ENCLOSURE (B) 12

STUDIES ON THE UTILIZATION OF ALCOHOL FOR AVIATION FUEL

by

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ENCLOSURE (B)12

SUMMARY

In order to eliminate the shortcomings of alcohol for aviation fuel; namely, the corrosive action on metals, the low antiknocking property, and the low volatility of alcohol, the experiments described herein were carried out. Since the research was stopped with the war's end, scarcely any of the results obtained were applied in practical service.

I. INTRODUCTION

In 1944, the third year of the war, in view of the scarcity of aviation fuel, it was decided to utilize alcohol for aviation fuel, since it could be produced in Japan.

Many difficulties were found in the utilization of alcohol for aviation fuel (even for training planes) due to the difference (compared with gasoline) in fuel-air ratio for the complete combustion, the low volatility due to its high latent heat of vaporization, the corrosive action on metals, the dissolving action on paints, etc. As a result of the low volatility, the distribution of the fuel to each cylinder of a full scale aviation engine was not uniform. Consequently, detonation or pre-ignition was likely to occur in the cylinder supplied with too weak a mixture, and irregular firing in the cylinder supplied with too rich a mixture, even when the operation was made at a proper overall mixture ratio. Although experiments were made by the author to eliminate these defects of alcohol, only one finding was given practical application. So the use of alcohol was developed for each particular engine mainly by the experiments made at the First Naval Technical Depot and Yokosuka Air Corps. All of the detailed data of the experiments made by the author were lost. Therefore, this report was written from memory.

II. DETAILED DESCRIPTION

A. On the Anticorrosive Additives of Alcohol

The accessories of the engine made of light alloy castings, especially the inner surface of the carburettor body which was made of aluminium alloyed with a small amount of copper, were corroded by the use of alcohol. Moreover, the parts made of brass and steel were also stained, although this corrosion was not as severe as that of the aluminium alloy. There were two types of corrosion of the aluminium alloys, one of which was the formation of a gelatinous deposit on the metals, and the other, the formation of pinholes. Steel and brass were stained but not corroded. Although the reasons for this corrosion were not fully understood when these experiments were made, anticorrosive additives for alcohol were sought.

The experiments made were as follows: Test pieces were cut from engine accessories and were polished by sand paper until they exhibited a glassy luster.

They were then submerged in glass bottles containing the samples of alcohol and held thermostatically at a temperature of 60°C. After 50 hr had elapsed, the test pieces were taken out, and washed by reagents to eliminate the deposit, then dried and weighed. The washing reagents were 5% cold nitric acid for aluminium alloy, 5% cold sulphuric acid for brass, and 10% solution of ammonium ferric citrate for steel. Although many kinds of additives were tested by measuring the decrease in weight per

cm^2 of the test pieces under the above conditions, aliphatic amines such as ethyl amine, diethyl amine, dibutyl amine, cyclohexyl amine, etc., showed good results on all of the metals tested, especially dibutyl amine, which was the best, in regard to the quantity to be added to alcohol, the addition of 0.3% by wt. decreased the corrosion considerably and 0.5% addition gave perfect results.

In connection with this work, it is of interest that Yokosuka First Technical Depot developed sodium arsenite for this purpose, and this compound was selected for practical use in view of availability, although dibutyl amine was superior.

B. On the Prevention of Detonation

Anhydrous alcohol showed a performance nearly the same as the 87 octane aviation gasoline when used by carburettor engines having less than 1,000 horse power out-put. The octane number of pure ethyl alcohol cannot be measured by the ordinary C.F.R. motor method due to the fact that the air-fuel ratio showing the maximum knocking rate is out of the range of mixture regulation by the carburettor. The octane number, as actually determined using a carburettor nozzle having a large diameter to obtain the air-fuel ratio for maximum knock, was 91-92. The difference in the antiknocking properties indicated by the C.F.R. engine and the practical engine was mainly due to the non-uniform distribution of fuel to each cylinder caused by its low volatility. The cylinders which were supplied a weak mixture were more likely to give what was later found to be auto-ignition with a high boost pressure than when an aviation gasoline was used; that is to say, the possible limit of safe operation for alcohol, relative to the mixture ratio and the boost pressure, was narrower than that of gasoline.

Although one method to extend this allowance is to increase the anti-knocking properties of the fuel, tetraethyl lead lowers rather than raises the antiknocking property of alcohol. Therefore, more than one hundred kinds of additives to increase the octane rating of alcohol were tested. Among these, iron-pentacarbonyl and diethyl selenide were effective. Although the octane rating of alcohol with 0.3% of iron-pentacarbonyl added was approximately 100, this fuel could not be used practically on account of misfiring with continued operation of the engine. This was due to the deposition of iron oxide (formed by combustion) on the insulator of the spark plugs. The use of additives to expel the combustion residue of the antidetonant, such as the use of ethylene bromide in ethyl fluid, was not at all successful.

Dimethyl selenide had an antiknock effect for alcohol one-half as great as iron carbonyl, and gave no cylinder or spark plug deposits. While this compound showed promise as a satisfactory antidetonant for alcohol, the experiments were not pursued, in view of the shortage of selenium.

C. On Increasing the Volatility of Alcohol

The greatest short-coming of alcohol as an aviation fuel is its low volatility. In spite of the fact that alcohol has a boiling point lower than that of the mean value of gasoline, its volatility is extremely low, owing to its high latent heat of vaporization. In general, the fuel is evaporated partly in the carburetor and the remainder is introduced in in the liquid state. The fuel which does not evaporate is apt to flow along the walls of the suction pipes and the super charger casing, and then flow down to the lower part of the engine. Hence, there are differences in the air-fuel mixture ratio on the upper part and the lower part of a radial type engine. This phenomenon is more pronounced with alcohol than gasoline due to alcohol's low volatility. In order to increase the volatility of alcohol, blending fuels suitable for this purpose were tested. The experiments carried out were as follows:

Measured volumes of the fuel and air at a constant temperature were introduced into a spiral glass tube which was insulated from the heat of the atmosphere by a Dewar's flask. The evaporated fuel escaped with air, and the part of the fuel which was not evaporated flowed down into a measuring graduate. The tests were made by varying the air-fuel ratio, and the relationship between the amount of the fuel evaporated and the air-fuel ratio was obtained. The volatilities of fuels having different latent heats of vaporization were compared by the curves which combined latent heat and volatility (boiling point) effects.

The effects of the blended fuels are summarized as follows:

1. Alcohol blended with 20% by volume of ethyl ether showed nearly the same volatility as ordinary aviation gasoline.

2. Alcohol blended with 30% of acetone or isopropyl ether was also about the same as the mixture described above in (1).

3. Methanol had scarcely any effect on the volatility of alcohol.

4. Water included in alcohol seriously suppressed the evaporation of alcohol.

5. The mixture of 75% of aviation gasoline and 25% of alcohol showed the maximum point on the volatility-mixing ratio curve. This maximum point seemed to be caused by the formation of an azeotropic mixture. The maximum point could be moved from 10% to 30% of alcohol depending on the properties of the gasoline.

Although the primary training planes having a 300 horse power engine could not stop and restart in the air during the cold season using alcohol alone, the difficulty was eliminated by the use of 3% ethyl ether blended with alcohol, the application of asbestos insulation between the cooling fins, and by heating the intake gases by means of the exhaust. This scheme was used at temperatures of +20°C and below.