ABSTRACT
Exhaust gas recirculating means for reducing the pollutants discharged from an internal combustion engine by regulating the flow of a portion of the exhaust gases from the exhaust manifold to the intake manifold by the use of plate valve means that precisely meters the flow of exhaust gases and/or ambient air in response to atmospheric pressure, intake manifold pressure and exhaust manifold pressure. In one form a single plate valve is provided in an improved exhaust gas recirculating valve, whereas in a second form, dual plate valves are used. Included with the ambient air and exhaust gas recirculating means is a velocity nozzle means for introducing the gases into the intake manifold and for helping to scavenge the PCV system’s crank case emissions.

26 Claims, 23 Drawing Figures
EXHAUST GAS RECYCLING VALVE

BACKGROUND OF THE INVENTION

The present invention relates to an improved pollution control device designed to utilize exhaust gas recirculation in an internal combustion engine as the means for reducing oxides of nitrogen and generally reducing carbon monoxide and hydrocarbons.

The ecology movement has made people more aware of airborne pollutants of all types. There has been considerable activity recently in attempting to reduce the level of pollutants discharged from an internal combustion engine as used commonly in vehicles. The increased quantity of pollutants passing into the atmosphere as a result of the increased use of vehicles having internal combustion engines has caused concern with respect to the health and well-being of human beings as well as other living organisms. One method proposed for reducing the pollutants discharged from an internal combustion engine was to seal the system and return a portion of the exhaust gases mixed with gases from the crank case to the intake manifold. An example of a patent illustrating such means is MacMahon U.S. Pat. No. 3,362,386. The MacMahon arrangement is relatively complex and undesirably reduces the exhaust gas temperatures before returning it mixed with crank case gases to the intake manifold. It does not provide for the introduction of controlled ambient air into the exhaust and/or intake manifolds.

Another arrangement for reducing the pollutants discharged from an internal combustion engine is shown in Cornelius U.S. Pat. No. 2,722,927. The Cornelius system introduces exhaust gases to the combustion chamber of an internal combustion engine to dampen out the surges normally resulting from the rapid opening and closing of the intake and exhaust valves. Exhaust gases are introduced only when required in order to effect maximum volumetric efficiency and at all other times the gases will pass out of the exhaust pipe. This complex for it utilizes governors, diaphragms and associated linkages and does not effectively control the discharge of pollutants during all operating conditions of the internal combustion engine.

It has also been suggested that catalytic converters be employed in mufflers to help break down the pollutants before they are discharged to the atmosphere. The pollutants are still found in the engine and in the event of malfunction would be discharged to the atmosphere. Further, such systems are relatively expensive.

There is a need for a system that can be designed for an produced in new automobiles and/or readily be installed in existing automobiles to reduce undesired emissions, with a minimum interference with engine operation. Such a system should be relatively inexpensive to manufacture and install.

In the co-pending application of Milford M. Scott, Jr., now U.S. Pat. No. 3,645,043 filed on the same date, this application, there is disclosed a system for reducing pollutants discharged from an internal combustion engine by precisely regulating a portion of the exhaust gases from the exhaust manifold to the intake manifold by the use of plate valve means that precisely meters the flow of exhaust gases and/or ambient air in automatic self-response to atmospheric pressure, intake manifold pressure and exhaust manifold pressure.

An object of this invention is to provide an improved exhaust gas recirculating means that is relatively inexpensive to make and install on used automobiles or on new automobiles.

Another object of the present invention is to provide improved exhaust gas recirculating means that are compatible with engines incorporating PCV valves, such recirculating means including an improved EGR valve and a velocity nozzle means for introducing the gases and/or air into the intake manifold and for helping to scavenge the PCV system’s crank case emissions.

Another object of this invention is to provide improved exhaust gas recirculating means for a vehicle that will reduce exhaust emissions from a motor vehicle engine without significantly adversely affecting vehicle performance.

Still another object is to provide improved exhaust gas recirculating means providing for fresh air intake during engine operation through a plate valve automatically self-responsive to the differential pressure of the atmosphere, the intake manifold, and the exhaust manifold for reducing oxides of nitrogen, and generally reducing hydrocarbons, carbon monoxide, aldehydes and hydrocarbon reactivity.

Yet another object of the present invention is to provide improved exhaust gas recirculating means embodying an EGR valve having dual plate valves therein for more precisely controlling the flow of exhaust gas and fresh air through the EGR valve. These and other objects and advantages of the present invention will become more apparent from the description which follows.

BRIEF DESCRIPTION OF THE DRAWING

There is shown in the attached drawing presently preferred embodiments of the present invention wherein:

FIG. 1 is a schematic view of an internal combustion engine incorporating the novel pollution control system of the present invention;

FIG. 2 is an enlarged detailed view partly in cross-section of the improved pollution control system of the present invention;

FIGS. 3, 4 and 5 are detailed cross-sectional views illustrating various operational positions of the plate valve within a modified exhaust gas recirculating valve of the present invention;

FIG. 6 is a plan view of the separator plate used in the exhaust gas recirculating valve of FIGS. 3-5;

FIG. 7 is a plan view of a typical plate valve utilized in the exhaust gas recirculation valve of FIGS. 3-5;

FIG. 8 is a cross-sectional view of a further embodiment of exhaust gas recirculating valve;

FIG. 9 is a plan view of a secondary plate valve utilized in the embodiment of FIG. 8;

FIGS. 10, 11, 12 and 13 are cross-sectional views of the modified exhaust gas recirculation valve of FIG. 8, illustrating the positions of the dual plate valves during various modes of engine operation;

FIGS. 14, 15, 16, 17 and 18 are cross-sectional views of a further modification of the exhaust gas recirculating valve, illustrating various operational positions of the dual plate valves therein;

FIG. 19 is a cross-sectional view of the exhaust gas recirculating valve of FIG. 15 taken generally along the line 19-19;
FIG. 20 is a plan view of the separator plate of the modification of exhaust gas recirculating valve of FIGS. 14-18.

FIG. 21 is a cross-sectional view of the exhaust gas recirculating valve of FIG. 17 taken generally along the line 21-21.

FIG. 22 is a schematic view of an exhaust gas recirculating system for an internal combustion engine incorporating a vacuum advance bleed control means; and

FIG. 23 is a further modification of exhaust gas recirculating valve.

DETAILED DESCRIPTION OF THE DRAWING

Referring now to FIG. 1 there is illustrated an improved pollution control system for an internal combustion engine which embodies the present invention. The internal combustion engine 10 with which the pollution control device 12 of the present invention is used may be of conventional design and comprise an engine block 14 having a pan secured to the bottom thereof which cooperates with the block 14 to define a crank case chamber. The usual pistons are operable within cylinders in the engine block 14 which is closed at the top by cylinder head 16a and valve cover means 16.

Attached to the engine 10 is an intake manifold 18 that is operatively associated with the carburetor mechanism 20 and the usual air cleaner 22. Also, associated with the engine block 14 is an exhaust manifold 24 which includes a conduit or pipe 26 adapted to communicate exhaust gases from the engine to a muffler mechanism (not shown) from which the gases may be discharged through a tailpipe to the atmosphere. The intake and exhaust manifolds may be connected directly to the block 14 or to the head 16a.

The internal combustion engine 10 includes a distributor mechanism 30 that is adapted to be connected by means or electrical cable to the spark plugs 32 positioned in the cylinder head 16a. The engine 10 may include a fly wheel 15 and the other conventional accessories.

Though it is possible to utilize the novel pollution control system of the present invention in a system that does not have a positive crank case ventilation (PCV) valve, more recent engines incorporate such valve and accordingly, it is desirable that the improved system of the present invention be compatible with a system including a PCV valve, indicated generally by the numeral 34. The novel pollution control system of the present invention includes in addition to the aforesaid elements a velocity nozzle means 36 adapted to be connected to the PCV inlet between the carburetor 20 and the intake manifold 18. In addition, the velocity nozzle 36 is connected by means of the conduit 40 to the PCV valve of the internal combustion engine 10 and through the conduit 42 to the exhaust gas recirculation valve 12.

It has been known heretofore that an effective system for reducing nitrogen oxide emissions involves exhaust gas recycling. By recirculating a portion of the exhaust gas from the exhaust manifold and introducing it back through the intake manifold to the engine the peak cycle temperatures in the cylinder can be reduced and the burning rate within the cylinders is controlled, with significant reductions in nitrogen oxide emissions. The amount of recirculation is critical, for with too much recirculation there is an increase in the hydrocarbon and carbon monoxide levels and losses in vehicle performance, power, economy and drivability. Through the present invention there is provided means for precisely controlling the amount of exhaust gas recirculated, by means of plate valve means that meters the flow of exhaust gases and/or ambient air in automatic selfresponse to the differential pressures of the exhaust manifold, the intake manifold and the ambient air pressure. Whereas penalties in fuel consumption ranging anywhere from five to twenty percent may result from use of conventional exhaust gas recirculating arrangements, the present system which includes a controlled bleed of fresh air from the atmosphere will help materially reduce or eliminate the penalty, while advantageously reducing the levels of pollutants formed and emitted from the engine. It has further been found that through use of the novel system the engine temperatures can be reduced and engine life can be increased.

With reference to FIG. 2 there is illustrated in further detail the exhaust gas recirculation valve 12 and the velocity nozzle 36. The body or housing 46 of the exhaust gas recirculation (EGR) valve 12 is connected to the exhaust gas manifold 24 or the heat riser 24a or the exhaust pipe 26 through a conduit 48. The body 46 has a separator plate member 50 secured to the bottom thereof by means of fastening means, for example screws 52 which also retain an inlet coupling 54 to the body 46. The inlet coupling 54 communicates with the carburetor air cleaner through the conduit 56. The separator plate member 50 is provided with opening means, for example, holes 58, for communicating with the chamber 60 of the valve body 46. An outlet coupling 62 in turn connects the valve body 46 to the conduit 42 that is connected to the velocity nozzle 36. Disposed within the chamber 60 is plate valve member 70 that is adapted to alternately cooperate with the ports 58 and conduit valve seat 61 to precisely regulate the flow of fresh air and exhaust gases into the pollution control system. Guide means 72 guide the movement of the plate valve 70 toward and away alternately from the ports 58 in the separator plate 50 and the conduit valve seat 61. As shown, the plate valve guide 72 is adapted to take the form of pins secured to the separator plate 50 and disposed in openings within the plate valve 70, such that the plate valve 70 can slide on the pins 72 with a minimum of friction.

Exhaust gases enter the EGR valve 12 through the conduit 48 that is adapted to be connected to either the manifold heat riser 24a or the exhaust gas manifold 24. Fresh air enters the EGR valve 12 from the air cleaner 22 via the conduit 56, inlet coupling 54 and opening means 58.

Referring to FIG. 3, when the engine is in the idle mode of operation, a quantity of exhaust gases mixed with fresh air is drawn through the EGR valve 12 into the intake manifold through the velocity nozzle 36. The quantity of exhaust gas and fresh air is precisely metered by the hole or orifice 71 in the plate valve 70. When there is high manifold vacuum, the plate valve 70 is tight against the seat at the bottom of the conduit 61, the holes or openings 58 in the separator plate 50 are wide open to the atmosphere and fresh air is allowed to enter the EGR valve 12 from the air cleaner 22 through conduit 56 and inlet coupling 54. When the engine is at idle, fresh air enters the recirculating valve, mixing with the exhaust gases, and is sucked through the me-
tering hole 71 in the center of the plate valve 70 and through the velocity nozzle 36 to the intake manifold. Fresh air also enters the exhaust manifold due to the positive and negative pressure experienced in the exhaust manifold during the idle and low cruise modes of operation. During idle the positive pulse forces spent exhaust gases into the EGR valve 12 where it is mixed with the incoming fresh air created by the intake manifold suction through the metering hole 71 and plate valve 70, plus the negative pulses in the exhaust manifold. During the negative pulse in the exhaust manifold, fresh air also enters the exhaust manifold via the holes 58 and the conduit 48. The fresh air entering the exhaust manifold will enter the cylinders during exhaust valve overlap and will help complete the combustion process. The metered quantities of exhaust gases and fresh air drawn into the intake manifold 18 during idle operation of the engine are heated, therefore better evaporating the fuel-air mixture during idle and giving a homogeneous fuel-air mixture which can travel to all cylinders without condensation drop-out. This automatically provides a leaner mixture without rough idling.

During low speed cruise operation, FIG. 3, the same cycle takes place with fresh air mixed with exhaust gases entering the intake manifold 18 and fresh air entering the exhaust gas manifold 24. At these cruise conditions, fresh air entering the exhaust manifold 24 also helps oxidize the unburnt hydrocarbons (HC) and carbon monoxide (CO), while the exhaust gases mixing with fresh air entering the intake manifold 18 give better vaporization and help reduce oxides of nitrogen.

During high speed cruise, FIG. 3, the positive pulses overcome the negative pulses in the exhaust manifold. Therefore, there is no fresh air drawn into the recirculating valve. The intake manifold 18 draws only exhaust gases through the metering hole 71 in plate valve 70 and exhaust gases also escape through the holes 58 and pass through the conduit 56 through the carburetor air cleaner. These exhaust gases reduce the oxides of nitrogen.

When the engine is accelerated, the plate valve 70 is forced against the separator plate 50, closing the openings 58 and exhaust gases only are drawn through conduit 61, coupling 62, conduit 42, and nozzle 36 to the intake manifold 18. This flow is increased since the plate valve 71 is away from the inlet to the conduit 61. Therefore the metering area to the intake manifold is greatly increased. There is also higher exhaust gas pressure forcing the exhaust gases through the conduit 61. No exhaust gases are passing through the holes 58 to the carburetor or air cleaner. It has been determined that exhaust gases entering the top of the carburetor in large quantities during maximum power reduce the volumetric efficiency due to the excessive heating and displacement of incoming air. Therefore, all exhaust gases recirculated during acceleration pass under the carburetor 20.

During deceleration (FIG. 5), the plate valve 70 is set tightly against the valve seat at the end of conduit 61 and a metered quantity of fresh air is drawn into the intake manifold via the metering hole 71 in the plate valve 70, the coupling 54 and conduit 56, reducing vacuum on the idle circuit and lowering the over-rich condition. There is also a high suction during deceleration created in the exhaust manifold due to piston pumping action. Therefore, fresh air is drawn through the holes 58 in the separator plate 50 via the conduit 48 into the exhaust gas manifold 24 where it enters the cylinder during exhaust valve overlap, thereby reducing the dilution of the air-fuel mixture by exhaust gases and thus creating better combustion and reducing all emissions.

The continued pulsation of the plate valve 70 keeps the valve seat at the bottom of conduit 61 and the metering holes 71 in the plate valve 70 clean. Only filtered air enters the EGR valve 12 from the carburetor air cleaner 22 via the coupling 54. The plate valve 70 is controlled by the differential in exhaust manifold, intake manifold, and ambient pressures to properly and precisely control the flow of exhaust gases and fresh air introduced when needed. The plate valve 70 is automatically responsive to the pressures acting on the surfaces thereof.

An advantage of the system utilizing the EGR valve of the present invention is that the need for solenoids, idle control valve and associated linkage, as is used in a prior known exhaust gas emission control system can be eliminated. The plate or reed valve 70 is so designed that during deceleration, fresh air is drawn into the EGR valve 12. This fresh air is not diluted with exhaust gases because fresh air is also entering the exhaust manifold. The fresh air enters the intake manifold metered by the control hole or orifice 71 in the plate 70 and then passes through the recirculation conduit 42 and the velocity nozzle to the carburetor 20, thereby completing the same metering action that the solenoid control valve or deceleration valve prior known systems accomplish, in a much simplified fashion. The solenoid control valve of one prior system holds the butterfly of the carburetor partially open, allowing more air to enter the intake manifold and thus reducing the over-rich mixture by reducing the vacuum on the idle circuit and thus lowering the emissions. However, this solenoid valve sometimes sticks, thereby holding the throttle partially open. There was a major automotive recall by one of the automotive manufacturers because the bracket holding this valve was defective, causing the throttle to stick partially open. This problem is obviated in the present invention in that if the exhaust recirculating valve 12 fails, the engine will only idle rough, but the throttle will not stick nor will the engine race due to malfunction of the plate valve 70. Even if the valve 12 is rendered completely inoperative, the engine 10 will not race, rather, it will tend to stall due to the off-balanced fuel-air ratio caused by the excess air entering the intake manifold 18.

When the engine is decelerated from an operating speed of approximately 3,000 rpm to an idle speed on the order of 650 rpm, the elapse time is longer than for an engine not equipped with an EGR valve 12 in accordance with the present invention. The reason for this is that fresh air drawn through the plate valve 70 enters the intake manifold 18 through a suitable opening in the intake manifold or an induction plate secured between the carburetor and intake manifold, thus simulating a partial throttle opening. Once the engine speed drops to approximately 1,000 rpm, the air becomes diluted with exhaust gases, thus simulating a closed throttle condition and normal idle speeds are maintained.

Though the novel EGR valve 12 employed in a system omitting the universal velocity nozzle 36 would provide advantages over a similar system not so equipped, it is preferable that the system include the
universal velocity nozzle 36. With reference to FIG. 2, it will be seen that the velocity nozzle 36 comprises a generally L-shaped body 80 which is connected at one end to a coupling 81 that is in turn connected to conduit 40. Conduit 40 is adapted to be secured to the outlet from the PCV valve 34. Fitting 82 is connected to the body 80 at an angle to the coupling conduit 81. Extending inwardly from the fitting 82 is an induction conduit 84. The cross-sectional area of the passage in conduit 84 must be less than the cross-sectional area of the passage in body 80. The said area of the passage in conduit 84 is used to meter the exhaust gas recirculating flow when the plate valve 70 is away from the valve seat on the end of conduit 61. The length of the passage in conduit 84 must be no less than twice the diameter of said passage. During idle operation of the engine, exhaust gases mixed with fresh air are drawn into the intake manifold 18 via the induction plate 37. It is noted that in some cases the induction inlet may be formed in the carburetor, rather than in a separate induction plate. Gases from the conduit 42 pass into the passage through body 80 through conduit 84 and port 85. During acceleration, the high velocity gases traveling up the conduit 42, coupling 82, conduit 84 and port 85 cause a low pressure in the PCV connection port 86, thus helping the flow of gases from the crank case to the carburetor through the port 87 to help scavange emissions in the crank case of the internal combustion engine and thus supporting the PCV system.

Turning now to FIG. 8 there is illustrated a further modification of the EGR valve of the present invention. The EGR valve 12 of FIG. 8 is essentially like the valve of FIGS. 2-5 except that it incorporates a dual plate valve construction. In addition, to the valve 70, there is provided a valve 69. As seen from FIG. 9, plate valve 69 is very much like the valve plate 70 except that the hole 68 in the center thereof is larger than the hole 71 in the plate 70 and the outer diameter of valve plate 69 is larger than that of plate valve 70. Both valves 69 and 70 are guided by suitable guide means for movement toward and away from openings 58 in the separator plate and conduit 61 as for example, by the guide pins 72.

The dual plate valve unit 12 shown in FIG. 8 operates in substantially the same manner as the single valve unit shown in FIGS. 2-5 except that at high speed cruise operation, as shown particularly in FIG. 12, plate valve 69 is pressed tightly against the separator plate 50, closing the openings 58 to fluid flow, namely the exhaust gas and/or air. The plate valve member 69 is slightly larger in area than the plate valve member 70 and has a larger hole 68 in the center thereof, which reduces the vacuum effect, thus making the plate valve 69 more responsive to exhaust pressure. At the high speed cruise mode of engine operation, the exhaust pressure forces the plate valve 69 tightly against the separator plate 50, thus increasing the pressure between the plate valves 69 and 70, which in turn forces more exhaust gases through the metering hole 71 in the plate valve 70. This provides more exhaust gas recirculation under the carburetor 20 and less through the air cleaner 22, thus eliminating the reduction in volumetric efficiency caused by recirculating hot gases into the carburetor inlet.

During low speed cruise (FIG. 13), the exhaust gases entering the valve body 46 are of low volume and pressure. Therefore exhaust gases are drawn through the metering hole 71 in the valve member 70 and enter the intake manifold 18 under the carburetor 20. In this low speed cruise mode, the plate valve 69 pulsates toward and away from its seat due to the positive and negative pressures in the exhaust manifold. This allows fresh air to enter the valve body 46 through openings 58 in separator plate 50 where it is mixed with the exhaust gases and then drawn through metering hole or orifice 71 into the intake manifold 18.

FIG. 10 discloses the positions of the valve plates 69 and 70 during the idle mode and deceleration mode of operation. FIG. 11 illustrates the position of the valves 69 and 70 during the acceleration mode of operation. FIG. 12 shows the valves 69 and 70 during the high speed cruise mode of engine operation. FIG. 13 indicates the position of the valves at the low speed cruise mode of operation.

It will be understood that the exhaust gas recirculating valve can be mounted on the exhaust manifold, the heat riser or the header pipe. Exhaust gas should enter the EGR valve from the exhaust manifold, heat riser, or exhaust pipe.

Turning now to FIGS. 14-21 there is illustrated an improved form of exhaust gas recirculating valve. The structure of the valve 112 is very much like that of the valve 12 except that the two disc or plate valves 169 and 170 are disposed on opposite sides of the separator plate 150, whereas in the embodiment of FIGS. 10-12 the dual plates 69 and 70 are on the same side of the separator plate.

The operation of the valve will now be considered and it is believed that the changes and improvements in the structure will be apparent hereafter. In FIG. 14 there is illustrated the position of the components during the idle mode of operation. During idle operation, the plate valve 169 is seated tight against the seat at the end of the conduit 161 and the plate or poppet valve 170 is up against the separator plate 150, such that there is a full flow of fresh air from the conduit 156, through the inlet portion 154 and the ports 158 in the separator plate 150. Some of the fresh air will pass through the metering orifice 168 in the plate valve 169 and flow through the conduit 161 to the pressure nozzle 36 from which it ends up in the intake manifold 18. Some of the fresh air, due to the pulsating action created in the exhaust manifold, travels back to the exhaust manifold and then up through the engine exhaust valves, during the overlap period and back into the cylinder where it is mixed with the incoming charge of fuel-air mixture.

With reference to FIG. 15 there is illustrated the position of the plate valves 169 and 170 during the acceleration mode of engine operation. The exhaust gases force the plate valve 169 against the separator plate 150, thereby closing the passages 158 and 158c in the separator plate 150 to the flow of exhaust gases. The exhaust gases reach a pressure of anywhere from 1 to 7 psi depending on the rpm of the engine and the exhaust muffler system. These exhaust gases are then allowed to travel up through the conduit 161 which is wide open, since the plate valve 169 is off of its seat at the end of the conduit 161. The gases can flow to the PCV system and then into the intake manifold. No fresh air enters the system during the acceleration mode of engine operation, since the valve 170 is against its seat 113 formed within the cover portion 154 of the housing 112.
Reffing to FIG. 16 there is illustrated the EGR valve 112 during the high cruise mode of engine operation. When the engine is operated at or above 50 to 60 miles per hour (high cruise operation), the plate 169 is up against its seat at the end of the conduit 161 due to the intake manifold vacuum which may be on the order of 10 to 16 inches mercury (Hg). Exhaust gas pressure seats valve plate 170 against seat 113. The exhaust gases entering the EGR system pass into the intake manifold and are then metered through the metering orifice 168 within the plate 169. It is to be noted that the metering orifice 168 in the plate 169 has a characterized orifice therein, the area of which is determined by the displacement of the engine with which the EGR valve 112 is used. The area of the opening 168 is in direct proportion to the cubic displacement of the engine. As shown, the poppet valve or plate valve 170 is seated against the seat 113. The exhaust pressures become sufficiently high so that they force the poppet valve closed and build up a pressure in the EGR chamber 160, thus forcing more exhaust gases through the metering orifice 168. Valve 170 functions to cut off the flow of exhaust gases and prevent them from going back through the fresh air system into the air cleaner where they might enter the carburetor and then cause over-rich air-fuel mixtures.

In FIG. 17 there is illustrated the positions of the valve components during the deceleration mode of operation of the engine. The plate valve 169 is set tight against its seat at the end of the conduit 161 due to the high intake manifold vacuum. Fresh air is allowed to enter the EGR valve 112 through the inlet portion 154 and the ports 158 in the separator plate 150. The poppet valve 170 is up tight against the separator plate 150, permitting the free flow of fresh air into the EGR system. The fresh air entering the EGR valve 112 travels through the orifice 168 in the plate 169 and into the velocity nozzle where it enters the intake manifold and thus reduces the high vacuum in the carburetor idling circuit. This reduces the fuel-air ratio during deceleration. Also, fresh air is allowed to enter the port or passage within the inlet portion 154 and pass through the conduit 148, thus reducing the pumping action caused by the pistons when the throttle valve is closed and there is no place for the cylinders to pull fresh air back through the exhaust system and through the exhaust valve during the overlap period into the cylinder, where it will mix with the incoming over-rich air-gas mixture, thus making a combustible fue-air mixture. Combustion does take place, thereby lowering the formation of hydrocarbons and carbon monoxide.

We refer to FIG. 18 there is illustrated the position of the valves 169 and 170 within the EGR valve 112 during the lower cruise mode of operation. The poppet valve 170 is pulsating off its seat and thus the exhaust gases and fresh air entering the EGR valve 112 through the inlet portion 154 may pass through the openings 158 and through the orifice 168 in the plate valve 169 seated against the conduit 161 into the conduit 161 and then to the intake manifold. At the same time, because of the pressure differential within the EGR valve 112, exhaust gases from the conduit 148 may enter the chamber within the EGR valve 112 below the metering orifice 168 and pass through the metering orifice to the velocity nozzle. In the low cruise mode of operation all fresh air and exhaust gases enter the velocity nozzle through the metering hole or orifice 168 in the center of the plate 169.

Turning to FIG. 20 there is illustrated a plan view of the separator plate 150. It is seen that there are a central plurality or inner circle of holes 158a of a smaller size and an outer circle of holes 158 of a larger size. Also, a plurality of holes 173 are provided near the peripheral edge of the separator plate 150 for receiving the screws 152 which secure the intake portion 154 to the main body 146 of the EGR valve 112. If desired, the inner circle of holes 158a can be replaced by a single central hole.

Turning to Figs. 19 and 21 there is better illustrated the construction of the housing 112 and showing the means for guiding the movement of the plate valves toward and away from their respective seats. From FIG. 19 it is evident that the plate valve 169 is a generally solid or imperforate plate member having a central metering orifice 168 therein. Inwardly extending projections or guide means 180, 181, 182 and 183 are provided on the side walls of the housing 146 in order to guide the movement of the plate 169 toward and away from its seat at the end of the conduit 161. In some environments it has been found that this means of guiding the plate 169 is as functional as if pins were to be secured to the interior of the housing and/or separator plate and passed through suitable holes in the plate valve 169 for guiding same.

Turning to FIG. 21 it is seen that a similar guide means are provided for guiding the valve 170 toward and away from its seat 113. A plurality of projections 186, 187, 188 and 189 extend upwardly from the bottom of the inlet portion 154. The internal diameter of the innermost surface of the guide means 186, 187, 188 and 189 is spaced just outwardly of the maximum diameter of the reed valve 170. The guide means thus retain the plate or poppet valve 170 for movement toward and away from its seat with a minimum of friction.

With reference to FIG. 22, there is shown schematically an improved exhaust gas recirculating system which includes in addition to the aforesaid EGR valve and velocity nozzle, a vacuum advance control mechanism inserted into the tube or conduit connecting the carburetor with the distributor vacuum advance diaphragm. The vacuum advance control mechanism is separately described and claimed in the copending application of Milford M. Scott, Case No. 72, 782, filed on the same date as this application. Essentially the tube mechanism 204 of distributor 30 has a bleed orifice means 203 for bleeding air into the vacuum advance system so as to retard the spark advance and help reduce formation of pollutants.

Referring to FIG. 23, there is shown further modification of exhaust gas recirculating valve. The exhaust gas recirculating valve 212 is functionally like the valve 112 of FIGS. 14-18, with some structural improvements. The valve seats 261 and 213 are formed from a suitable material, for example, stainless steel, and cast into the body or housing 246 and the cover 254, respectively. The guide means comprises pins 272 which are secured to the separator plate 250 and extend into recesses in the body 246 and cover 254 for retaining the ends of the pins 272. The pins 272 extend through holes in the plate 269 and the lower portions of the pins function to cage or guide the plate 270.
Tests using vehicles modified with the exhaust gas recirculating means of FIG. 22 have shown marked reductions in emissions. Three recent tests are tabulated below. Each test employs the California Air Resources Boards CVS–1 Hot Start Standards. The results are expressed in grams per mile. Chart I tabulates results for a 1969 Ford Mustang having a 302 CID engine, a 2-venturi carburetor with automatic transmission. Chart II tabulates results for a 1969 Plymouth 440 CID engine, 4-venturi carburetor, with automatic transmission. Chart III tabulates results for a 1970 Ford Maverick, 170 CID engine, 1-venturi carburetor, with automatic transmission. More extended preliminary tests completed for the California Air Resources Board on or about Oct. 25, 1972 substantiate the specific data presented in the following Charts I, II and III.

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<td>–19</td>
<td>–26</td>
<td>+5</td>
<td>–49</td>
<td>–56</td>
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There has been provided by the present invention an improved emission control system using exhaust gas recyling for reducing pollutants formed during engine operation without materially adversely affecting engine performance, power and economy. The disclosed system reduced peak cycle temperatures in the cylinders, the burning rate is controlled, and nitrogen oxide emissions are reduced. Essentially the disclosed system includes an EGR valve incorporating a single plate valve or dual plate valve which provides control of the amount of exhaust gas recirculated and the amount of fresh air bled in from atmosphere, said EGR valve system being automatically self-responsive to the differential pressures of the exhaust manifold, the intake manifold and the ambient of fresh air.

While presently preferred embodiments of the invention are shown in relation to a four-cycle internal combustion engine with carburetor(s) fueled by gasoline, it will be apparent to those skilled in the art, that the invention can be applied to both internal and external combustion engines powered with liquid or gaseous fossil fuels, as well as engine equipped with fuel injectors and/or superchargers, diesel engines rotary engines and all such embodiments as applied to two-cycle engines.

It will be understood that the foregoing details are given for the purposes of illustration and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

What is claimed is:

1. In an internal combustion engine that uses the compressing of a fuel-air mixture comprising an exhaust manifold means, intake manifold means and carburetor means, exhaust gas recirculating means for regulating the flow of a portion of the exhaust gases from the exhaust manifold to the intake manifold in automatic self-response to atmospheric pressure, intake manifold pressure and exhaust manifold pressure, so as to reduce the formation of pollutants formed within the internal combustion engine, the improvement wherein said recirculating means includes an exhaust gas recirculating valve being open to fresh air from the carburetor means and having plate valve means for controlling the flow of the exhaust gases and/or fresh air, and terminate flow of exhaust gas to the carburetor means during selected modes of engine operation.

2. The arrangement of claim 1 wherein the recirculating means includes a velocity nozzle for introducing fresh air and exhaust gases into the intake manifold and for scavenging the crank case gases of the internal combustion engine.

3. The arrangement of claim 2 wherein said exhaust gas recirculating valve is disposed between the intake manifold means and the exhaust manifold means.

4. The arrangement of claim 2 wherein said exhaust gas recirculating valve is disposed between the intake manifold means and the exhaust pipe means.

5. The arrangement of claim 2 wherein said exhaust gas recirculating valve is disposed between the intake manifold means and the heat riser means.

6. The arrangement as in claim 1 wherein the internal combustion engine includes a PCV valve and the velocity nozzle is disposed between the intake manifold, the PCV valve and the exhaust gas recirculating valve.

7. The arrangement of claim 6 wherein the exhaust gas recirculating valve includes a separator plate having openings therethrough and said recirculating valve including outlet to the intake manifold means, said plate valve means movable within said exhaust gas recirculating valve so as to control flow through said openings in said separator plate and said outlet.

8. The arrangement as in claim 7 wherein a metering orifice is provided in the plate valve means, said metering orifice permitting controlled flow even though the plate valve means is closing the said intake manifold means outlet.

9. The arrangement as in claim 7 wherein a metering orifice is provided in the plate valve means, the area of said metering orifice being a function of engine displacement.

10. The arrangement as in claim 1 wherein the exhaust gas recirculating valve includes a separator plate having openings therethrough, an inlet from the carburetor means, an outlet to the intake manifold means, and an inlet from the exhaust manifold means, said valve movable within said exhaust gas recirculating valve between said separator plate and said outlet to the intake manifold means, and guide means in said exhaust gas recirculating valve for guiding movement of said plate valve means toward and away from the separator plate and said outlet to the intake manifold means, respectively.

11. The arrangement as in claim 10 wherein the guide means comprise pins extending substantially perpendicularly to the separator plate and outlet.

12. The arrangement as in claim 10 wherein the guide means comprise projections in the exhaust gas recirculating valve disposed about the plate valve means and cooperating with the periphery thereof.
13. The arrangement as in claim 1 wherein the exhaust gas recirculating valve includes a separator plate having openings therethrough an inlet from the carburetor means, an outlet to the intake manifold means and an outlet from the exhaust manifold means, and two plate valves disposed in the exhaust gas recirculating valve for controlling flow therethrough.

14. The arrangement as in claim 13 wherein the two plate valves are disposed between the separator plate and the outlet to the intake manifold means.

15. The arrangement as in claim 13 wherein the two plate valves are disposed on opposite sides of the separator plate.

16. The arrangement as in claim 15 wherein a first plate valve is between the separator plate and the intake manifold means outlet and a second plate valve is between the separator plate and inlet from the carburetor means, and the chamber formed between the separator plate and exhaust gas recirculating valve body containing the first plate valve communicates with the exhaust manifold means inlet.

17. The arrangement as in claim 16 wherein the first plate valve has a metering orifice to permit flow there through when the first plate valve is seated closing said outlet to said carburetor means.

18. The arrangement as in claim 16 wherein the area of the metering orifice is a function of the displacement of the internal combustion engine.

19. The arrangement as in claim 6 wherein the velocity nozzle includes a body having a passage therethrough communicating at one end with the PCV valve and at the other end with the intake manifold means, and an induction inlet communicating with the outlet to the intake manifold means in the exhaust gas recirculating valve, with the flow through the induction inlet into the said passage in the velocity nozzle inducing a low pressure in the PCV system to help scavange emissions from the crank case of the internal combustion engine.

20. In an engine that uses the compressing of a fuel-air mixture comprising exhaust manifold means, intake manifold means, and fuel induction means, exhaust gas recirculating means for regulating the flow of a portion of the exhaust gases from the exhaust manifold means to the intake manifold means in automatic self-response to atmospheric pressure, intake manifold pressure, and exhaust manifold pressure, so as to reduce the formation of pollutants including oxides of nitrogen formed within the engine, characterized by said exhaust gas recirculating means including a body with a first passage communicating with the fuel induction means, a second passage communicating with the intake manifold and a third passage communicating with the exhaust manifold, said recirculating means controlling the flow of the exhaust gases and/or fresh air, and terminating flow of exhaust gases to the fuel induction means during selected modes of engine operation, a separator plate having openings therethrough in said body, and plate valve means movable within said body, so as to control flow of exhaust gases and fresh air through said body, and guide means in said body for guiding movement of said plate valve means.

21. In an internal combustion engine that utilizes the compressing of a fuel-air mixture comprising an exhaust manifold means, intake manifold means, and carburetor means, exhaust gas recirculating means for regulating the flow of a portion of the exhaust gases from the exhaust manifold to the intake manifold in automatic self-response to atmospheric pressure, intake manifold pressure, and exhaust manifold pressure, so as to reduce the formation of pollutants including oxides of nitrogen formed within the engine, characterized by said exhaust gas recirculating means including an exhaust gas recirculating body with a first passage communicating with a carburetor means, a second passage communicating with the intake manifold, and a third passage communicating with the exhaust manifold, said exhaust gas recirculating means controlling the flow of the exhaust gases and/or fresh air, and terminating flow of exhaust gas to the carburetor means during selected modes of engine operation, said exhaust gas recirculating body including a separator plate having openings therethrough, and an opening communicating with the carburetor means, and an opening communicating with the intake manifold means and an opening communicating with the exhaust manifold means, and two plate valves disposed within the exhaust gas recirculating body for controlling flow therethrough.

22. The arrangement as in claim 21 wherein the two plate valves are disposed on opposite sides of the separator plate and guide pins are disposed in the separator plate for guiding the movement of the two valve plates.

23. The arrangement as in claim 22 wherein the guide pins extend through complementary openings in one plate valve and cage the periphery of the other plate valve.

24. The arrangement of claim 6 wherein the internal combustion engine includes a carburetor and a distributor with a vacuum diaphragm, a vacuum advance line communicating the carburetor and vacuum diaphragm, and means for bleeding air into the vacuum advance line in order to retard the vacuum advance that would otherwise be obtained at a given speed of the internal combustion engine and help reduce formation of pollutants.

25. The arrangement of claim 20 including a distributor with a vacuum diaphragm and a vacuum advance line communicating the fuel induction means and the vacuum diaphragm, and orifice means for bleeding air from the atmosphere into the vacuum advance line to retard spark advance and help reduce formation of pollutants.

26. The arrangement as in claim 22 including a metering orifice provided in one plate valve, with an aligned opening in the other plate valve being of larger cross-section than said metering orifice, said other plate valve being of larger area than said one plate valve, whereby said other plate is more responsive to exhaust manifold pressure.