purpose of the present invention is to provide a method for diagnosing evaporative losses from a fuel tank of an internal combustion engine, said method of diagnosis being simple and cost-effective to implement and capable of overcoming the drawbacks described above.

[0009] According to the present invention a method for diagnosing evaporative losses from a fuel tank of an internal combustion engine is provided according to that set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present invention will now be described with reference to the attached drawings, illustrating some non-limiting embodiments thereof, in which:

- figure 1 is a schematic view of a liquid fuel delivery system in an internal combustion engine in which the method for diagnosing evaporative losses is implemented according to the present invention;
- figure 2 is a graph illustrating the time profile of the electric current absorbed by an electric motor of a unit for testing the vapour tightness of the fuel delivery system in figure 1;
- figure 3 is a graph illustrating the amplitude of the frequency range of the electric current of figure 2;
- figure 4 is a graph showing the increase in the frequency of the fundamental harmonic of the electric current absorbed by an electric motor of a unit used for testing the vapour tightness of the fuel delivery system in figure 1 as the value of the evaporative loss increases; and
- figure 5 is a schematic view of a variant of the fuel delivery system of figure 1.

PREFERRED EMBODIMENTS OF THE INVENTION

[0011] In figure 1, number 1 indicates an internal combustion engine as a whole provided with a liquid fuel delivery system 2.

[0012] The fuel delivery system 2 comprises a tank 3 containing a certain amount of fuel and a fuel pump 4 that draws the fuel from the tank 3 and delivers the fuel under pressure to an injection system (known and not illustrated) of the internal combustion engine 1.

[0013] The fuel delivery system 2 also comprises a breather pipe 5, which connects the tank 3 to the outside environment, i.e. to the atmosphere; the presence of the breather pipe 5 is necessary in order for the fuel pump 4 to work, in that air is gradually drawn into the tank 3 through the breather pipe 5 as the fuel pump 4 empties said tank 3. To prevent fuel vapour from being discharged into the atmosphere through the breather pipe 5, a canister 6, i.e. a spongy filter capable of trapping and withholding the fuel vapour is arranged along the breather pipe 5. Moreover, the breather pipe 5 is controlled by a CCV solenoid 7, which is arranged downstream of the canister 6 and is operated to open or close the breather pipe 5.

[0014] The fuel delivery system 2 comprises a recovery duct 8 to recuperate the fuel vapour, which connects the fuel tank 3 to an intake duct 9 of the internal combustion engine downstream of a throttle valve. The recovery duct 8 is controlled by a PCV solenoid 10 which is operated to open or close the recovery duct 8. The PCV solenoid 10 is normally closed and is opened in certain operating conditions of the internal combustion engine 1 to generate, thanks to the depression in the intake duct 9, a flow of air that "flushes" the canister 6 (i.e. freeing the canister 6 of the trapped fuel vapour) and delivers the fuel vapour released by the canister 6 into the intake duct 9 so that said fuel vapour is burned in the cylinders of the internal combustion engine 1.

[0015] Finally, the fuel delivery system 2 comprises a vapour tightness testing unit 11, which is connected to the tank 3 and comprises a compressor 12 (i.e. a pneumatic machine) which is driven by an electric motor 13 to pressurize the tank 3 (i.e. to increase the pressure in the tank 3); the electric motor 13 is operated by an electric drive 14 which also comprises a current meter to measure the electric current absorbed by the electric motor 13 in real time.

[0016] The internal combustion engine 1 comprises an electronic control unit 15, which, among other things, controls the CCV solenoid 7, the PCV solenoid 10 and the electric drive 14. Cyclically, (typically each time the internal combustion engine 1 is started) the electronic control unit 15 uses the vapour tightness testing unit 11 to verify the vapour tightness of the tank 3 (i.e. the rate of evaporative loss from the tank 3 and from the pipes connected to said tank 3), which (together with the ducts connected to said tank 3) must not discharge fuel vapour into the atmosphere at more than the set maximum rate prescribed by law. If the electronic control unit detects that fuel vapour is discharged from the tank 3 into the atmosphere at more than the prescribed maximum rate, the electronic control unit 15 signals a fault in the fuel delivery system 2 and generates a request for technical assistance.

[0017] The method used by the electronic control unit 15 to test the tank 3 for vapour tightness using the vapour tightness testing unit 11 is now described.

[0018] First, the electronic control unit 15 isolates the tank 3 from the atmosphere by closing the CCV solenoid 7 and isolates the tank 3 from the intake duct 9 by closing the PCV solenoid 10; once the tank 3 has been isolated, the electronic control unit 15 operates the electric motor 13 to start the compressor 12 in order to pressurize (or alternatively depressurize) the tank 3. When a prescribed period of time has elapsed after starting the compressor 12, the electronic control unit 15, using the current meter of the electric drive 14, measures the time profile of the electric current absorbed by the electric motor 13 over a set time (usually a few seconds); the electronic control unit 15 then diagnoses the rate of evaporative loss from the tank 3 as a function of the time profile of the electric current absorbed by the electric motor 13.

[0019] In particular, the electronic control unit 15 determines the frequency range of the electric current absorbed by the electric motor 13 by applying the Fourier transform (FFT - Fast Fourier Transform or STFT - Short Time Fourier Transform) to the time profile of the electric current absorbed by the electric motor 13 and thus diagnoses the rate of evaporative loss from the tank 3 as a function of the frequency range of the electric current absorbed by the electric motor 13. It is important to underline that the tank 3 is not expected to be fully pressurized in the stationary (or almost stationary) condition, as this would take too long (about ten minutes); rather, when a set time has elapsed after starting the compressor 12 (typically a few seconds) the electronic control unit 15 measures the time profile of the electric current absorbed by the electric motor 13 over a set time (approximately 1-4 seconds). It is important that the time profile of the electric current absorbed by the electric motor 13 is obtained over a relatively short time so that during that time the actual (or average) value of the electric current can be regarded as constant at first approximation (i.e. the electric motor 13 is regarded as stationary at first approximation).

[0020] According to a preferred embodiment, the electronic control unit 15 determines the fundamental harmonic of the frequency range (i.e. the harmonic with the greatest amplitude), determines the frequency of the fundamental harmonic, and diagnoses the rate of evaporative loss from the tank 3 as a function of the frequency of the fundamental harmonic. In particular, the electronic control unit 15 compares the frequency of the fundamental harmonic with at least one threshold value to diagnose the rate of evaporative loss from the tank 3; it has been observed that the higher the frequency of the fundamental harmonic, the higher the rate of evaporative loss from the tank 3. Consequently, if the frequency of the fundamental harmonic is higher than the threshold value, the evaporative loss from the tank 3 will exceed the prescribed threshold value. The electronic control unit 15 could of course compare the frequency of the fundamental harmonic with a plurality of threshold values, each of which is associated with a respective rate of evaporative loss from the tank 3; thus, in addition to determining whether the evaporative loss from the tank 3 exceeds the maximum prescribed rate, the electronic control unit 15 is also capable of estimating the actual value of the evaporative loss from the tank 3. If an estimated actual value of the evaporative loss from the tank 3 is known, the electronic control unit 15 is capable of determining the long-term profile of the actual value of the evaporative loss from the tank 3 to verify whether the actual value of the evaporative loss tends to increase towards the maximum prescribed value or whether the actual value of the evaporative loss tends to remain approximately constant.

[0021] In calculating and analysing the fundamental harmonic of the frequency range of the electric current absorbed by the electric motor 13 as described above, the electronic control unit 15 takes into account the level of fuel in the tank 3; in other words, in calculating and analysing the fundamental harmonic of the frequency range of the electric current absorbed by the electric motor 13 as described above, the electronic control unit 15 uses correction parameters the values of which depend on the level of fuel in the tank 3.

[0022] The threshold values with which the frequency of the fundamental harmonic is compared are determined experimentally in the design stage and during set-up of the vapour tightness testing unit 11; in other words, in a sample fuel delivery system 2 the tank 3 is set with a constant known evaporative loss (for example using gauged test holes) and the corresponding frequency of the fundamental harmonic of the electric current absorbed by the electric motor 13 is measured.

[0023] As mentioned previously, as the actual value of the evaporative loss from the tank 3 increases so does the frequency of the fundamental harmonic of the electric current absorbed by the electric motor 13. This relationship is explained by the increase in the speed of rotation of the compressor 12 (and thus of the electric motor 13) with the increase in the actual value of the evaporative loss from the tank 3 (i.e. as the overpressure in the tank 3 falls). In other words, the speed of rotation of the compressor 12 (and thus of the electric motor 13) is inversely related to the pressure drop between the upstream and downstream sides of the compressor 12 and the higher the actual value of the evaporative loss from the tank 3 the lower the overpressure in the tank 3 and thus the smaller the pressure drop between the upstream and downstream sides of the compressor 12 and the higher the speed of rotation of the compressor 12.

[0024] By way of example, figure 2 is a graph illustrating the time profile of the electric current absorbed by the electric motor 13 while testing the tank 3 for vapour tightness in the stationary condition; figure 3 is a graph illustrating the amplitude of the frequency range of the electric current of figure 2. The graph in figure 3 clearly shows that the frequency of the first harmonic is approx. 25 Hz, while the frequency associated with the harmonic with maximum amplitude, or fundamental harmonic, is approx. 75 Hz.

[0025] An analysis of the time profile and frequency range of the current absorbed by the electric motor 13 in the stationary condition reveals the presence of a significant periodicity in the signal; in particular, the significant harmonics are multiples of a "basic" frequency and, in the specific examples in figures 2 and 3, the third harmonic is the fundamental harmonic, i.e. the harmonic with maximum amplitude. The fact that it is the third harmonic which is significantly excited compared to the other harmonics is due to the characteristics of the electric motor 13 used to obtain the measurements shown in figures 2 and 3; this electric motor 13 had a three-lobe rotor.

[0026] Figure 4 is a graph illustrating the increase in the frequency of the fundamental harmonic (maximum amplitude) of the electric current absorbed by the electric motor 13 as the value of the evaporative loss from the tank 3 increases; in particular, four tests were carried out with the tank 3 in an integral state (i.e. with no holes or, from an alternative perspective, with a hole having a diameter of 0.00 mm), with the tank 3 provided with a gauged hole with a diameter of 0.40 mm, with the tank 3 provided with a gauged hole with a diameter of 0.55 mm and with the tank 3 provided with a gauged hole with a diameter of 0.93 mm.

[0027] According to an alternative embodiment, the electronic control unit 15 can diagnose the rate of evaporative loss from the tank 3 according to the procedures described above using a characteristic value of the electric motor 13 other than the electric current absorbed; for example, the electronic control unit 15 could use the supply voltage or the speed of rotation (which corresponds to the speed of rotation of the compressor 12).

[0028] The method for diagnosing evaporative losses from the tank 3 described above is capable of functioning satisfactorily even without the use of a controllable spool valve to connect the delivery pipe of the compressor 12 to the atmosphere through a gauged hole; according to the embodiment described above, a controllable spool valve is not used to connect the delivery pipe of the compressor 12 to the atmosphere through a gauged hole. However, the method for diagnosing evaporative losses from the tank 3 described above can also be implemented using a controllable spool valve to connect the delivery pipe of the compressor 12 to the atmosphere through a gauged hole.

[0029] According to a possible embodiment, the electronic control unit 15 occasionally performs self-learning of the functional parameters of the vapour tightness testing unit 11 comprising the compressor 12 and the electric motor 13 to compensate for construction tolerance and changes over time. To perform self-learning of the functional parameters of the vapour tightness testing unit 11 the electronic control unit 15 sets a known pressure value in the tank 3, it activates the compressor 12 by operating the electric motor 13 with a test supply voltage that has a set time profile (typically constant), measures the actual time profile of the electric current absorbed by the electric motor 13, determines an expected time profile of the electric current absorbed as a function of the current functional parameters of the vapour tightness testing unit 11, compares the actual time profile with the expected time profile, and diagnoses an inconsistency in the vapour tightness testing unit 11 if the actual time profile differs significantly from the expected time profile (i.e. if the difference is greater than the accidental and systematic measurement errors). The electronic control unit 15 can of course use a characteristic value of the electric motor other than the electric current absorbed to perform self-learning of the functional parameters of the vapour tightness testing unit 11; for example, the electronic control unit 15 could use the supply voltage or the speed of rotation.

[0030] In other words, the current functional parameters of the vapour tightness testing unit 11 are used to calculate an expected time profile of the electric current absorbed as a function of the test supply voltage (which is known) and of the value of the pressure in the tank 3 (also known); thus any significant differences between the expected time profile of the electric current absorbed and the actual time profile are attributed to the fact that the current functional parameters of the vapour tightness testing unit 11 used by the electronic control unit 15 are not exactly the same as the actual functional parameters. The current functional parameters of the vapour tightness testing unit 11 can therefore be corrected as a function of the difference between the actual time profile and the expected time profile of the electric current absorbed by the electric motor 13.

[0031] On the basis of the above description the functional parameters of the vapour tightness testing unit 11 are self-learned by comparing the expected time profile and the actual time profile of the electric current absorbed by the electric motor 13; alternatively, self-learning of the functional parameters of the vapour tightness testing unit 11 could be performed by comparing the expected frequency range and the frequency range of the electric current absorbed by the electric motor 13.

[0032] The electronic control unit 15 also performs self-learning of the functional parameters of the vapour tightness testing unit 11 described above by taking into account the level of fuel in the tank 3; in other words, to perform self-learning of the functional parameters of the vapour tightness testing unit 11 described above, the electronic control unit 15 uses correction parameters the values of which depend on the level of fuel in the tank 3.

[0033] The known pressure value in the tank 3 can be set by closing the CCV solenoid 7 which connects the tank to the outside and modulating the opening frequency of the PCV solenoid 10 which connects the tank 3 to the intake duct 9; in this way the pressure in the tank 3 is taken as a known function of the modulation implemented on the PCV solenoid 10 and of the pressure in the intake duct 9 (unless in case of a correction coefficient determined experimentally) which is measured with precision using a specific sensor (not illustrated) normally present in all modern internal combustion engines 1. Alternatively, the known pressure value can be set in the tank 3 by opening the CCV solenoid 7 which connects the tank 3 to the outside and closing the PCV solenoid 10 which connects the tank 3 to the intake duct 9 of the engine 1; in this way the pressure in the tank 3 is taken to be the same as the atmospheric pressure (unless in case of a correction coefficient calculated experimentally and particularly taking into account the pressure drop generated by the canister 6) which is conventionally assumed to be 1 bar or which is estimated in a known way by the electronic control unit 15.

[0034] According to a possible embodiment, the compressor can be a reversible pneumatic machine, i.e. depending on the direction of rotation set by the electric motor 13 it is capable of pressurizing or depressurizing the tank 3; in this case, the evaporative loss could be diagnosed by activating the compressor 12 to pressurize the tank and self-learning of the functional parameters could be performed by activating the compressor 12 to depressurize the tank 3 or vice versa.

[0035] According to the variant illustrated in figure 5, the compressor 12 is arranged along the breather pipe 5 which connects the tank 3 to the atmosphere and replaces the CCV solenoid 7; each time the tank 3 must be isolated from the atmosphere the compressor 12 is activated by means of the electric motor 13 to pressurize the tank 3. Preferably the compressor 12 is of the centrifugal type or of a similar type so that when the compressor 12 is not running it does not constitute an appreciable obstruction to the incoming airflow entering the tank 3 due to its "open" machine characteristic. In other words, if the compressor 12 is of the centrifugal type or of a similar type, when the compressor 12 is running to pressurize the tank 3 said compressor 12 acts as a closed valve, preventing air from leaving the tank 3, whereas when the compressor 12 is off said compressor 12 acts as an open valve and is not an appreciable obstruction to the entry of air into the tank 3.

[0036] In the embodiment illustrated in figure 5, the compressor 12 is arranged along the breather pipe 5 between the tank 3 and the canister 6. According to a different embodiment, the compressor 12 is arranged along the breather pipe 5 downstream of the canister 6 (i.e. between the canister 6 and the atmosphere); this embodiment has the advantage that the fluid processed by the compressor 12 is completely "clean" (i.e. filtered by the canister 6 and thus containing no fuel vapour) and also has the advantage of being able to verify the vapour tightness of the portion of the breather pipe 5 between the compressor 12 and the canister 6.

[0037] The method for diagnosing evaporative losses from the tank 3 described above has numerous advantages. In particular, the method for diagnosing evaporative losses from the tank 3 described above is particularly accurate and reliable thanks to the analysis of the frequency range of the electric current absorbed by the electric motor 13 (or possibly of a different characteristic value of the electric motor 13). In other words, the analysis of the frequency range of the electric current absorbed by the electric motor 13 is not influenced by significant accidental disturbances, so that the result of said analysis (i.e. the judgment regarding the vapour tightness of the tank 3) is particularly accurate and reliable.

[0038] Moreover, the method for diagnosing evaporative losses from the tank 3 described above is capable of operating satisfactorily even without the use of a controllable spool valve to connect the delivery pipe of the compressor 12 to the atmosphere through a gauged hole; consequently, this method of diagnosis is also simple and cheap to implement.

[0039] The embodiment illustrated in figure 5 is particularly economical, in that compared to the embodiment illustrated in figure 1 the presence of the CCV solenoid 7 is not necessary as the functions of the latter are performed by the compressor 12.

Claims

1. Method for diagnosing evaporative losses from a fuel tank (3) of an internal combustion engine (1); the method of diagnosis comprising the following steps:

   isolating the tank (3);
   pressurizing/depressurizing the tank (3) using a pneumatic machine (12) driven by an electric motor (13);
   measuring the time profile of at least one characteristic value of the electric motor (13); and
   diagnosing the rate of evaporative loss from the tank (3) as a function of the time profile of the characteristic value of the electric motor (13).
   the method of diagnosis being **characterized in that** it comprises the following additional steps of:

      calculating the frequency range of the characteristic value of the electric motor (13); and
      diagnosing the rate of evaporative loss from the tank (3) as a function of the frequency range of the characteristic value of the electric motor (13).

2. Method of diagnosis according to claim 1 and comprising the additional step of calculating the frequency range of the characteristic value of the electric motor (13) by applying the Fourier transformant to the time profile of the electric value.

3. Method of diagnosis according to claim 1 or 2 and comprising the following additional steps of:

   calculating the fundamental harmonic of the frequency range;
   calculating the frequency of the fundamental harmonic; and
   diagnosing the rate of evaporative loss from the tank (3) as a function of the frequency of the fundamental harmonic.

4. Method of diagnosis according to claim 3, wherein the fundamental harmonic of the frequency range is the harmonic with the greatest amplitude.

5. Method of diagnosis according to claim 3 or 4 and comprising the additional step of comparing the frequency of the fundamental harmonic with at least one threshold value to diagnose the rate of evaporative loss from the tank (3).

6. Method of diagnosis according to claim 5, wherein the higher the frequency of the fundamental harmonic, the higher the rate of evaporative loss from the tank (3).

7. Method of diagnosis according to claim 5 or 6, wherein if the frequency of the fundamental harmonic is higher than the threshold value the evaporative loss from the tank (3) will exceed the prescribed maximum value.

8. Method of diagnosis according to claim 5, 6 or 7 and comprising the step of comparing the frequency of the fundamental harmonic with a plurality of threshold values, each of which is associated with a respective rate of evaporative loss from the tank (3).

9. Method of diagnosis according to one of the claims from 1 to 8, wherein the time profile of the characteristic value of the electric motor (13) is measured over a set period of time.

10. Method of diagnosis according to claim 9, wherein the period of time during which the time profile of the characteristic value of the electric motor (13) is measured lasts a few seconds.

11. Method of diagnosis according to one of the claims from 1 to 10 and comprising the additional step of diagnosing the rate of evaporative loss from the tank (3) also as a function of the level of fuel in the tank (3).

12. Method of diagnosis according to one of the claims from 1 to 11 and comprising the additional step of occasionally self-learning the functional parameters of a vapour tightness testing unit (11) comprising the pneumatic machine (12) and the electric motor (13) to compensate for construction tolerance and changes over time; the process of self-learning the characteristics of the vapour tightness testing unit (11) comprises the following additional steps of:

setting a known pressure value in the tank (3);
activating the pneumatic machine (12) by operating the electric motor (13) with a test supply voltage having a set time profile;
measuring an actual value of at least one characteristic value of the electric motor (13);
determining an expected value of the characteristic of the electric motor (13) as a function of current functional parameters of the vapour tightness testing unit (11);
comparing the actual value with the expected value; and
diagnosing an inconsistency in the vapour tightness testing unit (11) if the actual value differs significantly from the expected value.

13. Method of diagnosis according to claim 12 and comprising the additional step of correcting the current functional parameters of the vapour tightness testing unit (11) as a function of the difference between the actual value and the expected value.

14. Method of diagnosis according to claim 12 or 13 and comprising the additional step of determining the expected value of the characteristic of the electric motor (13) also as a function of the level of fuel in the tank (3).

15. Method of diagnosis according to claim 12, 13 or 14, wherein the characteristic value of the electric motor (13) used for self-learning of the functional parameters of the vapour tightness testing unit (11) is a time profile.

16. Method of diagnosis according to claim 12, 13 or 14, wherein the characteristic value of the electric motor (13) used for self-learning of the functional parameters of the vapour tightness testing unit (11) is a frequency range.

17. Method of diagnosis according to one of the claims from 12 to 15, wherein the step of setting the known pressure value in the tank (3) comprises the following additional steps of:

closing a CCV valve (7) connecting the tank (3) to the outside environment; and
modulating the opening frequency of a PCV valve (10) connecting the tank (3) to an intake duct (9) of the internal combustion engine (1).

18. Method of diagnosis according to claim 17, wherein the known pressure value in the tank (3) is determined as a function of the pressure value in the intake duct (9).

19. Method of diagnosis according to one of the claims from 12 to 15, wherein the step of setting the known pressure value in the tank (3) comprises the following additional steps of:

opening a CCV valve (7) connecting the tank (3) to the outside environment; and
closing a PCV valve (10) connecting the tank (3) to an intake duct (9) of the internal combustion engine (1).

20. Method of diagnosis according to claim 19, wherein the known pressure value in the tank (3) is determined as a function of the atmospheric pressure value.

21. Method of diagnosis according to one of the claims from 12 to 20 wherein the pneumatic machine (12) is reversible; evaporative losses are diagnosed by activating the pneumatic machine (12) to pressurize the tank (3) and self-learning of the functional parameters is performed by activating the pneumatic machine (12) to depressurize the tank (3) or vice versa.

22. Method of diagnosis according to one of the claims from 1 to 21, wherein the pneumatic machine (12) is arranged along the breather pipe (5) which connects the tank (3) to the atmosphere; the method comprises the additional step of activating the pneu-

matic machine (12) to pressurize the tank (3) each time the tank (3) must be isolated from the atmosphere.

23. Method of diagnosis according to claim 22, wherein the pneumatic machine (12) is a centrifugal compressor.

24. Method for diagnosing evaporative losses from a fuel tank (3) of an internal combustion engine (1); the method of diagnosis comprising the following steps of:

isolating the tank (3);
pressurizing/depressurizing the tank (3) using a pneumatic machine (12) driven by an electric motor (13);
measuring the time profile of at least one characteristic value of the electric motor (13);
diagnosing the rate of evaporative loss from the tank (3) as a function of the time profile of at least one characteristic value of the electric motor (13); and
occasional self-learning of the functional parameters of a vapour tightness testing unit (11) comprising the pneumatic machine (12) and the electric motor (13) to compensate for construction tolerance and changes over time;
the method of diagnosis being **characterized in that** the process of self-learning of the characteristics of the vapour tightness testing unit (11) comprises the following additional steps of:

setting a known pressure value in the tank (3);
activating the pneumatic machine (12) by operating the electric motor (13) with a test supply voltage having a set time profile;
measuring an actual value of at least one characteristic value of the electric motor (13);
determining an expected value of the characteristic of the electric motor (13) as a function of current functional parameters of the vapour tightness testing unit (11);
comparing the actual value with the expected value; and
diagnosing an inconsistency in the vapour tightness testing unit (11) if the actual value differs significantly from the expected value.

25. Method of diagnosis according to claim 24 and comprising the additional step of correcting the current functional parameters of the vapour tightness testing unit (11) as a function of the difference between the actual value and the expected value.

26. Method of diagnosis according to claim 24 or 25 and comprising the additional step of determining the expected value of the characteristic of the electric motor (13) also as a function of the level of fuel in the tank (3).

27. Method of diagnosis according to claim 24, 25 or 26, wherein the characteristic value of the electric motor (13) used for self-learning of the functional parameters of the vapour tightness testing unit (11) is a time profile.

28. Method of diagnosis according to claim 24, 25 or 26, wherein the characteristic value of the electric motor (13) used for self-learning of the functional parameters of the vapour tightness testing unit (11) is a frequency range.

29. Method of diagnosis according to one of the claims from 24 to 28, wherein the step of setting the known pressure value in the tank (3) comprises the following additional steps of:

closing a CCV valve (7) connecting the tank (3) to the outside environment; and
modulating the opening frequency of a PCV valve (10) connecting the tank (3) to an intake duct (9) of the internal combustion engine (1).

30. Method of diagnosis according to claim 29, wherein the known pressure value in the tank (3) is determined as a function of the pressure value in the intake duct (9).

31. Method of diagnosis according to one of the claims from 24 to 28, wherein the step of setting the known pressure value in the tank (3) comprises the following additional steps of:

opening a CCV valve (7) connecting the tank (3) to the outside environment; and
closing a PCV valve (10) connecting the tank (3) to an intake duct (9) of the internal combustion engine (1).

32. Method of diagnosis according to claim 31, wherein the known pressure value in the tank (3) is determined as a function of the atmospheric pressure value.

33. Method of diagnosis according to one of the claims from 24 to 32 wherein the pneumatic machine (12) is reversible; evaporative losses are diagnosed by activating the pneumatic machine (12) to pressurize the tank (3) and self-learning of the functional parameters is performed by activating the pneumatic machine (12) to depressurize the tank (3) or vice versa.

34. Liquid fuel delivery system (2) for an internal combustion engine; the delivery system (2) comprising:

a tank (3) for containing fuel;
a fuel pump (4) that draws the fuel from the tank (3) and delivers the fuel under pressure to an injection system of the internal combustion engine (1);
a breather pipe (5), which connects the tank (3) to the atmosphere;
a canister (6) arranged along the breather pipe (5) to prevent the fuel vapour from being discharged into the atmosphere through the breather pipe (5);
a recovery duct (8) to recuperate the fuel vapour, connecting the fuel tank (3) to an intake duct (9) of the internal combustion engine;
a PCV valve (10) arranged along the recovery duct (8) to open or close said recovery duct (8); and
a vapour tightness testing unit (11), which is connected to the tank (3) and comprises a pneumatic machine (12) which is driven by an electric motor (13) to pressurize or depressurize the tank (3);
the fuel delivery system (2) is **characterized in that**:

the pneumatic machine (12) is arranged along the breather pipe (5) connecting the tank (3) to the atmosphere; and
the pneumatic machine (12) can be activated to pressurize the tank (3) each time the tank (3) must be isolated from the atmosphere.

35. Fuel delivery system (2) according to claim 34, wherein the pneumatic machine (12) is a centrifugal compressor.

36. Fuel delivery system (2) according to claim 34 or 35, wherein the pneumatic machine (12) is arranged downstream of the canister (6).

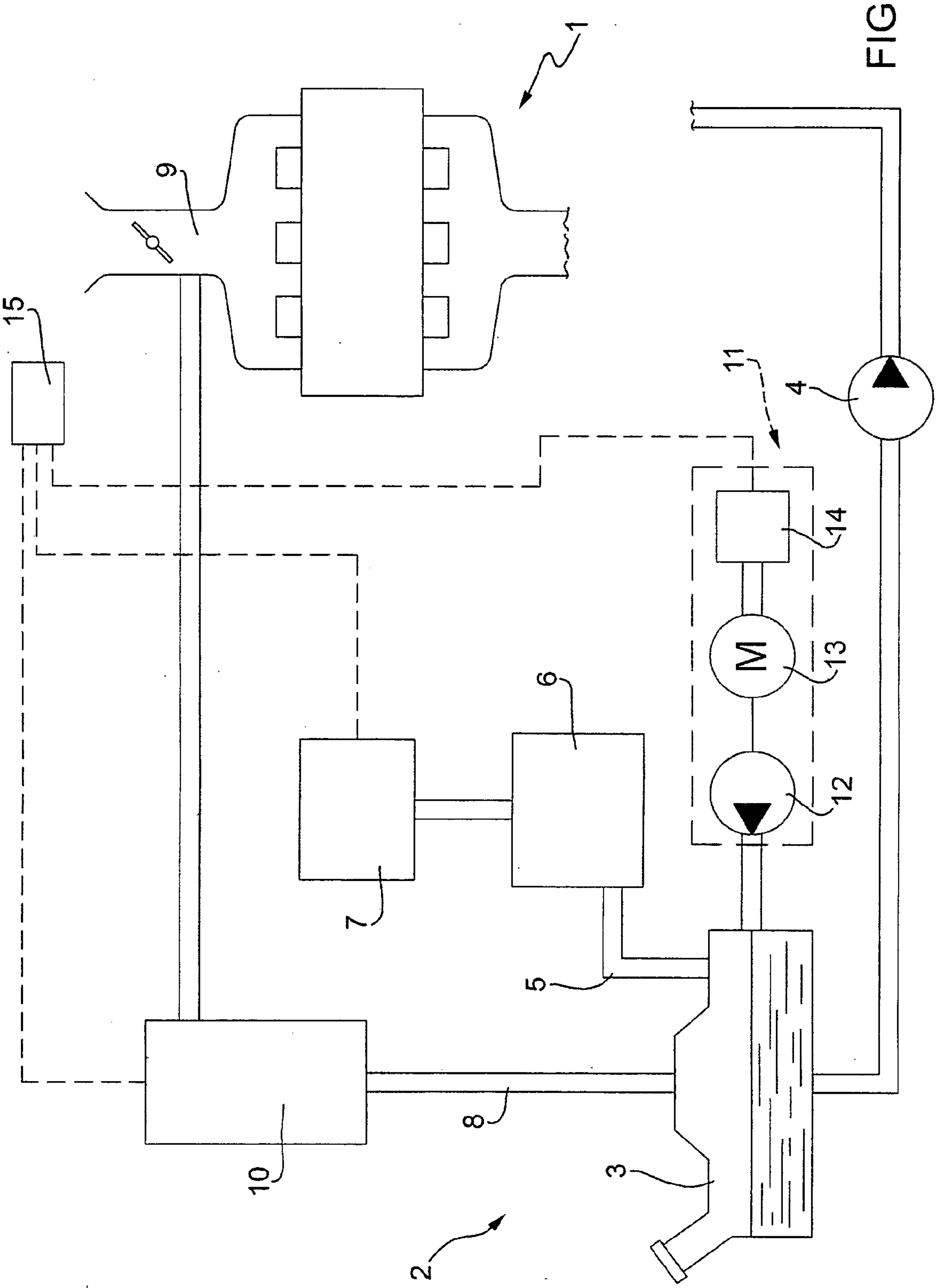


FIG.1

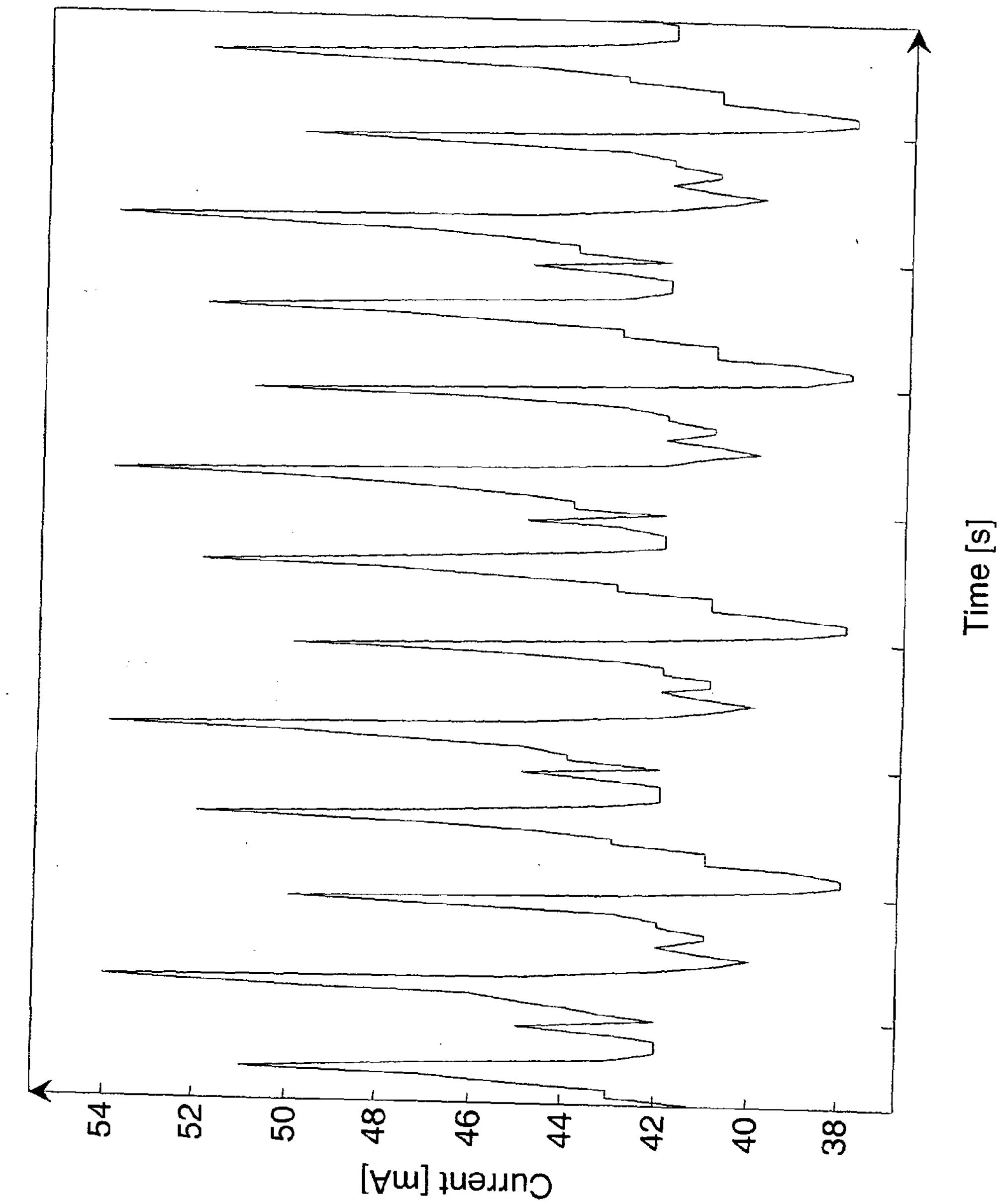


Fig. 2

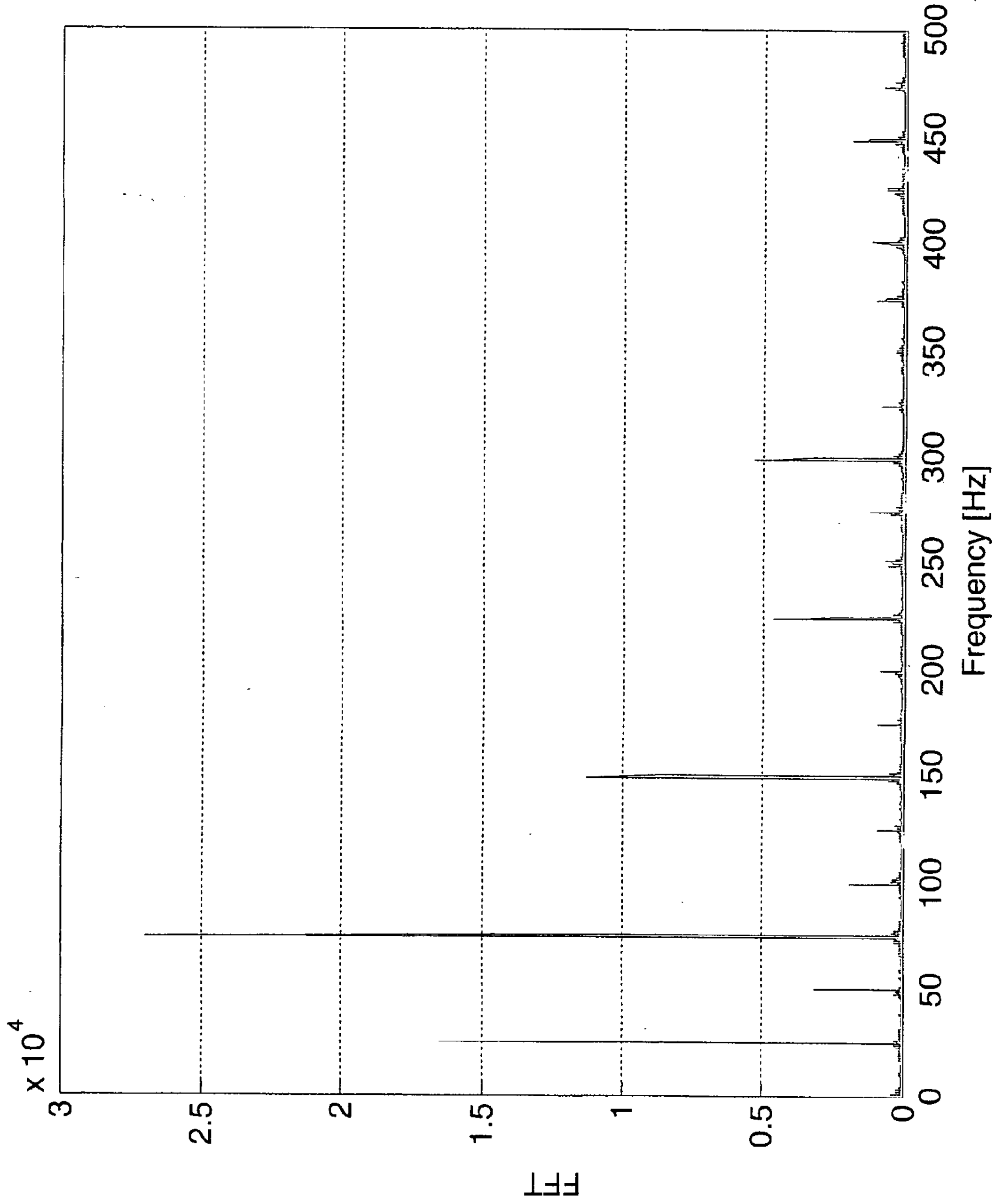
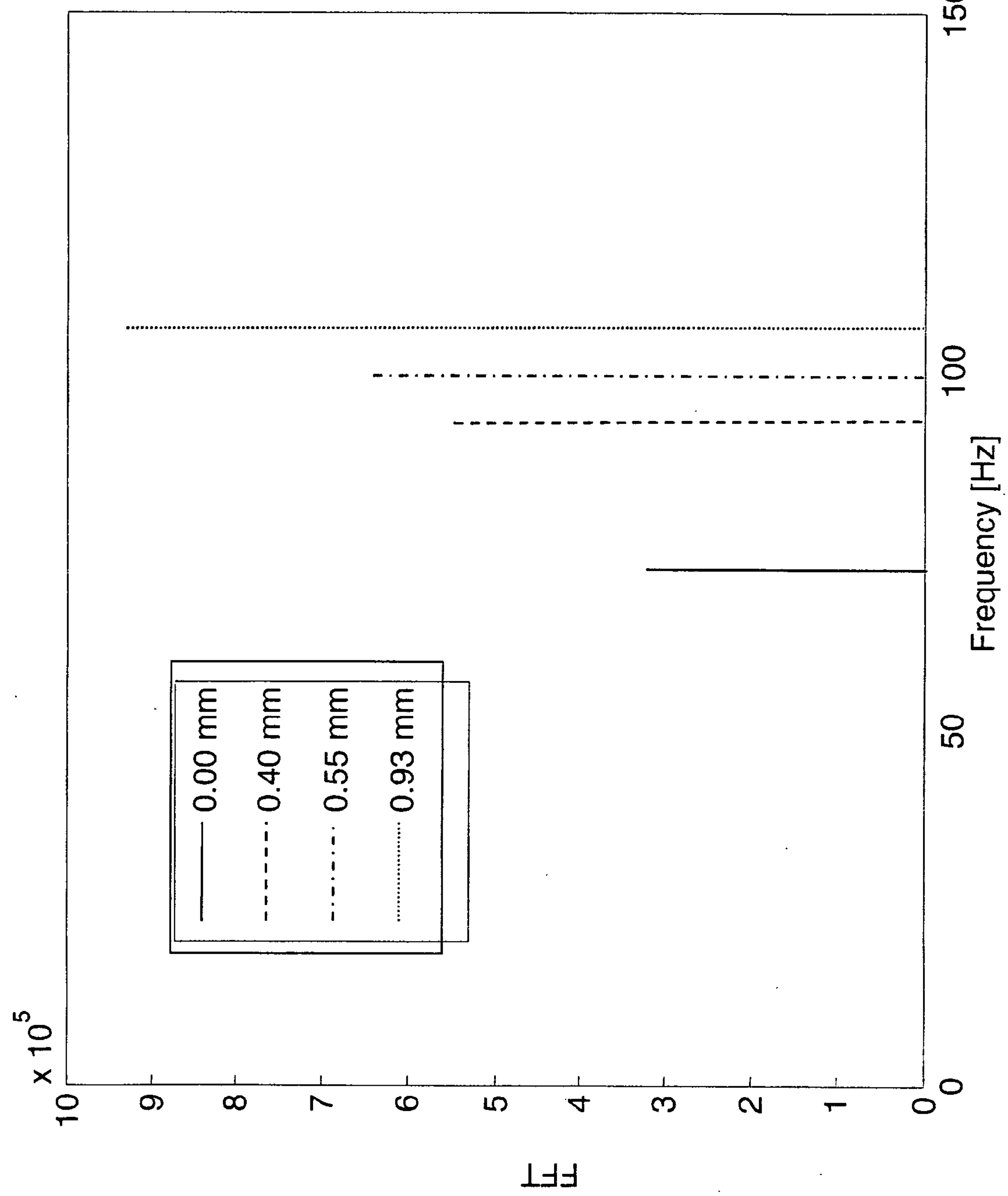

x 10^4
3
2.5
2
1.5
1
0.5
0
FFT
0
50
100
150
200
250
300
350
400
450
500
Frequency [Hz]

Fig. 3

Fig. 4


x 10^5
FFT
Frequency [Hz]
0.00 mm
0.40 mm
0.55 mm
0.93 mm
0
1
2
3
4
5
6
7
8
9
10
0
50
100
150

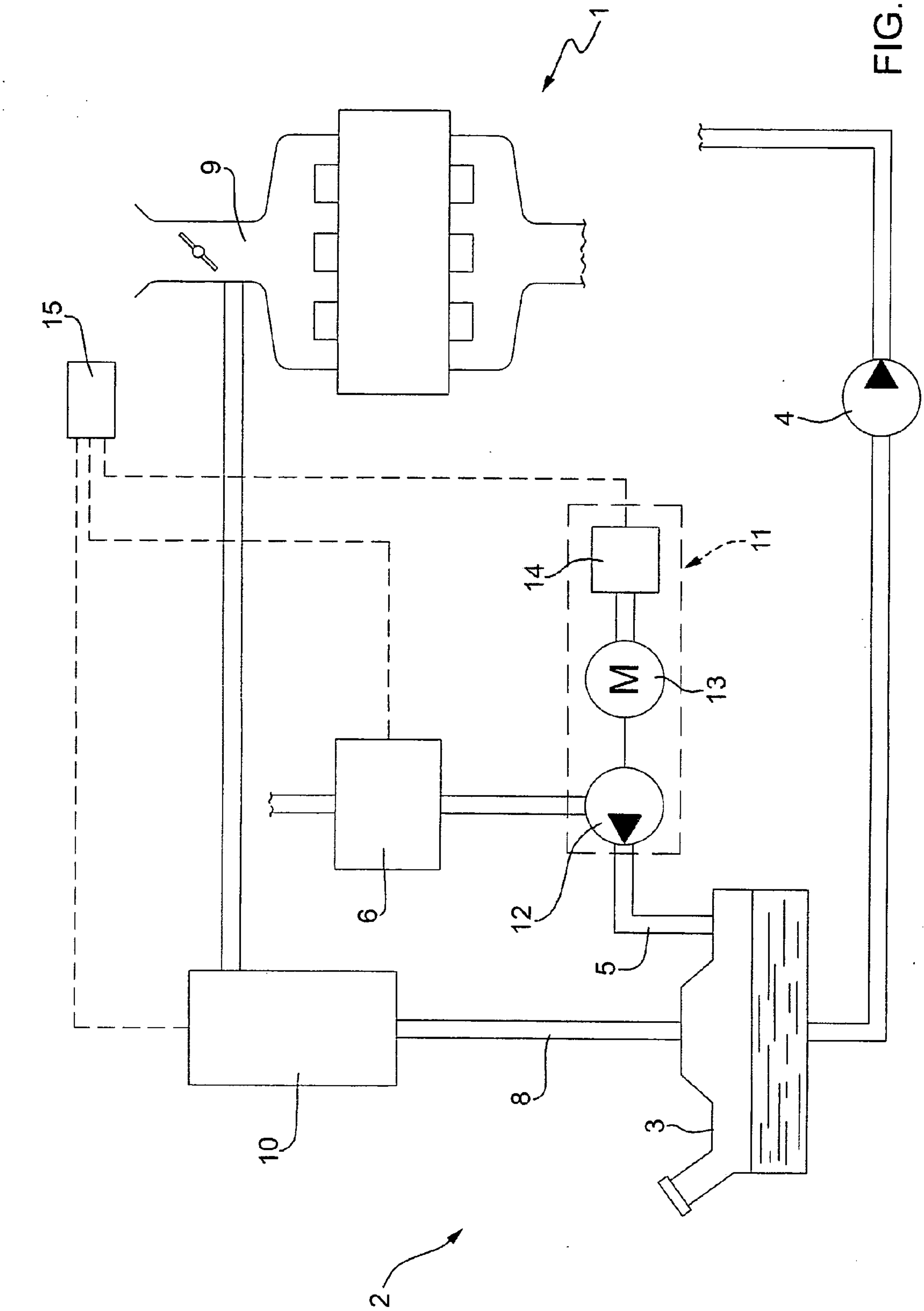


FIG.5

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PARTIAL EUROPEAN SEARCH REPORT

which under Rule 63 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 08 42 5230

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 Y	DE 196 20 231 C1 (AUDI NSU AUTO UNION AG [DE]) 16 October 1997 (1997-10-16) * column 2, line 54 - column 3, line 20; figures 1,3 *	1 2-23	INV. F02M25/08
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INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

2

Place of search	Date of completion of the search	Examiner
Munich	26 March 2009	Marsano, Flavio

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

EPO FORM 1503 03.82 (P04E07)

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PARTIAL EUROPEAN SEARCH REPORT

Application Number
EP 08 42 5230

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 Y	GB 2 335 047 A (BOSCH GMBH ROBERT [DE]) 8 September 1999 (1999-09-08) * page 9, line 8 - page 10, line 15; figures 1-3 *	24,27,28 26,29-33	
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2

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INCOMPLETE SEARCH SHEET C

Application Number
EP 08 42 5230

Claim(s) searched completely:
24,26-33

Claim(s) not searched:
25

Reason for the limitation of the search:

Claim 25 is not clear. Art.84 EPC. From the wording of claim 25 it is not possible to understand the actual meaning of it. In the description nothing is found to clarify what the wording "current functional parameters of the vapour tightness testing unit" means.

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Application Number
EP 08 42 5230

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 08 42 5230

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-23,34-36

   Method for diagnosing evaporative losses from a fuel tank (3) of an internal combustion engine (1); the method of diagnosis comprising the following steps:
   isolating the tank (3);
   pressurizing/depressurizing the tank (3) using a pneumatic machine (12) driven by an electric motor (13);
   measuring the time profile of at least one characteristic value of the electric motor (13); and
   diagnosing the rate of evaporative loss from the tank (3) as a function of the time profile of the characteristic value of the electric motor (13).
   the method of diagnosis being characterized in that it comprises the following additional steps of:
   calculating the frequency range of the characteristic value of the electric motor (13); and
   diagnosing the rate of evaporative loss from the tank (3) as a function of the frequency range of the characteristic value of the electric motor (13).

   ---

2. claims: 24-33

LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 08 42 5230

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

Method for diagnosing evaporative losses from a fuel tank (3) of an internal combustion engine (1); the method of diagnosis comprising the following steps of:
isolating the tank (3);
pressurizing/depressurizing the tank (3) using a pneumatic machine (12) driven by an electric motor (13);
measuring the time profile of at least one characteristic value of the electric motor (13);
diagnosing the rate of evaporative loss from the tank (3) as a function of the time profile of at least one characteristic value of the electric motor (13); and
occasional self-learning of the functional parameters of a vapour tightness testing unit (11) comprising the pneumatic machine (12) and the electric motor (13) to compensate for construction tolerance and changes over time;
the method of diagnosis being characterized in that the process of self-learning of the characteristics of the vapour tightness testing unit (11) comprises the following additional steps of:
setting a known pressure value in the tank (3);
activating the pneumatic machine (12) by operating the electric motor (13) with a test supply voltage having a set time profile;
measuring an actual value of at least one characteristic value of the electric motor (13);
determining an expected value of the characteristic of the electric motor (13) as a function of current functional parameters of the vapour tightness testing unit (11);
comparing the actual value with the expected value; and
diagnosing an inconsistency in the vapour tightness testing unit (11) if the actual value differs significantly from the expected value.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 42 5230

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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26-03-2009

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82