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SUMMARY OF
THE ALCOHOL RESEARCH PROGRAM
AT THE FIRST NAVAL FUEL DEPOT

by

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ENCLOSURE (A)I. INTRODUCTION

Studies on production of methanol, ethanol, and other alcohols were started prior to 1930 by the Navy. No attention was paid to the use of these alcohols for aviation fuel, since there was no demand for high octane fuel at that time. Owing to the rapid development of aircraft engines, and expansion of the air forces, an urgent demand for high octane fuel occurred in 1935. Consequently, research in fuel chemistry, and especially research on synthetic fuel, was greatly expanded by the Navy. In 1940, several alcohol factories were actually operated, producing both synthetic and fermented alcohol. Ethyl alcohol was first used as aviation fuel in 1945 to meet the shortage of natural gasoline.

II. GENERAL SUMMARY

The production of methanol on a semi-industrial scale was started in 1934 at the Naval Fuel Depot, TOKUYAMA. Methanol was first employed as a raw material in the manufacture of explosives, but in 1940, the use of methanol for aviation fuel was adopted to increase the output of aeroengines by taking advantage of its extremely high latent heat of vaporization. Since the supply of 100 octane fuel was scarce, the use of methanol was extended to various types of aircraft engines.

Research investigations were made to increase the yield of methanol by increasing space velocity and employing different catalysts. A copper catalyst gave a high space time yield but had low heat resistance. A zinc and copper chromite catalyst having high heat resistance was studied, and satisfactory results were obtained in commercial plants with its use. Studies were extended to the synthesis of methanol from carbon dioxide and hydrogen, waste gas from butanol fermentation. (Enclosure (B)7.) Almost the same conditions as for the water gas process, a space time yield of 0.5, were obtained. This process, however, was not developed commercially because the butanol fermentation program was stopped. The corrosion of the fuel system in aeroengines caused by the use of methanol was studied, and it was found that corrosion could be prevented by addition of 5% by volume of sodium bichromate and 0.1% caustic soda solution. (Enclosure (B)15).

In order to obtain isobutene as a raw material for the synthesis of iso-octane, the synthesis of isobutanol from water gas was studied, but the results were unsatisfactory. (Enclosure (B)10).

The cracked gas from petroleum, the hydration of propylene, butene, and isobutene in the presence of sulphuric acid ($H_2SO_4 \cdot 5H_2O$) was investigated. In spite of success in obtaining yields of the corresponding alcohols close to theoretical, this process was not developed on commercial scale. (Enclosure (B)8).

In 1937 a plant for synthesis of normal butanol from acetylene was planned at the Chosen Chisso Hiryo Co. (Korean Nitrogen Fertilizer Co.) to produce 60,000 kl of iso-octane per year. Research on this process was started independently at TOKUYAMA and at Korea, and continued up to the end of the war at the First Naval Fuel Dept. The butanol yield was more than 85% of theoretical. (Enclosure (B)10, Article 2 of this series). A plant based on this process was installed at KONAN, North Korea, with a capacity of 30,000 kl of iso-octane per year.

Before the war, butanol fermentation factories had been constructed to supply raw material for production of 100,000 kl of iso-octane per year. To improve the techniques of these factories, research was undertaken on new types of

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~~fermentation bacteria. A strain superior to that of Weizmann was discovered.~~ (Enclosure (B)5, Part II, Part III). Twenty per cent of butanol and ten per cent of acetone were obtained from sugar molasses. (Enclosure (B)5, Part I and (B)5, Part IV). Butanol could be produced in yields of only 20% by weight of sugar, whereas ethyl alcohol could be obtained in yields of 45%.

In 1944, the serious shortage of aviation gasoline forced the use of alcohol directly in aviation fuel, and the butanol fermentation factories were converted to produce ethanol. At first, the source of raw material for alcohol was cane sugar and molasses from Formosa, the Philippines, and Java; then it was necessary to change to grains from Manchuria and sweet potatoes from Japan. (Enclosures (B)1, (B)2, Part I and Part III.) Ethanol had been previously produced mainly from sweet potatoes by the amylo-process in Japan. For the alcohol-aviation program, however, the "Koji"-process was adopted which had been used formerly by the "Sake" brewers. The "Koji"-process when applied to grains and sweet potatoes gave a high yield of alcohol. (Enclosure (B)2, Part IV).

A simplified alcohol distillation plant was designed for production alcohol at "Sake" breweries. (Enclosure (B)6). Since food supplies were becoming critical, however, investigations of alternative sources of alcohol were necessitated, and in this connection the saccharification of wood cellulose and the hydrolysis of pine wood were studied. (Enclosure (B)4 and (B)2, Part I).

Many difficulties were encountered when alcohol was used in aviation fuel due to its low volatility, low anti-knocking properties, and corrosive action on metals. Ethyl ether and acetone were examined for increasing the volatility of alcohol. (Enclosure (B)11, Part II). The ethyl ether was produced from alcohol in the presence of acid clay at 200°C in a vapor phase. The yield was 90% of the alcohol. Acetone was also obtained from alcohol in yield of 90% with a mixed catalyst of zinc and iron oxides at 430°C. Ethyl ether was actually manufactured and used for facilitating starting and acceleration of training planes in cold weather. (Enclosures (B)9 and (B)12).

The uniform distribution of alcohol fuels to each cylinder of radial type aeroengines with carburetors was difficult, and tests were made in full-scale engines on alcohol-acetone, alcohol-ether, and other blended fuels. (Enclosures (B)11, Part II and (B)17). Acetone increased the volatility and anti-knocking properties of alcohol, but ethyl ether did not give satisfactory results.

In order to overcome the low anti-knocking properties and preignition caused by alcohol, as observed in the test with a mono-cylinder testing engine, many anti-detonants were studied, but none were successful.

The combustion characteristics of hydrocarbons and alcohols were studied spectroscopically, but these investigations had not been completed at the end of the war. (Enclosure (B)13).

To prevent corrosion of engine accessories, sodium arsenite and dibutyl amine were proposed as additives by the First Naval Technical Depot and the First Naval Fuel Depot respectively, and the former was actually used. (Enclosure (B)12). It was found that the corrosive action of alcohol on metals was caused by impurities such as chloride and copper ions present in the alcohol. (Enclosure (B)14.) To prevent the corrosion of alcohol tanks and containers, several types of paints were tested, and it was found that a paint made from synthetic resin and vegetable oil gave the best result. (Enclosure (B)16).