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[11] **3,809,042**

[45] **May 7, 1974**

[54] **INTERNAL COMBUSTION ENGINE EQUIPPED WITH MEANS FOR REDUCING THE AMOUNT OF NITROGEN OXIDE WHICH IS EXHAUSTED FROM THE ENGINE**

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[21] Appl. No.: **136,529**

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[52] **U.S. Cl.** .... **123/148 C,** 123/148 DS, 123/148 E
[51] **Int. Cl.** **F02p 3/06**
[58] **Field of Search** ..... 123/148 C, 8.09, 191 S, 123/148

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[57] **ABSTRACT**

An internal combustion engine for vehicles equipped with means for reducing harmful exhaust gases, especially nitrogen oxide, in which a first ignition plug and a second ignition plug are so installed in the combustion space of the engine that the combustion characteristic of the first plug is superior to that of the second plug. Either or both of these plugs are differently operated in accordance with the nitrogen oxide content in the exhaust gas.

9 Claims, 11 Drawing Figures

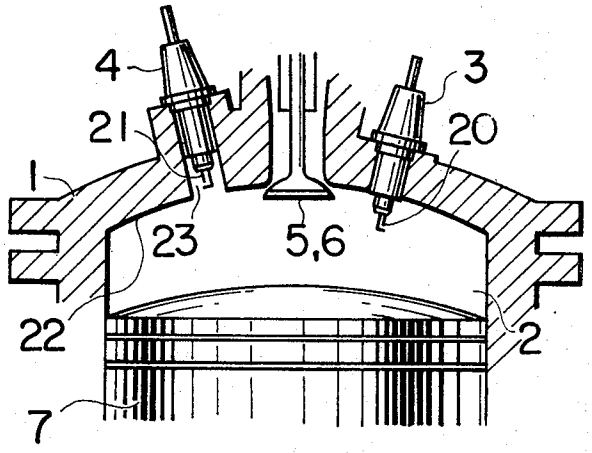

FIG. 1

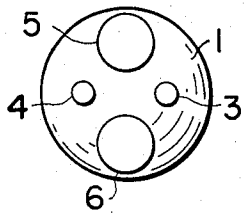

FIG. 3

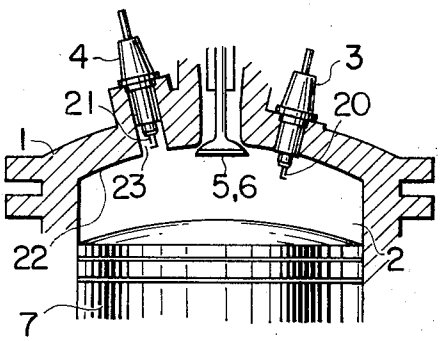

FIG. 2

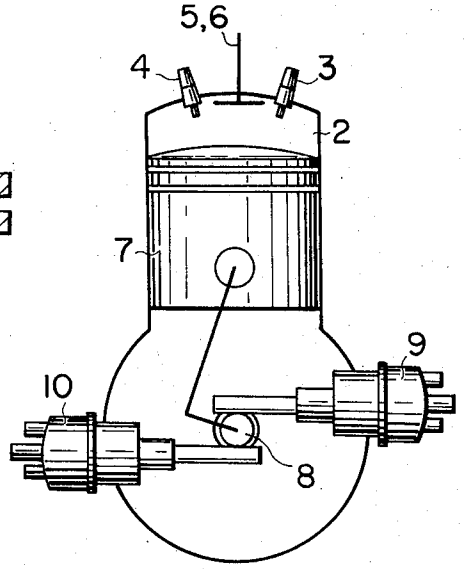

FIG. 4

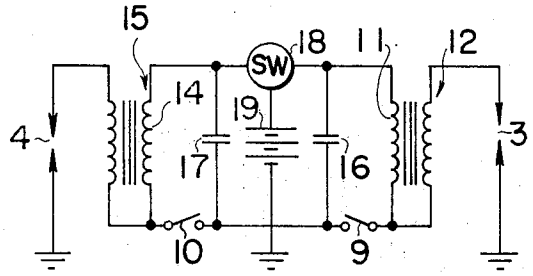

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FIG. 5a

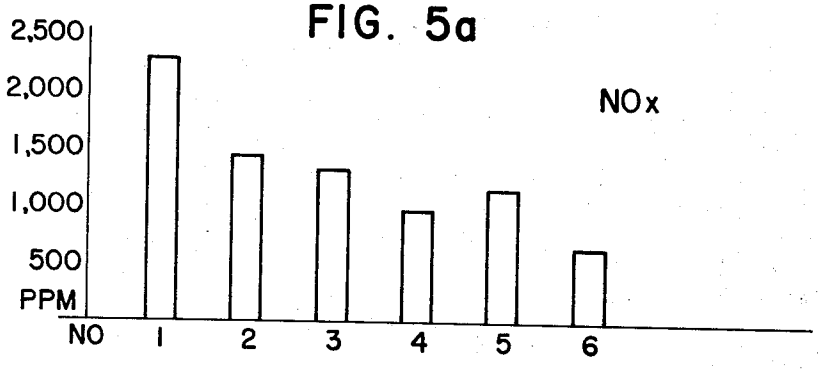

FIG. 5b

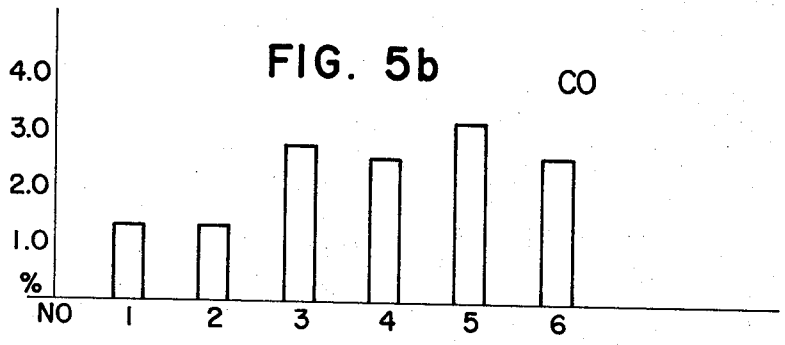

FIG. 5c

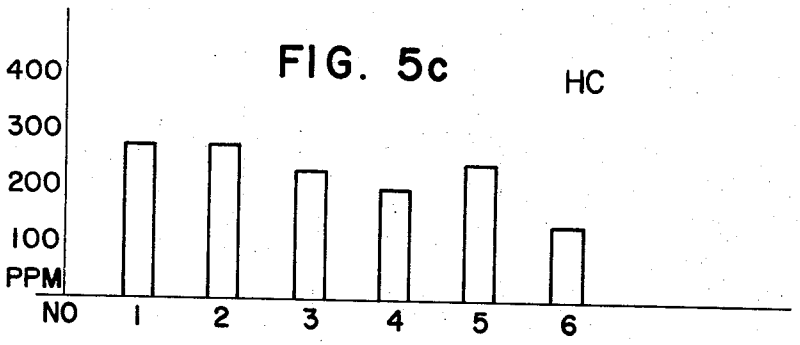

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FIG. 6a

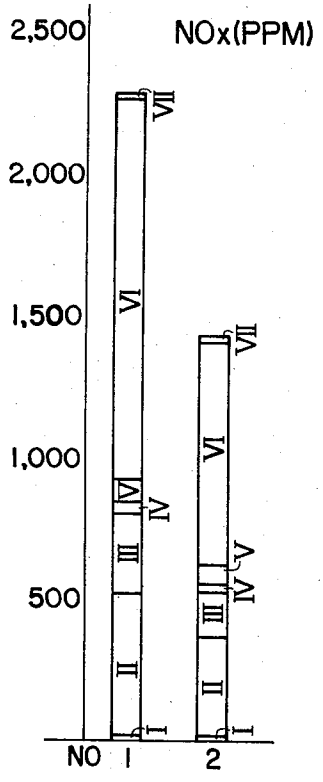


FIG. 6b

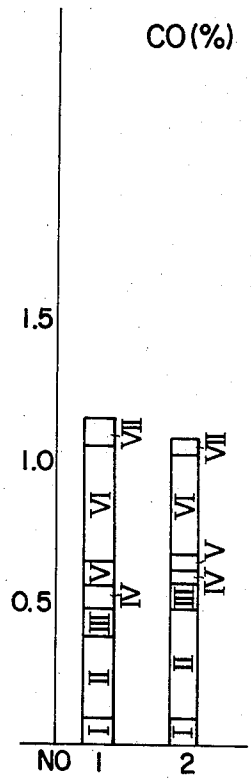


FIG. 6c

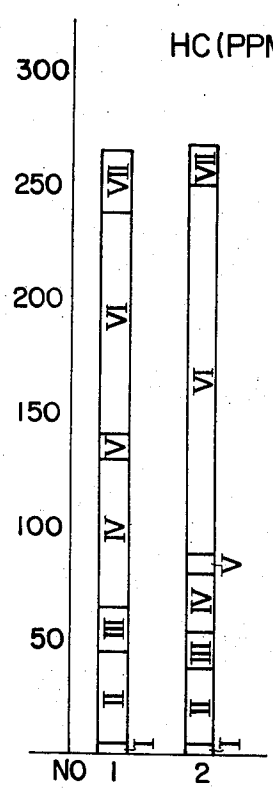
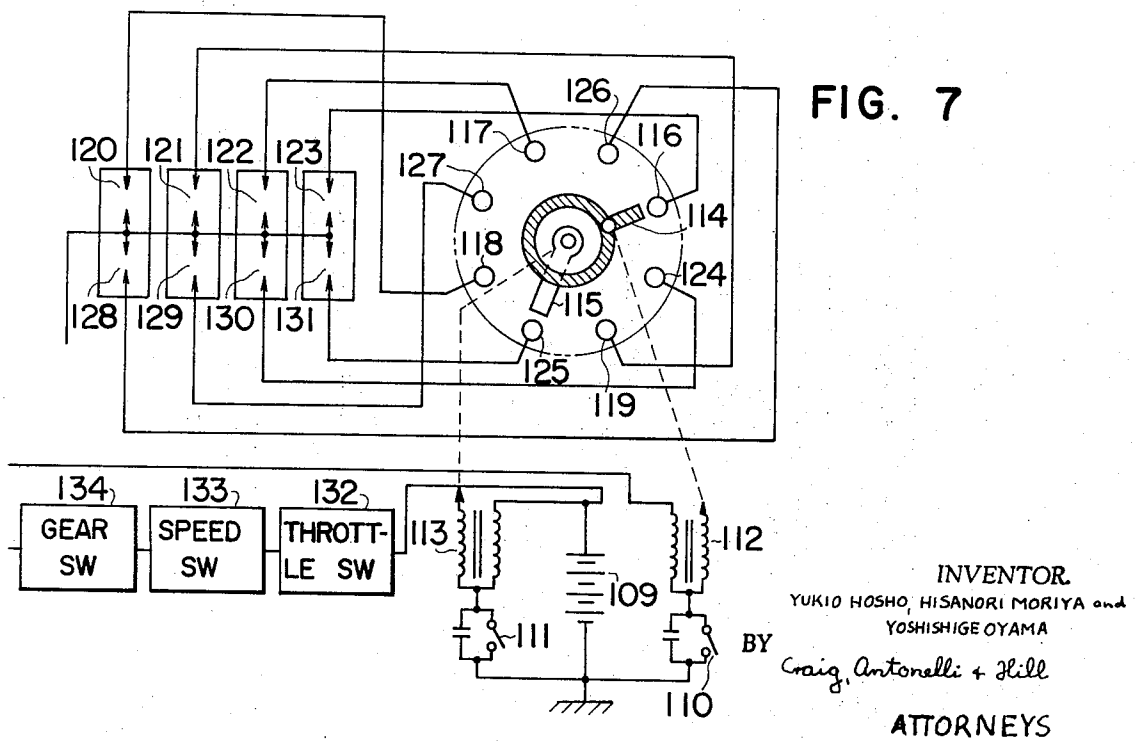


FIG. 7



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INTERNAL COMBUSTION ENGINE EQUIPPED WITH MEANS FOR REDUCING THE AMOUNT OF NITROGEN OXIDE WHICH IS EXHAUSTED FROM THE ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an internal combustion engine equipped with means for reducing the nitrogen oxide content in the exhaust gas thereof without increasing the amount of other harmful substances, such as carbon monoxide and hydrocarbons.

2. Description of the Prior Art

The problem of air pollution owing to an extraordinary increase in the number of automotive vehicles in city traffic has become a big social problem everywhere in the world; as a result, it has been decided to restrict the contents, not only of hydrocarbons and carbon monoxide in the exhaust gases, but also of nitrogen oxide (NO_x) because of the formation of smog by the photochemical reaction in the air and of its stimulative affectation of the eyes of human beings.

Incidentally, as is known, the production of the hydrocarbons and carbon monoxide takes place due to an insufficiency of combustion in the cylinders of the engine and, therefore, it is possible to considerably decrease the amounts of these components when the combustion is carried out completely by providing a sufficient amount of air at high temperatures, and this improvement in combustion efficiency causes an increase in the thermal effect of the engine.

In contrast thereto, since a lowering of the maximum combustion temperature has a tendency to suppress an increase of the combustion efficiency of the engine to prevent, as a result thereof, the formation of of nitrogen oxide in the exhaust gas, the following measures have been proposed heretofore as solution to the above problems:

1. controlling the spark advance;
2. providing such a mixture gas as avoids the peak air-fuel ratio;
3. recycling a part of the exhaust gas;
4. injecting water; and
5. employing a catalytic converter.

The above systems, however, are not yet practicable because they involve different problems. That is, in the case of changing the spark advance, the tendencies of a decrease in the output power and of an increase in the fuel cost in proportion to the reduction in the rate of nitrogen oxide are great and, furthermore, the value of the decrease in nitrogen oxide can not be made as large as is desired because the angle through which a change can be effected is limited at most to 10°. In the system of changing the mixing ratio of air-fuel, when the gas mixture is relatively thin or lean, an ignition failure takes place frequently causing an instability of the number of revolutions of the engine, whereas, to the contrary, when the gas mixture is relatively rich, the contents of hydrocarbons and carbon monoxide in the exhaust gases become large and the fuel cost increases.

In the system of recycling the exhaust gas in which a part of the exhaust gas is subjected to reintroduction into the engine by the suction effect of the latter, the ignition becomes unstable due to the presence of the uncombusted substances and, furthermore, carbon or

tar-like substances tend to be deposited in the suction pipe, suction vane, etc. Furthermore, in the water injection system, it is necessary to use as much water as fuel, and the apparatus for controlling the amount of water increases the cost of the vehicle. Finally, a catalytic system satisfying the desired purifying ability and the required service life has not been developed.

Among the above-mentioned systems, the system for recycling the exhaust gas is rather useful in view of the rate of decreasing the amount of nitrogen oxide and of the small decrease in the output loss, and such a device combined with both the mixing-ratio-changing system and the ignition-control system is therefore believed at present to be most available and practicable. In such a system, however, the drawbacks involved in the recycling system necessarily remain. The foregoing describes the present condition in connection with the measures involving the nitrogen oxide problem.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system for reducing the nitrogen oxide content in the exhaust gases of an internal combustion engine without increasing the amount of other harmful substances.

It is another object of the present invention to provide an internal combustion engine equipped with a system for remarkably reducing the amount of nitrogen oxide in the exhaust gas without increasing a loss of output power.

It is still another object of the present invention to provide such an apparatus for reducing nitrogen oxide as will produce no increase or only an extremely small increase in the contents of hydrocarbons and carbon monoxide in spite of a large decrease in the content of nitrogen oxide in the exhaust gas, so that all the problems owing to the above-mentioned harmful substances can be solved in an effective manner.

It is still another object of the present invention to provide a system for reducing the harmful substances in the exhaust gases substantially without any contamination within the engine.

It is a still further object of the present invention to provide an internal combustion engine equipped with such a nitrogen-oxide-reducing system as will not deteriorate the operation of the engine.

The present invention provides an internal combustion engine equipped with a system for reducing or suppressing the production of nitrogen oxide as well as for exhausting hydrocarbons and carbon monoxide, in which a combustion chamber is provided with a pair of ignition plugs different from each other with respect to their combustion characteristics, each of both of them being operated in accordance with the condition of the engine operation, whereby the nitrogen oxide content in the exhaust gas is reduced.

The foregoing objects as well as other objects, features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the attached drawings, in which:

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a plan view of a cylinder head embodying the present invention;

FIG. 2 is a vertical cross-sectional view of a cylinder embodying the present invention;

FIG. 3 is a vertical cross-sectional view of the important portion of the cylinder shown in FIG. 2;

FIG. 4 is a circuit diagram for an ignition device according to the present invention;

FIGS. 5*a* to 5*c* are graphs, respectively showing the content of nitrogen oxide, carbon monoxide and hydrocarbons in the exhaust gas from conventional engines of the prior art and from engines according to this invention, which are operated continuously;

FIGS. 6*a* to 6*c* are graphs, respectively showing the content of nitrogen oxide, carbon monoxide and hydrocarbons in the exhaust gas from conventional engines of the prior art and from engines according to this invention, which are operated under various conditions; and

FIG. 7 is a circuit diagram of another embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIGS. 1 to 4, a cylinder head 1 is provided with a pair of ignition plugs 3, 4, an intake valve 5 and an exhaust valve 6. The ignition plugs 3, 4 are disposed within a combustion space 2 to ignite the fuel which is present therein. A piston 7 connected through a suitable connecting means, such as a crank means, to shafts of distributors 9, 10, reciprocates in a cylinder.

The ignition plug 3, an ignition coil 11 and the distributor 9 constituting a first ignition means generally designated by reference numeral 12, and the ignition plug 4, an ignition coil 14 and the distributor 10 constituting a second ignition means generally designated by reference numeral 15, each include a respective condenser 16, 17, which are alternately connected through a conventional change-over switch 18 to a battery 19 (FIG. 4). In the first ignition means 12 an ignition portion 20 of an electrode of the ignition plug 3 projects into the combustion space 2 in a conventional manner, whereas, in contrast thereto, the ignition plug 4 is placed within a recess 23 formed in a cylinder wall 22 so as not to project with the ignition portion 21 of an electrode of the ignition plug 4 into the combustion space 2.

In the above construction, under operating conditions as will cause the amounts of nitrogen oxide in the exhaust gases to be large, for example, in the case of a small-load, high-speed operation or of an acceleration operation, only the second ignition means 15 is operated. In the other operating conditions, only the first ignition means 12 or both ignition means are operated. Since the control of the spark plugs 3 and 4 in the manner described above can be achieved by conventional means responsive to load and/or speed or acceleration, a detailed description thereof is dispensed with herein, especially as the engine parameters, such as vacuum in the intake manifold, etc., are known to those skilled in the art, which can be used as control magnitudes.

The volume and shape of the recess 23, in which the ignition plug 4 of the second ignition means is disposed, are properly determined and chosen in accordance with experiments; in any case the combustion characteristics of the second ignition means 15, i.e., the combustion characteristics that are imparted by the ignition means 15 including its ignition plug 4 to the gas mixture in the combustion space 2, must be made inferior to those of the first ignition means 12. For example, such a relationship between the two ignition means 12 and 15 is realized that the flame propagation speed, which is the speed of the flame propagation from the position of the electrode 21 of the ignition plug 4 over the entire combustion space 2, is made smaller than the speed obtained with the first ignition means 12. The above relationship is established by taking into consideration the desirability not to excessively increase the contents of carbon monoxide and hydrocarbons in the exhaust gases and not to lower the output power of engine.

Various ways and means of conventional nature exist which permit to determine the correct ignition times for the two ignition means 12 and 15, i.e., the operating condition of the change-over switch 18, taking into due consideration the running condition in city traffic, where the congestion of traffic is heavy, and the running condition in the country, where the exhaust gases do not represent as severe a trouble as in city traffic, or such items as stability of engine rotation, fuel-cost efficiency and output power, etc. For example, the ignition time can be decided by detecting the opening degree of a throttle valve and/or the back pressure, and/or by using the changing in the transmission and/or by adding the temperature condition of the engine to any of the foregoing parameters. As stated above, the ignition time condition is thus chosen by conventional means in accordance with the conditions of exhaust gas restrictions. Since switches 18 performing these functions are known in the art and are available, a detailed description thereof is also dispensed with herein.

The analytical results of the exhaust gas contents are shown in FIGS. 5*a* through 6*c*, in which an engine embodying the present invention has a capacity of 1,200 cubic centimeters.

In FIGS. 5*a* through 6*c*, data Nos. 1 and 2 show the results in connection with the engines provided with the same ignition means. In FIGS. 5*a* to 5*c*, data No. 1 relates to such engines as are of the ordinary type with respect to the diameter of the main jet of the evaporator, the position of the ignition plug and the spark advance, which corresponds to the first ignition means according to the present invention. On the contrary, data No. 2 relates to an ignition means in which the portion of the electrode 21 of the ignition plug 4 is recessed by 90 millimeters as compared with the conventional one, i.e., this arrangement of the ignition means corresponds to the second ignition means 15.

In the case of data Nos. 3 and 5, only the diameter of the main jet of the evaporator is changed as compared with that of the engine of data No. 1; in the case of data No. 4, the position of the ignition plug as used in data No. 3 is changed, and in the case of data No. 6, the position of the ignition plug of that of data No. 5 is changed and the ignition time is delayed by 10 degrees in angle as compared with that of data No. 5.

According to FIGS. 5*a* to 5*c*, it will be appreciated that a considerable reduction of the nitrogen oxide amount is attained and, furthermore, by combining the second ignition means with such changes as changes of the diameter of the main jet and the spark advance, it is possible to remarkably reduce the amount of nitrogen oxide. According to the present invention, the amounts of carbon monoxide and hydrocarbons do not change unfavorably, but rather decrease.

In the conventional systems, if the amount of nitrogen oxide is decreased, there exists a tendency for the amount of other harmful components to become remarkably large; however, there is no such undesirable relationship in the present invention.

There are shown in FIGS. 6*a* to 6*c* the analytical results of the amounts of nitrogen oxide, carbon monoxide and hydrocarbons in the exhaust gas, in which the tests were performed by changing the running conditions of the vehicle. According to FIGS. 6*a* to 6*c*, the largest amount of nitrogen oxide is found in the acceleration run, and it is appreciated that the reduction of the amount of nitrogen oxide is considerable when the present invention is employed. In connection with the amounts of carbon monoxide and hydrocarbons, a small change of the amount of carbon monoxide is produced, and the amount of hydrocarbons seems to become slightly larger. However, the amounts of these substances can be easily reduced by any suitable means and in any conventional manner, such as, for example, by blowing air for recombustion into an exhaust pipe. Thus, it is possible to reduce the amounts of nitrogen oxide, hydrocarbons and carbon monoxide to operate the second ignition means during acceleration running conditions and to operate the first ignition means during other running conditions. It is, of course, possible for effecting the reduction of nitrogen oxide in the operation other than the acceleration to determine the position of the ignition plug, the shape of the recess or the like of the second ignition means.

In FIGS. 6*a* to 6*c*, the running conditions are as follows:

I: idling
II: acceleration running (0 → 25 mile/hr.)
III: constant running (30 mile/hr.)
IV: deceleration running (30 → 15 mile/hr.)
V: constant running (15 mile/hr.)
VI: acceleration running (15 → 30 mile/hr.)
VII: deceleration running (50 → 20 mile/hr.)

In another example, both the first and second ignition means are used during the normal running condition, but when the amount of nitrogen oxide is undesirably large, only the second ignition means is operated, whereby the efficiency of engine during the high speed running can be increased.

According to the present invention, the first and second ignition means can be so modified as to be capable of producing a proper engine efficiency during the normal running operation by means of the two ignition means and capable of allowing only the second ignition means to operate at the time when the amount of nitrogen oxide is undesirably large. Furthermore, it is possible to delay the spark advance so as to operate only the second ignition means when the amount of nitrogen oxide is large. The objects of the present invention are attained by using a single distributor which is operatively connected to both the first and second ignition means in which the spark advances of respective ignition means are so regulated as to function properly themselves.

In the following example, a distributor is connected to a pair of rotary electrodes and a pair of ignition plugs are provided with fixed electrodes. Only the first ignition plug, which is fixed as in the ordinary case, is allowed to make and break by means of a suitable switch connected to the source.

In FIG. 7, a battery **109** is connected by way of contactors **110, 111** and coils **112, 113** to rotary contacts of electrodes **114, 115.** Between the battery **109** and the coil **112** for the main plug are inserted different switches such as, for example, a throttle valve switch **132** which is operated in accordance with the opening of the throttle valve, a speed switch **133** which is operated in accordance with the vehicle speed, a gear switch **134** which is changed over in accordance with the selected speed or gear position.

Fixed contacts or electrodes **116, 117, 118** and **119** are provided on the side of the main plugs, which respectively cooperate with the rotary contact or electrode **114** and are connected to the main plugs **120, 121, 122** and **123,** respectively, of the engine cylinders. Fixed contacts or electrodes **124, 125, 126** and **127** are provided on the side of auxiliary plugs which respectively cooperate with the rotary contact or electrode **115** and are connected to auxiliary plugs **128, 129, 130** and **131,** respectively. The rotary contacts or electrodes **114** and **115** are driven by a crank shaft.

According to the above-described construction, it is possible to energize both the main and auxiliary plugs or only each of the plugs by means of the single distributor. Selection of the switches to be operated is made in accordance with the characteristics of engine, the regulations of exhaust gas restriction, or other conditions. For example, in the case of the idling operation in which the opening of the throttle valve and the mixing ratio of fuel to air is small or in case that the opening of the throttle valve is large and a large output power is necessary, the throttle switch **132** for detecting the opening of the throttle valve is used in order to operate both the main plug **3** and the auxiliary plug **4.** In the case of a high speed operation, in which it is required to prevent a decrease in the amount of fuel consumption, the gear switch **134** which is operatively connected to the change-speed-gear system is used. In the case of the speed acceleration, the speed switch **133** and gear switch **134** are used by detecting the acceleration condition so as to operate only the auxiliary plug.

Further, in the case of operating the vehicle in the country where the air pollution is not as severe a problem as in city traffic, only the main plugs **3** are operated.

According to the above-described embodiments of the present invention, it is possible to greatly reduce the amount of nitrogen oxide without increasing the amounts of other harmful substances such as carbon monoxide and hydrocarbons in a reduced size system, while the conventional systems are difficult to employ in practice because they have technical or economical drawbacks.

It goes without saying that the recess for accommodating the auxiliary plug therein can be replaced by other means, such as by using such an ignition plug as has a cylindrical cover surrounding the end of the electrode and the vicinity thereof.

Although we have described specific preferred embodiments of the present invention, it is understood that the scope of the present invention is not limited thereto, but is susceptible of numerous changes and modifications as are known to those skilled in the art, and we therefore intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

What we claim is:

1. An internal combustion engine equipped with means for reducing the amount of nitrogen oxide in the exhaust gases thereof, without increasing other harmful substances such as carbon monoxide and hydrocarbons, characterized in that said means comprises first

ignition means and second ignition means, said two ignition means being operatively connected to means for changing the ignition thereof, said second ignition means being disposed in a recess communicating with a combustion space so that the combustion characteristics of said second ignition means is inferior to those of said first ignition means in order to carry out the combustion by said second ignition means at a relatively smaller rate than that in the case of said first ignition means, but to carry out the full combustion so as not to increase the amounts of carbon monoxide and hydrocarbons in the exhaust gases, said changing means operating only said second ignition means for acceleration and high speed operation of the engine such that the combustion at the time of acceleration and high speed operation is effected only by said second ignition means.

2. An internal combustion engine according to claim **1**, in which a cylinder wall of the engine is provided with said recess for accommodating an ignition plug of said second ignition means, an electrode head of said plug being retracted as compared to the normal position thereof so as to impart poor combustion characteristics to said second ignition means, and the position of an ignition plug of said first ignition means being located in the normal position.

3. An internal combustion engine according to claim **1**, in which said changing means includes means for changing over said first and second ignition means in accordance with instructions for reducing the amount of nitrogen oxide.

4. An internal combustion engine according to claim **1**, in which said first and second ignition means are so arranged that they are operated during the normal running of vehicle until an instruction for reducing the amount of nitrogen oxide and affecting the ignition of said second ignition means is given to said changing means.

5. An internal combustion engine according to claim **1**, in which each of said first and second ignition means is provided with means for advancing the ignition.

6. An internal combustion engine equipped with means for reducing the amount of nitrogen oxide in the exhaust gases of a vehicle, in which a combustion space of an engine is provided with a main ignition plug and an auxiliary plug, said main ignition plug being located in such a place where the combustion characteristics and thermal efficiency are superior to those of other places, said auxiliary ignition plug being disposed in a recess of the engine communicating with said combustion space so that the speed of flame propagation after the ignition is smaller than that of said main ignition plug, said ignition plugs being respectively connected to a single distributor means which has a pair of rotary electrodes and a pair of fixed electrodes, said main ignition plug and said auxiliary plug being operated by relay means, said relay means operating only said auxiliary plug for acceleration and high speed operation of the engine whereby the amount of nirogen oxide is properly reduced without excessively increasing the amounts of carbon monoxide and hydrocarbons during all of the running conditions of vehicle.

7. An internal combustion engine equipped with means for reducing the amount of nitrogen oxide in the exhaust gases thereof without substantially affecting the amounts of other harmful components, comprising at least one combustion chamber, first and second ignition means for each combustion space, said first and second ignition means providing different combustion characteristics for the fuel-air mixture in the combustion space, said second ignition means including an ignition plug disposed in a recess of the engine communicating with said combustion space so that the speed of flame propagation after the ignition is smaller than that of said first ignition means and control means operatively connected with said ignition means for controlling the operation thereof as a function of engine parameters affecting the contents of nitrogen oxide in the exhaust gases, said control means operating only said second ignition means for acceleration and high speed operation of said engine.

8. An internal combustion engine according to claim **1**, wherein said engine includes at least one cylinder and a piston disposed therein, and said first and second ignition means includes respectively first and second ignition plugs, said first ignition plug being disposed in the combustion space and second ignition plug being disposed in said recess in said cylinder wall.

9. An internal combustion engine according to claim **1**, wherein said changing means includes means responsive to the running condition of the vehicle.

* * * * *