Main Fuel Containing Deficiency of Scavenger

Auxiliary Fuel Containing Excess Scavenger

Carburetor

Electrical Control

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By A. W. Wright Attorney
The present invention is concerned with an improved process for operating internal combustion engines and a fuel therefor. The invention is more particularly concerned with the operation of aviation engines and with improved aviation fuels. In accordance with the present invention, an internal combustion engine is operated with a leaded fuel containing a deficiency of a scavenger agent at part-throttle, cruise conditions for aviation engines, and is at least partially operated with an auxiliary fuel containing an excess of a scavenger agent at full-throttle. A particular adaptation of the present invention is to operate an aviation engine during flight on moderately low antiknock fuel containing a deficiency of a scavenging agent. During full-throttle operation such as at take-off, an auxiliary relatively high antiknock quality fuel or anti-deonator liquid is supplied which is characterized by containing an excess of a scavenging agent.

It is well known in the art to operate internal combustion engines with fuels containing alkyl lead compounds for the suppression of knocking and to use in conjunction therewith various lead scavenging agents such as alkyl halides. It is also known in the art to operate aircraft engines at part-throttle on relatively low antiknock fuel and to get the necessary antiknock performance at high power output operation by injecting an auxiliary fuel. These fuels, as pointed out, contain alkyl lead compounds, such as tetraethyl lead, and scavenging agents such as ethylene dibromide adapted to scavenge the lead from the engine. It is also very desirable for maximum fuel economy to cruise, utilizing relatively lean mixtures and to only employ auxiliary fuels at full-throttle.

However, one disadvantage of this method of operation is that when employing a lean mixture of a leaded fuel and a scavenger agent, as, for example, an organic halide, premature spark plug failure occurs. This is thought to be due to the fact that the combination of lead and halide causes the formation of electrically conductive deposits on the spark plug. On the other hand, if a fuel were utilized which did not contain any scavenging agent, prohibitive lead deposits would occur around the exhaust valves. Exhaust valve deposits, which can be quite critical even with normal fuels containing a stoichiometric equivalent of halide, can be essentially eliminated by increasing the halide content of the fuel, but this course results in excess deterioration of valve seats and other metal parts and greatly accelerates the onset of spark plug failure. Thus, there has existed apparently two irreconcilable shortcomings of leaded aviation gasolines, namely their tendencies toward short-circuiting spark plugs and burning exhaust valves.

It has now been discovered that these shortcomings can be overcome or at least greatly reduced. In accordance with the present invention, a leaded fuel containing a stoichiometric deficiency of a scavenger agent is employed during part-throttle or cruise operation. During full-throttle or take-off operation, or at other selected intervals, an auxiliary fuel is injected into the engine, which auxiliary fuel is characterized by containing sufficient scavenging agent to provide a stoichiometric access for the total fuel going to the engine. Thus, the engine can be safely operated during the continuous or part-throttle phase at relatively low fuel-to-air ratios, thus securing maximum fuel economy. Also, it has been discovered that if this deficiency of scavenging agents be utilized, the formation of electrically conductive deposits on or around the spark plugs is materially reduced. It has also been discovered that although lead deposition does occur around the exhaust ports when employing the fuel containing a deficiency of scavenging agent, these deposits are at least substantially reduced by using the auxiliary fuel at full-throttle, which fuel contains scavenging agent in an amount sufficient to assure an excess for the total fuel.

The general process of the invention may be understood by reference to the accompanying drawing which diagrammatically illustrates the process and the apparatus employed in practicing the process of this invention. Referring to the drawing, the numeral 1 identifies a carburetor supplied with fuel from a fuel tank 2 by means of a conventional fuel pump 3. The fuel contained in tank 2 may be designated as the main fuel containing a deficiency of scavenging agent employed during part throttle operation of the engine. In accordance with the invention, an auxiliary fuel containing an excess of scavenger is contained in tank 3 to be supplied to the carburetor 1, at full throttle operation of the engine. This can be accomplished by positioning a pump 4 and a solenoid valve 5 in the fuel line leading from auxiliary fuel tank 3 to the carburetor 1. Thus an electrical control system 6 may control pump 4 and valve 5 to permit injection of an auxiliary fuel to the carburetor at full throttle operation. The auxil-
lary fuel during such periods may enter the induction system through the conventional blower spinner nozzle. It may be noted that the apparatus illustrated in the drawing is conventional and has been employed, for example, for the introduction of water or other auxiliary liquid.

The present invention may be readily understood by the following examples illustrating the same:

**EXAMPLE 1**

Tests were run on a universal test engine\(^1\) which consists essentially of a single "cylinder-and-piston" assembly from a full-scale multi-cylinder radial aircraft engine mounted as a test engine. In one operation, one theory of ethylene dibromide based upon tetraethyl lead was employed in an aviation fuel which contained 4.5 cc. of tetraethyl lead per gallon. The test conditions were 0.062 fuel-air ratio, 100° F. intake-air temperature and 145 lbs. per sq. in. as indicated mean effective pressure. The spark plug (conventional aircraft type) life was 25 hours. In another operation 1.1 cc. of ethylene dibromide were utilized. In this operation the spark plug life was 11 hours. In another operation, ethylene dibromide was eliminated from the fuel which resulted in successful operation for the full 40 hours of the test. However, heavy deposits of lead were noted around the exhaust valves and throughout the engine.

In another test, a fuel containing ethylene dibromide alone was successfully run to completion of the 40-hour test. In another operation, the ethylene dibromide was replaced with ethylene dichloride using 4.5 cc. of tetraethyl lead per gallon. The spark plug life was increased to 43 hours. The results of these operations may be summarized as follows:

**C. U. T. engine tests—Spark plug fouling**

\[\frac{F/A=0.062, \text{ Intake air}=100^\circ \text{ F.}, \text{ plugs (conventional aircraft type)}]}{\text{TEL, cc/gal.}}\]

<table>
<thead>
<tr>
<th>Scavenger</th>
<th>Hours to Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene Dibromide</td>
<td>1 25</td>
</tr>
<tr>
<td>Ethylene Dichloride</td>
<td>4.5 1 5 1 11</td>
</tr>
<tr>
<td></td>
<td>0 1 43</td>
</tr>
<tr>
<td>Ethylene Dichloride</td>
<td>1 1 10 43</td>
</tr>
</tbody>
</table>

\(^1\) Heavy deposits.

These data indicate that ethylene dibromide scavenging agent materially increases spark plug fouling at low temperature, lean mixture operating conditions, and also demonstrate that both tetraethyl lead and scavenging agent contribute to spark plug failure. Ethylene dichloride appears to be somewhat superior to the bromide in respect to this particular problem, but decreased exhaust valve life results from the use of chloride scavengers in aviation engines.

**EXAMPLE 2**

Additional tests were run on the C. U. T. engine under the same conditions using a regular aviation gasoline boiling in the range from about 111° F. to 320° F. containing 4.5 cc. of tetraethyl lead per gallon and only 8 mol or equivalent of the ethylene dibromide. The test was run for over 43 hours without spark plug failure. The test was interrupted for inspection of the cylinder, piston and valve. The engine was then reassembled without any of the parts having been cleaned and was operated for ten minutes under take-off conditions using the same main fuel as before but injecting as auxiliary liquid a methanol solution containing 1.8% ethylene dibromide, the rate of injection being such that the scavenging agent was supplied in the proportion of two molal equivalents in respect of the lead in the main fuel. The comparative operating conditions for the two periods of the test were as follows:

<table>
<thead>
<tr>
<th>Conditions simulated</th>
<th>Cruise</th>
<th>Take-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration, hours</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Engine speed, r.p.m.</td>
<td>1,000</td>
<td>1,200</td>
</tr>
<tr>
<td>Intake air temperature, °F</td>
<td>100</td>
<td>170</td>
</tr>
<tr>
<td>Cylinder head temperature, °F</td>
<td>300</td>
<td>250</td>
</tr>
<tr>
<td>Fuel-air ratio</td>
<td>0.062</td>
<td>0.060</td>
</tr>
</tbody>
</table>

At the end of the take-off period, the engine was dismantled and the exhaust valve was again weighed. It was found to have lost 354 mgs, or 35% of the total deposit accumulated after a normal cruise period. Furthermore, visual inspection of the combustion chamber clearly indicated that it was free of lead deposits than at the end of the cruise period.

The present invention is broadly concerned with a method of operating an internal combustion engine whereby during part-throttle or cruise operation relatively low fuel-to-air ratios are employed for fuel economy. The fuel utilized during the part-throttle operation is characterized by being leaded and having a deficiency of the scavenging agent present. During full-throttle operation the fuel is characterized by containing an excess of scavenging agent. In accordance with the present invention, it is particularly preferred to operate during the part-throttle cycle with a fuel which is characterized by being leaded and containing a theoretical deficiency of the scavenging agent present. It is realized that many fuels, however, contain the theoretical amount of scavenging agent present therein, which fuel must of necessity be used during part-throttle operation. It is within the broad concept of the present invention to use fuels of this character and at periodic intervals or during full-throttle operations, to employ auxiliary fuels, which fuels contain an excess of the scavenging agent.

The invention may be employed with respect to any leded fuel, as, for example, motor fuels boiling in the general range from about 80° F. to 420° F. However, the invention is particularly applicable to aviation fuels which boil in the range from 100° F. to 375° F. The alkyl lead compounds used may be any satisfactory knock suppressing agents, as, for example, tetraethyl lead, dimethyl, diethyl lead, and the like. The amount of lead utilized may vary appreciably, as, for example, from 1 to 6 cc. of lead compound per gallon of fuel. Here again, the invention is particularly adapted for use in fuels which contain more than 3 cc., and particularly more than 4 cc. of lead compound per gallon of fuel.

The invention may be used when any suitable lead scavenging compound is employed. Here again, it is particularly adapted for use when the lead scavenger compounds comprise organic halides, as, for example, ethylene bromide,
bromo xylenes, dibromo toluene, acetylene tetra-
bromide, dibromo propane, ethylene dichloride, etc.

In accordance with the preferred adaptation of the invention, a high antiknock fuel is employed as an auxiliary fuel, which auxiliary fuel contains sufficient excess of scavenging agent so as to have more than one theory of scavenging agent in the fuel being consumed during full-throttle. Suitable auxiliary antiknock liquids comprise aromatics, aromatic amines, low boiling aliphatic amines, water, alcohols, ethers, or concentrated lead alkyl solutions.

A particularly desirable auxiliary fuel for use in conjunction with the present invention is one which comprises an alkyl amine hydrohalide. In general, the compounds should contain from 1 to 4 carbon atoms in the molecule and be characterized by being water or alcohol soluble. A preferred class of auxiliary fuels of this character are the alkyl amine hydro-bromides, as for example, methyl-amino-hydro-bromide. Other specific compounds of this character which are desirable include dimethyl amine hydrobromide, ethyl amine hydrobromide, methyl aniline hydro-chloride, aniline hydrochloride, propylene di-
amine hydrobromide, ethylene diamine dihydro-
bromide, and the like.

When using auxiliary fuels of the above class, it is understood that they can be used in conjunction with other auxiliary fuel constituents. As a matter of fact, in order to avoid too great an excess of the scavenging agent during the period of full-throttle, it is very desirable that the alkyl-amine-hydro-halide be used in conjunction with another auxiliary fuel, such as an alkylamine, an ether such as methyl tetra butyl ether, an alcohol such as methyl alcohol, an aromatic amine such as aniline, xyldine or methyl aniline, an aromatic such as toluene or xylene, or lead compound concentrates.

Although satisfactory results will be secured in accordance with the present process by utilizing a deficiency of scavenging agent in the initial or continuous phase, it is preferred that from 0.5 to 3 theories of scavenging agent be employed based upon the lead present in the part-throttle operation. However, advantages will also result if the fuel contains the normal 1.0 theories. At intervals, or during the period of full-throttle, it is preferred that from 1.2 to 1.5 theories of scavenging agents be used per theory of lead present.

Having described the invention, it is claimed:

1. In the operation of an internal combustion engine utilizing a fuel containing an alkyl lead compound and no more than one theory of a lead scavenging agent, the improvement which comprises operating said engine at periodic intervals with a fuel which is characterized by containing a theoretical excess of said scavenging agent.

2. Improved process for operating an internal combustion engine which comprises running said engine for periods on a hydrocarbon mixture containing a lead alkyl compound and a scavenging agent, said scavenging agent being present in a concentration of less than one theory based upon the amount of lead compound present, then operating said engine at intervals with an auxiliary fuel mixture containing a scavenging agent, which scavenging agent in said auxiliary fuel is present in a concentration in excess of one theory based upon the amount of lead alkyl compound present.

3. Process as defined by claim 2 wherein said hydrocarbon mixture comprises a hydrocarbon fraction boiling in the range of about 100° F. to 375° F.

4. Process as defined by claim 2 wherein said hydrocarbon mixture comprises an aviation fuel boiling in the range from about 100° F. to 375° F.

5. Process for operating an internal combustion engine which comprises running said engine during part-throttle operation with a hydrocarbon mixture containing an alkyl lead compound and less than one theory of a scavenging agent based upon the alkyl lead compound present and running said engine during full-throttle operation with an auxiliary fuel which contains a scavenging agent present in a concentration sufficient so that an excess of one theory of scavenging agent based upon the total fuel utilized is present.

6. Process as defined by claim 5 wherein said alkyl lead compound comprises tetra ethyl lead.

7. Process as defined by claim 6 wherein during the part-throttle operation the scavenging agent is present in a concentration in the range from about 0.5 to 3 theories based upon the lead compound present, and wherein during full-throttle operation the scavenging agent is present in the concentration from 1.2 to 1.5 theories based upon the lead compound present.

8. Process as defined by claim 7 wherein the lead compound is present in a concentration of from 4 to 6 cc. per gallon.

9. In the operation of an internal combustion engine utilizing a fuel containing an alkyl lead compound and a lead scavenging agent the improvement which comprises operating the engine with a fuel containing an amount of scavenging agent sufficient to completely eliminate lead deposits in the engine combustion chamber and thereafter operating the engine with a fuel containing a theoretical excess of said agent for a time sufficient to remove the lead deposits.

10. In the operation of an internal combustion engine utilizing a fuel containing an alkyl lead compound and a lead scavenging agent, the improvement which comprises operating the engine with a fuel containing an amount of scavenging agent such that appreciable lead deposit in the engine combustion chamber occurs and thereafter operating the engine with a fuel containing a theoretical excess of said agent for a time sufficient to remove the lead deposit.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNIVERSAL STATES PATENTS

Number Name Date

2,486,983 Calingaert Feb. 7, 1950