JAPANESE FUELS AND LUBRICANTS, ARTICLE 6
RESEARCH ON DIESEL AND BOILER FUEL AT THE FIRST NAVAL FUEL DEPOT, OFUNA

"INTELLIGENCE TARGETS, JAPAN" (DNI) OF 4 SEPT. 1945
FASCICLE X-1, TARGETS X-09, X-10, AND X-38(N)

FEBRUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

MISCELLANEOUS TARGETS

JAPANESE FUELS AND LUBRICANTS - ARTICLE 6
RESEARCH ON DIESEL AND BOILER FUEL
AT THE FIRST NAVAL FUEL DEPOT, OFUNA

Japanese naval research pertaining to diesel and boiler fuels, as conducted at the First Naval Fuel Depot at OFUNA, has been investigated. No conspicuous progress was made in these fields, as the greater technical emphasis was on the aviation fuel research program. One interesting item was the Japanese Navy's minimum specific gravity specification for diesel fuel used in submarines, established in view of ballasting considerations. An important development was the use during the war period of 1% aluminum stearate as a pour point depressant for waxy Bunker fuels obtained from Netherlands East Indies crudes. In the last year of the war the supply of both diesel and bunker fuels from petroleum sources became most critical and substitute fuels were sought. The urgency of this problem is illustrated by the fact that as a last desperate measure, edible refined soya bean oil was used as bunker fuel on the Japanese battleship YAMATO in the battle of OKINAWA.

TABLE OF CONTENTS

LIST OF ENCLOSURES

REFERENCES

Location of Target:

First Naval Fuel Depot, OFUNA, Kanagawa Prefecture.

Japanese Personnel Interviewed:

T. ITAKURA (Ph.D.) - Naval Chemist, Japanese Navy, in charge of research on diesel and boiler fuels at the First Naval Fuel Depot.

H. FUJIMOTO (Ph.D.) - Engineering Commander, Japanese Navy (one of the most capable fuel research chemists in the Japanese Navy).

I. NORITAKE - Captain, Japanese Navy, in charge of diesel fuel and boiler fuel testing at the First Naval Fuel Depot.

I. KAGEHIRA (Ph.D.) - Engineering Captain, Japanese Navy, (a chemist of outstanding ability, specializing in lubricant synthesis).

M. HIRABE - Engineering Lieutenant, Japanese Navy, Assistant Testing Engineer.

K. HOSOI - Engineering Lieutenant, Japanese Navy, Research Engineer.

O. MIYATA - Engineer, Japanese Navy.

A. WAKANA- Engineering Lieutenant Commander, Japanese Navy, Research Chemist.

I. HARA - Engineering Lieutenant Commander, Japanese Navy.

M. KUMAMOTO - Engineering Lieutenant Commander, Japanese Navy.

T. IWASE - Engineering Lieutenant, Japanese Navy, Research Chemist.

M. SEO - Engineering Lieutenant,Commander, Japanese Navy, MAIZURU Navy Yard (specialized in boiler testing).

INTRODUCTION

Up until the beginning of the war, the Japanese Navy's chief source of diesel and bunker fuel was imports from California. From this source, Japan had placed in storage sufficient stockpiles to last until 1942. Cracked straight runs from SUMATRA and BORNEO crudes were then utilized as bunker fuels, and a blend of TARAKAN (BORNEO) crude and shale oil from FUSHUN (Manchuria) was specified for use as diesel fuel in Japanese submarines.

In 1944, due to Japanese merchant losses to U.S. submarines, it became mandatory to develop new fuel sources, and research and practical testing were undertaken on both diesel and boiler fuels to develop substitutes.

In January 1945 research on substitute fuels was intensified as the situation had become so serious that the only refinery operating continuously at that time on imported crudes was the Third Naval Fuel Depot at TOKUYAMA (See NavTechJap Report, "Japanese Fuels and Lubricants, Article 10 - Miscellaneous Oil Technology and Refining Installations," Index No. I-38(N)-10, Enclosure F). This refinery had a stock pile of 8,000,000 barrels of crude and refined products at the beginning of the war, but by the spring of 1945, it was necessary to utilize aircraft carriers as tankers to bring motor gasoline from SINGAPORE to be used as charging stock in the manufacture of even more desperately needed aviation fuel.

This report presents technical information solely on the diesel and boiler fuel research conducted by First Naval Fuel Depot at OFUNA during the war, which related principally to studies on substitute fuels, with a minor amount of research work on fuels of very high cetane number. Some supporting information was obtained by interviews with technical personnel of the Japanese Naval Boiler Laboratory at MAIZURU and the Third Naval Fuel Depot at TOKUYAMA, and with operating personnel on board a Japanese submarine and the cruiser SAKAWA.

Detailed reports of the diesel and boiler fuel research projects investigated at the First Naval Fuel Depot have been prepared in English by the Japanese technical personnel of the Depot and are included in this report as Enclosures (B)-1 to (B)-15. A summary of these reports has been prepared in English by Naval Engineer Dr. T. ITAKURA and is submitted herewith as Enclosure (A).

Since all of the research files of the First Naval Fuel Depot were burned in August 1945, by order of the Director of the Depot, it was necessary to recall the Japanese personnel to reconstruct this information from laboratory notebooks, laboratory apparatus and from memory. The preparations of these reports and pertinent drawings continued for a period of nearly three months, during which time each Japanese author was frequently interrogated and was assisted by the Petroleum Section of the U. S. Naval Technical Mission to Japan in the organization and necessary revisions of his reports. The material which is submitted as Enclosures (A) and (B) constitutes an integral part of this report, and although it may include minor errors in construction introduced in the translation, it does serve as an indication of the quality and extent of the Japanese research in these fields.

THE REPORT

PART I - DIESEL FUEL

Up until 1933, TARAKAN crude from BORNEO, having a cetane number of 28 to 30, was used by the Japanese Navy for diesel fuel. The cetane number of this fuel was found to be too low. As engine design improved, and during the period 1933 to 1942, Kettleman Hills (California) Distillate having a cetane number of 40, was specified. It is reported that when this fuel was used in the double-acting engines installed in Japanese submarines of the "I" type, smoking was experienced, due to clogging of injector tips with carbon deposits.

In 1942, the Japanese Navy modified its diesel fuel specifications to include, in addition to a minimum cetane number of 40, a minimum specific gravity of 0.915 at 15/4°C in view of ballasting requirements on submarines. As a result of research at the First Naval Fuel Depot at OFUNA, it was found that a mixture of Tarakan heavy oil (70%) and treated shale oil (30%) met these specifications, and this blend was adopted as a standard by the Japanese Navy in 1943. The Tarakan oil had a cetane number of 28-30, as stated above, and the shale oil, after light treatment with sulfuric acid, had a cetane number of 5. Treatment of the shale with sulfuric acid was found to be necessary to prevent precipitation of the blend in storage. An alternate diesel fuel blend, approved by the Japanese Navy, consisted of Tarakan heavy oil (90%) and Fischer-Tropsch condensate (10%).

It was well known that diesel fuel produced by Fischer-Tropsch synthesis is exceptionally well-suited for diesel use except for its high pour point characteristics. Research at OFUNA, on lowering the pour point by catalytic oxidation, instead of blending, showed this procedure to be economically unsound (Enclosure (B)4.

The production of diesel type fuels by Fischer-Tropsch synthesis in Japan during the war period is shown in the following tabulation.

Location of Fischer-Tropsch Plant	Annual Production (Kiloliters per Year)									
	1941		1942		1943		1944		1945	
	Gas Oil	Semi Diesel	Gas Oil	Semi Diesel	Gas Oil	Semi Diesel	Gas Oil	Semi Diesel	Gas Oil	Semi Diesel
TAKIKAWA			60			204	1631	653	564	81
AMAGASAKI					191		109			
OMUTA	775	2193	2561		3729		3556	314	663	17
Total	775	2193	2621		3920	204	5296	967	1227	98

It will be seen that the plant at OMUTA was the only one having substantial production during this entire period, and its maximum production in any one year was only 3,729 kiloliters. 72% of the diesel fuel output of the Omuta plant was shipped to the Third Naval Fuel Depot at TOKUYAMA for Navy use, as discussed in NavTechJap Report, "Japanese Fuels and Lubricants, Article 7 - Progress in the Synthesis of Liquid Fuels from Coal," Index No. X-38(N)-7. All other diesel fuel made by the Fischer-Tropsch process was required by the Japanese Army for use in diesel-driven tanks.

Chemical investigations of the manufacture of high cetane and low pour point fuel for torpedo boat and aviation diesel engines were carried out at the First Naval Fuel Depot through 1943 and 1944. For this purpose solvent extraction of various kerosenes by the Edeleanu Process (Enclosure (B)1) and hydrocracking of vegetable oils (Enclosure (B)2) were investigated.

In the year 1943 the Mitsubishi Company attempted the manufacture of diesel airplane engines following German design, and for tests of this engine the Mitsubishi Oil Company provided 55 cetane number fuel. High cetane test fuels having cetane numbers of 80 and 90, were supplied by the First Naval Fuel Depot, using blends of Fischer-Tropsch liquid, and fuels with 100 cetane number were synthesized from whale oil wax.

The research program on diesel fuels at the First Naval Fuel Depot relating to the utilization of non-petroleum substitutes included the following:

1. Cocoanut oil, hydro-cracked (Enclosure (B)2).
2. Pressed copra oil (Enclosure (B)7).
3. Esterified copra oil (Enclosure (B)7).
4. Soya bean oil (Enclosure (B)8).
5. Creosote oil obtained from high temperature carbonization of coal (Enclosures (B)6 and (B)9).
6. Pine root oil (Enclosure (B)8).
7. Dry distilled copra oil (Enclosure (B)8).

Satisfactory diesel fuels were produced from the sources included in 1 to 4, but 5, 6, and 7 were unsatisfactory due to the formation of gummy deposits in the engine.

Pine root oil was unsatisfactory for diesel fuel, not only because of the formation of gummy deposits in the engine, but also because it precipitated in storage. This was believed to be caused by the auto-oxidation of unsaturated substances. Therefore, where pine root oil was used as a diesel fuel it was necessary that it be used directly after manufacture (Enclosure (B)8).

The supply of diesel fuel in Japan had become extremely critical by the end of 1944. For that reason, the Navy Department of Material issued orders to the Yokosuka Naval Arsenal to make further tests on certain diesel and semi-diesel engines utilizing as fuel, creosote oil, a by-product of low temperature carbonization of coal. Creosote oil proved to be very unsatisfactory due to its low ignition quality and the excessive formation of engine deposits. The tests on creosote were paralleled by tests on wood gas, which was unsatisfactory in view of engine operational difficulties (Enclosure (B)8).

PART II - BOILER FUEL

The boiler fuel investigations conducted at the First Naval Fuel Depot during the war were few and of the miscellaneous type, dealing primarily with lowering the pour-point of waxy bunker fuels and a minor amount of practical testing of boiler fuels of non-petroleum types. As a rule, test fuels were prepared by the First Naval Fuel Depot and practical tests in regard to their suitability were conducted at the Naval Boiler Laboratory at the Kaizuru Navy Yard. The test results were reported to the First Naval Fuel Depot and to the Japanese Fleet.

Up until the outbreak of the war, bunker fuel for the Japanese Navy came from California, meeting the viscosity specifications of 2,000 seconds Redwood at 0°C. As the fuel supplies diminished, specifications were changed to permit 7,000 seconds Redwood at 0°C, which high viscosity product required preheating to 80°C for proper atomization. No trouble was reported by the Japanese Fleet regarding deposits on the preheaters. When the source of bunker fuel was displaced from California to the Netherlands East Indies it was planned to manufacture low cold test fuels by cracking, since the capacity of the available dewaxing plants was insufficient to supply dewaxed bunker fuel. Topped crude from PALEMBANG contained about 20% wax and had a pour point of approximately +35°C. Thermal cracking using the Dubbs Process reduced the pour-point to approximately +15°C (the cracked fuel contained from 3 to 5% wax) which was too high for satisfactory use during cold weather (Enclosure (B)13). Studies were then directed toward the use of pour-point depressants of the type usually

found satisfactory for refined lubricating oils, but these were not effective. However, as a result of the research program, it was found that the addition of 1% aluminum stearate to the cracked waxy fuel oil reduced the pour-point to less than -10°C. The Mitsubishi and Showa Oil Companies used this method of depressing the pour-point of waxy fuel oils for civilian use and the Japanese Navy incorporated it in the specifications of their winter-type bunker fuel. This product was used by the Japanese Navy during the winter of 1944-45.

The manufacture of liquid fuel from pine roots is discussed in NavTechJap Report, "Japanese Fuels and Lubricants, Article 4 - Pine Root Oil Program," Index No. X-38(N)-4. It was found that pine root oil distilled in a simple retort gave a yield of 65% of bunker fuel, complying with the heavy oil specifications of the Japanese Navy, but the supply of bunker fuel from this source was too small to be of significance.

Other outlets of bunker fuels included shaly coal tar and lignite, which, after carbonization, was distilled in a simple retort as reported in Enclosure (B)11). Creosote oils thus obtained were not used by the Japanese Navy, but by civilian outlets.

The supply of fuel oil had become so critical by the spring of 1945 that edible refined soya bean oil was used as a last desperate measure on one battleship, the YAMATO, which was sunk in the battle of OKINAWA. While soya bean oil was critically needed for food, the need for bunker fuel for the fleet was even more urgent. The use of soya bean oil had been tried experimentally some ten years previously at the Third Naval Fuel Depot at TOKUYAMA.

No recorded data were obtained in regard to compatibility studies for fuel oil blends, but it was reported that shale oil proved most troublesome in blending, and that blends of shale oils and petroleum oils of the KETTLEMAN HILLS type precipitated in storage. In order to forestall compatibility problems, indiscriminate blending of fuels was not allowed in the Navy. The plan adopted was to maintain bunker fuels of the same origin at the Japanese Navy Yards located at SASEBO, KURE and YOKOSUKA. For example, when the Netherlands East Indies oils became available, these oils were distributed at the above three outlets. Shale oil as bunker fuel was limited to use in a certain class of destroyers, and this arrangement consumed all the bunker type Shale oil available for fleet use. At no time were reports received at the First Naval Fuel Depot from ships in the Japanese Fleet relating to compatibility problems.

Only a minor amount of work was done at the First Naval Fuel Depot during the war on solid fuels, and this included tests on pitchless briquettes obtained by mixing certain coals (Enclosure (B)13), and tests of coiva pressed residue as a substitute for coal as fuel (Enclosure (B)14).

Other information on Japanese research pertaining to the solid and liquid type boiler fuels is contained in a group of Japanese research reports covering the Japanese Navy's investigation for the years 1926 to 1933. These reports are listed in the Enclosure (C) and they have been forwarded through ATIS to the Washington Documents Center.