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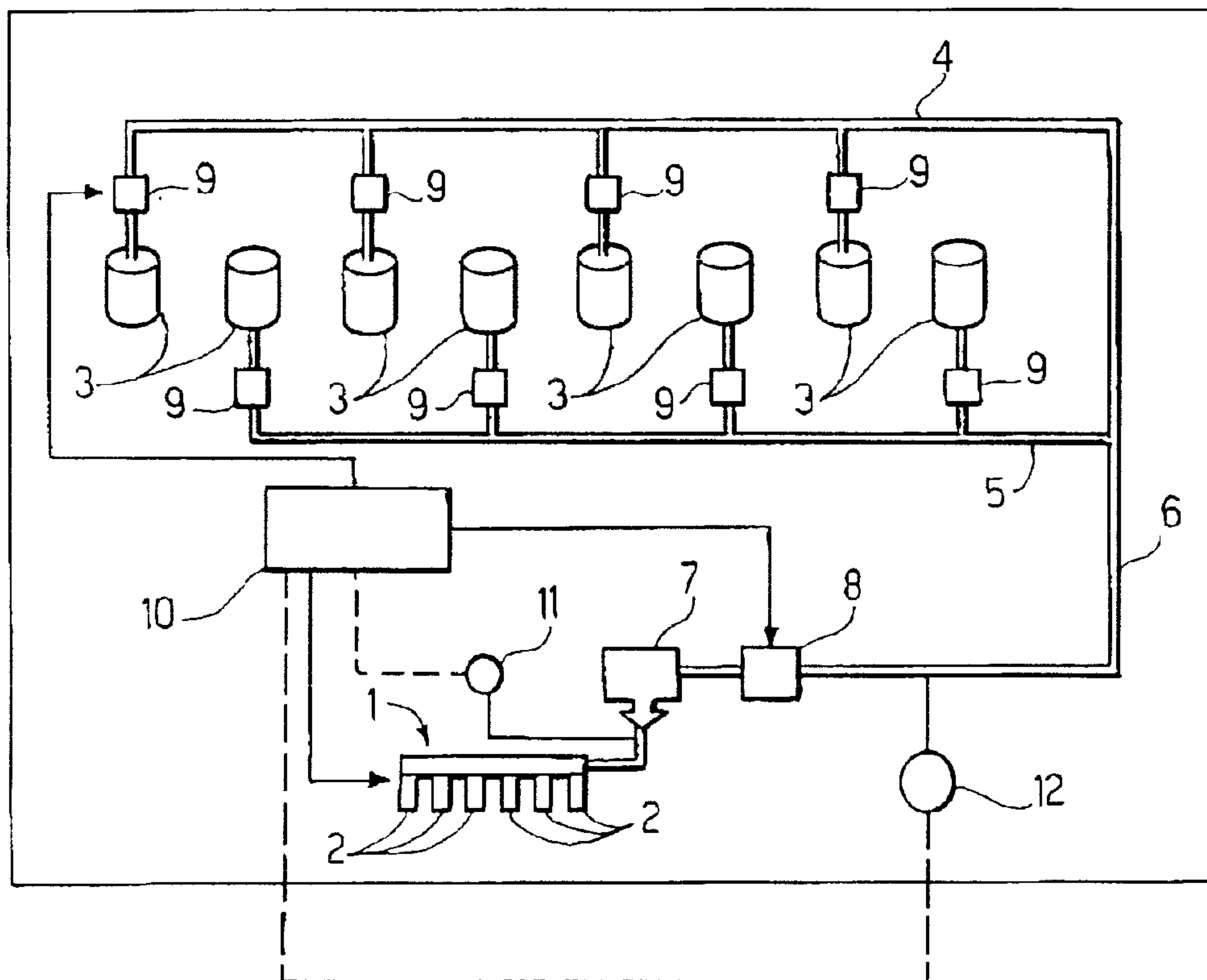
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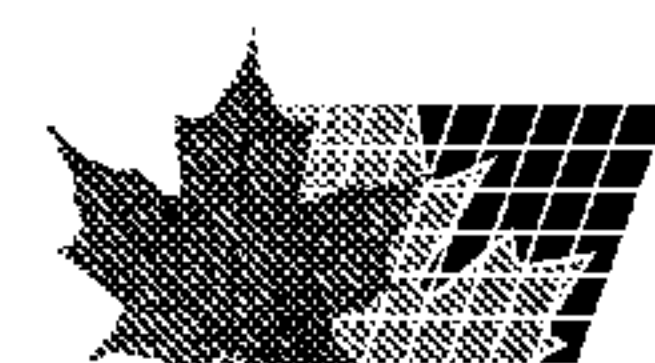
(54) Titre : SYSTÈME DE DIAGNOSTIC PERMETTANT DE DETECTER LES FUITES D'UN SYSTÈME D'ALIMENTATION EN GAZ ET DE VÉRIFIER LE FONCTIONNEMENT DES SOUPAPES FAISANT PARTIE DE CE SYSTÈME PARTICULIER

(54) Title: DIAGNOSTICS SYSTEM FOR TRACING LEAKS FROM A GAS-SUPPLY SYSTEM AND FOR CHECKING OPERATION OF THE VALVES FORMING PART OF SAID SYSTEM



(57) Abrégé/Abstract:

In a gas-supply system for supplying a generic engine of a vehicle type, comprising electronic control means for controlling delivery devices associated to various engines, said electronic control means are programmed for processing the data regarding the low-



(57) Abrégé(suite)/Abstract(continued):

pressure part of the system according to a predetermined algorithm, at predefined instants, in order to enable timely detection of incorrect functioning of a solenoid valve (8) set in a position corresponding to a pressure-reducing device (7) set between the gas tank (3) and a manifold (1) for distribution of the gas to the delivery devices. The system is moreover able to detect possible gas leaks from the low-pressure part of the system. The electronic control means (10) are moreover able to process the data regarding the high-pressure part of the system, according to a predetermined algorithm, during operation of the system in order to enable timely detection of incorrect functioning of the valve (8) set immediately at the outlet of the tank or to detect a possible gas leak from the high-pressure part of the system.

ABSTRACT

In a gas-supply system for supplying a generic engine of a vehicle type, comprising electronic control means for controlling delivery devices associated to various engines, said electronic control means are programmed for processing the data regarding the low-pressure part of the system according to a predetermined algorithm, at predefined instants, in order to enable timely detection of incorrect functioning of a solenoid valve (8) set in a position corresponding to a pressure-reducing device (7) set between the gas tank (3) and a manifold (1) for distribution of the gas to the delivery devices. The system is moreover able to detect possible gas leaks from the low-pressure part of the system. The electronic control means (10) are moreover able to process the data regarding the high-pressure part of the system, according to a predetermined algorithm, during operation of the system in order to enable timely detection of incorrect functioning of the valve (8) set immediately at the outlet of the tank or to detect a possible gas leak from the high-pressure part of the system.

(Single figure)

**DIAGNOSTICS SYSTEM FOR TRACING LEAKS FROM A GAS-SUPPLY SYSTEM
AND FOR CHECKING OPERATION OF THE VALVES FORMING PART OF SAID
SYSTEM**

TEXT OF DESCRIPTION

The present invention relates to fuel systems for supplying gas, for example methane, LPG or hydrogen, to vehicle engines. In particular, the invention relates to fuel systems for supplying gas, of the type comprising:

- at least one tank, in which gas under high pressure is accumulated;

- a manifold for distribution of the gas, which has an inlet connected to the tank and a plurality of outlets connected to respective delivery devices;

- a pressure-reducer device set in the connection between the tank and the manifold;

- one first valve and one second valve set respectively at the outlet of the gas from the tank and in a position corresponding to the pressure-reducer device;

- first and second sensor means for detecting pressure, temperature and mass consumption of the gas, set respectively downstream of the pressure-reducer device, i.e., in the low-pressure part of the system, and upstream of the pressure-reducer device, i.e., in the high-pressure part of the system; and

- electronic control means for controlling the delivery devices according to a plurality of signals sent thereto, which indicate the conditions of operation of the system;

- wherein said electronic control means are set for receiving the signals from said first and second sensor means and are programmed for:

- processing the data regarding the low-pressure part of the system, which come from said first sensor means, according

to a predetermined algorithm, immediately after each command for cessation of gas delivery, in order to enable timely detection of incorrect functioning of said second valve or a possible gas leak from the low-pressure part of the system; and

- processing the data regarding the high-pressure part of the system, which come from said second sensor means, according to a predetermined algorithm, during operation of the system, in order to enable timely detection of incorrect functioning of said first solenoid valve or a possible gas leak from the high-pressure part of the system,

- wherein the aforesaid electronic control means are programmed for carrying out a check on the low-pressure part of the system in a first step immediately after the command for cessation of gas delivery, but prior to the actual cessation thereof, in order to enable detection of any possible malfunctioning of the second valve, and in a second step, following upon said cessation of operation, in order to enable detection of any possible gas leaks.

A system of this type is disclosed in JP-A-2000303909.

The purpose of the present invention is that of providing a diagnostics system for tracing leaks from a fuel system of the type referred to above and for checking proper operation of the valves of the system.

With a view to achieving the above purpose, the subject of the invention is a gas-supply system of the type referred to above, which further characterized in that the aforesaid electronic control means are programmed for executing the following operations:

- a) measuring the values of initial pressure - p_0 , initial temperature - T_0 , and initial mass consumption of gas q_0 signalled by said first sensor means at an initial instant i_0 ;

b) at each subsequent instant i , after a time interval Δt_i measuring pressure p_i and updating mass consumption of gas $q_i = \sum(j = 0, i) (q_0 \Delta t_j)$;

c) when the value of pressure p_i measured becomes equal to or lower than a pre-determined threshold value of pressure p_{thr} , or else after a pre-set time x , measuring a final pressure p_{fin} , and a final temperature T_{fin} , and calculating the following quantities:

$$m_0 = p_0 V_{LP} / (R T_0)$$

$$q_{fin} = \sum(j = 0, fin) (q_0 \Delta t_{fin})$$

$$m_{fin} = m_0 - q_{fin}$$

$$p_{fin} = m_{fin} V_{LP} / (R T_{fin})$$

$$\Delta p_{fin} = p_0 - p_{fin}$$

$$\Delta p_{fin} = p_0 - p_{fin}$$

$$S = \Delta p_{fin} / \Delta p_{fin};$$

wherein:

- R is the constant of the gas contained in the system,
- V_{LP} is the volume of the low-pressure part of the system,
- m_0 is the initial number of moles of gas,
- q_{fin} is the final mass consumption of gas,
- m_{fin} is the final number of moles of gas,
- Δp_{fin} is the measured final pressure difference,
- Δp_{fin} is the calculated final pressure difference, and
- S is the pressure ratio parameter;

d) comparing the value of the parameter S thus calculated with a coefficient $c > 1$ defined in the calibration of the system, the condition being an index of proper operation of the second valve; and

e) generating a warning signal, should the aforesaid condition of proper operation not be met.

Further characteristics and advantages of the present invention will emerge from the ensuing description, with

reference to the attached drawing, which is provided purely by way of non-limiting example and which is a schematic illustration of a gas-supply system for the internal-combustion engine of a bus, equipped with an electronic diagnostics system according to the invention.

With reference to the drawing, number 1 designates, as a whole, a manifold for distributing gas to a plurality of injectors 2, associated to the various cylinders of the internal-combustion engine of a bus. The engine is supplied with gas, for instance methane, which is accumulated at high pressure in a plurality of tanks 3. The gas arrives at the manifold 1 from each tank 3 through respective lines 4, 5 which converge in

a line 6, which terminates in a pressure-regulating device 7 that is designed to reduce the pressure from the value at which the gas is accumulated in the tanks 3 to the value at which the gas is to be supplied to the distribution manifold 1. Immediately upstream of the pressure-regulating device 7, and possibly integrated therein, is provided a solenoid valve 8, which is illustrated separately for greater clarity. Immediately adjacent to the outlet of each tank 3 there is provided a solenoid valve 9. The part of the circuit set upstream of the solenoid valve 8 constitutes the high-pressure section of the system, whilst the remaining part, set downstream of the solenoid valve 8, constitutes the low-pressure section of the system. According to a technique in itself known, the system further comprises an electronic control unit 10, which controls the injectors 2 and the solenoid valves 8 and 9 and which receives the signals coming from sensors of pressure, temperature and mass consumption of the gas, the said sensors being indicated as a whole by 11 and 12 and being set, respectively, downstream of the pressure-regulating device 7 and upstream of said device, in the high-pressure part of the system. The electronic control unit 10 moreover receives signals 10a coming from one or more sensors (not illustrated) indicating one or more operating parameters of the engine.

Each of the components described above is of a type in itself known. Consequently, in the present description they are not illustrated in greater detail.

According to the invention, the electronic control unit 10 is programmed for carrying out diagnostics on the system in order to detect any possible leaks therein and to check proper operation of the solenoid valves 8 and 9.

In the ensuing description and in the claims, the following symbols are used:

p	pressure
T	temperature
ρ	density of gas
q	mass consumption of gas
V	volume of system
R	constant of the gas contained in the system
HP	subscript for high pressure
LP	subscript for low pressure
thr	subscript for a limit value defined at calibration
Δt	generic time interval
x	time interval defined at calibration
0	subscript for initial instant
fin	subscript for final instant
Nm3	subscript for quantities measured under normal conditions
theor	subscript for quantities calculated
c, V_x , W_x	coefficients defined at calibration
$n_{injectors}$	number of injectors in system
limit	subscript for limit-of-admissibility condition
rnd()	function of rounding off to the nearest integer
T_x	maximum leakage admissible for gas injector [see page 11]

Diagnostics test carried out on low-pressure (LP) circuit

Described in what follows is the test used for carrying out diagnostics on the low-pressure (LP) circuit.

As already indicated, the diagnostics on the low-pressure circuit involves verification of proper

functioning of the solenoid valve 8, which is usually integrated in the pressure-reducing device 7, as well as tracing of any possible leaks from the pipes of the system. In particular, the diagnostics test involves two steps (Step I and Step II).

The sequence of operations is described in what follows.

Step I - Verification of operation of the solenoid valve 8 integrated in the reducer device 7

The following set of operations is carried out immediately after key-off (instant 0) and envisages that the engine will continue to operate for an interval of time that is variable according to the conditions of operation immediately prior to key-off; however, with a top limit for reasons of safety.

In what follows, the symbols that are underlined refer to quantities measured, whilst the ones that are not underlined refer to quantities calculated.

The operations that are to be carried out are the following:

1. Measure p_0 , T_0 and q_0 (indicated by electronic control unit).

2. At each instant i , after Δt_i , measure p_i and update $q_i = \sum (j = 0, i) (q_0 \Delta t_j)$.

3. When $p_i \leq p_{thr}$, or else if $t_i \geq t_{thr}$ terminate injection/ignition, measure p_{fin} , T_{fin} , and calculate the following quantities:

$$m_0 = p_0 V_{LP} / (R T_0) \quad q_{fin} = \sum (j = 0, fin) (q_0 \Delta t_j)$$

$$m_{fin} = m_0 - q_{fin} \quad p_{fin} = m_{fin} V_{LP} / (R T_{fin})$$

$$\Delta p_{fin} = p_0 - p_{fin} \quad \Delta p_{fin} = p_0 - p_{fin} \quad S = \Delta p_{fin} / \Delta p_{fin}$$

If $S \leq c$, with $c > 1$, it is confirmed that the solenoid valve 8 is operating properly. If $S > c$, the solenoid valve 8 presents malfunctioning.

Step II - Verification of presence of leakages from LP system

The following set of operations is carried out upon completion of each turning-off step, i.e., at the end of step I (instant 0) and in the case where the latter step has not revealed any malfunctioning of the solenoid valve 8 integrated in the pressure reducer 7.

The operations that are to be carried out in step II are as follows:

1. Open the solenoid valve integrated in the pressure reducer in order to restore the nominal pressure in the LP system.

2. Measure p_0 and T_0 .

3. Calculate $\rho_r = \rho_{Nm3} p_r T_{Nm3} / (p_{Nm3} T_r)$.

4. At the end of a time interval equal to Δt_{test} , measure p_{fin} , T_{fin} and calculate the following quantities:

$$m_0 = p_0 V_{LP} / (R T_0) \quad \Delta m_{lim} = n_{injectors} T_r \rho_r \Delta t_{test}$$

$$m_{fin} = m_0 - \Delta m_{lim}$$

$$p_{fin} = m_{fin} V_{LP} / (R T_{fin})$$

$$\Delta p_{fin} = p_0 - p_{fin} \quad \Delta p_{fin} = p_0 - p_{fin} \quad S = \Delta p_{fin} / \Delta p_{fin}$$

5. If $S < 1$, leakages are present in the system.

Diagnostics test on high-pressure (HP) circuit

Described in what follows is the diagnostics test on the high-pressure circuit. The said test involves verification, with the engine started, of any possible leaks from the pipes of the fuel system (Step I) and of any possible malfunctioning of the individual solenoid valves 9 applied on the gas cylinders (Step II).

Step I - Verification of leakages from pipes of HP system

This step is carried out when the minimum engine r.p.m. is reached for the first time immediately after filling of the gas tank (which is identified following an appropriate strategy).

The operations to be carried out are as follows:

1. Engine at minimum r.p.m.

2. Carry out the operations listed below only if $P_{HP} > P_{thr}$.

3. At the initial instant, close all solenoid valves on the gas cylinders (instant 0).

4. Measure pressure p on HP part (p_{HP0}).

5. At each instant X calculate, using an appropriate algorithm, the Δp_{theor} that should be found in the time interval $t_X - t_0$ in the absence of leakages, considering the effective consumption in said interval.

6. Repeat steps 4 and 5 until $\Delta p_{theor} \geq \Delta p_{thr}$.

7. Measure pressure (p_{HP}) again.

8. Calculate pressure difference $\Delta p = p_{HP0} - p_{HP}$.

9. Calculate the ratio S between Δp_{theor} and Δp .

10. If S is lower than a threshold V_X , then signal a leak in the circuit; if S is higher than another threshold value W_X , then signal that one of the solenoid valves integrated in the gas cylinders is not closing properly.

Step II - Verification of state of system solenoid valve

This step of the test is carried out prior to setting the vehicle in motion, with the engine running, immediately after the filling step (identified by means of an appropriate strategy).

In particular, the diagnostics in this step is based upon the calculation of n parameters S_i (n = number of gas cylinders of system), upon analysis of the numerical value assumed by the parameters S_i , and upon the comparison between the two.

The operations to be carried out are as follows:

1. Engine operating in stationary or transient conditions.

2. Carry out test only if $p_{HP} > P_{thr}$.

3. Close all solenoid valves on gas cylinders, except for solenoid valve No. 1 (instant 0).

4. Measure pressure p_1 on HP part ($p_{1\text{ HP } 0}$).
 5. At each instant Y calculate, using an appropriate algorithm, the $\Delta p_{1\text{ theor}}$ that should be found in the time interval $t_Y - t_0$ in the absence of leakages, considering the effective consumption in said interval (q_{Y-0}).
 6. Repeat steps 4 and 5 until $\Delta p_{1\text{ theor}} \geq \Delta p_{1\text{ thr}}$.
 7. Measure pressure ($p_{1\text{ HP}}$) again.
 8. Calculate $\Delta p_{1\text{ eff}} = p_{1\text{ HP } 0} - p_{1\text{ HP}}$.
 9. Calculate the ratio S_1 between $\Delta p_{1\text{ theor}}$ and $\Delta p_{1\text{ eff}}$.
 10. Repeat steps 2 to 9 a further $n - 1$ times, alternately leaving the other $n - 1$ solenoid valves open.
 11. Analyse the S_i values thus obtained and compare them with one another following the criteria specified below:
 - If $1 - \eta < S_i < 1 + \eta$, for $i = 1..n$, then no leakage is present and the solenoid valves are working properly. If the above condition is not verified, proceed as described below:
 - If $S_{i+1} - v < S_i < S_{i+1} + v$, for $i = 1..n-1$, AND $S_i < 1 - \eta$, for $i = 1..n$, then there is a leakage in the circuit.
 - If for some instants i it is found that $S_i < e$ and, at the same time, for all the other instants i it is found that $1 - \eta < S_i < 1 + \eta$, then the solenoid valves for which the first condition applies remain closed.
 - If $S_i < 1 - \eta$ for each instant i , and for some instants i it is found that $(S_i < S_{i-1} - \mu \text{ OR } S_i < S_{i+1} - \mu)$, then there are leakages in the circuit and moreover the solenoid valves for which the second condition applies are not functioning properly.
- η , μ , v are thresholds that can be calibrated.
- If for some instants i it is found that $(\text{rnd}(S_i) = \text{rnd}(S_{i+1}) - 1$, or else $(\text{rnd}(S_i) = \text{rnd}(S_{i-1}) - 1)$, then there

is a malfunctioning in the i -th solenoid valve. Given m solenoid valves that present malfunctioning, the solenoid valves for which it is found that $\text{rnd}(S_i) = m$ leak, whilst the others remain closed.

From the foregoing description it is evident that the system according to the invention is able to carry out, in an altogether automatic way, diagnostics of leakages in the gas system and verification of the operation of the system solenoid valves.

WHAT IS CLAIMED IS:

1. A gas-supply system of the type comprising:
 - at least one tank (3), in which gas under high pressure is accumulated;
 - a manifold (1) for distribution of the gas, which has an inlet connected to the tank (3) and a plurality of outlets connected to respective delivery devices;
 - a pressure-reducer device (7) set in the connection between the tank and the manifold;
 - one first valve (9) and one second valve (8) set respectively at the outlet of the gas from the tank (3) and in a position corresponding to the pressure-reducer device (7);
 - first and second sensor means (11, 12) for detecting pressure, temperature and mass consumption of the gas, set respectively downstream of the pressure-reducer device, i.e., in the low-pressure part of the system, and upstream of the pressure-reducer device, i.e., in the high-pressure part of the system; and
 - electronic control means (10) for controlling the delivery devices according to a plurality of signals sent thereto, which indicate the conditions of operation of the system,
 - wherein said electronic control means (10) are set for receiving the signals from said first and second sensor means (11, 12) and are programmed for:
 - processing the data regarding the low-pressure part of the system, which come from said first sensor means (11), according to a predetermined algorithm, immediately after each command for cessation of gas delivery, in order to enable timely detection of incorrect functioning of said second valve (8) or a possible gas leak from the low-pressure part of the system; and
 - processing the data regarding the high-pressure

part of the system, which come from said second sensor means (12), according to a predetermined algorithm, during operation of the system, in order to enable timely detection of incorrect functioning of said first solenoid valve (9) or a possible gas leak from the high-pressure part of the system,

wherein the aforesaid electronic control means (10) are programmed for carrying out a check on the low-pressure part of the system in a first step immediately after the command for cessation of gas delivery, but prior to the actual cessation thereof, in order to enable detection of any possible malfunctioning of the second valve (8), and in a second step, following upon said cessation of operation, in order to enable detection of any possible gas leaks,

characterized in that, in said first step, the aforesaid electronic control means are programmed for executing the following operations:

a) measuring the values of initial pressure p_0 , initial temperature T_0 , and initial mass consumption of gas q_0 signalled by said first sensor means at an initial instant i_0 ;

b) at each subsequent instant i , after a time interval Δt_i , measuring pressure p_i and updating mass consumption of gas $q_i = \sum(j = 0, i) (q_0 \Delta t_j)$;

c) when the value of pressure p_i measured becomes equal to or lower than a pre-determined threshold value of pressure p_{thr} , or else after a pre-set time x , measuring a final pressure p_{fin} , and a final temperature T_{fin} , and calculating the following quantities:

$$m_0 = p_0 V_{LP} / (R T_0)$$

$$q_{fin} = \sum(j = 0, fin) (q_0 \Delta t_{fin})$$

$$m_{fin} = m_0 - q_{fin}$$

$$p_{fin} = m_{fin} V_{LP} / (R T_{fin})$$

$$\Delta p_{fin} = p_0 - p_{fin}$$

$$\Delta p_{fin} = p_0 - p_{fin}$$

$$S = \Delta p_{fin} / \underline{\Delta p}_{fin};$$

wherein:

- R is the constant of the gas contained in the system,
 - V_{LP} is the volume of the low-pressure part of the system,
 - m_0 is the initial number of moles of gas,
 - q_{fin} is the final mass consumption of gas,
 - m_{fin} is the final number of moles of gas,
 - $\underline{\Delta p}_{fin}$ is the measured final pressure difference,
 - Δp_{fin} is the calculated final pressure difference,
- and

- S is the pressure ratio parameter;

d) comparing the value of the parameter S thus calculated with a coefficient $c > 1$ defined in the calibration of the system, the condition being an index of proper operation of the second valve; and

e) generating a warning signal, should the aforesaid condition of proper operation not be met.

2. The system according to Claim 1, characterized in that, in said second step, the aforesaid electronic control means are programmed for executing the following operations:

a) opening said second solenoid valve to restore the nominal pressure in the low-pressure part of the system;

b) measuring the values initial pressure p_0 , initial temperature T_0 signalled by said second sensor means at an initial instant i_0 ;

c) calculating the value of the density

$$\rho_T = \rho_{Nm3} p_T T_{Nm3} / (p_{Nm3} T_T),$$

where ρ_T and ρ_{Nm3} are the values of the gas density respectively at the temperature T and pressure p_T and in normal conditions, corresponding to the temperature T_{Nm3} and pressure p_{Nm3} in normal conditions;

d) at the end of a time interval equal to Δt_{test} , measure the final pressure p_{fin} , and the final temperature T_{fin} and calculate the following quantities:

$$m_0 = p_0 V_{\text{LP}} / (R T_0)$$

$$\Delta m_{\text{lim}} = n_{\text{injectors}} T_R \rho_T \Delta t_{\text{test}}$$

$$m_{\text{fin}} = m_0 - \Delta m_{\text{lim}}$$

$$p_{\text{fin}} = m_{\text{fin}} V_{\text{LP}} / (R T_{\text{fin}})$$

$$\Delta p_{\text{fin}} = p_0 - p_{\text{fin}}$$

$$\Delta p_{\text{fin}} = p_0 - p_{\text{fin}}$$

$$S = \Delta p_{\text{fin}} / \Delta p_{\text{fin}},$$

wherein

- $n_{\text{injectors}}$ is the number of injectors in the system,
- Δm_{lim} is the variation of number of moles for limit-of-admissibility condition, and
- T_R is the maximum leakage admissible for gas injector;

the condition $S < 1$ being an index of leakages in the system; and

e) generating a warning signal, should the aforesaid condition that is an index of leakages be verified.

3. The system according to Claim 1, characterized in that the aforesaid electronic control means are programmed for carrying out a check on the high-pressure part of the system in a first step, when the condition of minimum delivery is reached for the first time immediately after filling of the gas tank, in order to enable detection of any possible gas leaks, and in a second step, upon the first reactivation of the system after filling of the gas tank, in order to enable detection of any possible malfunctioning of the first solenoid valve, and

in that, in said first step, the aforesaid electronic control means are programmed for executing the following operations:

- a) System delivering a pre-set amount;
- b) Carry out the operations listed below only if the value of pressure p_{HP} of the high pressure part of the system is grater than a pressure threshold P_{thr}
 $p_{HP} > P_{thr}$;
- c) At the initial instant, close all solenoid valves on the gas cylinders (instant 0);
- d) Measure the value of pressure of the high-pressure part at initial instant ($p_{HP\ 0}$);
- e) At each instant X calculate the pressure variation Δp_{theor} that should be found in the time interval $t_x - t_0$ in the absence of leakages, considering the effective consumption in said interval;
- f) Repeat step e) until the pressure difference is $\Delta p_{theor} \geq \Delta p_{thr}$;
- g) Measure the value of pressure of the high-pressure part (p_{HP}) again;
- h) Calculate pressure difference $\Delta p = p_{HP\ 0} - p_{HP}$;
- i) Calculate the pressure ratio parameter S between Δp_{theor} and Δp ; and
- j) If S is lower than a threshold V_x defined at calibration, then signal a leak in the circuit; if S is higher than another threshold W_x defined at calibration, then signal that one of the solenoid valves integrated in the gas cylinders is not closing properly.

4. The system according to Claim 3, characterized in that, in said second step, the aforesaid electronic control means are programmed for executing the following operations:

- a) System supplying a pre-set amount;
- b) Carry out the operations listed below only if the value of pressure p_{HP} of the high pressure part of the system is grater than a pressure threshold p_{thr}
 $p_{HP} > p_{thr}$;

- c) At the initial instant, close all solenoid valves on the gas cylinders (instant 0);
- d) Measure the value of pressure of the high-pressure part at initial instant ($p_{HP\ 0}$);
- e) At each instant X calculate the pressure variation Δp_{theor} that should be found in the time interval $t_x - t_0$ in the absence of leakages, considering the effective consumption in said interval;
- f) Repeat step e) until $\Delta p_{theor} \geq \Delta p_{thr}$;
- g) Measure the value of pressure of the high pressure part (p_{HP}) again;
- h) Calculate pressure difference $\Delta p = p_{HP\ 0} - p_{HP}$;
- i) Calculate the pressure ratio parameter S between Δp_{theor} and Δp ; and
- j) If S is lower than a threshold V_x defined at calibration, then signal a leak in the circuit; if S is higher than another threshold value W_x defined at calibration, then signal that one of the solenoid valves integrated in the gas cylinders is not closing properly.

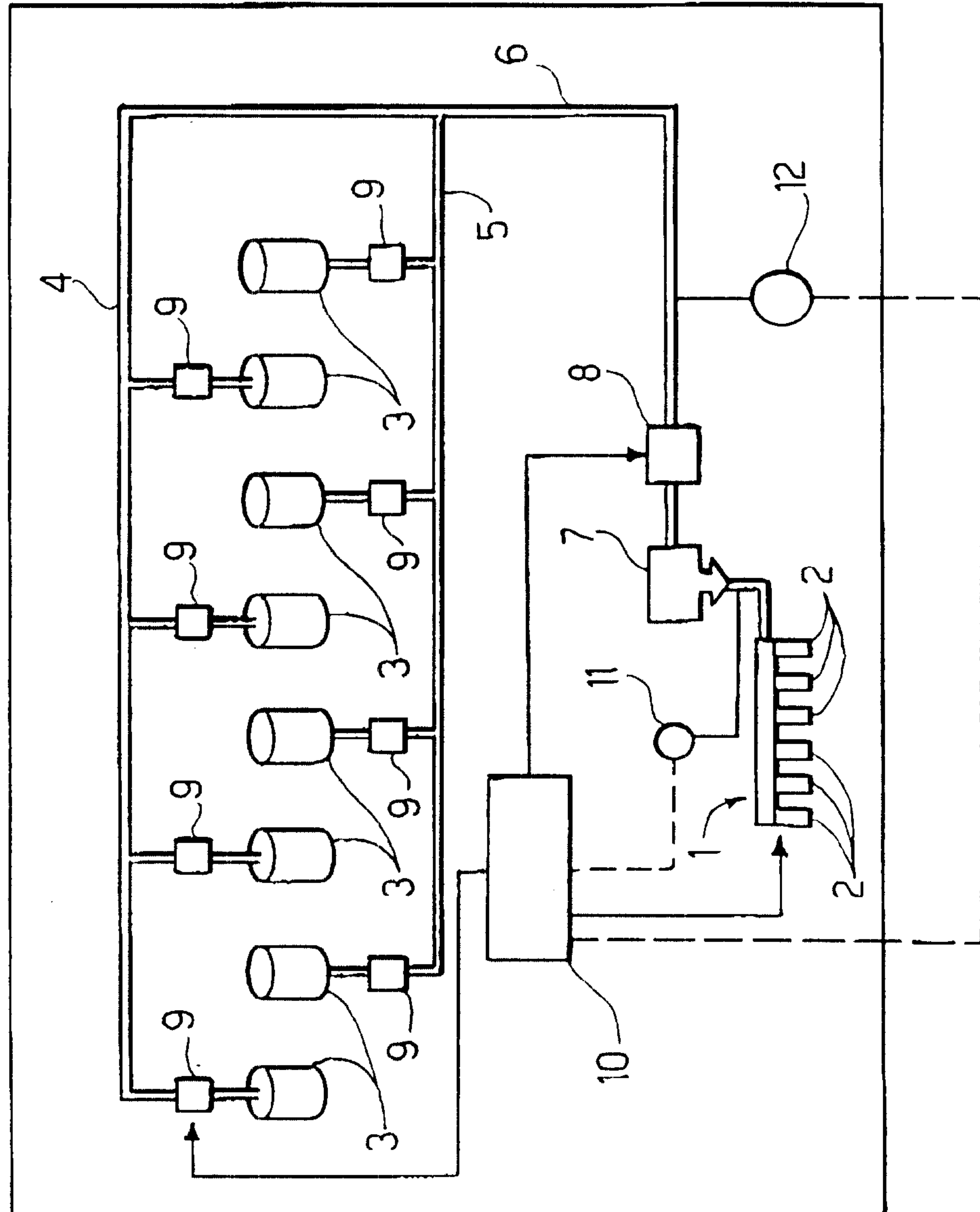


FIG. 1

