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(71) Applicant: SIEMENS ELECTRIC LIMITED [CA/CA]; 700 Park Avenue East, Chatham, Ontario N7M 5M7 (CA).

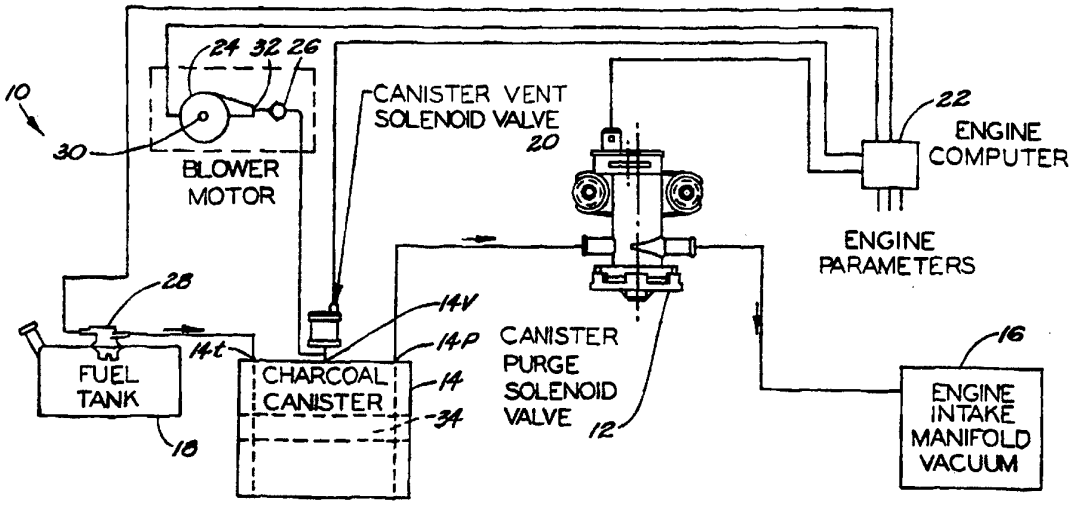
(72) Inventors: COOK, John, E.; 17 Kingway Drive, Chatham, Ontario N7L 2S8 (CA). BUSATO, Murray, F.; 304-97 Bedford Street, Chatham, Ontario N7L 2V4 (CA).

(74) Agent: MACRAE & CO.; P.O. Box 806, Station B, Ottawa, Ontario K1P 5T4 (CA).

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(54) Title: POSITIVE PRESSURE CANISTER PURGE SYSTEM INTEGRITY CONFIRMATION



(57) Abstract

The tank/canister volume's integrity against unacceptable leakage is either confirmed or denied by a diagnostic test performed by an on-board diagnostic system which includes an electrically operated air pump (24) and tank-mounted analog pressure transducer (28). At the beginning of a test, the engine management computer (22) closes the canister purge solenoid valve (12) and operates the pump to begin pressurization of the tank/canister volume. The pumped air is introduced via the canister's atmospheric vent port (14V) so that the pressurizing air is entrained with fuel vapors previously collected in, but not yet purged from, the canister. Failure to build to a predetermined pressure within a predeterminedtime indicates a gross leak. Upon attainment of the predetermined pressure, the pump is shut off. If the pressure drops by more than a certain amount during the test, integrity is denied. If not, integrity is confirmed.

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POSITIVE PRESSURE CANISTER PURGE SYSTEM INTEGRITY CONFIRMATION

Field of the Invention

This invention relates generally to evaporative emission control systems that are used in automotive vehicles to control the emission of volatile fuel vapors. Specifically the invention relates to an on-board diagnostic system for determining if a leak is present in a portion of the system which includes the fuel tank and the canister that collects volatile fuel vapors from the tank's headspace.

Reference to A Related Patent

In certain respects this invention is an improvement on the invention of Applicants' commonly assigned U.S. Patent No. 5,146,902.

Background and Summary of the Invention

A typical evaporative emission control system in a modern automotive vehicle comprises a vapor collection canister that collects volatile fuel vapors generated in the fuel tank. During conditions conducive to purging, the canister is purged to the engine intake manifold by means of a canister purge system that comprises a canister purge solenoid valve that is operated by an engine management computer. The canister purge valve is opened in an amount determined by the computer to allow the intake manifold vacuum to draw vapors from the canister through the valve into the engine.

U.S. governmental regulations require that certain future automobiles that are powered by volatile fuel such as gasoline have their evaporative emission control systems equipped with on-board diagnostic capability for determining if a leak is present in a portion of the system which includes the fuel tank and the canister. One proposed response to that requirement is to connect a normally open solenoid valve in the canister vent, and to energize the solenoid when a diagnostic test is to be conducted. A certain vacuum is drawn in a portion of the system which includes the tank headspace and the canister, and with the canister and

the tank headspace not being vented due to the closing of the canister vent, a certain loss of vacuum over a certain time will be deemed due to a leak. Loss of vacuum is detected by a transducer mounted on the fuel tank. Because of the nature of the construction of typical fuel tanks, a limit is imposed on the magnitude of vacuum that can be drawn. Too large a vacuum will result in deformation and render the measurement meaningless. In order to avoid this problem, a relatively costly vacuum transducer is required. Since typical automotive vehicles are powered by internal combustion engines which draw intake manifold vacuum, such vacuum may be used for performance of the diagnostic test, but typically this requires that the engine be running in order to perform the test.

The invention disclosed in commonly assigned allowed application Serial No.: 07/770,009, filed October 2, 1991, provides a solution to the leak detection problem which is significantly less costly. The key to that solution is a new and unique vacuum regulator/sensor which is disposed in the conduit between the canister purge solenoid and the canister. The vacuum regulator/sensor is like a vacuum regulator but with the inclusion of a switch that is used to provide a signal indicating the presence or the absence of a leak. A diagnostic test is performed by closing the tank vent and using the engine manifold vacuum to draw, via the canister purge solenoid valve and the vacuum regulator/sensor, a specified vacuum in the tank headspace and canister. Upon the requisite vacuum having been drawn, the vacuum regulator/sensor closes to trap the drawn vacuum. If unacceptable leakage is present, a certain amount of vacuum will be lost within a certain amount of time, and that occurrence causes the switch of the vacuum regulator/sensor to give a signal indicating that condition.

U.S. Patent No. 5,146,902 discloses a diagnostic system and method for evaluating the integrity of a portion of the canister purge system that includes the tank and canister by means of positive pressurization rather than negative pressurization (i.e., rather than by drawing vacuum). In certain canister purge systems, such a diagnostic system and method may afford certain advantages over the system and method described in the aforementioned commonly assigned allowed patent application.

For example, certain types of leaks, for example cracked hoses and faulty gas caps, may be more susceptible to successful detection. Moreover, the evaporative emission control system may be diagnosed either with or without the automobile's engine running. One means to perform positive pressurization of the fuel tank's headspace and the canister is a devoted electric-operated air pump, which can be of quite simple construction, and therefore relatively inexpensive. If the vehicle already contains a source of suitably pressurized air, that could constitute another means, thereby eliminating the need for a separate devoted pump. Another means for performing positive pressurization of the tank's headspace is a vacuum-actuated, electrically controlled pump. If such a pump is actuated by engine intake manifold vacuum, then the engine must be run to perform the test.

A further benefit of positive pressurization over negative pressurization is that the increased pressure suppresses the rate of fuel vapor generation in the tank, and such attenuation of fuel vapor generation during a diagnostic test reduces the likelihood that the test will give, under hot weather conditions which promote fuel vapor generation, a false signal that would erroneously confirm the integrity of the canister and tank whereas the same test during cold weather would indicate a leak.

According to the disclosure of U.S. Patent No. 5,146,902, atmospheric air is pumped directly into the fuel tank's headspace where it is entrained with fuel vapor that is already present. Concern has been expressed about pumping air directly into the fuel tank particularly if for some reason the pump continued to pump beyond the time when it should have shut off. Overpressurization of the tank headspace and vapor collection canister may create atypical pressures and/or air-fuel ratios in the canister/tank headspace. One possible consequence of overpressurization is that some fuel vapor may be forced out the atmospheric vent of the canister.

The present invention relates to a means for introducing the pumped air into the evaporative emission system that can alleviate the tendency toward such consequences; specifically it relates to introducing the pumped air into the evaporative emission system through an atmospheric vent port of the canister after that port has been closed to

atmosphere by the closing of a canister vent solenoid (CVS) valve through which the canister is otherwise vented to atmosphere during non-test times.

Should the air pump continue to run for any reason after a diagnostic test has concluded, the pumped air will not be forced into the tank headspace. The pumped air will not even enter the canister, but rather will be returned to atmosphere through the CVS valve which re-opens at test conclusion to relieve the tank test pressure.

The canister contains an internal medium that collects fuel vapors so that the vapors do not pass to the atmospheric vent port. During a diagnostic test, air pumped into the canister vent port must pass through that medium before it can enter the tank headspace, and consequently it is fuel vapor laden air, rather than merely air alone, that pressurizes the tank headspace.

Further specific details of the construction and arrangement of the inventive system, and of the method of operation thereof, along with additional features and benefits, will be presented in the ensuing description.

Drawings accompany this disclosure and portray a presently preferred embodiment of the invention according to the best mode presently contemplated for carrying out the invention.

Brief Description of the Drawing

Fig. 1 is a schematic diagram of a representative canister purge system, including a diagnostic system embodying principles of the present invention.

Figs. 2-4 are respective graphs useful in appreciating certain aspects of the invention.

Description of the Preferred Embodiment

Fig. 1 shows a representative canister purge system 10 embodying principles of the invention. System 10 comprises a canister purge solenoid (CPS) valve 12 and a charcoal canister 14 associated with the intake manifold 16 of an automotive vehicle internal combustion engine and with a fuel tank 18 of the automotive vehicle which holds a

supply of volatile liquid fuel for powering the engine. Canister 14 comprises a tank port 14t, an atmospheric vent port 14v, and a purge port 14p. A normally closed canister vent solenoid (CVS) valve 20 is disposed between atmosphere and atmospheric vent port 14v of canister 14 to control the opening and closing of the canister atmospheric vent port 14v to atmosphere. Both CPS valve 12 and CVS valve 20 are under the control of an engine management computer 22 for the engine.

For use in conducting the on-board diagnostic testing that confirms integrity of the canister purge system against leakage, an electric operated pump (blower motor) 24, a check valve 26, and an analog pressure transducer 28 are provided. Pump 24 has an air inlet 30 that is communicated to ambient atmospheric air and an air outlet 32 that is communicated through check valve 26 to canister vent port 14v, there being a tee via which the conduit from the check valve connects into the conduit between port 14v and CVS valve 20. There is a circuit connection whereby operation of pump 24 is controlled by computer 22.

Analog pressure transducer 28 is part of a combination transducer/roll-over valve like that described in commonly assigned pending application Ser. No. 07/876,254. The transducer senses pressure in the tank headspace and provides a corresponding signal to computer 22.

The canister purge system operates in conventional manner, and may be briefly described as follows. Under conditions conducive to purging, computer 22 causes the normally closed CPS valve 12 to open in a controlled manner. CVS valve 20 is open at this time since it is normally open at all times other than a diagnostic test. The result of opening CPS valve 12 is that a certain amount of the engine manifold vacuum is delivered to canister 14 via purge port 14p causing collected vapors to flow from the canister through CPS valve 12 to the engine manifold where they entrain with the induction flow entering the engine's combustion chamber space to be ultimately combusted.

The system functions in the following manner to perform a diagnostic test of the integrity against unacceptable leakage of that portion of the CPS system upstream of, and including, CPS valve 12. First, it may be deemed desirable to measure the pre-existing pressure in the

tank/canister to assure that excessively high pressures that might adversely affect the validity of a test are not present. In such a case, after computer 22 has commanded CPS valve 12 and CVS valve 20 to close, it reads the pressure from transducer 28. If too high a pre-existing positive pressure condition exists in the tank/canister, the test is deferred to a later time, and in this regard it should be mentioned that the timing at which tests are attempted is determined by various other inputs to or programs of computer 22 that need not be mentioned here. It is believed that the most favorable test condition occurs when the engine is cold and ambient temperature low, and hence a typical schedule may comprise conducting a test each time the engine is started. If a start is a hot start and/or if the ambient temperature is high, it is possible that an accurate test cannot be conducted, and in such case the measurement of tank pressure at the beginning of a test may be used to determine whether a valid test can be conducted at the time, even though certain aspects of the invention that will be explained in more detail hereinafter comprise compensation for variation in certain ambient conditions that may allow a test to proceed even if the engine or the ambient temperature are other than cold. Assuming that a suitable tank pressure for conducting the test is detected by computer 22 reading transducer 28 at the beginning of a test, then the pre-existing pressure in the tank/canister is deemed suitable for the test to proceed.

The test proceeds by computer 22 commanding pump 24 to operate and thus increasingly positively pressurize the tank/canister. In accordance with principles of the present invention, air is pumped into the tank/canister via canister 14. Canister 14 contains an internal medium 34, charcoal for example, that collects fuel vapors emitted from volatile fuel in the tank. The air pumped into vent port 14c must pass through this medium, and therefore some of the collected fuel vapor will entrain with the pumped air as it passes through the canister to the tank headspace. Consequently, an air/fuel mixture, rather than merely air alone, pressurizes the tank headspace. This will avoid creating atypical air-fuel mixtures in the tank headspace. As the pump operates, the tank/canister positive pressure should build. However, the presence of a grossly unacceptable leak in the tank/canister could prevent the pressure from

building to a predetermined positive pressure within a predetermined time. Thus, if transducer 28 fails to detect the attainment of a predetermined tank pressure within a predetermined amount of time, a fault is indicated. Such fault may be attributed to any one or more of: a gross leak in the tank/canister, faulty circuit connections, a faulty pump 24, a faulty check valve 26, or a faulty transducer 28. In such an event the test is terminated and a fault indication given.

However, if the pressure in the tank/canister builds within a predetermined time to a predetermined level, then the test proceeds. Once that predetermined pressure is achieved, the computer immediately shuts off pump 24. Check valve 26 functions to prevent loss of pressure back through the pump. This traps the pressure in the tank/canister. If a leak is present in the tank/canister, positive pressure will begin to decrease. The rate at which the positive pressure decreases is a function of the severity of the leak. An unacceptable leak will cause the positive pressure to drop to at least a certain preselected level within a given time; the absence of a leak or the presence of a leak that is so small as to not be deemed unacceptable will not cause the pressure to drop below that preselected level within that given time.

Associated with computer 22 is a timer which begins counting time once the predetermined test pressure has been reached and the pump shut-off. If, after a certain preselected amount of time has been counted by the timer, the pressure remains above the minimum level of acceptability, the integrity of the test-ensealed tank/canister volume is deemed to have been confirmed, and computer 22 may so indicate in any appropriate manner such by an internal flag or an external signal.

On the other hand, if the pressure falls below the minimum level of acceptability during the preselected amount of time, an unacceptable leak is indicated, and such occurrence will be flagged by the computer as a fault signal or called to the attention of the vehicle operator by any suitable means such as a warning lamp on the instrument panel.

If the pump had continued to operate after it should have shut off, the creation of excessively high pressure in the tank/canister due to such continued pumping will not result in accidental discharge of fuel vapors to atmosphere because it will be the excess pumped air that will be

discharged through the CVS valve which re-opens at the conclusion of a test.

It may be mentioned at this point that the invention can enable a test to be performed at relatively small positive pressure levels in the canister and fuel tank so that the pressure will not cause deformation of properly designed canisters and tanks. At the completion of a test the CPS valve is once again operated by computer 22 in the usual way for conducting canister purging.

If a diagnostic test is conducted above a certain temperature, it is possible that fuel vapors may be generated in the tank at a rate that is sufficiently fast that the increase in vapor pressure will mask at least to some extent the existence of a leak. This tendency is somewhat better countered by positive pressurization testing because such pressurization tends to attenuate the vapor generation rate.

The disclosed embodiment possesses the capability for measuring, with reasonable accuracy over a range of test conditions, the effective orifice size of a leak. Fig. 2 presents a series of graph plots depicting pressure decay as a function of time for several effective leak diameters. These graph plots were obtained using a sixty liter fuel tank that was one-quarter full of 12 RVP fuel at 20 degrees Centigrade. They demonstrate ample discrimination between different, relatively small leaks, so that reasonably accurate measurements can be obtained.

When testing is conducted over a range of various conditions, correction factors may be used, such as by programming them into computer 22. Fig. 3 present series of graph plots depicting the influence of the rate of vapor generation on testing. Each of the graph plots of Fig. 3 was obtained by filing a tank to one-quarter full with a particular fuel, heating the tank and fuel at atmospheric pressure to a certain temperature, sealing the tank, and then measuring the rise in pressure as a function of time. Fig. 4 is a series of graph plots presenting the effect of tank fuel fill level on pressure decay. The fuller the tank, the smaller the tank headspace volume; and since decay time is a function of tank headspace volume, the fuel fill level in the tank will be a factor that needs to be taken into account for best test measurement accuracy. The graph plots of Fig. 4 were obtained for a known one millimeter diameter leak

using 12 RVP fuel at 20 degrees Centigrade. Correction factors may be derived from graph plots, like those shown, and programmed into data storage media of computer 22. Additional sensor inputs, such as fuel temperature and tank fuel level, are used by the computer to select appropriate correction factors based on actual fuel temperature and tank fuel level and apply the appropriate correction factors to the pressure measurements. Correction for the rate of vapor generation may be made by measuring the rate of vapor generation at the beginning of a test and then utilizing the measurement to correct the test results. The rate is determined by closing the evaporative emission space, and measuring the pressure rise over a given period of time. This measurement is stored in memory, and used later to correct the result of a subsequently performed diagnostic test, as described above. Assuming that the effective size of any leakage remains constant, the presence or absence of any such leakage has no net effect on the corrected result because the correction measurement is made on the system as it actually exists, leakage or not, and the effect of leakage will cancel out when the correction measurement is applied.

Having disclosed generic principles of the invention, this application is intended to provide legal protection for all embodiments falling within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A canister purge system comprising a collection canister for collecting volatile fuel vapors from a fuel tank, and means for selectively purging collected fuel vapors from said canister to an internal combustion engine's intake manifold for entrainment with a combustible mixture that passes from the intake manifold into combustion chamber space of the engine for combustion therein, said means including a purge flow path between said canister and intake manifold, said canister having tank port means for communicating said canister with said fuel tank and other port means for communicating said canister with other than said fuel tank, characterized by an associated diagnostic system for detecting leakage from a portion of the canister purge system, which portion includes said canister and tank, said diagnostic system comprising means for positively pressurizing said portion to a predetermined positive pressure, detecting means for detecting loss of said predetermined positive pressure indicative of leakage from said portion, and signaling means for giving a signal indicative of such loss, and further characterized in that said means for positively pressurizing said portion of said canister purge system comprises means for positively pressurizing said portion through said other port means by pumping atmospheric air into said portion through a vapor collection medium within said canister so that pressurizing air entering said portion is entrained with some of the fuel vapors previously collected in said canister.

2. A canister purge system as set forth in claim 1 characterized further in that said means for positively pressurizing said portion to a predetermined positive pressure comprises an electrically operated pump.

3. A canister purge system as set forth in claim 1 characterized further in that said detecting means comprises an analog pressure transducer.

4. In an automotive vehicle comprising an internal combustion engine for powering the vehicle, an engine management computer for

controlling certain functions associated with the operation of said engine, said engine comprising an intake manifold within which vacuum is created during operation of the engine, said vehicle comprising a fuel tank for containing a supply of a volatile liquid fuel for the engine, and an evaporative emission control system comprising a collection canister for collecting volatile fuel vapors from the fuel tank, a vent valve that is between atmosphere and an atmospheric vent port of said canister, and means for selectively purging collected fuel vapors from said canister to an intake manifold of said engine for entrainment with a combustible mixture that passes from the intake manifold into combustion chamber space of the engine for combustion therein, said means including a purge flow path comprising a canister purge solenoid valve that is between a purge port of said canister and said intake manifold and is under the control of said engine management computer, the improvement characterized in that said vent valve is solenoid-operated and under the control of said engine management computer, and further characterized by an associated diagnostic system for detecting unacceptable leakage from a portion of the evaporative emission control system, which portion includes said canister and tank, said diagnostic system comprising an electrically operated pump for positively pressurizing said portion to a predetermined positive pressure by pressurizing said portion via said atmospheric vent port of said canister, a check valve for preventing loss of positive pressure from said portion of said canister purge system back through said pump, detecting means for detecting pressure in said portion, and means operatively relating said canister purge solenoid valve, said detecting means, said pump, said vent valve, and said computer in performing a diagnostic test for confirming the integrity of said portion against unacceptable leakage wherein both said vent valve and said canister purge solenoid valve are operated closed and said pump is operated to build positive pressure in said portion until pressure in said portion has been built to a predetermined positive pressure whereupon said pump ceases building positive pressure in said portion so that the positive pressure in said portion as trapped therein by said check valve upon said pump ceasing to build positive pressure in said portion is essentially equal to said predetermined positive pressure, and

unacceptable leakage from said portion is indicated by pressure in said portion decreasing from said predetermined positive pressure by a predetermined amount within a predetermined time.

5. The improvement set forth in claim 4 further including correction factor means comprising means for storing correction factors based on at least one of fuel temperature, rate of fuel vapor generation in the tank, and tank fill level, and means for applying said correction factors to the measured decrease in pressure in said portion to correct for at least one of actual fuel temperature, actual rate of fuel vapor generation in the tank, and actual tank fill level.

6. In an automotive vehicle comprising an internal combustion engine for powering the vehicle, an engine management computer for controlling certain functions associated with the operation of said engine, said engine comprising an intake manifold within which vacuum is created during operation of the engine, said vehicle comprising a fuel tank for containing a supply of a volatile liquid fuel for the engine, and an evaporative emission control system comprising a collection canister for collecting volatile fuel vapors from the fuel tank, a vent valve that is between atmosphere and an atmospheric vent port of said canister, and means for selectively purging collected fuel vapors from said canister to an internal combustion engine's intake manifold for entrainment with a combustible mixture that passes from the intake manifold into combustion chamber space of the engine for combustion therein, said means including a purge flow path comprising a canister purge solenoid valve that is between said canister and said intake manifold and that is under the control of said engine management computer, the improvement characterized in that said vent valve is solenoid-operated and under the control of said engine management computer, and further characterized by an associated diagnostic system for detecting unacceptable leakage from a portion of the evaporative emission control system, which portion includes said canister and tank, said diagnostic system comprising an electrically operated pump for positively pressurizing said portion to a predetermined positive pressure by pressurizing said portion via said

atmospheric vent port of said canister, a check valve for preventing loss of positive pressure from said portion back through said pump, detecting means for detecting pressure in said portion, and means operatively relating said canister purge solenoid valve, said detection means, said pump, said vent valve, and said computer in performing a diagnostic test for confirming the integrity of said portion against unacceptable leakage wherein both said vent valve and said canister purge solenoid valve are operated closed and said pump is operated to build positive pressure in said portion, and unacceptable leakage in said portion is indicated if pressure in said portion is not built to a predetermined positive pressure within a predetermined amount of time.

7. A canister purge system comprising a collection canister for collecting volatile fuel vapors from a fuel tank, and means for selectively purging collected fuel vapors from said canister to an internal combustion engine's intake manifold for entrainment with a combustible mixture that passes from the intake manifold into combustion chamber space of the engine for combustion therein, said means including a purge flow path from said canister to said intake manifold, characterized by an associated diagnostic system for confirming the absence of unacceptable leakage from a portion of the canister purge system, which portion includes said canister and tank, said diagnostic system comprising means for positively pressurizing said portion to a predetermined positive pressure by means of air drawn from atmosphere and passed through a vapor collection medium within said canister so that pressurizing air entering said portion is entrained with some of the fuel vapors previously collected by said canister, detecting means for detecting the absence of a predetermined amount of decrease in the positive pressure in said portion from said predetermined positive pressure within a predetermined amount of time, which predetermined amount of decrease with said predetermined amount of time is indicative of unacceptable leakage from said portion, and signaling means for giving a signal indicative of such absence.

8. A canister purge system as set forth in claim 7 characterized further in that said means for positively pressurizing said portion to a predetermined positive pressure comprises an electrically operated pump.

9. A canister purge system as set forth in claim 7 characterized further in that said detecting means comprises an analog pressure transducer.

10. A canister purge system as set forth in claim 7 further including correction factor means comprising means for storing correction factors based on at least one of fuel temperature, rate of fuel vapor generation in the tank, and tank fill level, and means for applying said correction factors to the measured decrease in pressure in said portion to correct for at least one of actual fuel temperature, actual rate of fuel vapor generation in the tank, and actual tank fill level.

11. In a canister purge system comprising a collection canister for collecting volatile fuel vapors from a fuel tank, and means for selectively purging collected fuel vapors from said canister to an internal combustion engine's intake manifold for entrainment with a combustible mixture that passes from the intake manifold into combustion chamber space of the engine for combustion therein, said means including a purge flow path between said canister and intake manifold, a method for diagnosing unacceptable leakage from a portion of the canister purge system, which portion includes said canister and tank, said method comprising positively pressurizing said portion to a predetermined positive pressure by pumping atmospheric air into said portion through a vapor collection medium within said canister so that pressurizing air entering said portion is entrained with some of the fuel vapors previously collected by said canister, detecting a predetermined amount of decrease in the positive pressure in said portion from said predetermined positive pressure within a predetermined amount of time, which predetermined amount of decrease within said predetermined amount of time is indicative of unacceptable leakage from said portion, and giving a signal to indicate such unacceptable leakage.

12. A method as set forth in claim 11 further including applying correction factors obtained from stored correction factor data based on at least one of fuel temperature, rate of fuel vapor generation in the tank, and tank fill level to the measured decrease in pressure in said portion to correct for at least one of actual fuel temperature, actual rate of fuel vapor generation in the tank, and actual tank fill level.

13. In a canister purge system comprising a collection canister for collecting volatile fuel vapors from a fuel tank, and means for selectively purging collected fuel vapors from said canister to an internal combustion engine's intake manifold for entrainment with a combustible mixture that passes from the intake manifold into combustion chamber space of the engine for combustion therein, said means including a purge flow path between said canister and intake manifold, characterized by a method for confirming the absence of unacceptable leakage from a portion of the canister purge system, which portion includes said canister and tank, said method comprising positively pressurizing said portion to a predetermined positive pressure by pumping atmospheric air into said portion through a vapor collection medium within said canister so that pressurizing air entering said portion is entrained with some of the fuel vapors previously collected by said canister, detecting the absence of a predetermined amount of decrease in the positive pressure in said portion from said predetermined positive pressure within a predetermined amount of time, which predetermined amount of decrease within said predetermined amount of time is indicative of unacceptable leakage from said portion, and giving a signal indicative of such absence.

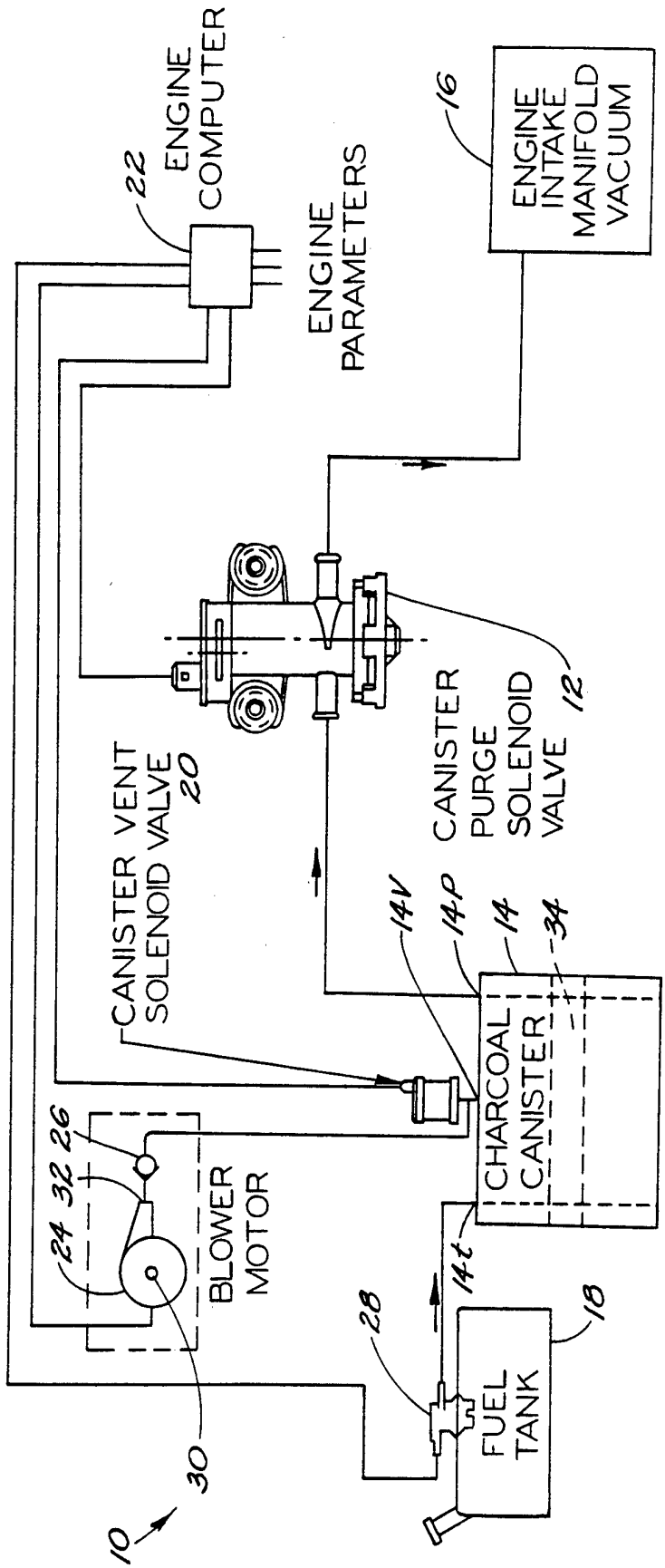

ENGINE COMPUTER
22
ENGINE PARAMETERS
16
ENGINE INTAKE MANIFOLD VACUUM
12
CANISTER PURGE SOLENOID VALVE
CANISTER VENT SOLENOID VALVE
20
14V
14P
14
34
CHARCOAL CANISTER
24
32
26
BLOWER MOTOR
30
28
14T
18
FUEL TANK
10

Fig. 1

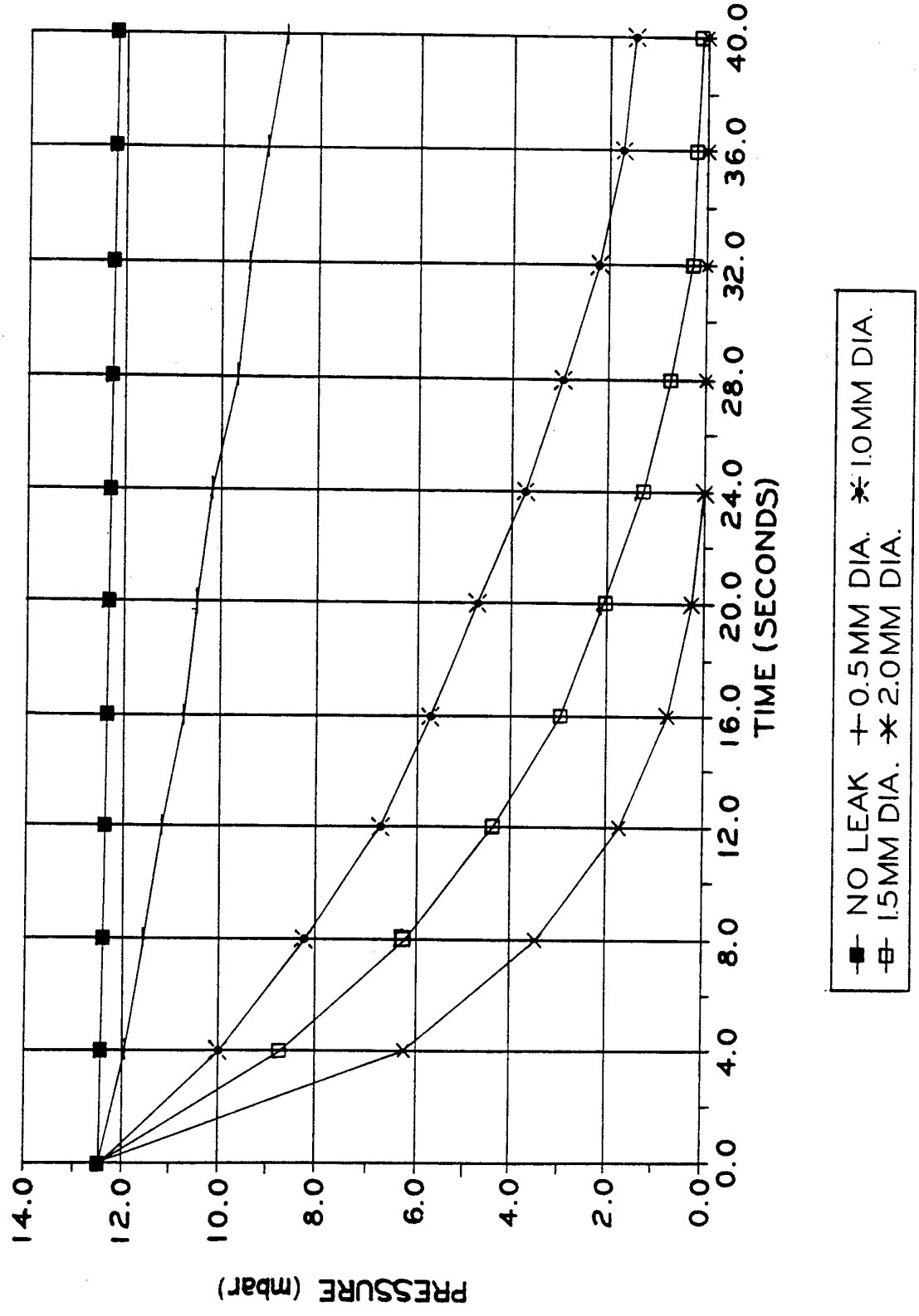

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12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
36.0
40.0
TIME (SECONDS)
NO LEAK
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1.0MM DIA.
1.5MM DIA.
2.0MM DIA.

Fig. 2

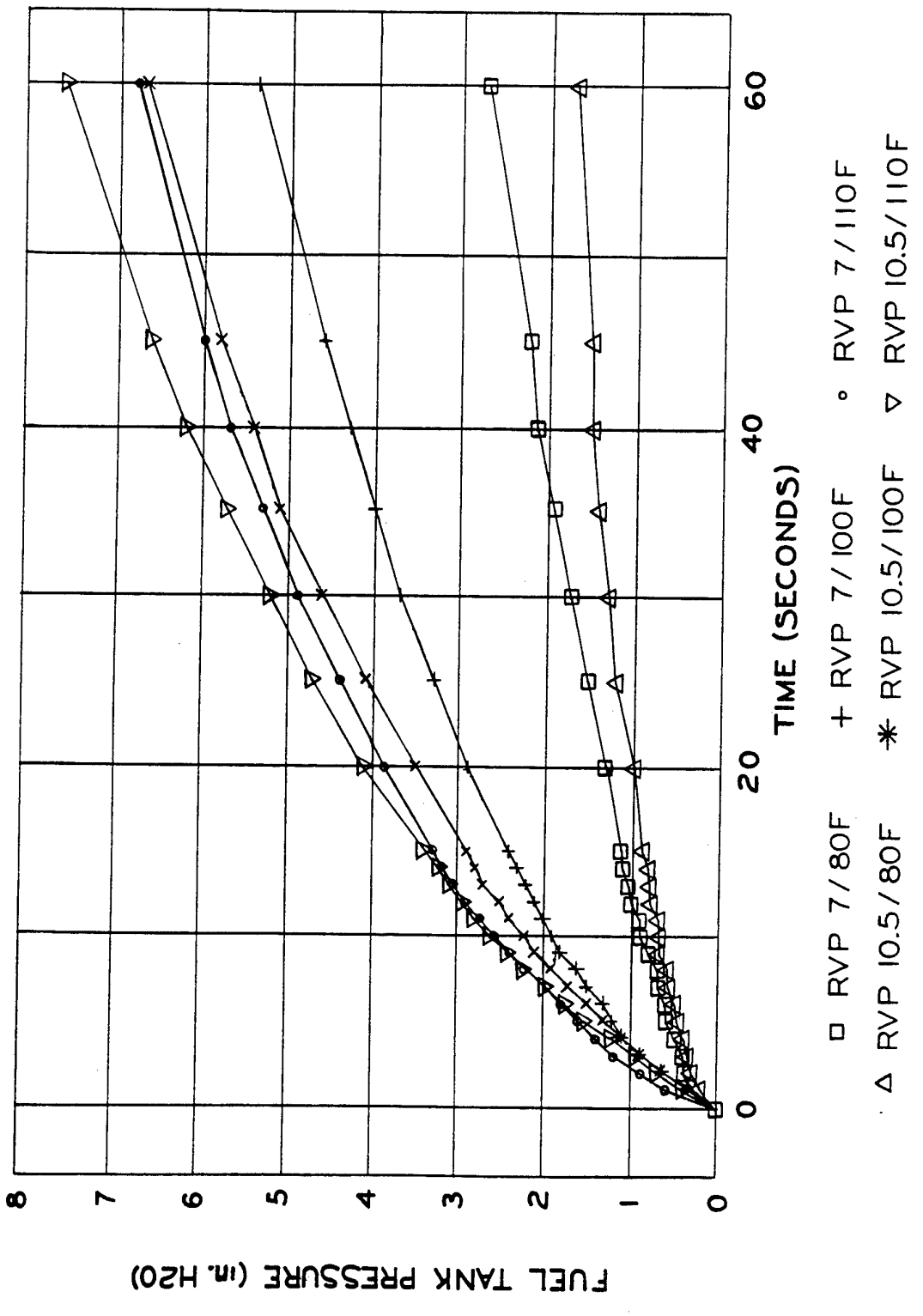

FUEL TANK PRESSURE (in. H2O)
0
1
2
3
4
5
6
7
8
0
20
40
60
TIME (SECONDS)
□ RVP 7/80F
+ RVP 7/100F
○ RVP 7/110F
△ RVP 10.5/80F
✱ RVP 10.5/100F
▽ RVP 10.5/110F

Fig. 3

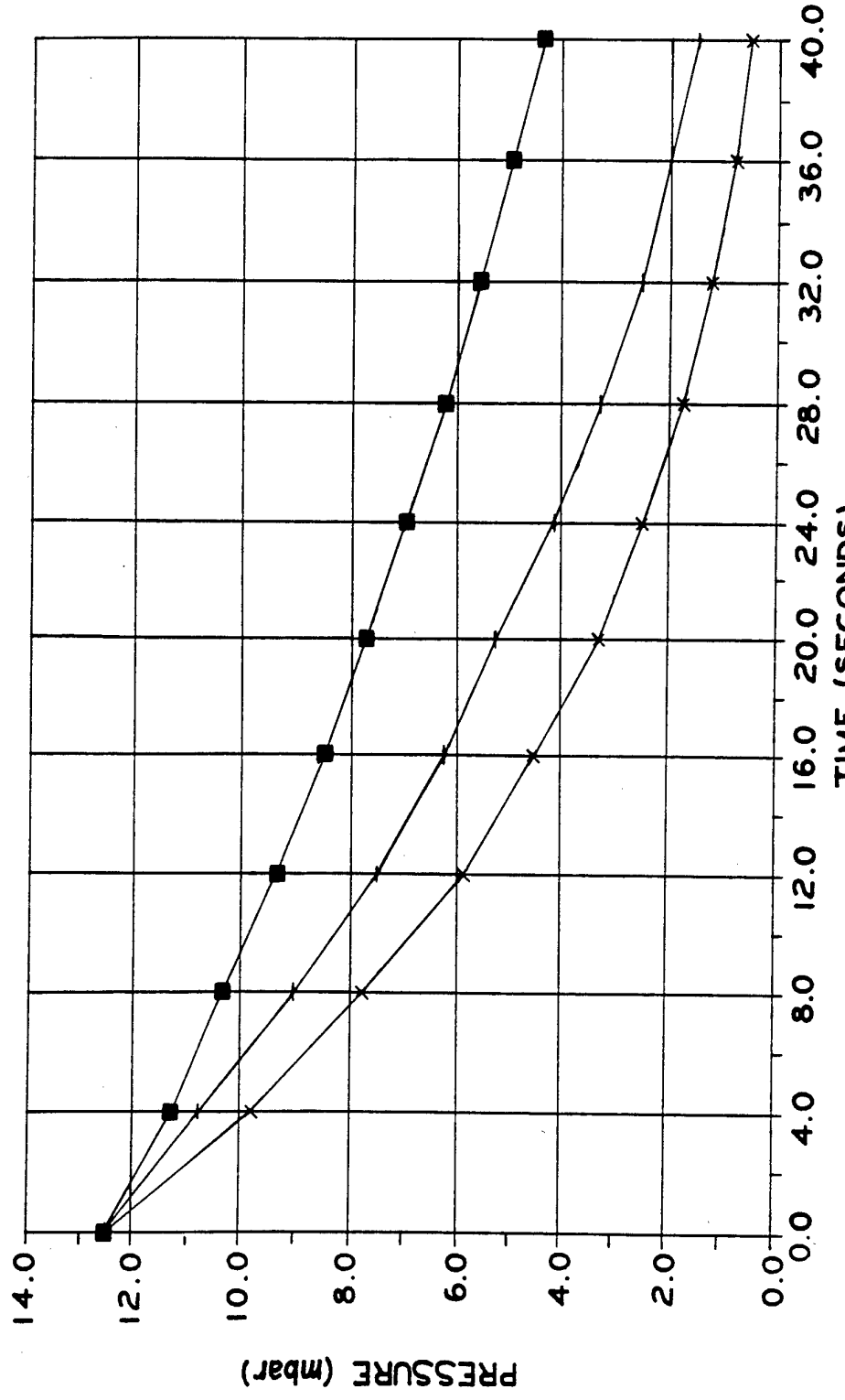

PRESSURE (mbar)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
36.0
40.0
TIME (SECONDS)
EMPTY
1/2 FULL
FULL

Fig. 4

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/CA 94/00038

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 F02M25/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO,A,93 02283 (ROBERT BOSCH GMBH) 4 February 1993 see page 7, paragraph 3 - page 10, last paragraph; figures 1,2 ---	1-13
A	US,A,5 146 902 (COOK ET AL.) 15 September 1992 cited in the application see the whole document ---	1-13
A	WO,A,92 17698 (SIEMENS AG) 15 October 1992 cited in the application see abstract; figures -----	1-13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 April 1994	20. 04. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Alconchel y Ungria,J

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter ›nal Application No
PCT/CA 94/00038

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9302283	04-02-93	DE-A-	4124465	28-01-93
US-A-5146902	15-09-92	CA-A-	2082684	03-06-93
		EP-A-	0545122	09-06-93
WO-A-9217698	15-10-92	US-A-	5191870	09-03-93
		EP-A-	0577625	12-01-94