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FUEL FOR INTERNAL-COMBUSTION ENGINES.

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This invention relates to liquid fuels for use in internal combustion engines. More particularly this invention pertains to improvements in gasoline or light petroleum distillate for use in automotors.

The main object of the present invention is to adapt ordinary, commercial gasoline, such as generally offered in the market as motor fuel, for more efficient and satisfactory use in the internal combustion motors of automobiles and other automotors, by improving combustion, increasing operating efficiency, reducing the stench and the formation of carbon monoxide in the exhaust, and reducing the deposit of carbon which now attend the operation of gasoline explosion motors.

Other objects will more fully appear during the course of the following description, and the novel features and advantages of the invention will be set forth in the appended claims.

As stated in the premises, this invention does not contemplate the production of a gasoline substitute for use as a fuel in internal combustion engines; but it does contemplate the production of a fuel for internal combustion engines, the basis of which is gasoline, containing some correcting agents which tend to improve its general performance.

The term "gasoline" does not imply a strictly definite compound having a set chemical composition. While hexane C_6H_{14} may be regarded for the purposes of this application, as typical of good gasoline, it is well known that wide variations from this standard may be found in the market, owing to varying quantities of a number of different constituents. The term "gasoline" as employed during the course of this description must therefore be understood as applied to the wide variety of light petroleum distillates which are sold and used under this name, and which may vary all the way from a density 0.640 to 0.730, or even more.

In a general way, it may be stated that the feature which characterizes gasoline as compared with kerosene and other heavier distillates, is its volatility, which should at all times be sufficient to permit starting of a motor cold, under all ordinary conditions of temperature.

The enormous development of the automobile in recent years, has created a demand

for motor fuel which has more and more taxed the capacity of the ordinary sources of production. While a great deal of study and effort have been devoted to the production of fuels having compounds other than gasoline as a basis, yet gasoline still represents the great bulk of the fuel used. However, the great consumption of this product has led to the gradual introduction in the market of lower, or heavier grades, which have automatically raised to problems of first importance some troubles in motor operation, which in connection with good gasoline could only assume the proportion of minor occasional difficulties.

The chief difficulties encountered in motor operation today, are knocking of the engine, the formation of carbon deposits in the cylinder and on piston heads and valve settings, and an excessive production of carbon monoxide in the exhaust. Other minor difficulties may also be experienced, such as difficulty of starting in cold weather, production of bad smelling gases, etc.

These various drawbacks cannot be attributed to a single cause, but rather to a complexity of conditions, some of which, due to factors of construction and design, are foreign to the nature of the fuel itself. Another cause resides in the widespread lack of intelligent attention being given to carburetor adjustment. Almost in all cases, the carburetor is permanently set for winter conditions, on the rich mixture side, and this leads not only to considerable waste of fuel, but to incomplete combustion, which is the main cause of carbon deposits and of objectionable gases in the exhaust.

Rich mixtures are also to a certain extent responsible for the knocking of the engine, at least when fuels of the paraffin series are employed; and for reasons which I will explain later, a gasoline performing efficiently and without difficulty when a mixture containing a sufficient quantity of air is employed, may very well produce knocking when the proportion of air to fuel is decreased.

Other factors affecting the performance of a fuel, however, are directly linked with its chemical structure and with its physical characteristics; and these are the factors with which the present invention is more particularly concerned.

It is well known that given the same operating conditions, a fuel will knock, while

another fuel will run quite smoothly; a fuel will give way to the formation of heavy carbon deposits, while another fuel will be free of objections on this ground; and generally a fuel may be free of some objectionable feature or result, while another fuel may give evidences of it, but unfortunately not all the desirable qualities are to be found in one type of fuel. A fuel which may be desirable in one respect, may be quite objectionable on some other ground.

I have made extensive investigations concerning the causes of the various phenomena mentioned, and while in a problem of such a complex nature it is difficult and dangerous to resort to generalizations, I have reached some more or less general conclusions, upon which the present invention is based, as follows:

(a). Knocking, or detonation of the fuel, is due to too rapid propagation of the flame, and is not necessarily due to pre-ignition; only, when caused by pre-ignition (whether due to self combustion produced by the compression pressure used, or to advanced spark), it is prone to be much more violent than when ignition has taken place at the proper time. This is due to the fact that the flame propagates with far greater velocity under conditions of constant volume, such as obtain when the piston has not yet reached its dead center, than under constant pressure conditions such as realized when the piston proceeds to move in its expansion stroke. At the same time detonation under these constant volume conditions is bound to be much more severe on the engine, due to its virtual rigidity at the time the detonation takes place.

(b). Knocking is affected, more than by the percentage of hydrocarbon present in the fuel, by the percentage of releasable hydrogen in the fuel-air mixture. Under given conditions of carburetor adjustment it may be assumed that the relative ratios of fuel-air mixtures by volume may be practically constant, except as affected by the volatility of the various fuels under engine running conditions. This assumption, however, can only be extended to fuels of the alcohol series, by taking into account the high latent heat of vaporization of these compounds, which affects the volumetric efficiency of the engine to a considerable extent. While the alcohols have many possibilities, both as fuels and as additions to other fuels, this application is not specifically directed to this phase of the problem, and therefore we may neglect the effects of the latent heat of vaporization.

When these fuel-air mixtures by volume are reduced to ratios by weight, many startling differences in the relative contents of the various elements may be noted.

In the case of the paraffins, with which we

are chiefly concerned, a progressive increase of the hydrogen percentage may be noted from the lighter to the heavier compounds in the series. At the same time a progressively increasing deficiency in the oxygen contents of the mixtures may also be observed.

The increasing percentage of hydrogen is responsible for the tendency to detonate, which is more pronounced in the heavier than in the lighter paraffins. The increase in the oxygen deficiency tends to a certain extent to counteract this tendency to detonate, but not enough to counterbalance the effect of the hydrogen. At the same time the oxygen deficiency is directly responsible for poor combustion, leading to the formation of carbon deposits, and to the production of carbon monoxide in the exhaust.

(c). Knocking is also affected by the ratio of the oxygen in the fuel-air mixture, to the quantity required for complete combustion of the mixture. When the quantity of oxygen present is in excess of that needed for complete combustion, there will be a certain tendency to detonate, even though the percentage of hydrogen may not be excessive.

The effect of the oxygen seems to be relatively much less pronounced than that of hydrogen. In the various fuel-air mixtures considered, where only elementary fuels were used, and no mixed fuels, it has been found that for mixtures in proportions such as used in practice, either a deficiency of oxygen was found with an excess of hydrogen over 0.98% which is the approximate quantity to be found in the "optimum" gasoline-air mixture, or else an excess of oxygen was present with a contents of hydrogen less than the above figure. Apparently, therefore, there is no cumulative effect of the two elements, but only predominance of the positive effect due to the excess of one, over the negative effect due to the deficiency of the other.

Consequently, while the detonation of kerosene is due to an excess of hydrogen in the kerosene-air mixtures, not sufficiently counterbalanced by a deficiency of oxygen, the detonation of ether is due to an excess of oxygen not sufficiently counterbalanced by a deficiency of hydrogen.

The ideal conditions are approached when the oxygen contents is about the quantity required for complete combustion, and the hydrogen contents is about, or a little less than the quantity that compression pressure conditions will permit. For ordinary compression pressures of about 75 lbs. per square inch, this quantity is the one mentioned, 0.98%.

(d). The effects of the hydrogen and oxygen on detonation occur only in so far as the two elements are not combined with each other. Thus, in the case of alcohols, where a hydroxyl group is present, a hy-

drogen molecule may be considered as inactive, and one molecule of oxygen may be considered active only to the extent of one-half normal.

5 This to a certain extent explains the differences between ethers and alcohols; thus ethyl ether C_2H_5O as compared with butyl alcohol C_4H_9OH , having the same molecular composition but not the same molecular structure, is a detonator because the excess of oxygen in an ethyl ether-air mixture is more than sufficient to counterbalance the deficiency of hydrogen; while butyl alcohol is not a detonator, because the deficiency of hydrogen more than counterbalances the excess of oxygen in the mixture. Furthermore, the volatility of the alcohol is much less than that of the ether, although other factors besides the difference in releasable hydrogen contents may be responsible for this, for instance the boiling points, which are 117 C. and 35 C. respectively.

(e). Under certain conditions certain fuels may prove to be the worst detonators, while in other conditions other fuels may take the precedence in this respect.

Thus for rich mixtures, say a fuel-air mixture of 1-12.3, representing the average used in practice (while the mixture for the complete combustion of hexane is 1-15.3), the paraffins, especially heptane and octane, will detonate more violently than ethyl ether; while for a mixture in the proportions of 1-15.3, ethyl ether will detonate more violently than the paraffins. In the first case hydrogen had the prevalence, while in the second oxygen is the predominating factor.

(f). To avoid the formation of carbon deposits it is not sufficient to provide an amount of oxygen in the mixture sufficient for complete combustion. A 1-12.3 benzol-air mixture contains sufficient oxygen for the complete combustion of the fuel, and yet the formation of carbon deposits is one of the main objections to the use of benzol. An increased amount of air in the mixture has been advocated as the remedy, but it is more likely that an increase in the hydrogen contents, producing an increase in the temperature of combustion, is what is needed. The percentage of hydrogen in such a mixture is practically the same as that resulting from a mixture methyl-alcohol-air in the same proportions, although the formula for benzol is C_6H_6 , while the formula of methyl-alcohol is CH_3OH , showing a much lower hydrogen contents.

At the same time the amount of carbon in the benzol-air mixture is six times as large as the amount in the methyl-alcohol-air mixture, and this explains why methyl-alcohol, also with a low hydrogen contents, does not produce carbon deposits. However, it may be assumed that while an oxy-

gen contents equal to or larger than that required by complete combustion of the fuel may not be sufficient as a condition to insure freedom from carbon deposits, it is however necessary that this condition be present.

(g). The tendency to knock is not only a function of the relative amounts of hydrogen and oxygen in the mixture, but is also a function of the temperature of combustion, and of the compression pressure used. Disregarding the effect of the compression pressure, and assuming that a given compression pressure is a condition to be met in adapting a fuel for use in a given engine, it may be observed that two fuels producing the same percentages of hydrogen and oxygen in the fuel air mixture may behave in an entirely different manner one from the other. One of the fuels may produce higher temperatures of combustion and develop a tendency to knock, while the other may run quite smoothly.

The temperature of combustion is not solely a function of the hydrogen contents, but also depends on the amount of other combustible matter, such as carbon, contained in the mixture. It also depends upon the nature and the amount of thermal diluents contained in the mixture, in the form of inert gases, or water vapor, and the like, which have the effect of modifying temperature conditions within the cylinder. In addition to this it also depends on other factors, such as heat losses through walls, speed, etc., which are not, however, directly related to the chemical composition of the fuel mixture.

Therefore, given a fuel mixture which will knock under certain conditions, while a corrective action may be exerted by suitable modifications to the hydrogen and oxygen ratios of the mixture, the same effect may also be obtained merely by correcting the amount of thermal diluent in the mixture, and the nature of the thermal diluent. The cooling effect of a thermal diluent is not merely dependent upon its quantity, but also and principally upon its ability to absorb heat. Water vapor, for instance, having a very high latent heat of vaporization, is enormously more efficient in this respect than nitrogen, the latent heat of vaporization of which is much lower.

From the above discussion it clearly appears that in order to adapt a fuel for given conditions of running, it is advisable to first correct the oxygen contents of the fuel-air mixture, to provide for complete combustion of the fuel; this insures freedom from carbon deposits, and elimination of obnoxious and dangerous gases from the exhaust, and also improves the thermal efficiency of the engine.

This stage being reached, it is then neces-

sary to correct the conditions more directly affecting the tendency of the fuel to detonate, these being, principally, the percentage of hydrogen in the fuel-air mixture, and the temperature of combustion. Detonation may be prevented by correcting one or the other of these two factors, or by correcting partly one and partly the other factor.

In the case of the paraffins we are chiefly concerned with the correction of a deficiency of oxygen, and an excess of hydrogen. The deficiency of oxygen may be corrected by the addition of a compound, such as tetra-nitromethane, $C(NO_2)_4$, containing sufficient oxygen in excess to that required by its carbon constituent, to improve combustion conditions of the mixture. This method forms the object of two patent applications previously filed by me, one entitled "Motor fuels," filed October 8, 1924, Serial No. 742,428 and the other entitled "Fuels for heat engines," filed October 14, 1924, Serial No. 743,636.

However, as explained above, the necessity of correcting a deficiency of oxygen, usually implies the necessity of correcting an excess of hydrogen; and since the decrease of the amount of fuel in the mixture without altering the oxygen contents is in reality equivalent to an increase in the oxygen contents in relation to the fuel, it follows that another way of correcting a deficiency of oxygen resides in the possibility of decreasing the amount of fuel in the mixture. This may mean reduction of the hydrogen contents only, or of both hydrogen and carbon, and at one stroke accomplishes three results: improvement of combustion conditions, reduction of the hydrogen contents, and reduction of the temperature of combustion.

A decrease in the amount of fuel elements in the mixture may be brought about by the introduction of some inactive substance, such as nitrogen, or by mixing with the fuel another compound containing a smaller percentage of combustible matter. To determine the relative proportion of combustible matter, it is not enough to compare the percentages and the molecular weights; it is necessary to compare the relative volumes in the charge, and to reduce these volumes to weights taking into account the relative densities.

For instance, the addition of an alcohol to gasoline will cause a decrease of both the hydrogen and the carbon contents in the mixture. For the same reason, methyl alcohol, CH_3OH , will be more active in this respect than butyl alcohol C_4H_9OH , on account of its lower contents of hydrogen and carbon. The hydroxyl group in the alcohol will provide an addition to the thermal diluent, and will eventually increase the oxygen in the mixture in a proportion equivalent to one-half its own oxygen contents.

This shows the possibility of adding substances which will at the same time decrease the percentages of hydrogen and carbon, and increase both the percentage and the absolute amount of oxygen contained in the fuel-air mixture. The addition of an ether, such as ethyl ether, will better illustrate this point, its formula being $C_4H_{10}O$, equivalent in composition to butyl alcohol, with the same molecular weight but with a different molecular structure. Ethyl ether will, on the surface, cause less decrease in the hydrogen contents, and more increase in the oxygen, and this is true for weights of ethyl ether corresponding to weights of butyl alcohol; but if the same volumes are compared, the difference is more than offset by the effect of the latent heat of vaporization, which is greater for alcohol than for ether.

These comparisons are of course made for purposes of illustration only, entirely disregarding other factors which must in practice be considered; such, for instance, as the fact that while ether is miscible with gasoline, alcohol is not, unless a suitable carrier is used.

It is quite possible, especially with the heavier grades of gasoline, that the correction of the oxygen deficiency solely by the addition of a substance less rich in fuel than the gasoline, may call for excessive additions of the substance or substances considered. This may be undesirable for one reason or other, such as considerations of cost, possible sources of supply, miscibility, volatility, etc., which may make it advisable to limit the additions to amounts which are insufficient to correct the oxygen deficiency in its entirety. In this case the possibility may be considered of making up the remaining deficiency by the addition of an oxygen carrier, such as tetra-nitro-methane, or of some other suitable combustion supporter, such as ammonium chloride or the like.

The above considerations are more or less of a general character, and may be applied to a great number of different fuels. The selection of a proper mixture, however, must also be guided by a number of other considerations, which are quite as important as the purely chemical characteristics of the fuel, and which create an immense variety of practical problems.

The present invention is specifically directed to fuel mixtures having gasoline as a basis, especially adapted for ordinary compression pressures, and for carburetor adjustments such as ordinarily used in practice; these mixtures however being prepared within suitable proportions for the various constituents employed, owing to the variety of practical conditions which remain to be met, notwithstanding the set limitation of the scope of the present ap-

plication. These conditions may be due to different design of engines, making for variations in the air-fuel ratios in the mixture, or to engine speed, or to reasonable variations in the compression pressures used, or to the wide variety of grades of gasoline found on the market, or to a number of other factors; one of these factors being also the surrounding temperature, which will influence the performance of any fuel.

The present invention is purposely directed to fuel mixtures containing gasoline, in recognition of the fact that gasoline still represents the most important source of fuel supply for automotors; this limitation, however, is made without prejudice of the inventive idea, and of its possible application to a variety of other fuels.

After careful study of the subject involved, I have found that mixtures of gasoline with dimethyl ketone and a certain amount of water, with or without the addition of a small proportion of kerosene, very satisfactorily answer all the requirements for a good motor fuel under the practical conditions mentioned. I also have found that at times a small addition of tetra-nitro-methane, or an addition sufficient to offset the remaining oxygen deficiency, will further improve the mixture, the tetra-nitro-methane being replaceable, however, by some other suitable combustion supporter.

Owing to the great variety of factors to be considered, it is of course impossible to specify any given mixture as the best in all cases. The main controlling factor is of course the grade of gasoline used, and the amount and nature of the correction required; and in a general way it may be stated that less additions of the ingredients mentioned will be required by the lighter grades than by the heavier grades of gasoline, with the exception of kerosene, which has the object of assisting in the mixing and blending of the dimethyl ketone with the gasoline. The heavier grades of gasoline may mix sufficiently well with the dimethyl ketone, without the addition of kerosene, while when the lighter grades of gasoline are used, an addition of kerosene may become useful or necessary.

A typical mixture for the average grades of commercial gasoline, and for average conditions, comprises

	Parts by weight.
Gasoline	75
Dimethyl ketone	10
Kerosene	5
Water	9
Tetranitromethane	1

By including both gasoline and kerosene under the denomination of petroleum distillate, various mixtures may be prepared with these ingredients varying between the following proportions:

Petroleum distillate, from 50 to 98 parts; dimethyl ketone, from 2 to 30 parts; water, from 2 to 15 parts; tetra-nitro-methane, from 0 to 10 parts.

The tetra-nitro-methane, as stated, may be substituted by some other suitable combustion supporter.

The specific functions of the dimethyl ketone, which may be assisted into the solution by kerosene when needed, are the decrease of the hydrogen contents of the mixture, and the reduction of the fuel contents of the mixture as a whole, reducing the tendency to detonate due to an excessive amount of hydrogen, and that due to an excessive temperature of combustion. At the same time, as a consequence, this ingredient also acts toward reducing the deficiency of oxygen in relation to the fuel elements, both by reducing the percentages of the fuel elements, and by increasing the absolute amount of oxygen in the mixture.

The dimethyl ketone is a liquid having a very good volatility, and will not tend to decrease the volatility of the gasoline. Another advantage of this ingredient is that, being an excellent solvent of carbon, while not contributing towards the prevention of carbon formation, it will however cause whatever carbon may be formed to remain in solution, and to be readily expelled with the exhaust. Owing to this property, the further addition of a combustion supporter, to counterbalance the remaining deficiency of oxygen, if any, is therefore optional, as far as prevention of carbon deposits is concerned.

The specific functions of the water, which is assisted into the solution by the dimethyl ketone, are to add its diluting action in reducing the percentage of fuel elements in the fuel-air mixture, thereby reducing the necessary proportion of dimethyl ketone and reducing the cost of the fuel, and also to introduce a powerful thermal diluent, reducing the tendency to detonate, the temperature of combustion, and heat losses from various causes. The presence of water vapor therefore permits the retention in the mixture of a greater proportion of hydrogen than would otherwise be possible, without detonation, and this also means a decrease in the necessary amount of dimethyl ketone to be added.

The water vapor also has been found to be beneficial in exerting a scavenging effect, and in assisting in preventing the deposition of carbon.

The addition of tetra-nitro-methane has for its primary object to furnish some additional oxygen to further improve combustion conditions, incidentally providing also additional nitrogen acting as a thermal diluent; and furthermore, owing to its high volatility, it will also tend to improve vola-

tilization of the fuel, which may have been reduced to a certain extent by the addition of water. This consideration is not very important in hot climates, but in winter conditions it may become a factor of sufficient importance. It is obvious that ether, which indirectly also acts as a combustion supporter by decreasing the percentages of the fuel elements, and by increasing the supply of oxygen, and which also has a high vapor tension, may be used instead of tetra-nitro-methane to improve the volatility of the fuel mixture.

I claim:

1. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, dimethyl ketone and water.
2. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, kerosene, dimethyl ketone and water.
3. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, dimethyl ketone and a combustion supporter containing oxygen in excess of that required by the combustion of its own combustible elements.
4. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, kerosene, dimethyl ketone and a combustion supporter containing oxygen in excess of that required by the combustion of its own combustible elements.
5. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, dimethyl ketone, water, and a combustion supporter.
6. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, kerosene, dimethyl ketone, water, and a combustion supporter.
7. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate, dimethyl ketone, and tetra-nitro-methane.
8. A liquid fuel adapted for use in an

internal combustion engine, comprising a mixture of petroleum distillate, dimethyl ketone, water, and tetra-nitro-methane.

9. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate from 50 to 98 parts, and dimethyl ketone from 2 to 30 parts.

10. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate from 50 to 98 parts, dimethyl ketone, from 2 to 30 parts, and water, from 2 to 15 parts.

11. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate from 50 to 98 parts, dimethyl ketone, from 2 to 30 parts, and a combustion supporter containing oxygen in excess of that required by the combustion of its own combustible elements from 0 to 10 parts.

12. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate from 50 to 98 parts, dimethyl ketone, from 2 to 30 parts, and tetra-nitro-methane, from 0 to 10 parts.

13. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate from 50 to 98 parts, dimethyl ketone, from 2 to 30 parts, water, from 2 to 15 parts, and a combustion supporter from 0 to 10 parts.

14. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of petroleum distillate from 50 to 98 parts, dimethyl ketone, from 2 to 30 parts, water from 2 to 15 parts, and tetra-nitro-methane from 0 to 10 parts.

15. A liquid fuel adapted for use in an internal combustion engine, comprising a mixture of gasoline, 75 parts by weight, kerosene, 5 parts by weight, dimethyl ketone, 10 parts by weight, water, 9 parts by weight, and tetra-nitro-methane, 1 part by weight.

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