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F. G. ROUNDS ET AL

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ADDITION OF FLAME MODERATORS TO COMBUSTION CHAMBERS

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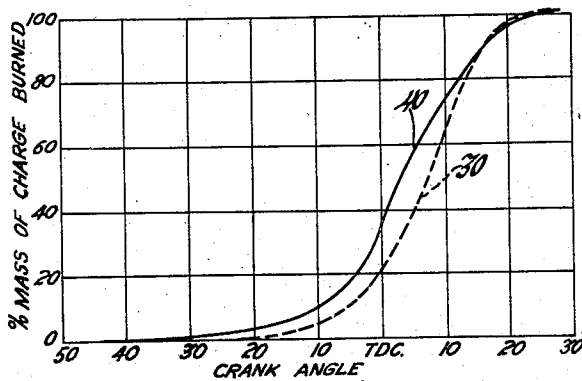
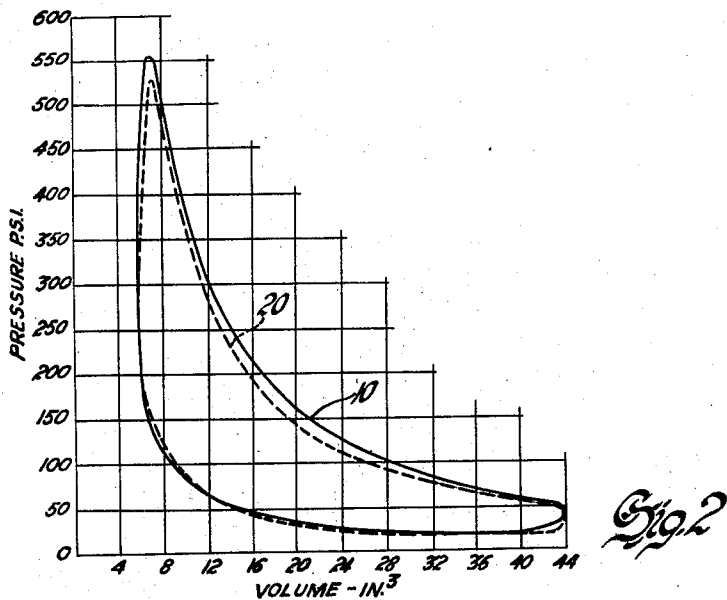
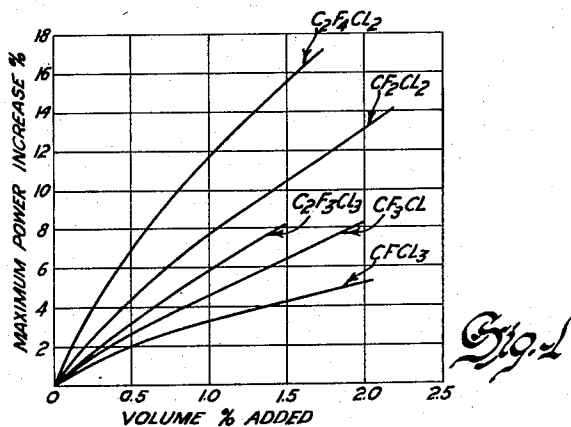


Fig. 3
INVENTORS
Fred G. Rounds &
Ralph E. Schwind
BY
Willis Helwig & Baillio
ATTORNEYS

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ADDITION OF FLAME MODERATORS TO COMBUSTION CHAMBERS

Fred G. Rounds and Ralph E. Schwind, Detroit, Mich.,
assignors to General Motors Corporation, Detroit,
Mich., a corporation of Delaware

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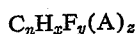
This invention relates to improvements in the operation of internal combustion engines and particularly to the introduction of controlled amounts of certain addition agents into the fuel supply system of such engines.

The principal object of this invention is to improve the performance, particularly the maximum power output and thermal efficiency, of internal combustion engines. A further object is to provide a method of regulating the combustion reactions in an internal combustion engine. Other objects and advantages of this invention will more fully appear in the description which follows.

We have discovered that the maximum power obtainable from an internal combustion engine is greatly increased by introducing fluoro-halogenated aliphatic hydrocarbons into the engine fuel supply system. The presence of the addition agents of the present invention in the combustion chamber not only improves the maximum power output of the engine but lessens engine knock and regulates the speed of the combustion reaction to provide smoother engine operation in which "roughness" and other vibrational stresses are substantially reduced.

The expression "fluoro-halogenated," as used herein, is intended to indicate halogenated aliphatic hydrocarbon compounds containing one or more fluorine atoms, as well as compounds containing one or more fluorine atoms and at least one atom of chlorine. Illustrative of the type of fluoro-halogenated compounds contemplated are the commercially available Freons which generally include such compounds as trichlorofluoromethane, dichlorodifluoromethane, trifluorochloromethane, tetrafluoromethane, dichlorofluoromethane, difluorochloromethane, tetrachlorodifluoroethane, trichlorotrifluoroethane, tetrafluorodichloroethane, and pentafluorochloroethane.

In general, the type of addition agent contemplated by the present invention is one or a mixture of compounds having the generic formula:



where

n is any positive number,
 x is a number from 0 to $2n+1$,
 y is a number from 1 to $2n+2$,
 A is a halogen other than fluorine, and
 z is a number from 0 to $2n+1$.

We have found that superior results are obtained in many instances by employing fluoro-halogenated derivatives having a ratio of fluorine atoms to carbon atoms in the molecule of about two to one. At present, we prefer to employ fluoro-halogenated compounds containing at least one atom of fluorine and one or more atoms of chlorine having boiling points not substantially in excess of the boiling point range of the fuel. Specific examples of the presently preferred addition agents are dichlorodifluoromethane and tetrafluorodichloroethane available commercially as "Freon 12" and "Freon 114" respectively.

In general, the practice of this invention contemplates

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the introduction of relatively small, controlled amounts of one or more fluoro-halogenated compounds into the engine fuel supply system. In practice, these addition agents may be introduced at any point or points in the engine fuel supply system, including mixing with the liquid fuel, introduction into the air-intake stream, addition directly into the combustion chamber, and, in a preferred embodiment, injection into the intake manifold at a point between the carburetor and the intake manifold so that the additive will be equally distributed to all cylinders yet the fuel-air ratio won't be affected.

Referring now to the drawing:

Fig. 1 is a graph illustrating the increased maximum power output in an internal combustion engine obtained by introducing controlled amounts of various fluoro-halogenated compounds to the fuel supply system;

Fig. 2 is a pressure-volume graph showing the improvement in an internal combustion engine cycle obtained by adding 1.85% by volume of dichlorodifluoromethane to the air-intake stream; and

Fig. 3 is a graph comparing the rates of burning of treated and untreated fuels in accordance with the present invention.

Referring more particularly to the drawing, Fig. 1 illustrates how the maximum power of an engine may be substantially increased by introducing relatively small, controlled amounts of various fluoro-halogenated compounds into the fuel supply system. To obtain an optimum power increase, it is necessary in many cases to alter the normal adjustment of engine spark timing. The addition of a small amount of a fluoro-halogenated compound increases the thermal efficiency and the work available from an engine as illustrated in the pressure-volume graph of Fig. 2. In this figure solid line curve 10 is obtained by operating a test engine with a 100 octane research fuel and injecting into the fuel supply system 1.85% dichlorodifluoromethane by volume of the air-intake stream. As a basis of comparison, broken line curve 20 is obtained using the same engine and the same fuel without adding dichlorodifluoromethane. It will be seen that the addition of dichlorodifluoromethane provides an engine cycle having not only a higher peak pressure but a higher pressure throughout the entire expansion portion of the cycle thus more nearly approaching the theoretical Otto cycle.

Although the chemical kinetics of the combustion reaction, together with all the complex organic and physical chemical changes occurring during combustion, are not fully understood, experimental results indicate that the fluoro-halogenated additives of the present invention improve the engine performance primarily by their effect on the rate of combustion. As shown in Fig. 3 broken line curve 30 indicates the rate of burning of a conventional research fuel charge measured in terms of the engine crank angle under normal conditions, while solid line curve 40 illustrates how the rate of burning of the same fuel is affected by the addition of 1.85% by volume of dichlorofluoromethane. Although the addition of dichlorodifluoromethane initially retards the combustion reaction, a larger amount of the fuel charge is burned rapidly near the top dead center crank position with the result that a greater amount of the energy liberated in the combustion reaction is employed to raise the peak cylinder pressure and consequently to provide a greater pressure throughout the entire expansion stroke of the piston.

In practice, we have found that a fluoro-halogenated derivative may be employed in an amount ranging from a small but effective amount up to, in certain cases, about 15% by volume of the air-intake stream. The amount to be used in a particular application depends upon such factors as the type of engine, the chemical properties of

the fuel-employed, the particular fluoro-halogenated compound used and, to a large degree, the speed of the engine. In general, since at higher engine speeds the combustion reaction time necessarily is much shorter, a larger amount of fluoro-halogenated additive is necessary.

Typically practicable amounts for an engine operating at about 1000 R. P. M. are within the range of about 0.01% to 2% by volume. The same engine operating 2000 R. P. M. may, in certain cases, require up to about 3% by volume. Normally, the amount to use would seem to be approximately proportional to the engine speed. Hence, for engines operating at about 4000 R. P. M. it may be desirable in certain cases to use as high as 6% by volume of the air-intake stream. In general, for use in typical automobile engines, experimental data indicate that excellent results are obtained in many cases using about 0.5% to 3.0% by volume of the air-intake stream.

The following data obtained by injecting 1.5% by volume of dichlorodifluoromethane into the fuel supply system of an experimental engine illustrate the improvement in maximum engine power obtained by adding fluoro-halogenated additives to hydrocarbon fuels.

Fuel:	Percent power increase
Paraffin (iso-octane) -----	8.4
Olefin (di-isobutylene) -----	6.4
Naphthene (cyclopentane) -----	5.5
Aromatic (benzene) -----	7.1

While automobile engines may operate, at times, with air-fuel ratios ranging from 8.5 to 21 pounds air per pound of fuel, in most instances the air-fuel ratio is near the theoretical air-fuel ratio of about 14.7 pounds of air per pound of fuel for typical commercial fuels. Because of difficulties encountered in fuel distribution the air-fuel ratio frequently employed is from about 12 to 17 pounds air per pound of fuel. Experimental data indicates that the addition of fluoro-halogenated compounds provide an increase in maximum power throughout the entire practical range of air-fuel ratios.

Superior results are obtained when the fluoro-halogenated additive is introduced intermittently, preferably only when needed to supply an increased power. We have found that after an injection of a fluoro-halogenated compound into the engine fuel supply system, there is a residual beneficial effect of the additive which exists, in some cases, up to as long as two hours after the introduction. In a preferred embodiment the intermittent injection of the addition agent when needed to supply an increased power is regulated by an automatic control valve operating in response to an opening of the throttle and/or to a decrease in the engine manifold vacuum. Optimum results are obtained employing a control valve of this type which additionally automatically adjusts the engine spark advance to permit obtaining maximum power increase.

In a practical application the addition agent, if a liquid, may be maintained in any suitable tank mounted on or near the engine or, if a gas, may be supplied from a standard type cylinder capable of maintaining the gaseous additive under a high pressure. It will be understood, of course, that when a gaseous additive is employed, the compressed gas cylinder will be equipped with a reducing valve to supply the gas at a lower pressure of about 1 to 10 p. s. i. In some cases it is desirable to insulate the tank or otherwise maintain it at a relatively constant temperature so that the injection may be more accurately controlled.

An example of a typical combustible mixture incorporating the invention would be a gaseous mixture of air, hydrocarbon fuel, and the added fluoro-halogenated compound, such as a mixture containing from 8.5 to 21 pounds of air per pound of hydrocarbon fuel with a fluoro-halogenated compound, such as a fluorochloro derivative, being present in an amount not in excess of about 15% by volume of the air in the mixture. This is

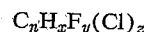
equivalent, of course, to a mixture of about 4.5% to 10.5% by weight of hydrocarbon fuel and 89.5% to 95.5% by weight of air to which a fluoro-halogenated compound has been added in an amount up to about 15% by volume of the air in the mixture.

Various changes and modifications of the embodiments of the invention described herein may be made by those skilled in the art without departing from the spirit and principles of the invention.

10 What is claimed is:

1. A method of improving the performance of an internal combustion engine comprising introducing separately into the air-hydrocarbon fuel supply system of said engine a small amount of a halogenated derivative of an aliphatic hydrocarbon containing at least one fluorine atom and one or more chlorine atoms, said derivative having a boiling point not substantially in excess of said hydrocarbon fuel.

2. A method of improving the performance of an internal combustion engine comprising introducing separately into the air-hydrocarbon fuel supply system of said engine 0.01% to 15% by volume, based on the air-intake stream, of a compound having the formula



where n is a positive number, x is a number from 0 to $2n+1$, y is a number from 1 to $2n+2$, and z is a number from 0 to $2n+1$.

3. A method of improving the maximum power output of an internal combustion engine by introducing separately into the air-hydrocarbon fuel supply system of said engine a fluoro-halogenated aliphatic hydrocarbon in which the ratio of fluorine to carbon atoms is about two to one.

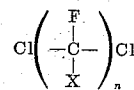
4. A method of improving the performance of an internal combustion engine comprising introducing separately into the air-hydrocarbon fuel supply system of said engine, in response to increased engine load, a fluoro-halogenated aliphatic hydrocarbon derivative having a boiling point not substantially in excess of the boiling point range of the engine fuel.

5. A method of improving the performance of a spark ignition engine comprising introducing separately into the air-hydrocarbon fuel intake stream of said engine a small amount of an aliphatic hydrocarbon derivative containing both chlorine and fluorine atoms in which the ratio of fluorine to chlorine is approximately two to one, said introduction being in response to increased engine load.

6. The method of improving the performance of an internal combustion engine comprising intermittently and separately injecting dichlorodifluoromethane into the air-hydrocarbon fuel supply system of said engine.

7. The method of improving the performance of an internal combustion engine comprising intermittently and separately injecting tetrafluorodichloromethane into the air-hydrocarbon fuel supply system of said engine in an amount equal to about 0.01% to 3% by volume of the air in said system.

8. The method of improving the performance of an internal combustion engine comprising introducing into the air-hydrocarbon fuel supply system of said engine a small amount of a compound having the structural formula



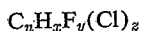
where n is a positive number, and X is selected from the group consisting of chlorine, fluorine, bromine and iodine radicals.

9. A method of improving the performance of a spark-ignition engine comprising intermittently and separately introducing into the engine intake manifold in response to increased engine load a fluoro-chlorinated compound

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in an amount within the range of about 0.01% to 3% by volume of the air-intake stream.

10. A gaseous fuel for internal combustion engines comprising a mixture of about 4.5% to 10.5% by weight of a hydrocarbon fuel, and 89.5% to 95.5% by weight of air to which has been added approximately 0.01% to 15% by volume of a fluoro-halogenated compound having the formula



where n is a positive number, x is a number from 0 to $2n+1$, y is a number from 1 to $2n+2$, and z is a number from 0 to $2n+1$.

11. A fuel for internal combustion engines comprising a gaseous mixture consisting essentially of air and a hydrocarbon fuel in a ratio of from 8.5 to 21 pounds of air per pound of hydrocarbon and containing a fluoro-halogenated derivative of an aliphatic hydrocarbon in an amount equal to about 0.01% to 15% by volume of said air.

12. A fuel for internal combustion engines comprising an air-hydrocarbon fuel mixture containing at least one compound selected from the group consisting of trichloro-fluoromethane, dichlorodifluoromethane, trifluorochloromethane, tetrafluoromethane, dichlorofluoromethane, difluorochloromethane, tetrachlorodifluoroethane, trichlorotrifluoroethane, tetrafluorodichloroethane, and pentafluorochloroethane, said compound being present in an amount equal to about 0.01% to 15% by volume of the air in said mixture.

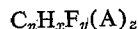
13. A fuel for internal combustion engines comprising an air-hydrocarbon fuel mixture containing a fluoro-halogenated aliphatic compound having not more than two carbon atoms, said compound being present in an amount equal to about 0.01% to 6% by volume of the air in said mixture.

14. A fuel for internal combustion engines comprising an air-hydrocarbon fuel mixture containing a fluoro-halogenated aliphatic compound containing at least one fluorine atom and one chlorine atom, said compound being present in an amount equal to about 0.01% to 15% by volume of the air in said mixture.

15. A fuel for internal combustion engines comprising

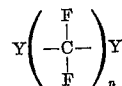
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an air-hydrocarbon fuel mixture containing a compound having the formula



where n is a number greater than zero, x is a number from 0 to $2n+1$, y is a number from 1 to $2n+2$, A is a halogen other than fluorine and z is a number from 0 to $2n+1$, said compound being present in an amount equal to about 0.01% to 6% by volume of the air in said mixture.

16. A fuel for internal combustion engines comprising an air-hydrocarbon fuel mixture containing a compound having the formula



where n is a positive number and X any Y are halogens, said compound being present in an amount equal to about 0.01% to 15% by volume of the air in said mixture.

17. A fuel for internal combustion engines comprising an air-hydrocarbon fuel mixture containing a fluoro-halogenated aliphatic hydrocarbon compound having a boiling point not substantially in excess of the boiling point range of the hydrocarbon fuel, said compound being present in an amount equal to about 0.01% to 6% by volume of the air in said mixture.

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