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[54] **AIR-POLLUTION PREVENTIVE SYSTEM FOR MOTOR VEHICLES**

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[52] **U.S. Cl.** .... **123/119 A**

[51] **Int. Cl.** **F02m 25/06**

[58] **Field of Search** .... 123/119, 119 A, 119 D, 124 B, 123/75 B

[56] **References Cited**

UNITED STATES PATENTS

1,963,628	6/1934	Mallory	123/124 B
2,354,179	7/1944	Blanc	123/119 A
2,700,967	2/1955	Maker	123/119 A
2,722,927	11/1955	Cornelius	123/119 A
3,204,621	9/1965	Holliday	123/119 A
3,368,345	2/1968	Walker	123/97 B X
3,491,736	1/1970	Walker	123/119 A
2,889,904	6/1959	Martinoli	123/119 A X
3,507,260	4/1970	Walker	123/119 A

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[57] **ABSTRACT**

An air-pollution preventive system for use with an internal combustion engine of motor vehicles, which system is adapted to reduce the concentration of nitrogen oxides in the exhaust gases emitted from the engine during the city-road driving of the motor vehicle, wherein the exhaust gases are recirculated from the exhaust manifold into the intake manifold and cooled therein when, and only when, the vacuum in the intake manifold is lower than a predetermined level and concurrently the engine is driven at a speed within a predetermined range, such predetermined level and range being determined as corresponding to the vehicle speed at which the motor vehicle is accelerated or climbs up a hill as frequently experienced during city-road driving.

4 Claims, 6 Drawing Figures

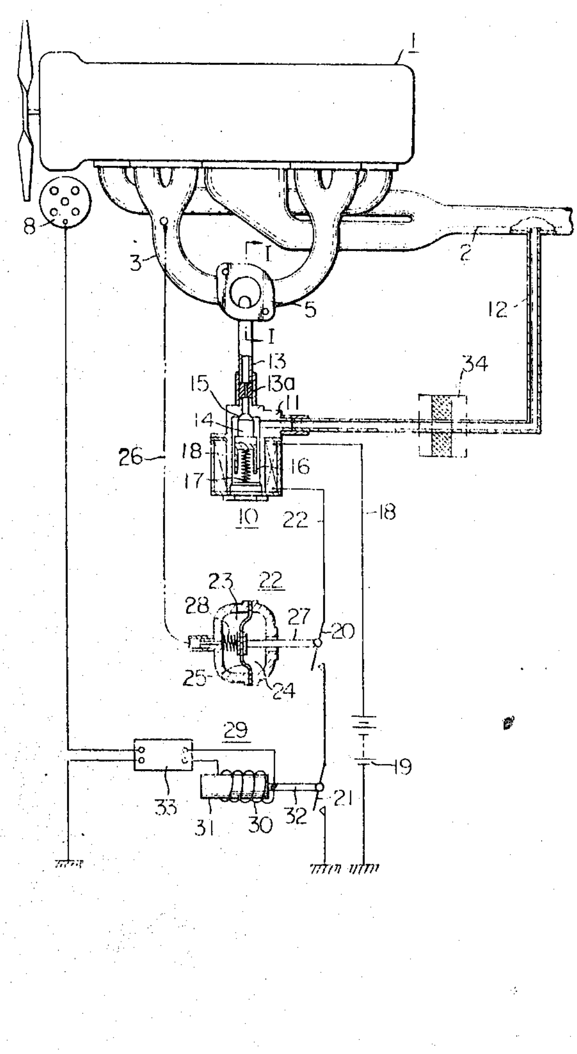

Fig. 1

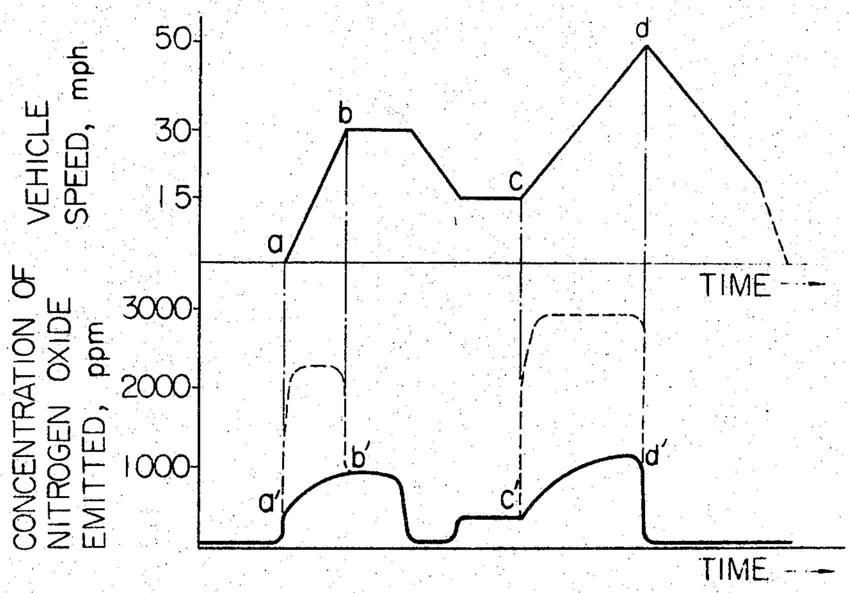

Fig. 6

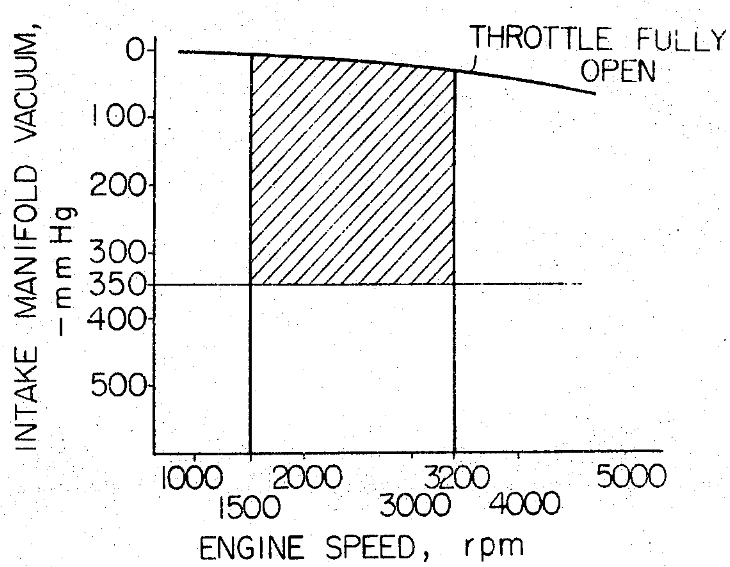

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Fig. 2

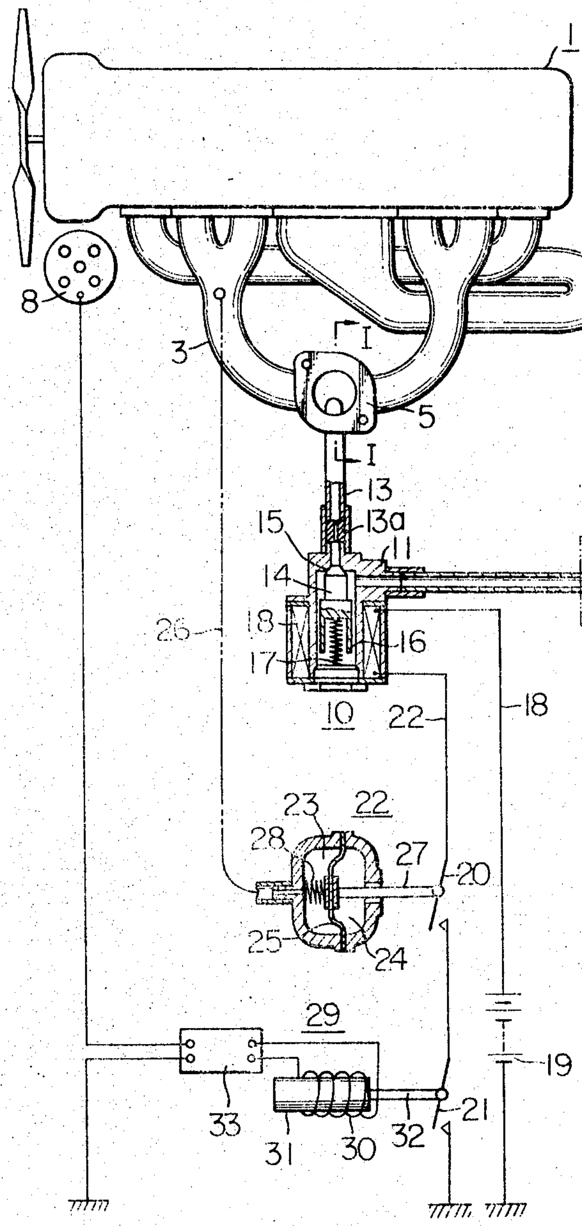

Fig. 3

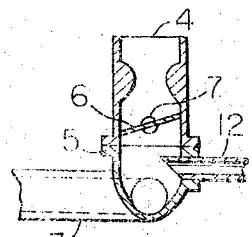

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Fig. 4

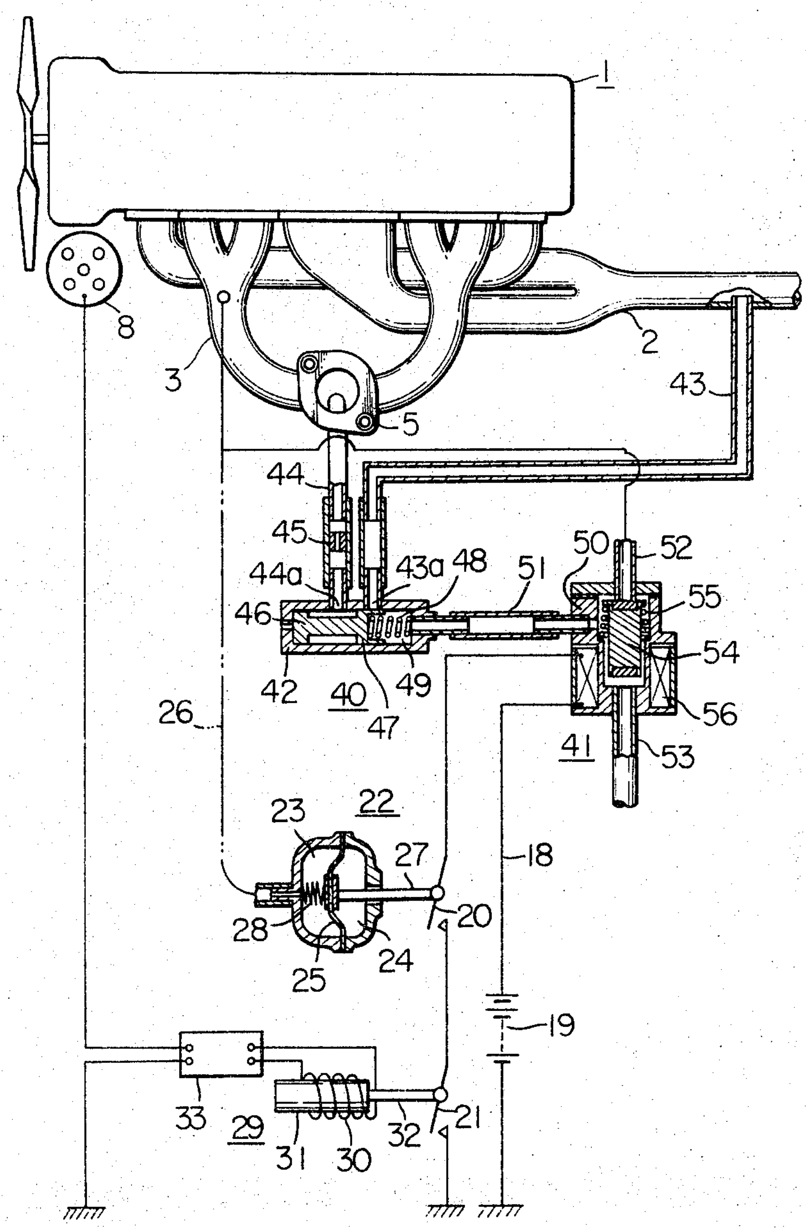

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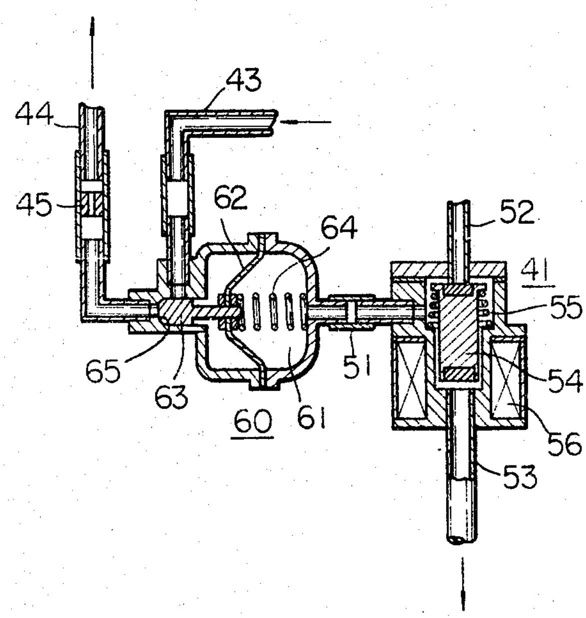
Fig. 5



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AIR-POLLUTION PREVENTIVE SYSTEM FOR MOTOR VEHICLES

This invention relates to an air-pollution preventive system of a motor vehicle and, more particularly, to a system which is adapted to reduce the concentration of nitrogen oxides contained in the exhaust gases emitted from the internal combustion engine of the motor vehicle. The system proposed by this invention is characterized in that the exhaust gases are recirculated into the intake manifold only when the engine is driven under predetermined conditions represented by the engine speed and the level of the vacuum in the intake manifold of the engine.

It is well known that toxic nitrogen oxides are produced in large quantities when the vacuum in the intake manifold of the engine is decreased and the combustion temperature in the engine increased. To prevent the thus produced nitrogen oxides from being admitted to the open air, it has heretofore been proposed and put into practice to have the once emitted exhaust gases recirculated into the intake manifold and mixed with an inert gas to lower the combustion temperature so that the objectionable reaction which would otherwise take place between nitrogen and oxygen is precluded.

Continuous recirculation of the exhaust gases without respect of the operating conditions of the ending, as has thus far been the practice, results in unstable engine operation, decreased engine output and contamination within the engine and, as such, is considered unsuitable for practical purposes.

The problem of air-pollution resulting from the emission of toxic nitrogen oxides from automotive engines is a matter of great concern especially in urban areas of today and it is desired to reduce to a minimum the amount of nitrogen oxides emitted when the motor vehicle is running on ciry-roads. The extensive investigations conducted by the inventors have revealed that the nitrogen oxides emitted in such quantities as to cause a serious air-pollution problem in urban areas are produced mostly when the motor vehicle is accelerating or climbing a hill, as will be discussed in more detail.

The invention was thus completed under the recognition that the drawbacks which result from the continuous recirculation of the exhaust gases can be effectively eliminated by selectively recirculating the exhaust gases only when the engine is driven under predetermined conditions in which the motor vehicle accelerates or climbs up a hill as frequently experienced in the driving in urban areas.

Such conditions of the engine providing the acceleration or hill-climbing of the motor vehicle are represented, as preferable according to the invention, by two particular factors — the revolution speed of the engine and the vacuum in the intake manifold of the engine.

A primary object of the invention is therefore to provide a system for reducing the concentration of toxic pollutants emitted from the engine when the motor vehicle is running in urban areas.

Another primary object of the invention is to provide a system which is adapted to reduce the concentration of nitrogen oxides to be admitted to the open air without detriment to the operation stability and power output of the engine and without contamination of the components and parts of the engine.

Still another primary object of the invention is to provide a system which is constructed and arranged to have the exhaust gases recirculated into the intake manifold only when the engine is driven under predetermined conditions in which the motor vehicle accelerates or climbs up a hill.

Still another primary object of the invention is to provide a system whereby the engine exhaust gases containing nitrogen oxides are recirculated into the intake manifold only when the engine is driven at a speed in a predetermined range and concurrently the vacuum in the intake manifold of the engine is maintained at predetermined levels.

In the drawings:

FIG. 1 is a graphical representation of a typical example of the relationships between the vehicle speed of a motor vehicle running on city-roads and the concentration of nitrogen oxides in the then emitted exhaust gases when the system according to the invention is used and not used;

FIG. 2 is a sectional view showing a preferred embodiment of the air-pollution preventive system of the invention as combined with a usual automotive engine which is shown in a schematical end view;

FIG. 3 is a section on line I—I of FIG. 2;

FIG. 4 is similar to FIG. 2 but shows a modification of the system according to the invention;

FIG. 5 is also similar to FIG. 2 but shows partially another modification of the system; and

FIG. 6 is a graphical representation of a region of the conditions in which the engine exhaust gases are to be recirculated by means of the system illustrated in FIGS. 2 and 5.

According to the investigations conducted by the inventors on an automotive engine of usual construction, it has turned out that the concentration of nitrogen oxides in the engine exhaust gases increases abruptly during acceleration and hill-climbing of the motor vehicle as indicated by the dotted curves *a'–b'* and *c'–d'* which correspond to the vehicle speed indicated by the lines *a–b* and *c–d*, respectively, in FIG. 1. In view of the fact that frequent decelerations, stops and accelerations occur and steep hills encountered in city driving, it will be conducive to the reduction of air pollutants to lower the concentration of nitrogen oxides during the acceleration and hill-climbing of the vehicle, viz., when the vehicle is driven under the conditions represented by the lines *a–b* and *c–d* in FIG. 1.

In order to accomplish this purpose, the invention proposes to have the ranges *a–b* and *c–d* of the driving conditions of the motor vehicle represented by the revolution speed of the engine and the vacuum level in the intake manifold of the engine. In other words, the air-pollution preventive system of this invention is constructed in such a manner that the engine exhaust gases are recirculated into the intake manifold of the engine when, and only when, the engine is driven at a speed within a predetermined range and simultaneously the intake manifold vacuum is lower than a predetermined level.

A preferred embodiment of such system is illustrated in FIGS. 2 and 3.

As best seen in FIG. 2, the system according to the invention is used in combination with a usual automotive internal combustion engine which is generally designated by numeral 1. The engine 1 has, as customary, an intake manifold 3 and exhaust manifold 2, and is combined with a carburettor 4 which is removed in FIG. 2 for simplicity of illustration. The carburettor 4 is, however, to be mounted on the intake manifold 3 by a mounting flange 5. The carburettor 4 has, also as customary, a throttle valve 6 which is mounted on rotary shaft 7, as shown in FIG. 3.

The air-pollution preventive system of the invention is essentially comprised by an exhaust recirculation control valve assembly 10, which is actually a solenoid valve device. The valve assembly 10 has a casing 11 which communicates on one side with the exhaust manifold 2 through an exhaust recirculation conduit 12 and on the other with the carburettor 4 downstream of the throttle valve 6 through an exhaust recirculation nozzle 13. If preferred, the nozzle 13 may be opened into the intake manifold 3, though not so illustrated.

The valve assembly 10 has provided in its casing 11 a valve head 14 which is positioned relative to a valve seat 15 formed integrally with the casing 11 in such a manner that the nozzle 13 is isolated from the conduit 12 when the valve head 14 is seated on the valve seat 15. The valve head 14 is integrally combined with a hollow cylinder 16, which is axially movably mounted in the casing 11. A compression spring 17 is accommodated within this hollow cylinder 16 in a manner to force the valve head 14 toward the valve seat 15. The valve head 14 is operated by a solenoid coil 18 which is connected with a power source 19.

The control valve assembly 10 thus constructed is controlled by two switches connected in series with the solenoid coil 18 of the assembly 10 — a vacuum switch 20 and engine speed switch 21.

The vacuum switch 20 is controlled by a diaphragm device 22, which is intended to detect the vacuum in the intake manifold 2. The diaphragm device 22 has a vacuum chamber 23 and atmospheric chamber 24 which is separated from the former by a diaphragm member 25. The vacuum chamber 23 communicates with the intake manifold 2 of the engine 1 through a vacuum conduit 26, while the atmospheric chamber 24 is vented to the atmosphere. The diaphragm member 25 is connected with the vacuum switch 20 through a connecting rod 27 extending through the atmospheric chamber 24. In the vacuum chamber 23 is mounted a compression spring 28 whereby the diaphragm member 25 is forced toward the atmospheric chamber 24. Thus, when the intake manifold vacuum is at an elevated level, the diaphragm member 25 is pulled toward the vacuum chamber 23 against the action of the spring 28 thereby to keep the switch 20 open. When, in contrast, the intake manifold vacuum drops under a predetermined level, say, −350 mm of Hg, then the spring 28 overpowers the vacuum and the diaphragm member 25 is moved toward the atmospheric chamber 24 to permit the switch 20 to close. The compression of the spring 28 may be determined in a manner to yield to the vacuum at such predetermined level.

The engine speed switch 21, on the other hand, is controlled by a solenoid device 29 having a solenoid coil 30 and moving core 31. The moving core 31 is connected with the switch 21 through a connecting rod 32 and positioned to normally keep the switch 21 to open and to close the switch when the solenoid coil 30 is excited. The solenoid coil 30 is connected to and excited by the output terminal of a pulse counter 33, the input terminal of which is connected to an ignition distributor 8 of the engine. The pulse counter 33 thus detects the number of pulses fed from the primary winding of the ignition coil (not identified) of the ignition distributor 8. The pulse counter 33 is so selected as to excite the solenoid coil 30 when it detects pulses in a number proportional to an engine speed within a predetermined range so that the switch 21 is closed only when the engine is driven at a speed within a predetermined range, for example, from 1,500 to 3,200 rpm.

If preferred, a filter 34 may be provided in the exhaust recirculation conduit 12, whereby the carbons contained in the exhaust gases are removed before they are introduced into the control valve assembly 10. Thus, exhaust gases cleared of carbons will be recirculated into the intake manifold 3.

Also, if preferred, an orifice 13*a* may be provided in the nozzle 13 to control the flow of exhaust gases to be drawn into the intake manifold.

When, in operation, the engine is driven under conditions in which the amount of nitrogen oxides emitted therefrom is allowable from the practical standpoint as during the deceleration or normal cruising, then the revolution speed of the engine and/or the level of the vacuum in the intake manifold are outside the ranges within which the vacuum switch 20 and/or engine speed switch 21 are open. In this condition, the solenoid coil 18 of the solenoid device 10 is kept de-energized so that the valve head 14 remains seated by the action of the spring 17, isolating the conduit 12 from the nozzle 13. Thus the exhaust gases in the exhaust manifold 2 is prohibited from recirculating into the intake manifold 3.

When, on the other hand, the engine output increases to such an extent as to produce nitrogen oxides in quantities to cause a serious pollution problem as represented by the dotted curve a'–b' or c'–d' in FIG. 1, then the intake manifold vacuum drops under the aforesaid predetermined level, for example, −350 mm of Hg and the engine speed falls within the aforesaid predetermined range, for example, anywhere between 1,500 and 3,200 rpm. In this condition, the spring overpowers the vacuum in the vacuum chamber 23 to cause the diaphragm member 25 to move into a position in which the switch 20 is closed. At the same time, the number of pulses from the ignition distributor 8 falls within the range corresponding to the predetermined range of engine speed, say

between 1,500 to 3,200 rpm. The solenoid coil 30 is consequently excited and the moving core 31 protruded to close the switch 21. The two switches 20 and 21 being now closed, the solenoid coil 18 of the solenoid valve device 10 becomes energized to cause the valve head 14 to be unseated from the valve seat 15 against the action of the spring 17, thereby permitting the exhaust gases to recirculate from the exhaust manifold 2 into the intake manifold 3 through the conduit 12 and nozzle 13. The combustion temperature in the engine is lowered and the concentration of nitrogen oxides emitted to the open air is reduced from the levels represented by the dotted curves a'–b' and c'–d' to the solid curve a'–b'–c'–d' in FIG. 1.

The exhaust recirculation control valve assembly which has been shown as a solenoid valve device 10 may be constructed otherwise inasmuch as the intent of recirculating the exhaust gases only when the engine is driven at predetermined speeds and the intake manifold vacuum lowered under a predetermined level, one of such modifications being illustrated in FIG. 4.

The modified embodiment of the system according to the invention is essentially similar to that shown in FIGS. 2 and 3 and, as such, like numerals are assigned to corresponding parts.

As shown, the exhaust recirculation control valve is now constructed as a combination of a spool valve device 40 and a solenoid valve device 41 to control the former.

The spool valve device 40 has a casing 42 communicating on one side with the exhaust manifold 2 through a conduit 43 and on the other with the intake manifold 3 through a nozzle 44. The conduit 43 is shown to debouch into the casing 42 at an inlet port 43*a* and the nozzle 44 to lead from the casing at an outlet port 44*a*. An orifice 45 may be provided in the nozzle 44 to control the flow through the nozzle.

The casing 42 has accommodated therein a spool valve 46 having a land 47. A compression spring 48 is mounted in a chamber 49 formed between the end walls of the casing and land 47 in such a manner that the spool 46 is forced toward a position in which the inlet port 43*a* is closed by the land 47, as shown.

The casing 42 further communicates with a casing 50 of the solenoid device 41 through a conduit 51. This casing 50 in the solenoid valve device 41 communicates on one side with the intake manifold 3 through a conduit 52 and on the other with the atmosphere, or with an air cleaner if preferred, through a conduit 53. A moving core 54 is axially movably mounted in the casing 50 to act as a valve member and a compression spring 55 is mounted around this moving core or valve member 54 in a manner to force the valve member toward a position in which the conduit 52 is closed and the conduit 53 opened. In this condition, the casing 50 is prevented from communicating with the intake manifold 3 and is internally maintained at an atmospheric pressure.

The valve member 54 is operated by a solenoid coil 56 which is connected at one end with a power source 19 and at the other with a vacuum switch 20 and engine speed switch 21, similarly to the system illustrated in FIG. 2.

The switches 20 and 21 are controlled by a diaphragm device 22 and solenoid device 29, respectively, which are entirely similar in construction and function so that the discussion previously given applies thereto.

During the deceleration or normal cruising of the motor vehicle when the emission of nitrogen oxides from the engine is too low in concentration to cause a serious air-pollution problem, the solenoid valve device 41 remains inoperative because the solenoid coil 56 thereof is kept de-energized with the switches 20 and/or 21 open.

When, on the other hand, the engine output increases and nitrogen oxides are produced from the engine in quantities that can not be neglected from the practical standpoint as indicated by the dotted curves a'–b' and c'–d' in FIG. 1, then the intake manifold vacuum decreases under a predetermined level to yield to the compression of the spring 28 of the diaphragm device 22 and concurrently the engine is driven at a speed within a predetermined range to cause the solenoid device 29 to be actuated. The switches 20 and 21 are now closed and the solenoid coil 56 of the solenoid valve device 41 energized. The valve member 54 is moved against the action of the spring 55 to a position to open the conduit 52 and close the conduit 53. The intake manifold vacuum that is now at a lowered level is communicated to the chamber 49 formed by the end walls of the casing 42 and land 47 of the spool valve 46.

The spring 48 being selected to yield to the thus lowered vacuum, the spool valve 46 is pulled by the vacuum over to a position in which the land 47 leaves and opens the inlet port 43*a*. The conduit 43 is permitted to communicate with the nozzle 44 to enable the exhaust gases to recirculate from the exhaust manifold 2 into the intake manifold 3.

As an alternative to the spool valve device 40 used in the above-described embodiment, a diaphragm valve device may be combined with the solenoid valve device 41 to constitute an exhaust recirculation control assembly in the system according to the invention, example being shown in FIG. 5.

In FIG. 5, only the diaphragm valve device which is generally denoted by 60 and the solenoid valve device which is similar to the counterpart in FIG. 4 and is numbered accordingly are illustrated, because the remaining essential elements are the same as used in the system in FIG. 4.

Referring to FIG. 5, the diaphragm valve device 60 has a vacuum chamber 61 defined by a diaphragm member 62 and the structural wall of the device 60, as shown. The vacuum chamber 61 communicates with the casing 50 of the solenoid valve device 41 through a conduit 51. A valve head 63 is connected with the diaphragm member 62 on its side opposite to the vacuum chamber 61. A compression spring 64 is mounted in the vacuum chamber 61 in a manner to force the diaphragm member 62 and accordingly the valve head 63 away from the vacuum chamber 61. The valve head 63 in this protruded position projects into a port 65 between an exhaust recirculation conduit 43 and nozzle 44 thereby to isolate the conduit and nozzle from each other.

Now, as the engine output increases and the switches 20 and 21 are closed, then the solenoid valve device 41 becomes actuated to permit the vacuum to flow into the vacuum chamber 61. The compression spring 64 is selected so as to yield to the vacuum so that the diaphragm member 62 and accordingly the valve head 63 are moved toward the vacuum chamber 61 and away from the port 65. The valve head 63 thus retracted, the conduit 43 communicates with the nozzle 44 thereby to pass the exhaust gases from the exhaust manifold to the intake manifold, similarly in function to the previously described embodiments.

The range in which the engine exhaust gases are recirculated into the intake manifold is shown in FIG. 6, wherein it is assumed, by way of example, that the exhaust gases are recirculated when the engine is driven at a speed ranging from 1,500 to 3,200 rpm and the intake manifold vacuum is lower than −350 mm of Hg. The recirculation range is indicated by the hatched area.

What is claimed is:

1. An air-pollution preventive system for a motor vehicle having an internal combustion engine, adapted to reduce the concentration of nitrogen oxides in the exhaust gases emitted from the engine to the open air, comprising:

1. an exhaust recirculation control valve assembly having a chamber communicating on one side with an exhaust manifold of said engine and on the other with an intake manifold of said engine;
2. first means responsive to the intake manifold vacuum for controlling said control valve assembly, which means includes a vacuum switch and a diaphragm device having a vacuum chamber communicating with the intake manifold, an atmospheric chamber vented to the atmosphere, a diaphragm member separating said vacuum and atmospheric chambers with each other, said diaphragm member being connected with said vacuum switch, and a compression spring forcing said diaphragm member toward a position in which the vacuum switch is open, the loading of said spring being determined to overpower the intake manifold vacuum higher than a predetermined level, said vacuum switch being closed when the intake manifold vacuum is below said predetermined level; and
3. second means responsive to the engine speed for controlling said control valve assembly, which means includes an engine speed switch and a solenoid device having a solenoid coil and moving core, said moving core being connected with said engine speed switch and normally held in a position to open the same, and a pulse counter connected at its outer terminal with the ignition distributor for detecting the number of pulses within a predetermined range of the engine speed whereby said moving core protrudes into a position to close said engine speed switch; said control valve assembly being open to permit the exhaust gases to recirculate into the intake manifold only when said vacuum and engine speed switches are closed.

2. A system according to claim 1, wherein said control valve assembly includes a casing communicating on one side with the exhaust manifold through an exhaust recirculation conduit and on the other with the intake manifold through an exhaust recirculation nozzle, a valve head which is positioned relative to a valve seat formed in said casing, a compression spring accommodated in said casing to force said valve head against said valve seat to isolate said conduit from said nozzle, a moving core connected with said valve head, and a solenoid coil associated with the last named moving core and connected with a power source and with said vacuum and engine speed switches, said moving core being moved away from said valve seat against the action of the last named spring to cause said valve head to be unseated when the last named solenoid coil is excited with said vacuum and engine speed switches closed concurrently, whereby said conduit is permitted to communicate with said nozzle.

3. A system according to claim 1, wherein said control valve assembly includes a spool valve device and a solenoid valve device, said spool valve device including a casing communicating on one side with the exhaust manifold through an exhaust recirculation conduit and on the other with the intake manifold through an exhaust recirculation nozzle, a spool valve axially movably mounted in said casing and having a land at one end, and a compression spring mounted in said casing to force said spool valve toward a position in which said land isolates said conduit from said nozzle, the loading of said compression spring being determined to yield to the intake manifold vacuum lowered to said predetermined level, said solenoid valve device including a solenoid valve casing communicating with said casing of the spool valve device, said solenoid valve casing further communicating on one side with the intake manifold through a vacuum conduit and on the other with the atmosphere, a moving core axially movably mounted in said solenoid valve casing and acting at the same time as a valve member, said moving core being normally forced into a position to isolate said vacuum conduit from said casing of said spool valve device by a spring action, and a solenoid coil associated with said moving core and connected with a power source and with said vacuum and engine speed switches, said moving core being moved to a position to permit said vacuum conduit to communicate with said casing of said spool valve device to cause said spool valve to be moved against the action of said spring in said spool valve device to a position in which said land is moved to a position in which sad exhaust recirculation conduit is permitted to communicate with said nozzle when said solenoid coil of said solenoid valve device is excited with said vacuum and engine speed switches closed concurrently.

4. A system according to claim 1, wherein said control valve assembly includes a diaphragm valve device and a solenoid

valve device, said diaphragm valve device including a vacuum chamber, a diaphragm member forming part of the structure of said vacuum chamber, a port communicating on one side with the exhaust manifold through an exhaust recirculation conduit and on the other with the intake manifold through an exhaust recirculation nozzle, a valve head connected with said diaphragm member and directed toward said port, and a compression spring mounted in said vacuum chamber to force said diaphragm member toward a position in which said valve head closes said port, the loading of said compression spring being determined to yield to the intake manifold vacuum lowered to said predetermined level, said solenoid valve device including a solenoid valve casing communicating with said casing of the diaphragm valve device, said solenoid valve casing further communicating on one side with the intake manifold through a vacuum conduit and on the other with the atmosphere, a moving core axially movably mounted in said solenoid valve casing and acting at the same time as a valve member, said moving core being normally forced into a position to isolate said vacuum conduit from said casing of said diaphragm valve device by a spring action, and a solenoid coil associated with said moving core and connected with a power source and with said vacuum and engine speed switches, said moving core being moved to a position to permit said vacuum conduit to communicate with said casing of said spool valve device to cause said diaphragm member to be moved against the action of said spring in said diaphragm valve device to a position in which said valve head is moved to a position to open said port whereby said exhaust recirculation conduit is permitted to communicate with said nozzle when said solenoid coil of said solenoid valve device is excited with said vacuum and engine speed switches closed concurrently.

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