U. S. NAVAL TECHNICAL MISSION TO JAPAN
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6 February 1946

RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To :   Chief of Naval Operations.

Subject: Target Report – Japanese Fuels and Lubricants, Article 6 –
Research on Diesel and Boiler Fuel at the First Naval Fuel
Depot, OFUNA.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

      1.   Subject report, covering Diesel and boiler fuel research as
outlined by Targets X-09, X-10, and X-38(N) of Fascicle X-1 of refer-
ence (a), is submitted herewith.

      2.   The investigation of the target and the target report were
accomplished by Comdr. G. L. Neely, USNR, Lt. Comdr. C. S. Goddin,
USNR, and Lieut. W. H. Millet, USNR, assisted by Ens. E. R. Dalbey,
USNR, as interpreter and translator.

C. G. GRIMES
Captain, USN

30704

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.

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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 residues 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 tanker 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. X-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.
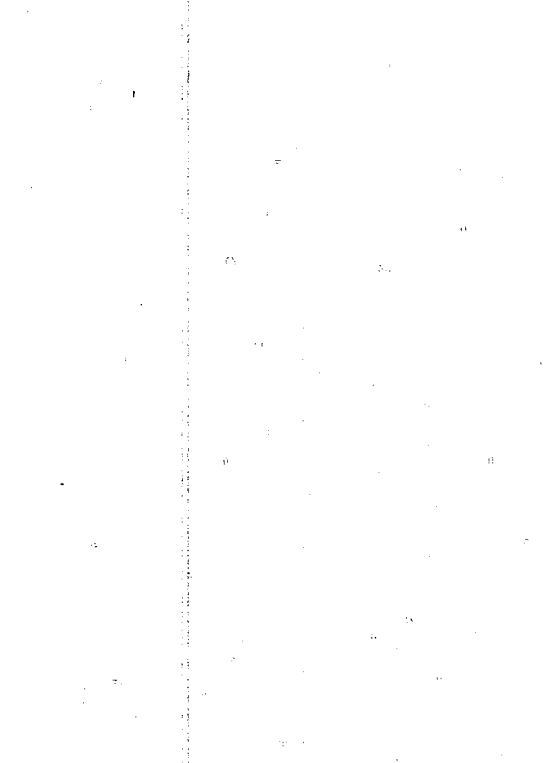
THE REPORT

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 52. 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	773	2193	2561		3729		3556	314	663	17
Total	773	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 kilcliters. 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 Maizuru 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 $0^{o}C$. As the fuel supplies diminished, specifications were changed to permit 7,000 seconds Redwood at $0^{o}C$, which high viscosity product required preheating to $80^{o}C$ 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 $+35^{o}C$. Thermal cracking using the Dubbs Process reduced the pour-point to approximately $+15^{o}C$ (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 then -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 spe-
cifications 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 experi-
mentally 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 pro-
blems, 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 obtain-
ed by mixing certain coals (Enclosure (B)15, and tests of copra pressed resi-
due 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 cover-
ing the Japanese Navy's investigation for the years 1926 to 1933. These re-
ports are listed in the Enclosure (C) and they have been forwarded through
ATIS to the Washington Documents Center.
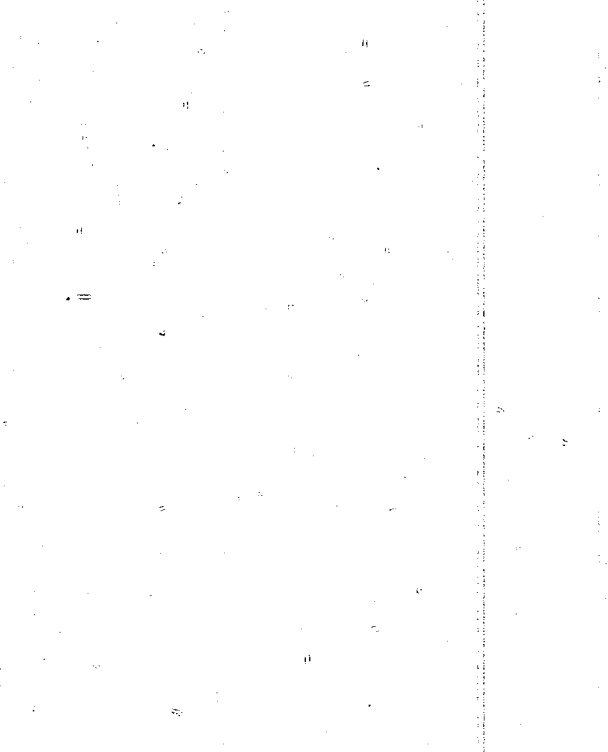
ENCLOSURE (A)

ENCLOSURE (A)

S U M M A R Y   O F

D I E S E L   A N D   B O I L E R   F U E L   R E S E A R C H

A T   T H E   F I R S T   N A V A L   F U E L   D E P O T,   O F U N A

b y

NAVAL ENGINEER
T. ITAKURA, PH.D

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

I.   INTRODUCTION

Up to 1942, straight run distillates (boiling range 200-340°C and 30-35 cetane rating) of various petroleum crudes (Enc. (B) 3, (B) 5.) from California and Tarakan crudes, had been used in submarine and other diesel engines; chemical studies on diesel fuel had not been attempted to the extent as in the case of aviation gasoline, due to the fact that advanced diesel engines were not required in the Japanese navy.

Since 1942, however, with the progress of submarine engines, it was necessary to use a somewhat higher cetane rating fuel with a high specific gravity for ballasting purposes, (40 cetane and sp. grav. above 0.915 at 15/4°C) and various blending tests (Enc. (B) 3) of high specific gravity fuel with high cetane rating oils, were tried.

Investigation of the manufacture of a high cetane and low pour-point fuel for torpedo boat or aviation diesel engines, was started in 1942. For these purposes, the Edeleanu process (Enc. (B) 1) was applied to various kerosenes, and hydrocracking of vegetable oils (Enc. (B) 2) was also investigated.

With regard to bunker fuel, various attempts (Enc. (B) 12, (B) 13) were made to lower the pour points of waxy topped residues from East Indies and Southern Sumatra crudes.

The next investigations were made to obtain boiler fuel from pine root oil and to prepare heavy oil from shaly coal and lignite which were obtainable throughout Japan, (Enc. (B) 11).

Owing to the shortage of diesel and boiler fuel, various practical engine tests were undertaken to develope substitute diesel or bunker fuels. (Enc. (B) 6, 7, 8, 9, 10, 14).

II.   DIESEL OIL

After extensive diesel blending tests of diesel oil, Tarakan heavy oil (sp. grav. 0.94, 15/4°C, cetane value 27-30) and dil. H_2SO_4 treated shale oil from Fushun (sp. grav. 082, 15/4°C, cetane value 52, pour pt. 5°C) were chosen for use by the navy in 1943. (Enc. (B) 3, (B) 5) A mixture of Tarakan heavy oil, 70 parts, and treated shale oil, 30 parts, gave a fuel with sp. grav. 0.915 and 38-40 cetane rating, satisfactory for practical use. By treating the shale oil 7 to 8 times with 3-5% H_2SO_4, precipitation or emulsion in the oil mixture during storage was prevented.

On applying the Edeleanu process to Sanga Sanga kerosene in Borneo, a fuel of cetane rating 65-70 and pour-pt. -20 to -30°C, was obtained in 70% yield. (Enc. (B) 1). According to preliminary engine tests, the fuel thus obtained gave peak pressure in the cylinder lower by 10 kg/cm².

The hydrocracking of coconut oil gave 90-95 weight per cent yield of a diesel fuel of 80-100 cetane rating and -20°C pour point. (Enc. (B) 2). Engine tests of ordinary pressed copra oil and esterified copra oil showed that both were suitable for either diesel or semidiesel engines. (Enc. (B) 7). Creosote oil from high temperature carbonization was unsuitable for engine operational periods of long duration due to piston deposits and ring sticking. (Enc. (B) 6, (B) 9).

When soya bean oil was used the running characteristics of the engine were satisfactory. (Enc. (B) 8) Pine root oil was undesirable because the resinous matters gummed the fuel injection system.

All these laboratory developments, however, were not applied in practice,
because the advanced diesel engines for torpedo boats and aircrafts were still
under design at the end of the war. Details of test equipment used at OFUNA
are given in Enc. (B) 9. A description of the method of preparation of d-
methyl naphthalene used as a standard fuel, is given in Enc. (B) 10.

III. BOILER FUELS

An investigation of the lowering of heavy oil pour points by thermal cracking,
which was conducted on topped residues from SANGA SANGA or PALEMBANG, resulted
in actual utilization of Dubbs or Cross Cracking plants for this purpose. By
this method, pour-points were lowered to about 15°C from 20-35°C, and the
yields of the oil were 60-70% (Enc. (B) 13).

Another investigation related to the mixing of cracked heavy oil, with 1% by
weight of Al-stearate to emulsify it. (Refer to Enclosure (B)12.) The
addition of Al-stearate gave a 15 to 20 C pour point depression. These
cracked heavy oils compounded with the metallic soap, had a pour-point of 0°C
and were satisfactory for practical use.

Pine root tar, when distilled in a goose neck retort, gave 50-65% by weight
of boiler fuel with specific gravity 1.01 (15/4°C), pour point -15°C, and
flash point 85°C. These properties complied with heavy oil specifications
of the Japanese Navy.

Shaly oval tar and lignite, which had been manufactured by carbonizing at
300-450°C for 20-30 hours, were distilled in a simple goose neck retort, after
dehydration of the tar by holding at a temp. of 80-90°C for 0.5-1.0 hr
(Enc. (B)5-(B)11).

The yield of distillate was 50-65% by weight. The oil had a boiling point
of 200-340°C, flash point of 75-80°C and pour point of 87°C.

Research on obtaining heavy oil from pine root tar, shaly coal tar and
lignite tar was still in progress when the war ended.

Another investigation was made of pitchless briquettes for use as boiler
fuel, obtained by mixing caking and anthracite coals (Enc. (B) 15).

Boiler tests showed that copra and copra pressed residue were satisfactory
substitutes for coal fuel (Enc. (B) 14).

ENCLOSURE (B)

ENCLOSURE (B) 1

S T U D I E S   O N   T H E   P R O D U C T I O N   O F

D I E S E L   F U E L   B Y   L I Q U I D SO_2 E X T R A C T I O N

b y

NAVAL ENGINEER
DR. T. ITAKURA

Research Period: 1942-1944

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)1

LIST OF TABLES

AND ILLUSTRATIONS

ENCLOSURE (B)1

SUMMARY

This investigation was begun in order to obtain a high
cetane rating diesel fuel with low pour-point from petro-
leum kerosenes by the Edeleanu Process. The most sig-
nificant results were that the aromatic hydrocarbons
were for the most part removed from the kerosenes and
the raffinate gave about 60-70 cetane rating.

I. INTRODUCTION

It was well known that the aromatic hydrocarbon components decreased the
cetane value of petroleum oil. Accordingly, in order to obtain high cetane
diesel fuel oil from petroleum, it was necessary to remove the aromatic hydro-
carbon from the crude oil. In our laboratory, various kinds of petroleum oils
were extracted under various conditions. This work was carried out by Naval
Eng. Lieut. S. SONODA, C. NISHIMURA Naval Eng. Y. FUJIEDA and others, during
the period Apr.,1942-Sept.,1944.

II. DETAILED DESCRIPTION

A. Test Procedures

Liquid SO_2 was inserted into a **3 liter flask** which was maintained at the
required temperature by dry ice. The mixture of one **liter** sample and
liquid SO_2 in various ratios was mixed with a stirrer for 30 minutes,
then, the raffinate and extract respectively were allowed to flow into
the SO_2 evaporator, where SO_2 was evaporated by heating up to 80°C elec-
trically. The diagram of extraction apparatus is given in Figure 1(B)1.

The properties of the products were determined by the ordinary methods.
The method of measuring the spontaneous ignition temperature was mainly
that of J. S. Lewis (Japanese Chem. Soc., 1558, (1927)), as shown in
Figure 2(B)2. The sample oil (0.1cc) was first introduced into a reac-
tion vessel (240cc pyrex glass tube), and the vessel was evacuated. The
vessel was heated at the rate of 4°C/min., after which CO_2 free air was
introduced into it. The increase in vapour pressure in the vessel was
recorded every minute. The spontaneous ignition temperature was measured,
at the time when a sudden ebullition of gas occurred in the mercury mano-
meter, caused by the ignition and burning of the sample in the vessel.

B. Experimental Results

1. Petroleum sample from various sources were extracted with
100 wt % of liquid SO_2 at temperature -10°C. The results are given
in Table I(B)1. According to this table, it was concluded that paraf-
finic petroleum kerosenes were more suitable than aromatic ones, for
providing diesel fuel of high cetane rating.

2. Tarakan kerosene (aromatic) and Sanga Sanga kerosene (paraffin-
ic), both obtained from Borneo, were extracted with 100% of liquid
SO_2 at temperature -20°C. These results were given in Table II(B)1,
Figure 3(B)1, Table III(B)1 and Figure 4(B)1. The appreciable ten-
dencies in those results were as follows:

   a. The extraction effect for Tarakan kerosene was not appre-
   ciable.

   b. The effect for Sanga Sanga kerosene was recognized to be
   appreciable.

    c.   The extraction effect increased with higher boiling point in the same kerosene.

3.   A pilot plant which was begun on 15 August 1945, had a capacity of 100 liters per hour; the flow sheet was exactly the same as the so-called Edeleanu Process.

The pre-cooled kerosene raw stock was fed into the bottom of the extractor, and the pre-cooled liquid SO_2 descended from the top in a spray, and the solvent and oil were mixed with each other in counter current, the solvent extracting the aromatic hydrocarbons from the oil. The optimum conditions for operating the extraction tower were :

> Extraction temperature .... -25°C
> Extraction pressure .... atmospheric
> Solvent ratio 100%

The remaining SO_2 in the raffinate and extract oils was removed by heating the SO_2 extractors up to temperature 80°C. However, many difficulties in operation were experienced, due to the leakage of SO_2 from valve glands and packings of plunger pumps employed. The properties of raw stock and raffinate produced from the preliminary operation are given in Table IV(B)1. Roughly, the yield of raffinate was thought to be about 70%.

III. CONCLUSION

In the research laboratory experiments, it was recognized that it was possible to remove the great   part of the aromatic hydrocarbons from petroleum

The extration effects increased almost proportionally with the increase of boiling range and paraffinicity of the raw kerosenes.

In the pilot plant operations, many difficulties were experienced, chiefly due to the leakage of SO_2 gas from valve glands. It was found to be very difficult to operate the Edeleanu Plant with packing materials produced in Japan.

ENCLOSURE (B)1

Table I(3)1
PROPERTIES OF RAFFINATE*

Sample	Yield (%)	Sp.gr (15°C)	Viscosity (R-1. 30°C)	Flash.pt (°C)	Pour.pt (°C)	Cetane Value
Bahrein (204-365°C)	86.2	0.8093	33.0	none	-24	64.0
Oha (259-372°C)	82.4	0.8834	52.1	none	-29	45.4
Kettleman Hills (50% topped residue)	85.0	0.8194	31.8	none	-40	54.5
Midway (200-350°C)	72.5	0.8534	38.0	none	-26	49.5
Tarakan (200-300°C)		0.8606	34.6	none	-30	49.0
Innai, Japan (200-300°C)	88.0	0.8582	34.8	none	-50	39.3
California (200-300°C)	77.5	0.8474		none	-45	48.3
Tarakan (F.D.-50%)	72.4	0.8965	44.6	none	-33	41.7
California (217-335°C)	71.9	0.8603		none		48.2
Mexico (200-350°C)		0.8191	36.4	none	-12	65.7
Sumatra (164-255°C)	88.4	0.7951	30.0	none	-44	51.2
Tarakan (105-356°C)	67.5	0.8571		none	-1	45.4

*Extraction Temp - 10°C
  Solvent ratio   100%

ENCLOSURE (B)

Table II(B)1
EXTRACTION EFFECTS FOR TARAKAN KEROSENE

	Tarakan Kerosene (200-300°C)	200~220 A	220~240 A	220~240 B	240~260 A	240~260 B	260~280 A	260~280 B	280~300 A	280~300 B	300~320 A	300~320 B	320~340 A	320~340 B	340~E.P A	340~E.P B
Sp.gr. (15/4 °C)	0.8960	0.8512	0.8666	0.8699	0.8811	0.8790	0.8942	0.8890	0.9030	0.8963	0.9166	0.9045	0.9329	0.9170	0.9458	0.9385
Viscosity (B-1 30°C sec)	43.4	30.6	32.8	32.8	36.0	35.0	38.4	39.2	46.0	44.4	53.0	54.6	70.8	71.8	130.8	167.2
Flash pt. (°C)	81.0	38.5	52.8	58.0	60.5	80.0	86.5	98.0	99.5	115.0	122.5	126.0	131.5	114.5	140.0	96.5
Pour pt. (°C)	49.0	below -50	below -50	below -50	below -50	below -50	below -50	below -50	-44	-37	-21	-25.5	-16	-13	-3.8	+6.0
Cetane Value	34.0	32.0	32.9	31.4	34.0	33.1	33.5	34.9	34.6	37.1	31.1	36.9	35.7	36.3	37.7	
Aniline pt. (°C)	70.2	58.9	62.8	54.9	66.2	56.1	70.4	57.6	75.8	58.5	82.8	58.9	88.3	57.8	87.3	57.7
Diesel Index			47.4		49.3		51.2		52.4		53.2		52.9		51.9	
Surface Tension (dyn/cm 25°C)			22.2	24.0	24.0	26.4		26.6		27.7		28.0		29.8		
Spont. Ignit.Temp. (°C)																
Unsaturates and Aromatics	48.2	16.0	22.2		24.0		30.8		38.5		50.7		61.5		73.6	
Naphthenes and Paraffins	51.8	84.0	77.8		76.0		69.2		61.5		49.3		38.5		26.4	

B: Raffinate

Table III(B)1
EXTRACTION EFFECTS FOR SANGA SANGA KEROSENE

	Sanga Sanga Crude Petroleum	F.D~180 A	F.D~180 B	180~200 A	180~200 B	200~220 A	200~220 B	220~240 A	220~240 B	240~260 A	240~260 B	260~280 A	260~280 B	280~300 A	280~300 B	300~320 B
Sp.gr. (15/4 °C)	0.867	0.7766	0.7756	0.7826		0.7915		0.8087	0.8019	0.8129	0.8670	0.8766	0.8214	0.8829	0.8818	0.8272
Viscosity (B-1 30°C sec)	36.4	27.1	27.1	27.7		28.7	29.2	30.6	30.3	31.8	33.4	35.2	33.9	40.6	37.7	48.7
Flash pt. (°C)	27.0	6.1	below -50	14.5	below -50	49.0	58.2	68.5	69.0	85.0	92.0	106.5	97.5	114.5	114.5	70.5
Pour pt. (°C)	20.8	below -50	below -50	below -50	below -50	below -50	-50	-33	-41.5	-34.5	-50	-9.5	-22.5	5.5	-3.0	18.5
Cetane Value	40.9	43.7	54.1	43.1	58.7	48.3	64.6	43.7	76.2	52.6	55.1	44.3	44.9	61.4	46.9	48.5
Aniline pt. (°C)	impossible to measure	54.1		58.7		64.6		76.2		77.3	69.8	73.6	82.0	85.9	77.6	90.6
Diesel Index	impossible to measure															
Surface Tension (dyn/cm 25°C)	impossible to measure															
Spont. Ignit.Temp. (°C)	impossible to measure	240		235		228		227		229		235		235		
Unsaturates and Aromatics	impossible to measure			55.0		51.3				99.2		61.0		65.4		
Naphthenes and Paraffins	impossible to measure			45.0		48.7				40.8						

A: Raw Kerosene   B: Raffinate

Table IV(B)1
PROPERTIES OF RAW MATERIALS AND PRODUCTS

	Kerosene (Sanga Sanga 200-260°C)	Product (Raffinate)
Yield (%)		70
Sp.gr. (15/4°C)	0.8487	0.8129
Viscosity (R-1 30°C sec)	30.6	29.9
Flash pt. (°C)	58.5	69.0
Pour pt. (°C)	-33.0	-39.5
Conradson's carbon (%)	Trace	Trace
Ash (%)	Trace	Trace
Impurities (%)	Trace	Trace
Cetane Value	43.1	65.0
Aniline pt.	67.3	75.5
Sp. ignit.Temp.(°C)	293	225
Unsat. and arom. (%)	55.0	13.0
Naphthene and Pararfin (%)	45.0	87.0

ENCLOSURE (B)1
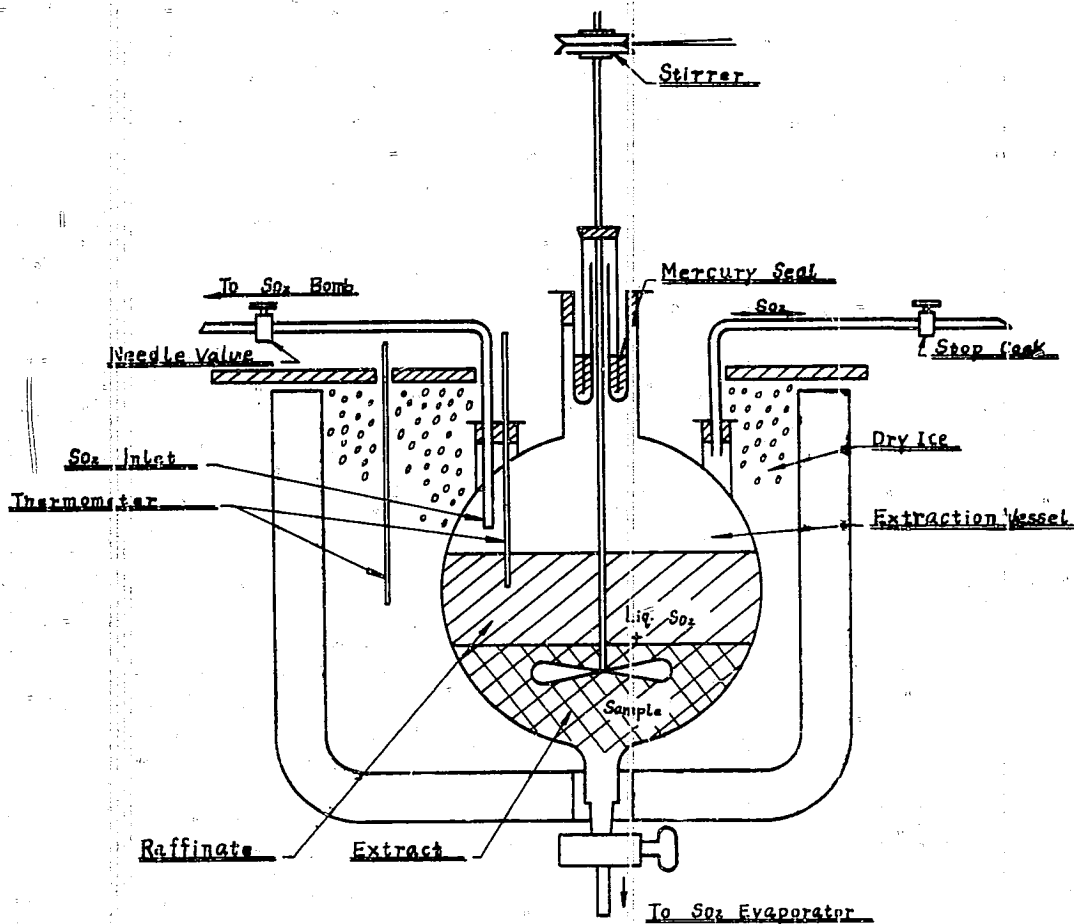
Figure 1(B)1
DIAGRAM OF EXTRACTION APPARATUS

ENCLOSURE (B)1
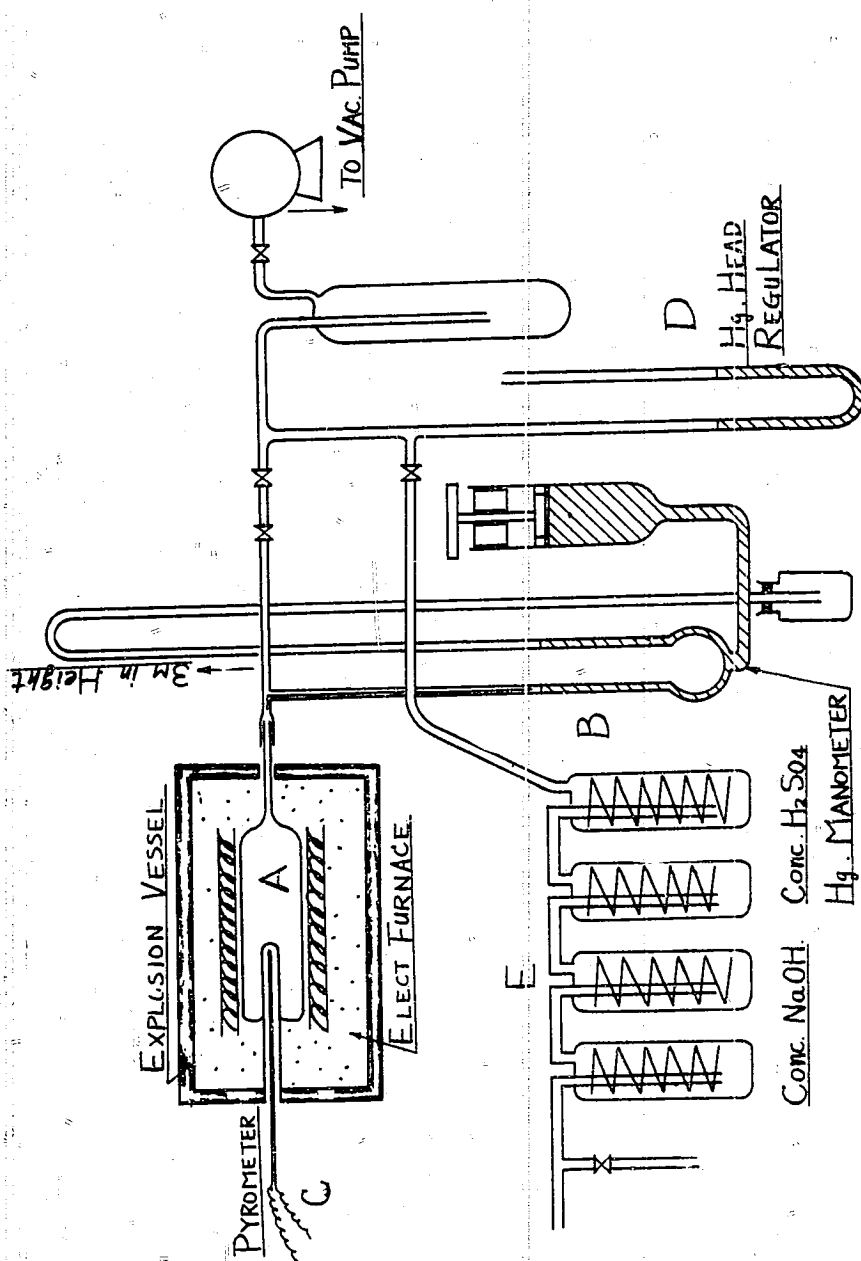
Figure 2(B)1

APPARATUS FOR MEASURING SPONTANEOUS IGNITION TEMPERATURE
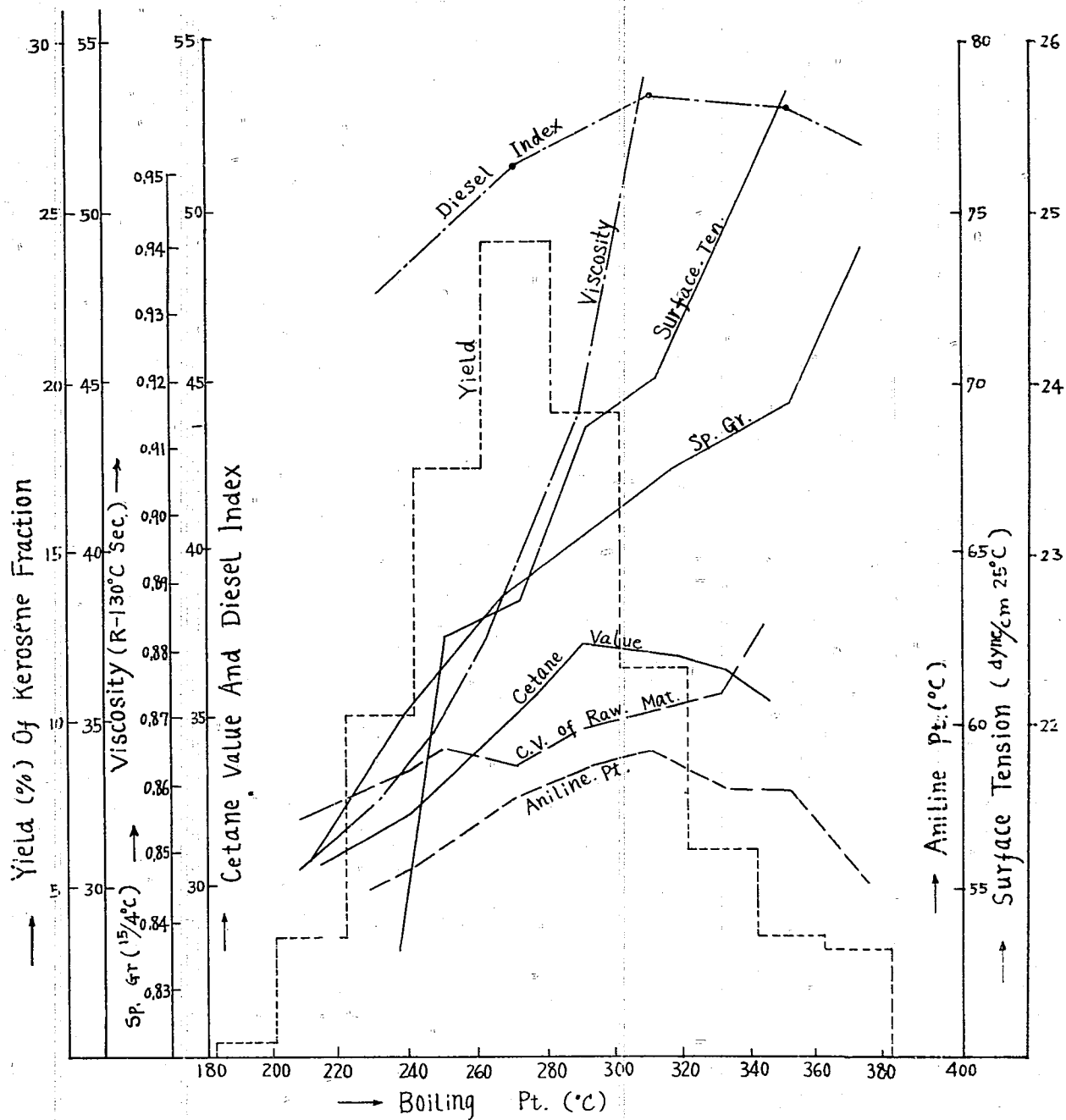
ENCLOSURE (B)1

Figure 3(B)1

RELATIONS BETWEEN B.P. OF TARAKAN KEROSENE
RAFFINATE AND ITS DIESEL PROPERTIES
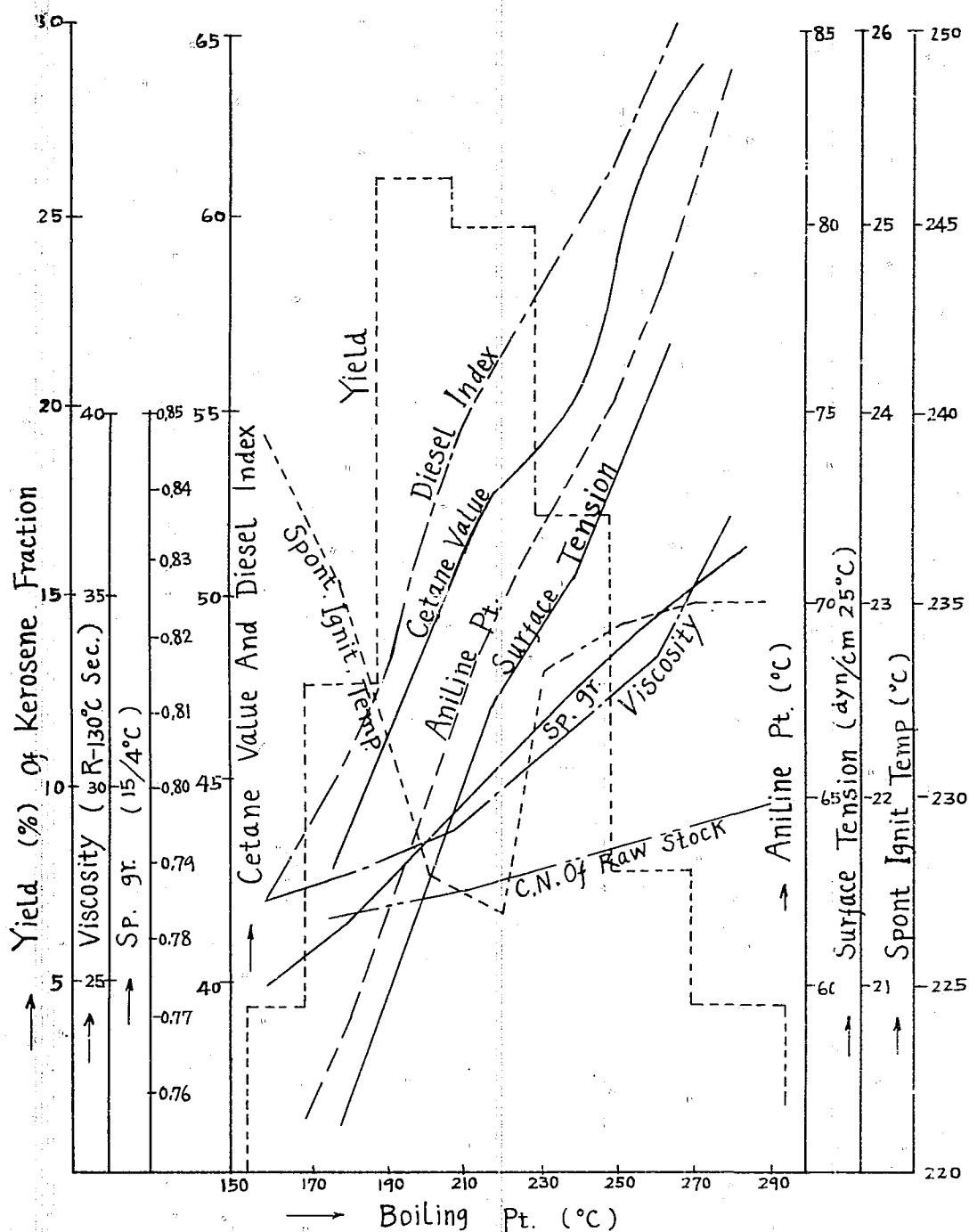
Figure 4(B)1

RELATIONS BETWEEN B.P. OF SANGA SANGA
KEROSENE RAFFINATE AND ITS DIESEL PROPERTIES
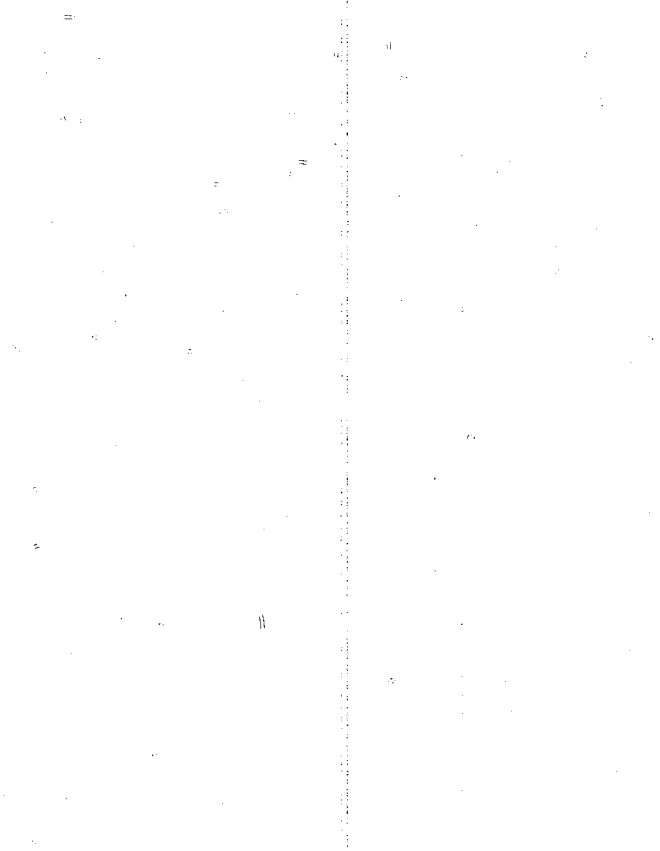
ENCLOSURE (B) 2

STUDIES ON THE SYNTHESIS OF HIGH CETANE FUEL BY HIGH PRESSURE HYDROGENATION OF FATTY OIL

By

CHEM. ENG. COMDR. DR. H. FUJIMOTO

CHEM. ENG. LIEUT. T. IWASE

Research Period: 1943

Prepared for and Reviewed with Authors
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)2

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B)2

SUMMARY

It was the object of this project to compare catalyst be-
havior and activity in the hydrogenation of fatty oils
using methyl laurate as a sample. Nickel oxide, copper
chrome oxide and molybdenum sulphide were taken as cata-
lysts and it was recognized that methyl laurate changes
directly into hydrocarbon of C_{11} under nickel catalyst
and into the hydrocarbon of C_{12} passing the corresponding
alcohol as an intermediate under copper chrome catalyst
and into hydrocarbon of C_{12} under molybdenum catalyst.

I.   DETAILED DESCRIPTION

A.   Nickel Oxide-Clay Catalyst

Eighty grams of methyl laurate and eight grams of catalyst were taken
in a autoclave which had 240 cc of inner volume, and after charging the
hydrogen pressure up to 100 atmospheres, it was heated to each reaction
temperature for one hour. Reaction products had properties according
to the reaction temperature as shown in Table I(B)2.

The reaction product at 350°C was fractionated under reduced pressure
of 15mm Hg as follows:

Distilling Temp. °C	Yield %
72.5 — 80	6.05
80 — 82	18.77
82 — 83	14.15
83 — 84	19.88
84 — 86	14.41
86 — 88	6.19
88 — 89	13.82
residue	2.01

The 83 - 84°C fraction has following physical properties and it may
be considered to be n-undecane, $C_{11}H_{24}$

$$d_4^{20} = 0.7401$$

$$n_D^{20} = 1.4188$$

B.   Copper-chrome Oxide Catalyst

The same experiments were undertaken using copper chrome oxide as cata-
lyst and the following results (Table II(B)2) were obtained:

The reaction product at 400°C was fractionated under reduced pressure
of 15mm Hg as follows:

Distilling Temp. °C	Yield %
15 — 50	3.76
50 — 80	5.59
80 — 90	6.93
90 — 92	4.33
92 — 94	5.99
94 — 95	5.46
95 — 96	17.72
96 — 96.5	21.49
96.5 — 97	4.00
97 — 100	2.76

ENCLOSURE (B)2

The fraction boiling between 96-96.5°C contained some unsaturates but after washing with sulfuric acid its physical properties agreed well with those of dodecane, $C_{12}H_{26}$.

C.   Molybdenum Sulphide Catalyst

The same experiments were undertaken using molybdenum sulphide as catalyst and the following results Table III(B)3 were obtained:

The reaction product at 350°C was fractionated under reduced pressure of 15mm Hg as follows:

Distilling Temp. °C	Yield %
89.5 - 95.0	1.67
95 - 96	35.87
96	54.92
96 - 98	3.24

The fraction boiling at 96°C has the following physical properties and may be considered as n-dodecane, $C_{12}H_{26}$

$$d_4^{20} = 0.7493$$

$$n_D^{20} = 1.4220$$

II.   CONCLUSIONS

In order to get pure n-hydrocarbons by the hydrogenation of the corresponding fatty oils it is desirable to use a molybdenum sulphide catalyst.

Table I(B)2
REACTION PRODUCT PROPERTIES
CLAY CATALYST

Reaction Temperature (°C)	300	350	400
Final Hydrogen Pressure (atm)	78.3	44.5	43.6
Density of Product (20/4)	0.8224	0.7415	0.7416
Index of Refraction of Product (20/D)	1.4359	1.4184	1.4187
Saponification Value	122.3	8.2	0.0
Iodine Value	5.0		

Table II(B)2
REACTION PRODUCT PROPERTIES - COPPER CATALYST

Reaction Temperature (°C)	250	300	350	400
Final Hydrogen Pressure (atm)	78.6	79.0	81.5	73.1
Density of Product (20/4)	0.8299	0.8229	0.7889	0.7496
Index of Refraction of Product (20/D)	1.4337		1.4325	1.4241
Acid Value of Product	0	0.1	0.3	0.3
Saponification Value of Product	52.9	12.9	4.0	1.7
Hydroxyl Value of Product	232.2	274.9	115.3	12.9
Iodine Value of Product	1.9	0.3	0.3	6.9

Table III(B)2
REACTION PRODUCT PROPERTIES - MOLYBDENUM CATALYST

Reaction Temperature (°C)	300	350	400
Final Hydrogen Pressure (atm)	79.7	61.7	61.1
Density of Products (20/4)	0.8369	0.7479	0.7452
Index of Refraction (20/D)	1.4409	1.4219	1.4214
Acid Value	46.6	0.3	0.1
Saponification Value	247.4	3.7	3.6
Hydroxyl Value	28.8	3.1	0.9
Iodine Value	26.3	0.7	0.8

ENCLOSURE (B) 3

S T U D I E S   O N   T H E   S Y N T H E S I S

O F   D I E S E L   F U E L   A N D   I T S   P R E P A R A T I O N

F R O M   C R U D E   P E T R O L E U M

by

NAVAL ENGINEER
DR. T. ITAKURA

Research Period: 1938-1940

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)3

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B)3

SUMMARY

This investigation was carried out to obtain the most suit-
able submarine diesel oil from crude petroleum by blending
with other high cetane fuels. It was confirmed that the
mixture, Tarakan crude oil 70%, acid-treated diesel oil 30%,
was the most useful for submarine purposes.

I.   INTRODUCTION

It was well known that such fuels as Fischer oil or shale oil had high cetane
ratings in spite of their lower specific gravity. For submarine diesel engines
a superior diesel fuel should have a cetane value higher than 40 and a specific
gravity in excess of 0.9150 (15/4°C). The high specific gravity is important
in connection with the ballasting requirements for submarines. Accordingly,
various kinds of heavy fractions of petroleum diesel oils were blended with
high cetane-rating light oils, and the properties of these mixtures were deter-
mined. This work was carried out by Nav. Comdr. Y. KANEZAKI, Nav. Eng. Lieut.
S. SONODA and others, from April, 1938 to April, 1940.

II. DETAILED DESCRIPTION

Pertinent physical and chemical properties of various petroleum fractions were
determined in order to ascertain which fractions of petroleum crude were suit-
able for submarine diesel oil. These results are given in Table I(B)3. Sev-
eral blending tests were carried out in order to evaluate the suitability of
the various blends for submarine use. The results are shown in Table II(B)3.
The mixture, Tarakan crude 70%, acid treated Fushun shale oil 30% was found to
be the most suitable for submarine purposes because the specific gravity, pour
point and cetane value of the mixture were 0.915 - 0.920, below -5°C, and 37 -
40 units, respectively.

III. CONCLUSIONS

In Blending Tests No. 1 and 3 in Table II(B)3, the properties of every mixture
were unsatisfactory for naval use.

In Blending Test No. 2 in the table, the mixture, Tarakan crude 70%, acid
treated Fushun shale oil 30, was the best for submarine purposes.

ENCLOSURE (B)3

Table I(B)3
PROPERTIES OF VARIOUS PETROLEUM FRACTIONS

I. Oha Fraction (Heckmann's vacc. Distill)							
Fraction (%)	Treatment	Sp.Gr. (1514°C)	Viscosity (R-1.30°C)	Flash pt. (°C)	Pour pt. (°C)	Aniline pt. (°C)	Cetane Value
F.D.~10	Distillates	0.8232	27.4	27.5	no	no	51.0
10~15		0.8581	29.5	72.0	no	no	42.4
15~20		0.8718	31.5	88.5	no	no	39.5
20~25		0.8805	33.3	107.0	no	no	37.5
25~30		0.8883		117.0	no	no	36.1
30~35		0.8970	37.2	133.0	no	no	34.4
35~40		0.9053	40.5	145.0	no	no	32.8
40~45		0.9153	45.6	159.0	no	no	30.6
45~50		0.9267	61.0	195.0	no	no	28.6
II. Kettleman Hill's Fraction of 36% Topped Residue							
F.D.~10	Distillates	0.8313	31.2	no	no	no	53.5
F.D.~20		0.8399	33.9	no	no	no	53.9
F.D.~30		0.8549	37.8	no	no	no	51.9
F.D.~40		0.8664	45.8	no	no	no	51.2
F.D.~50		0.8832	117.1	no	no	no	47.5
F.D.~60		0.9021	141.1	no	no	no	43.3

ENCLOSURE (B)₃

Table I(B)3-Cont.
PROPERTIES OF VARIOUS PETROLEUM FRACTIONS

			III. Bahrein Fraction				
Fraction (%)	Treat-ment	Sp. Gr. (1514°C)	Viscosity (R-1.30°C)	Flash pt. (°C)	Pour pt. (°C)	Aniline pt. (°C)	Cetane Value
F.D.~50		0.8136	no	no	-5.0	179.0	70.6
22~62		0.8518	no	no	-6.0	151.3	59.9
22~27		0.8018	no	no	below -20	137.9	51.7
27~32	Distillates	0.8166	no	no	below -20	144.1	56.7
32~37		0.8293	no	no	below -20	148.5	58.2
37~42		0.8452	no	no	-17	150.1	61.4
42~47		0.8591	no	no	-7	154.9	64.7
47~52		0.8729	no	no	+2.0	157.9	69.5
52~57		0.8877	no	no	+8.0	159.4	67.1
57~62		0.9019	no	no	+14.0	159.4	31.7
		IV. 200~360°C Fraction of Fushun Shale Oil					
	Distilled Amount						
F.D.~240	5.0%	0.8125	no	no	no	48.2	49.3
240~260	19.1	0.8240	no	no	no	52.2	53.0
260~280	22.6	0.8300	no	no	no	56.5	55.0
280~300	21.1	0.8365	no	no	no	60.5	57.0
300~320	18.5	0.8420	no	no	no	65.4	59.0
320~340	9.7	0.8490	no	no	no	68.4	64.0
340~	4.0	0.8510	no	no	no	71.1	65.0
Crude	100.0	0.8360	no	no	no	61.0	56.0

ENCLOSURE (B)3

Table II(B)3
BLENDING TESTS

I.   Shale Diesel – Tarakan Diesel

Blending Ratio (%)		Treatment	Sp.Gr. (20/4°C)	Pour Pt. (°C)	Cetane Value
Shale	Tarakan				
100	0		0.8715	+4.5	52.0
80	20	Both	0.8790	+2.0	50.0
60	40	200∼300°C	0.8890	-2.3	47.0
50	50	Distillate	0.8940	-4.8	46.6
40	60		0.8990	-7.2	44.5
20	80		0.9090	-11.5	40.0
0	100		0.9132	-19.5	35.0

II.   Tarakan Crude – Treated Shale Diesel

Tarakan	Shale				
100	0		0.9408	-38.0	33.7
80	20	Shale Diesel	0.9242	-10.0	37.0
60	40	treated with	0.9076	-1.0	40.1
50	50	dil H_2SO_4	0.8911		
40	60		0.8845	-3.0	43.7
20	80		0.8740	-4.0	48.7
0	100		0.8508	-7.0	51.1

III.   Tarakan Crude – Fischer's Condensate

Tarakan	Fischer				
100	0		0.9408	-38.0	33.7
80	20	Fischer's	0.9074	-7.0	50.0
60	40	Condensate	0.8841	+5.0	58.6
50	50	topped Residue			
40	60	(200°∼)	0.8407	+7.0	62.0
20	80		0.8073	+10.5	76.9
0	100		0.7740	11.0	94.6

ENCLOSURE (B) 4

STUDIES ON THE APPLICATION

OF FISCHER OIL

by

NAV. CHEM. ENG.
DR. T. ITAKURA

Research Period: 1944

ENCLOSURE (B)4

LIST OF TABLES
AND ILLUSTRATIONS

40

ENCLOSURE (B)4

SUMMARY

It is well known that Fischer condensate oil has a high ce-
tane rating and also a high pour-point. To use this stock
as a diesel fuel it is necessary to lower the pour point,
and for this purpose treatment with mildly oxidizing cata-
lysts was considered most promising. In preliminary tests
it was found that treatment over CrO_3 supported on acid
clay lowered the pour point of Fischer oil about 15°C. The
investigation was stopped due to economic unattractiveness
of the process.

I. INTRODUCTION

The 200-300°C. fraction of Fischer condensate oil has a high cetane value
(about 80) owing to the fact that it is composed mainly of normal hydrocarbons
$C_{13}-C_{17}$. This fraction, however, has a pour-point of 8-10°C., and it is ne-
cessary to reduce same to below -5°C, in order to produce a satisfactory die-
sel fuel. This work was undertaken to investigate the lowering of pour point
by the catalytic action of mild oxidizing agents. It was carried out during
April-May, 1944 by Nav. Eng. Lieut. H. TAKEMURA and G. NISHIMURA. This work
was stopped because the process appeared economically unattractive due to the
low space velocity required.

II. DETAILED DESCRIPTION

A diagram of experimental apparatus employed is shown in Figure 1(B)4.

A catalyst boat was inserted in the middle of the pyrex glass reaction tube
(3 x 100cm), which was electrically heated to maintain the required temperature.
The raw oil was dropped into the upper part of the reaction vessel and vapor-
ized. The vapor passed over the catalyst and was partially converted into
cyclic hydrocarbons.

The product was then condensed and collected in the receiver.

III. EXPERIMENTAL RESULTS

The extent of conversion of condensate oil into naphthenic or aromatic hydro-
carbons was not determined. The pour point of the product, however, was low-
ered about 15°C, through treatment over CrO_3 catalyst. This was due to the
fact that a part of the raw oil was changed into cyclic hydrocarbons. Accord-
ingly, the cetane rating of the product dropped about 4.5 units. In so far as
the activity of catalyst is concerned a mixture of one part of CrO_3 and nine
parts (by weight) of acid clay was the most effective of the three catalysts
tried under the reaction conditions (temp. 250-300°C, gaseous space velocity
about 350, and atmospheric pressure). When ZnO was used instead of CrO_3, the
activity was inferior. The activity of CuO catalyst was slightly below that
of ZnO catalyst. All catalysts tested were composed of one part of the oxide
plus 9 parts (by weight) of Japanese acid clay. The materials were mixed to-
gether in form of a water slurry and were oven-dried. The yield of product
was about 99% with the use of CrO_3 catalyst, the loss being mainly gas.

IV. CONCLUSIONS

By treatment over CrO_3 catalyst, the pour point of Fischer condensate oil was
lowered 15°C, and its cetane number dropped 4.5 units.

The activity of the three catalysts employed was as follows:
$$CrO_3 \; > \; ZnO \; > \; CuO$$

ENCLOSURE (B)4

Table I(B)4
RESULTS OF TREATMENT OVER CrO₃ CATALYST

	Fischer condensate	Treated oil
Sp. gr. (15/4°C)	0.7832	0.7940
Viscosity (R-1,30°C)(sec)	34.4	31.6
Pour pt., °C.	9.0	-7
Ash, wt. %	trace	0.02
Conradson carbon	trace	trace
Impurities	trace	trace
Cetane number	81	76.5

Distillation (°C)

```
F.D.................................................172
10%.................................................192
50%.................................................224
90%.................................................296
95%.................................................320
D.P.................................................331
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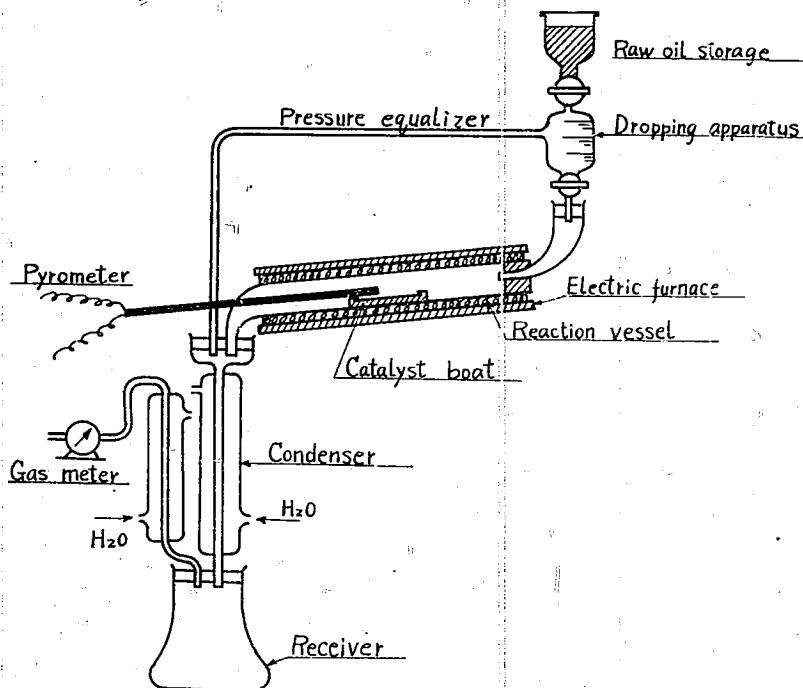

Figure 1 (B)4
DIAGRAM OF EXPERIMENTAL APPARATUS

ENCLOSURE (B) 5

STUDIES   ON   THE   PROPERTIES

OF   DIESEL   FUEL   OILS

by

CHEM. ENG. COMDR.
DR. H. FUJIMOTO

Research Period: 1941 - 1943

Prepared for and Reviewed with Author by
the U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)₅

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B)5

SUMMARY

Physical and chemical properties of representative diesel
oils used by the Japanese Navy and of twenty degree frac-
tions of each of those fuels were measured. It was shown
that the fraction near 320°C has the maximum cetane rat-
ing, independent of the initial oil, and that there is no
acceptable relation between cetane value and other physi-
cal and chemical properties.

This work was done by Ass't Eng. S. IKAZAKI.

I.   DETAILED DESCRIPTION

The properties of the diesel oils used in this experiment are given in Table I
(B)5 through Table VI(B)5.

Physical and chemical properties of 20 degree fractions from each crude oil
are shown in Table II(B)5 through Table VI(B)5. Spontaneous ignition tempera-
tures were measured as follows with the apparatus shown in the Figure 1(B)5.
0.1 grams of sample are taken in the quartz reaction vessel and the air dis-
placed by pure oxygen. The vessel is heated at the rate of 2°C per minute,
maintaining mercury head constant at F, and the break of the temperature-pres-
sure curve is measured as spontaneous ignition temperature.

From the above experimental results, the cetane value, spontaneous ignition
temperature, U.O.P. Characterization Factor (Watson, Nelson and Murphy, Ind.
Eng. Chem., Vol 27, P. 1460), Diesel Index (Backer and Fischer, S.A.E.J., Vol.
35, P. 376), and Viscosity Gravity Constant (Moore and Kaye, Oil & Gas J., Vol.
33, P. 108), were plotted against the mean boiling points as shown in Figure 1
(B)5 through Figure 6(B)5.

It is shown that the fraction near 320°C has the maximum cetane rating, inde-
pendent of the initial oil, and that there is no acceptable relation between
cetane value and other physical and chemical properties.

ENCLOSURE (B)5

Table I(B)5
PROPERTIES OF DIESEL OILS USED

	Fischer Kogasin	Kettleman Hills crude	Oha crude	Tarakan crude	Shale diesel base stock
Sp. Gr. (15/4)	0.7665	0.8440	0.9464	0.9388	0.8570
Vis. R.W.I. 30° sec	32	38	707	131	42
Pour pt. (°C)	+3	-12	-15	-38	0
Flash pt. (°C)	30		18	93	97
Conradson Carbon (%)	0.0	2.59	5.13	2.08	0.13
Sulfur (%)	0.04	0.32	0.40	0.29	0.40
Aniline pt.	88.0				60.3
Cetane Value	86.7	40.5	27.1	29.5	58.3

Table II(B)5
PROPERTIES OF FRACTIONS FROM FISCHER KOGASIN

Fraction (°C)	Mean B.P. (°C)	H/C ratio	d_4^{15}	Vis. 30°C Sec.	V.I.	Pour Pt. (°C)	Flash Pt. (°C)	O.C. (%)	S (%)	Cetane V	Aniline Pt. (°C)	Spontaneous Ign.temp.
150-160	162	2.13	0.7354	26.8	100		14.0	trace	0.028		69.6	
160-180	175	2.14	0.7419	27.6	95	-50.0	27.0	trace	0.031	68.0	71.8	223
180-200	191	2.14	0.7470	28.7	93	-40.0	42.0	trace	0.026	70.5	74.8	224
-100 (at 10mm)*	207	2.11	0.7546	29.2	92	-31.0	64.0	trace	0.026	72.7	78.2	221
100-120	230	2.11	0.7636	30.9	90	-18.5	79.0	trace	0.030	74.7	83.2	220
120-140	257	2.11	0.7720	33.2	87	- 6.5	95.0	trace	0.029	79.7	89.2	222
140-160	286	2.10	0.7804	35.9	84	6.0	115.0	trace	0.032	86.0	95.2	221
160-180	319	2.08	0.7719 /40	40.4	82	18.5	138.0	trace	0.044	91.0	99.4	222
180-200	345	2.07	0.7786 /40			27.5	159.0	0.002	0.038	87.5	104.8	235
200-220	372	2.05	0.7868 /40			31.0		0.002	0.036	87.5	110.4	248
200-240		2.04	0.7934 /40			33.0		0.010	0.043		115.5	

* All the following fractions are at 10mm.

ENCLOSURE (B)5

Table III(B)5
PROPERTIES OF FRACTIONS FROM KETTLEMAN HILLS CRUDE

Fraction (°C)	Mean B.P. (°C)	H/C ra- tio	d_4^{15}	Vis. 30°C Sec.	V. I.	Pour Pt. (°C)	Flash Pt. (°C)	C.C. (%)	S (%)	Ce- tane V.	Aniline Pt. (°C)	Sponta- neous Ign. temp.
150-170	140	1.94	0.7709	26.3	96				0.06	34.0	50.6	
170-190	161	1.90	0.7900	27.5	96		19.0		0.05	37.0	51.4	243
190-210	187	1.87	0.8050	28.5	94		32.5	0.007	0.06	41.2	53.6	242
-100 (at 10mm)*	208	1.83	0.8222	31.1	87	-55.0	58.0	0.009	0.05	43.2	54.2	242
100-120	239	1.81	0.8362	32.2	87	-38.0	82.0	0.014	0.08	50.2	60.2	240
120-140	260-	1.80	0.8455	34.4	86	-25.5	99.0	0.026	0.13	53.4	63.6	240
140-160	284	1.78	0.8535	35.5	82	-12.5	114.0	0.034	0.16	56.4	66.6	237
160-180	312	1.77	0.8623	45.6	77	- 1.5	129.5	0.081	0.22	58.0	73.0	238
180-200	340	1.75	0.8765	62.5	60	9.5	144.5	0.120	0.30	57.0	69.2	246
200-220	365	1.72	0.8940	97.5	44	14.3	158.0	0.162	0.34	55.0	78.5	252
220-240	380	1.71	0.9098			24.0	171.0	0.232	0.34	53.4	82.0	252

Table IV(B)5
PROPERTIES OF FRACTIONS FROM OHA CRUDE

Fraction (°C)	Mean B.P. (°C)	H/C ra- tio	d_4^{15}	Vis. 30°C Sec.	V.I.	Pour Pt. (°C)	Flash Pt. (°C)	C.C.	S (%)	Ce- tane V.	Aniline Pt. (°C)	Spontaneous Ign. temp. (°C)
-100 (at 10mm)*	211	1.79	0.8557	32.0	91				0.12	33.5	52.0	
100-220	238	1.78	0.8629	33.2	89	-65.0	75.0	0.022	0.14	36.0	53.0	242
120-140	262	1.73	0.8747	35.7	85	-53.5	94.0	0.048	0.17	38.6	57.6	243
140-160	283	1.71	0.8852	40.5	79	-40.0	109.0	0.036	0.19	40.0	54.4	241
160-180	299	1.67	0.8919	46.5	72	-31.0	120.0	0.036	0.26	41.5	56.4	242
180-200	315	1.63	0.9016	52.3	68	-23.5	132.5	0.076	0.29	42.7	63.8	237
200-220	339	1.63	0.9136	80.3	50	-13.0	149.6	0.167	0.29	40.0	59.2	249
220-240	359	1.60	0.9258	147.2	30	-6.5	160.5	0.210	0.32	39.0	58.4	254

* All the following fractions are at 10mm.

ENCLOSURE (B)5

Table V(B)5
PROPERTIES OF FRACTIONS FROM TARAKAN CRUDE

Fraction (°C)	Mean B.P. (°C)	H/C ratio	d_4^{15}	Vis. 30°C Sec.	V.I.	Pour Pt. (°C)	Flash Pt. (°C)	C.C. (%)	S (%)	Co-tane V.	Aniline Pt. (°C)	Spontaneous Ign. temp. (°C)
-100 (at 10mm)*	212	1.78	0.8616	31.2	90		56.0	0.018	0.05	31.7	51.2	246
100-120	238	1.73	0.8807	34.5	86		80.0	0.025	0.06	32.5	51.4	246
120-140	259	1.70	0.8934	37.5	82		100.0	0.024	0.08	33.5	51.4	245
140-160	283	1.70	0.9046	43.3	76	-48.0	117.0	0.022	0.12	34.7	50.6	238
160-180	307	1.61	0.9164	53.9	65	-30.0	137.0	0.030	0.15	36.5	50.0	242
180-200	333	1.54	0.9353	84.7	47	-14.5	157.5	0.038	0.23	36.5	47.4	251
200-220	358	1.50	0.9534	180.8	27	-4.5	177.0	0.042	0.29	34.0	47.6	258
220-240	380	1.46	0.9656	551.6	13	4.5	197.0	0.046	0.32	31.5	38.3	262

Table VI(B)5
PROPERTIES OF FRACTIONS FROM SHALE DIESEL BASE STOCK

Fraction (°C)	Mean B.P. (°C)	H/C ratio	d_4^{15}	Vis. 30°C Sec.	V.I.	Pour Pt. (°C)	Flash Pt. (°C)	C.C. (%)	S (%)	Ce-tane V.	Aniline Pt. (°C)	Spontane-ous Ign. temp. (°C)
-100 (at 10mm)*	206	1.80	0.8115	29.1	93	-42.5	62.0	0.010	0.45	46.0	43.3	240
100-120	241	1.77	0.8271	31.7	90	-23.3	93.0	0.013	0.42	50.3	54.0	236
120-140	264	1.80	0.8341	34.4	86	-12.0	111.0	0.025	0.43	55.3	55.4	241
140-160	285	1.80	0.8410	37.1	84	-2.9	125.5	0.026	0.77	59.1	60.2	239
160-180	308	1.79	0.8491	41.3	79	4.1	141.0	0.031	0.41	61.3	63.4	238
180-200	339	1.75	0.8658	50.3	70	10.3	153.0	0.033	0.37	64.0	65.0	234
200-220	366	1.70	0.8805 /20	69.8	56	13.2	179.5	0.040	0.57	60.0	64.0	242
220-240	387	1.70	0.8929 /20	106.7	45	6.5	185.0	0.067	0.40	54.9	64.8	271

* All the following fractions are at 10mm.

ENCLOSURE (B)5

A---- Quartz Reaction Vessel
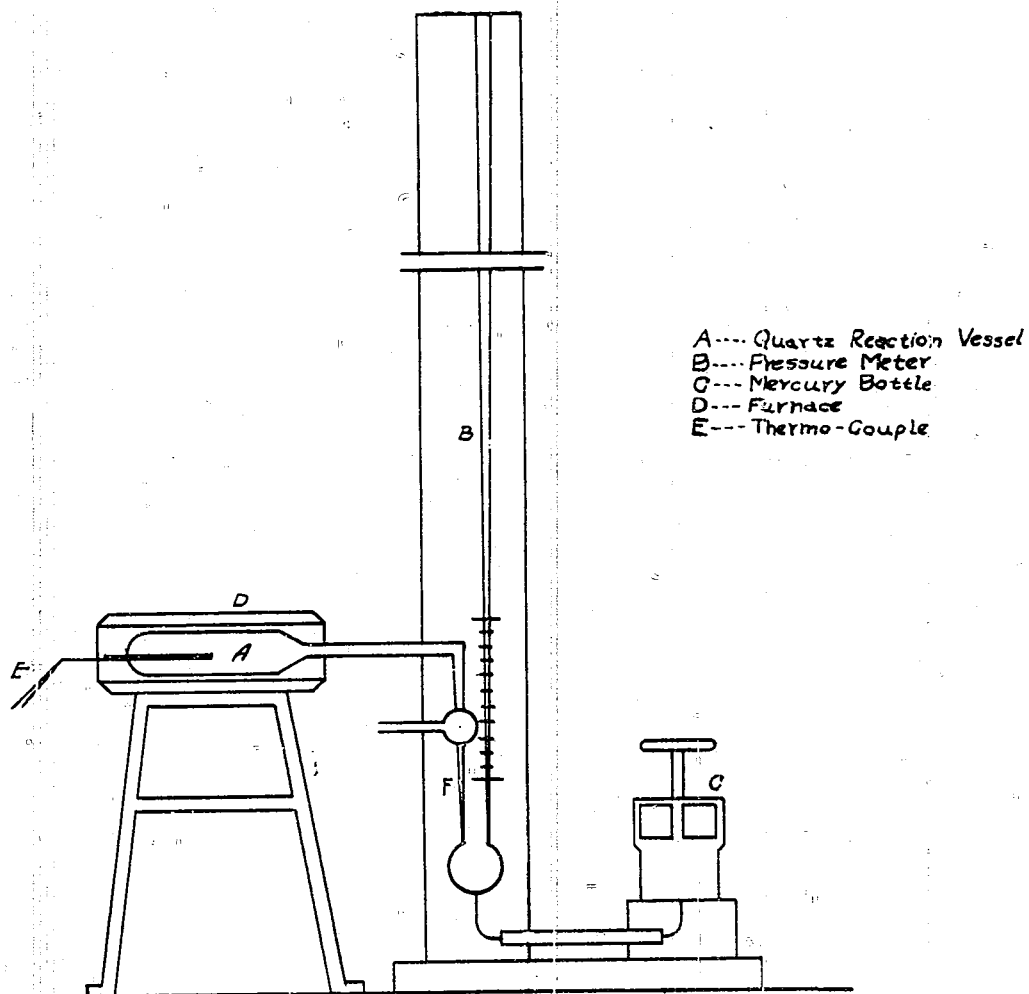B----Pressure Meter
C--- Mercury Bottle
D--- Furnace
E--- Thermo-Couple

Figure 1 (B)5
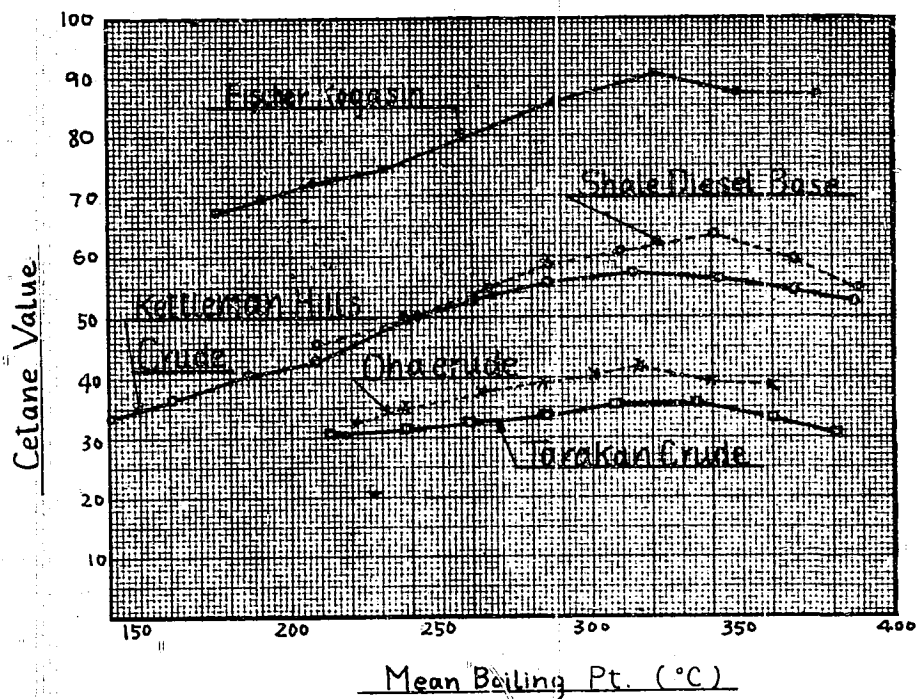APPARATUS FOR MEASURING SPONTANEOUS IGN. TEMP.

Figure 2 (B)5
RELATIONSHIP BETWEEN MEAN BOILING POINT
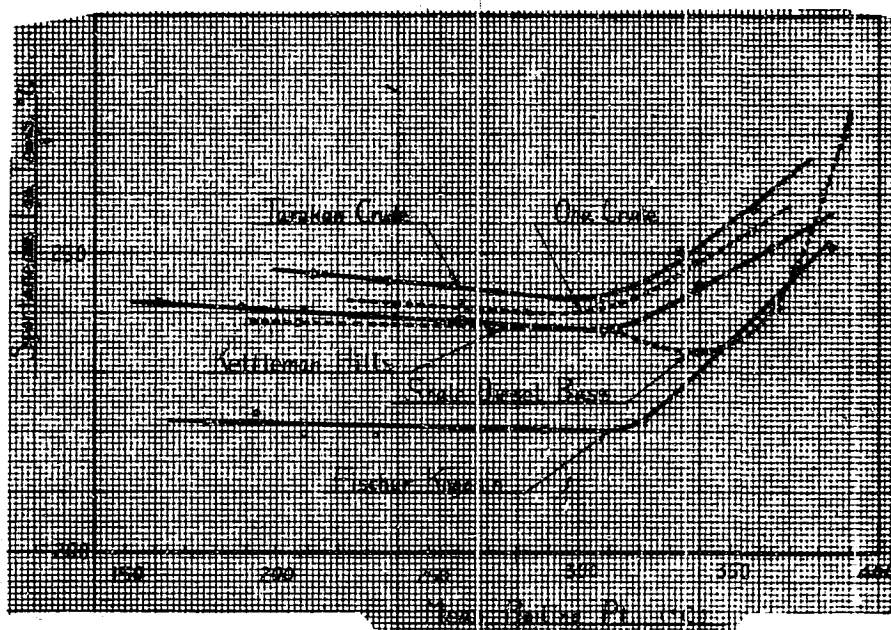AND CETANE VALUE

ENCLOSURE (B)5

Figure 3 (B)5
RELATIONSHIP BETWEEN MEAN BOILING POINT
AND SPONTANEOUS IGNITION TEMPERATURE

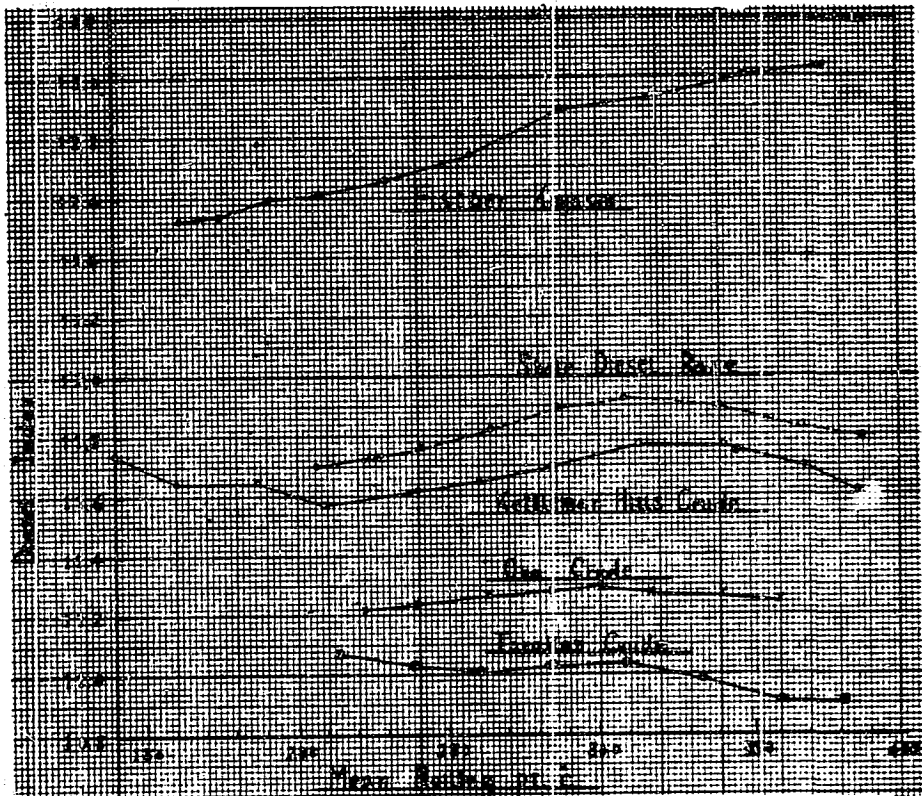ENCLOSURE (B)5

Figure 4 (B)5
RELATIONSHIP BETWEEN
MEAN BOILING TEMPERATURE AND DIESEL INDEX
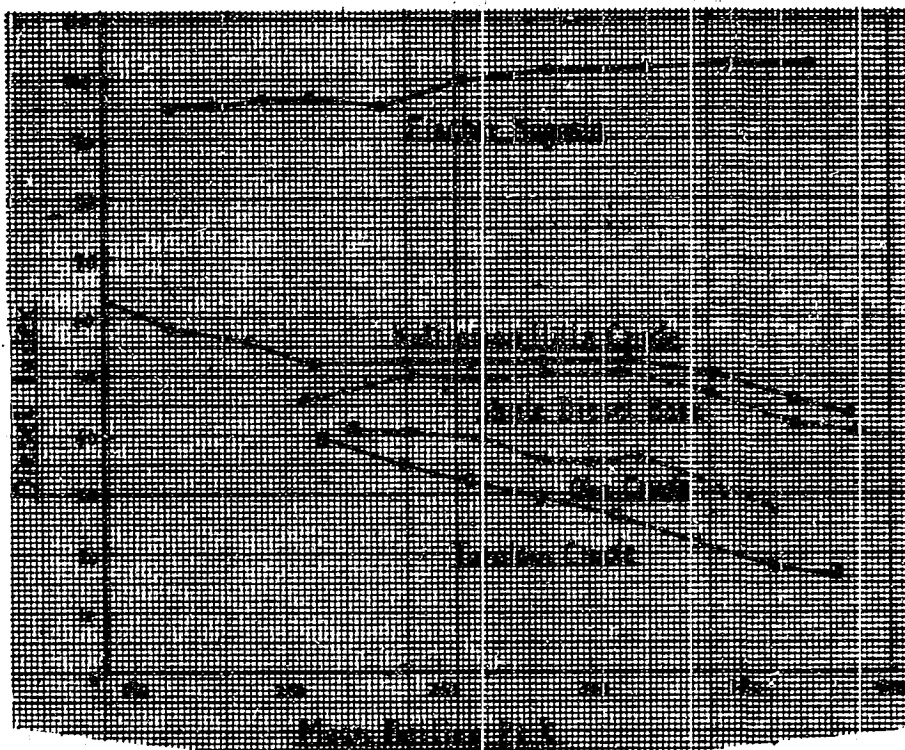
Figure 5 (B)5
RELATIONSHIP BETWEEN MEAN BOILING POINT
AND DIESEL INDEX
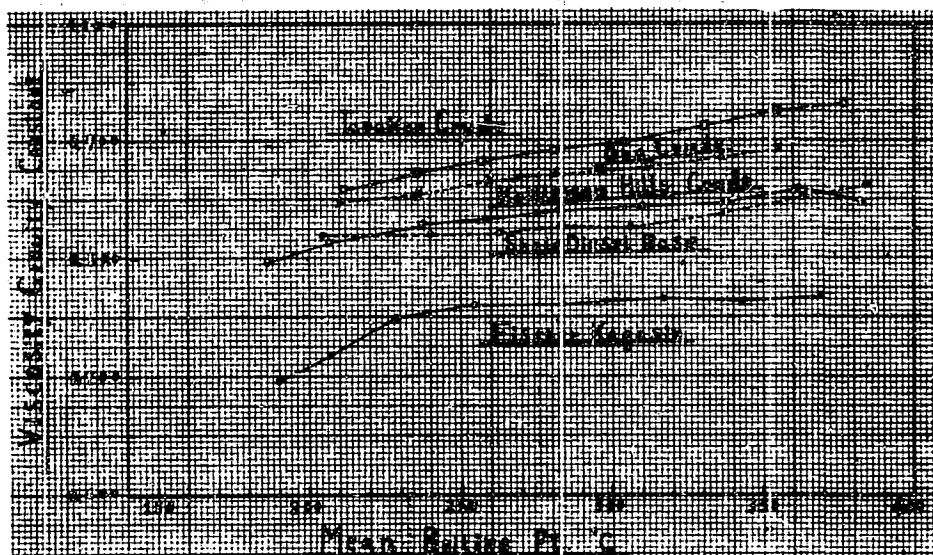
Figure 6 (B)5
RELATIONSHIP BETWEEN MEAN BOILING POINT
AND VISCOSITY GRAVITY CONSTANT

ENCLOSURE (B) 6

P R A C T I C A L   T E S T

O F   S U B S T I T U T E   D I E S E L   F U E L S

(In Two Parts)

by

CHEM. ENG. LIEUT.
M. HIRABE

Research Period: 1945

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)6

LIST OF TABLES
AND ILLUSTRATIONS

PART I

C R E O S O T E   O I L

SUMMARY

It was confirmed that creosote oil was unsuitable for all
types of engine operation for periods of long duration
due to piston deposits and ring sticking. However, it
can be used for a short time except in high speed Diesel
engines.

I.   INTRODUCTION

The purpose was to acquire another source of Diesel fuels. Hence, the creosote
oil which is a by-product of low temperature distillation of coal was investi-
gated. Samples were brought from Showa-Seiko Co., Ltd. in MANCHURIA.

There were no key research personnel assisting Lt. HIRABE.

II. DETAILED DESCRIPTION

A. Samples Tested

The samples which were tested are shown in Table I(B)6.

B. Test Engines Used

The test engines which were used are shown in Table II(B)6.

C. Test Procedure

1.   The first test series related to states of combustion under
various conditions; that is, smoke condition, knocking phenomena, ex-
haust gas temperature, maximum explosion pressure, etc. Since the
details of the experimental data were burned, the following is des-
cribed from memory. Various injection air pressures were tried, and
when the pressure of injection air was near 85 kg/cm², combustion was
best and satisfactory performance was shown at full load.

2.   Then at the following loads - 4/10, 6/10, 8/10, 10/10, and 11/10
of rated power, additional data were acquired; i.e. fuel consumption,
revolutions per minute, brake horsepower, exhaust gas temperature and
pressure, maximum explosion pressure, lubricant temperature at both
inlet and outlet, cooling water temperature, smoke condition, etc.

3.   The 10hp small, high speed, Diesel engine was operated in the
same way as the 25hp Diesel engine.

At low power rate the smoke was very bad, black, and excessive, and
the speed was not smooth.

At high power rates, the engine exhibited good performance, but smoke
was rather bad.

On inspection of the cylinder after 20 hours running, there was some
scoring, and the piston head and cylinder head were coated with car-
bon deposits. There were also deposits in the tip of the injection
nozzle.

ENCLOSURE (B)6

Carbon deposits on the piston head were directly opposite to each nozzle hole.

As a result, the engine had to be cleaned after 20 hours running. The fuel filter was not clogged.

III. CONCLUSIONS

Creosote oil cannot be used as a starting fuel. Starting with this fuel was very difficult even when cranking with the dynamometer; but creosote oil can be used at high power rates quite satisfactorily except for considerable smoking. At low power rates, its running was not smooth and the smoking was excessive. This fuel cannot be used for long time running periods and engine cleaning is required every 20 hours. Care must be taken when using this fuel, as it will burn the skin.

Table I(B)6
PROPERTIES OF SAMPLES TESTED

	Creosote Oil	Tarakan Pitch-less Oil*
Color	black and dark brown	blue brown
Specific weight (15/4°C)	1.078	0.931
Flash point (°C)	62	78.5
Viscosity (Redwood No.1 at 30°C)	52.6	
Freezing point (°C)	$<-20°C$	-38.5
Carbon (%)	2.23	
Water (%)	0.06	
Ash (%)	0.027	
Cetane value (calculated)	approximately -3	38
Reaction	acidic	

* Tarakan pitchless oil, prepared at 3rd Naval Fuel Depot by deasphaltizing with propane, was used for comparison.

Table II(B)6
CHARACTERISTICS OF TEST ENGINES USED

	25HP Air Injection Diesel Engine*	10HP Solid Injection Diesel Engine**
Cylinder bore	220mm	100mm
Cylinder stroke	300mm	140mm
B.H.P.	25	10
Speed (RPM)	450	1800
Comp. ratio	14.5	16.5

*Manufactured by Okiko (Osaka Kikai Kosakusho), 4-cycle, single-cylinder, vertical.
**Manufactured by Niigata, 4-cycle, single-cylinder, vertical, small high speed Diesel engine.

ENCLOSURE (B)6

PART II

S O Y   B E A N   O I L

SUMMARY

It was found that the soy-bean oil (treated with acid clay)
was as suitable for both high speed Diesel engines and low
speed Diesel engines as other mineral oils.

I.   INTRODUCTION

The purpose was to acquire another source of Diesel fuels. Accordingly, soy-
bean oil was investigated, and the results agreed with expectations - in that
it was found satisfactory.

II.   DETAILED DESCRIPTION

A.   Data on Sample

color	sap yellow
specific weight (15/4°C)	0.925
flash point	173
viscosity (Redwood No.1 at 30°C)	176
freezing point (°C)	-15
carbon (%)	0.353
water (%)	28
reaction	neutral

B.   Test Engines Used

1.   Junkers small, high speed, solid injection, single cylinder ver-
tical Diesel engine. Specifications were:

   2 cycle   10hp   1800 RPM

   Bore 65mm   opposed piston type.

2.   OKIKO, 25hp low speed, air injection, verticle single cylinder
Diesel engine. Specifications were:

   4 cycle   25hp   450RPM

   Bore 220mm   stroke 300mm

   Compression ratio: 14.5

C.   Test Procedure

Test procedure was done under the following conditions at the various
power rates: 2/10, 4/10, 6/10, 8/10, 10/10 brake horsepower. Data of
thermal efficiency, fuel consumption, and maximum explosion pressure was
obtained by a "Farns Boro" indicator. At the same time the combustion
state was observed by using indicator cards.

A twenty five horsepower low speed Diesel engine was operated in the same way as the 10hp, small, high speed Diesel engine. At every power rate, running state and smoke condition were very good and engine exhibited good performance.

III. CONCLUSION

The soy-bean oil was found suitable for high speed Diesel engines and exhibited satisfactory performance at both low and high power rates. There was also no phenomena of sticking nor engine deposits. The smoke condition was very satisfactory. No starting test was made, cranking being done by the dynamometer.

ENCLOSURE (B) 7

PRACTICAL   TESTS   OF   COPRA   OILS

AS   SUBSTITUTE   DIESEL   FUELS

by

CAPTAIN I. NORITAKE

Research Period: 1942

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)7

L I S T   O F   T A B L E S
A N D   I L L U S T R A T I O N S

ENCLOSURE (B)7

SUMMARY

It was confirmed that dry distilled copra oil was unsuit-
able as a fuel for either diesel or semi-diesel engines.
It was also confirmed that widely-used, pressed-out copra
oil and esterified copra oils were both suitable.

I. INTRODUCTION

To utilize the oily and fatty products of the South Sea Islands for fuel oil,
various copra oils were chosen for the purpose of finding a substitute for
diesel fuels. Samples were prepared in July 1942, and tests were finished in
October 1942. Chief researcher: Assistant Engineer KAJIWARA.

II. DETAILED DESCRIPTION OF PRODUCTS

    A. Data on samples are given in Table I(B)7.

    B. Data on Testing Engines are given in Table II(B)7.

    C. Test Procedures

    At the following loads, 40%, 60%, 80%, and 100% load factor, the fuel
    consumption, bhp, maximum pressure in cylinder, exhaust gas tempera-
    ture and composition, smoke condition, cooling water temperature, and
    various other data required were measured.

    The results of tests are compared using Tarakan pitchless heavy oil as
    standard.

    D. Experimental Results

        1. Results using 25 hp air-injection diesel engine are given in
        Table III(B)7.

        2. Results using 10 hp solid-injection diesel engine are given in
        Table IV(B)7.

III. CONCLUSIONS

Each copra oil tested was found to be suitable for starting, and from this
standpoint each was better than Tarakan pitchless oil. Nearly smokeless com-
bustion (almost equal to that of Tarakan pitchless oil) can be expected when
copra oil is used.

The exhaust temperature was comparatively low, viz. about 230°C for copra oil,
about 265°C for Tarakan oil.

None of the fuel compound was found to be corrosive against engine materials,
except dry distilled copra oil.

Each oil exhibited smooth running in engine performance tests.

Carbon deposits on piston head, cylinder cap, etc. were not great, and no ring
sticking occurred in any case.

The high freezing point of dry distilled copra oil and pressed-out copra oil
prohibits the use of these oils under cold weather conditions.

ENCLOSURE (B)7

Esterified copra oil is believed to be suitable for use in diesel and semi-
diesel engines in summer and winter, and there is no need of special caution
in connection with its use. It can be utililized therefore, as easily as
mineral oils.

Table I(B)7
SAMPLES

Property	Copra oil			Tarakan pitchless oil##
	Dry distilled*	Pressed-out**	Esterified#	
Color	Dark brown	Orange	Orange	Blue brown
Specific gravity	0.9	0.92	0.97	0.93
Calorific value (kcal/kg)	9200	9200-9300	9250	9670
Cetane no.	54	45	54	32
Flash point (^{o}C)	85	180	42	78.5
Freezing point (^{o}C)	+7	+20	-8	-38.5
Yield (%)	60	60	80	

  * Distilled from dry and crushed copra at 500^{o}C. Contains acrolein
      and has sharp odor.
 ** Pressed-out oil from copra, has aromatic smell.
  # Pressed-out copra oil treated with methyl alcohol of same volume,
      under the catalyst HCl (3%) forming methyl laurate.
 ## Shipped from Tokuyama 3rd Naval Fuel Depot after deasphalting with
      propane.

ENCLOSURE (B)7

Table II(B)7
TESTING ENGINES*

Name of Engine	Type of Engine	Cylinder Diameter (mm)	Dimension			Compression Ratio
			Stroke (mm)	bhp	RPM	
Okika	4 cycle air-injection	220	300	25	450	14.5
Niigata	4 cycle solid-injection	100	140	10	1800	16.5
Ikegai	semi-diesel	115	120	2	800	8.0

* Testing Engines Used (all single cylinder)

Table III(B)7
RESULTS USING 25 hp AIR-INJECTION DIESEL ENGINE

	Copra oil			Tarakan pitchless oil
	Dry distilled	Pressed-out	Esterified	
Power rate	10/10 (Full)	10/10 (Full)	10/10 (Full)	10/10 (Full)
bhp	25.	25	25	25
Fuel consumption (gm/hp/hr)	208	220	210	190

Table IV(B)7
RESULTS USING 10 hp SOLID-INJECTION DIESEL ENGINE

	Copra oil			Tarakan pitchless oil
	Dry distilled	Pressed-out	Esterified	
Power rate	10/10 (Full)	10/10 (Full)	10/10 (Full)	10/10 (Full)
bhp	10	10	10	10
Fuel consumption (gm/hp/hr)	300	300	305	230

ENCLOSURE (B)7

Table V(B)7
TABLE OF COMPARISON

| | Copra Oil | | | | | | | | | Tarakan Pitchless Oil (Reference Oil) | | |
| | Dry Distilled | | | Pressed Out | | | Esterified | | | | | |
	A	B	C	A	B	C	A	B	C	A	B	C
Maximum pressure in cylinder	49			48			47			56		
Fuel consumption (gm/hp/hr)	208	295		219	290		210	305		187	220	
Exhaust temperature		233			228			232			265	
Cetane no. (C.F.R.)		54			45			54			32	
Starting		easy			easy			easy			slightly difficult	
Smoke (visual)		very slight			very slight			very slight			almost no smoke (best)	
Corrosion (visual) (fuel pump lunger -steel-)		corrosive (red color)			none			slightly corrosive (red color) (due to HCl remaining)			none	
Carbon deposit (pistonhead & crown)		slight			none			none			none	

Remark. A: Okiko   25 hp air injection diesel engine
         B: Niigata 10 hp solid injection diesel engine
         C: Ikegai   2 hp semi-diesel engine

Table VI(B)7
PROPERTIES OF FUELS TESTED

Name of Fuel	Treatment	Cetane Value	Viscosity (R-1 oo°C)	Density (15/4°C)	Pour Pt. (°C)	Test Engine	Test Condition
Tarakan pitchless oil*	Deasphaltized with propane	32	37"	0.93		Okiko 25 hp air injection	Max. speed 450 rpm Compression ratio 14.5
Distilled copra oil**	Distilled at 500°C from dry and crashed copra	54		0.9		Okiko 25 hp air injection	Max. speed 450 rpm Compression ratio 14.5
Pressed out copra oil#	Compressed out oil from copra	45		0.92		Okiko 25 hp air injection	Max. speed 450 rpm Compression ratio 14.5
Esterified copra oil	Treated the pressed out copra oil with methyl alcohol of same volume under the catalyst, HCl (3%), forming methyl laurate	54		0.97		Okiko 25 hp air injection	Max. speed 450 rpm Compression ratio 14.5
Oha - Kerosene	250 to 370°C	37.0		0.89		Okiko 25 hp air injection	Max. speed 450 rpm Compression ratio 14.5
Sumatra - Kerosene	165 to 260°C	46	32	0.82			
Kettleman Hills	50% topped residue	47.5	31.8	0.8293	-45		
California	200 to 300	43.3	35	0.8574	-42		
Midway	200 to 350	44.5	39.5	0.8634	-26		
Bahrein	200 to 365	39.0	36.5	0.8193	-28		
Tarakan##	200 to 350	35.0	36.5	0.8806	-30	Okiko 25 hp air injection Diesel Engine Niigata 10 hp Diesel Engine	Max. speed 1800 rpm Compression ratio 16
Mexico	200 to 350	33.7	38.4	0.8555	-17		
Innai, Japan	200 to 300	34.3	36.8	0.8682	-50		
Tarakan¢	200 to	29.5	39.0	0.9401	-30		

*Fuel Composition: 190 gm/hp/hr
Advantage or Disadvantage: (+) smooth running
Practical Use: for submarine

**Fuel Composition: 200 to 210 gm/hp/hr
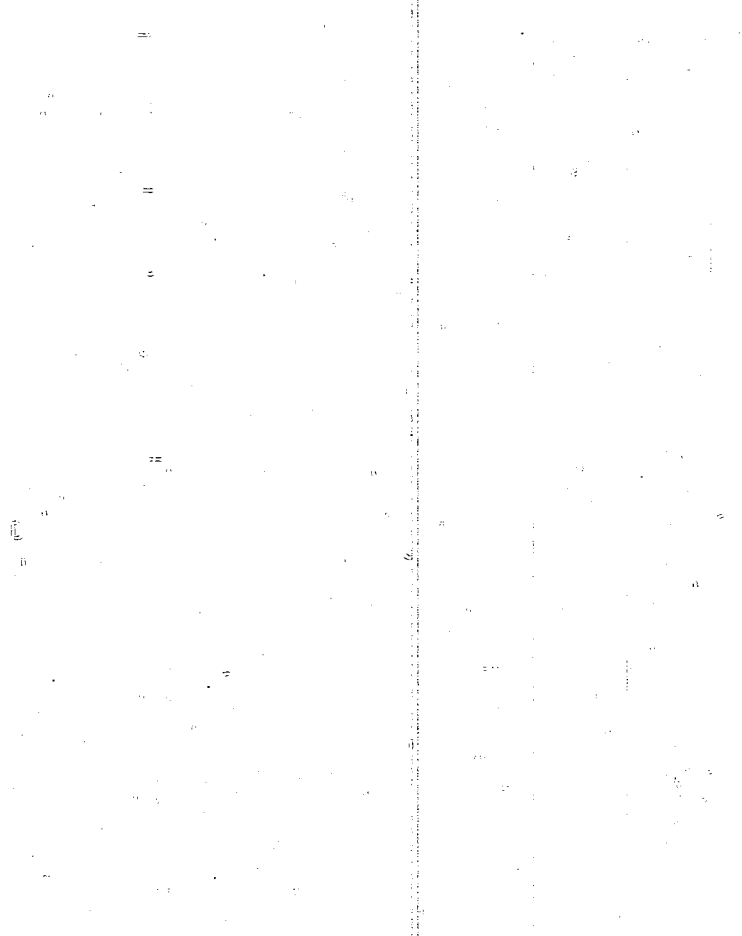Advantage or Disadvantage: (+) easy starting (-) corrosive

#Advantage or Disadvantage: (+) easy starting (-) slight smoke

##Practical Use: for submarine

¢Practical Use: for submarine

ENCLOSURE (B) 8

PRACTICAL ENGINE TESTS

FOR SUBSTITUTE DIESEL FUELS

Creosote Oil
Wood Gas
Soy-bean Oil and Pine-root Oil

by

ENG. LIEUT. K. HOSOI

Research Period: 1945

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L I S T   O F   T A B L E S

A N D   I L L U S T R A T I O N S

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C R E O S O T E   O I L

SUMMARY

Creosote oil was examined to determine whether it was
suitable for No.51-10 diesel engine (used in high-speed
boat) and for 75 hp hot bulb engine (for small tramp
use).

The following conclusions were obtained:

1.   For Diesel Engine No.51-10. Combustion was irreg-
ular owing to poor ignition, and the maximum pressure
in the cylinder was very high (about 70 kg/cm^2). These
results show that the use of creosote oil is unsatis-
factory.

2.   For 75 hp Hot Bulb Engine. When no alteration was
made on the engine, the operation of the engine was
impossible unless the scavenging air adjusting valve
was opened a little, and the hot bulb was heated by a
blow lamp every 5 to 10 minutes to keep the bulb at
high temperature.

When the engine design was altered as shown in Figure
1(B)8, (Hot metal was made of Si-Cr steel) both partial
and full load operations were possible holding the
bulb at ordinary temperature. Though the maximum
pressure in the cylinder was 2 to 3 kg/cm^2 higher than
the pressure when heavy oil No.1 was used, operating
results were the same as those of heavy oil No.1, and
this shows that in this case creosote oil can be used
practically; more over, if the hot bulb was suffi-
ciently heated by a blow lamp before starting the engine
could be easily started.

I.   INTRODUCTION

A.   History of Project

As a result of American victories on Saipan and in the Philippines, the
supply of heavy oil from the South Sea Islands was cut off, making the
shortage of heavy oil imminent. Therefore, the substitution of creosote
oil for heavy oil was considered by the Naval Department of Material, and
orders were issued to the Yokosuka Naval Arsenal in January, 1945, to test
certain diesel engines and hot bulb engines using creosote oil. Diesel
engine No. 51-10 and 45 hp hot bulb engine were tested with creosote oil
obtained from the First Fuel Depot. Tests with diesel engine No. 51-10
were abandoned after two or three trials in March, 1945, for the reason
stated in the summary. Tests were made with the 75 hp hot bulb engine
from April to June, 1945. The experiments were discontinued, when it was
found that creosote oil could be practically used if the hot bulb was
equipped with "hot metal". "Hot metal" was made or ordinary steel plate
in the first test. Metal made of Si-Cr steel was used for the second test
and it was found that the latter was better than the former because of its
heat resisting properties.

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B.   Key Reasearch Personnel Working on Project

                              Eng. Lt. T. YASUMA
                              Eng. Lt. M. TOMITA

II. DETAILED DESCRIPTION

A.   Description of Apparatus

   1.   Engines. See Table I(B)8.

   2.   Testing Apparatus. The apparatus is shown in Figure 2(B)8 and Figure 3(B)8.

B.   Test Procedure

   1.   For Diesel Engine No.51-10.

      a.   The engine was started by light oil.

      b.   Operation was continued for 5 to 10 minutes at 4/10 of full load, until a smooth driving state was reached.

      d.   Light oil was changed to creosote oil previously heated to 50-60°C. No changes were made in the diesel engine.

   2.   For 75 hp Hot Bulb Engine.

      a.   No changes were made in either parts or settings of the hot bulb engine at first, and research was carried out on the starting and running characteristics.

      b.   Secondly, in order to improve the ignition of creosote oil, "hot metal" was equipped in the hot bulb as shown in Figure 1(B)8, and investigations were made on effect of hot metal and its durability in starting and in operating characteristics.

      Hot metal was made of ordinary steel or Si-Cr steel, and creosote oil was preheated to 50-60°C.

C.   Experimental Results

   1.   For Diesel Engine No.51-10. Soon after the fuel was changed, the engine revolutions decreased and the maximum pressure in the cylinder increased to about 70 kg/cm^2, combustion becoming irregular and operation very difficult. No data are available from this experiment.

   2.   For 75 hp Hot Bulb Engine.

      a.   No design alterations made:

         (1) Ease of starting: Though it was more difficult than with heavy oil No.1, the engine could be started using starting air (air pressure being 6 to 8 kg/cm^2 if the hot bulb was previously heated to a red color by a blow lamp.

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(2) Running characteristics: Satisfactory engine running
was not possible unless the scavenging air adjusting valve
was opened slightly and the hot bulb was heated by a blow
lamp every 5 to 10 minutes and was kept at a high tempera-
ture. No data are available from this experiment.

b. Using hot bulb equipped with "hot metal":

(1) Ease of starting: Same as in (a) (1) above.

(2) Running characteristics: It was possible to drive
engine at any load while maintaining the surface tempera-
ture of the hot bulb at 300°C. The temperature was
measured with a thermocouple, and results showed the same
temperature as in the case of using heavy oil No.1.
Table III(B)8 shows the operating results at full load.

(3) Durability of hot metal: Hot metal made of steel
plate was partially melted after full load operation for
5 hours.

Hot metal made of Si-Cr steel was in good condition after
20 hours of full load driving.

III. CONCLUSIONS

A. According to the several experiments with diesel engines, it was
concluded that the low cetane creosote oil obtained from the First Naval
Fuel Depot was not suitable for diesel engine fuel.

(Note: The above is not too conclusive as only one kind of
creosote oil was used.)

B. It was concluded that creosote oil was satisfactory for hot bulb
fuel providing, "hot metal" made of Si-Cr steel was equipped in the hot
bulb when a bad quality creosote oil was used.

Table I(B)8
DETAILS OF TEST ENGINES (SINGLE-ACTING, SOLID INJECTION)

	Cycles	bhp	rpm	Bore	Stroke	No. of Cyl.
Diesel engine No.51-10	4	300	1500	140mm	200mm	10
75 hp hot bulb engine	2	75	335	12mm	13 1/2mm	2

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Table II(B)8
CHARACTERISTICS OF TEST FUELS

Oil	Reaction	Sp. Gr.	Flash Pt. (°C)	Viscosity Red. Sec. 30°C	40°C	80°C	Ash	H2O	S	Solid. Pt.	Calorific Value	Cetane
Soya-bean	Neutral	0.914	161	271	137	68		0.6	0.028	-19°C	9442 Cal/gm	37-38
Pine-root	Acid	0.998	46	82	51	36	0.028	2.3		-20°C	9152 Cal/gm	

Table III(B)8
EXPERIMENTAL RESULT USING CREOSOTE OIL AT FULL LOAD

rpm	bhp	Regulating Condition Scavenging Air Adjusting Valve	Fuel Handle	Fuel Consumption lit/hr	gm/bhp hr	Max. Pressure in Cylinder (kg/cm²)	Temperature (°C) Exhaust Gas	Fuel	Color of Hot Bulb
335	75	6/10	4.8/10	22.2	319	24	264	53	Black

Table IV(B)8
CHARACTERISTICS OF TEST FUELS

	Reaction	Sp. Gr.	Flash Pt.	Viscosity Red. Sec. 30°C	50°C	80°C	Solid. Pt.	Ash	H2O	S	Calorific Value
Creosote oil	Neutral	1.08	74.5°C	88	46	34	-19°C	0.103%	9.6%	0.625%	9305 cal/gm
Heavy oil no.1	Acid	0.942	93.5°C	110	59	40	<-20°C	0.005%		0.146%	10600 cal/gm

ENCLOSURE (B)8

HOT BULB   AIR MANTLE
                                          IGNITION METAL

HOT METAL

CYLINDER COVER
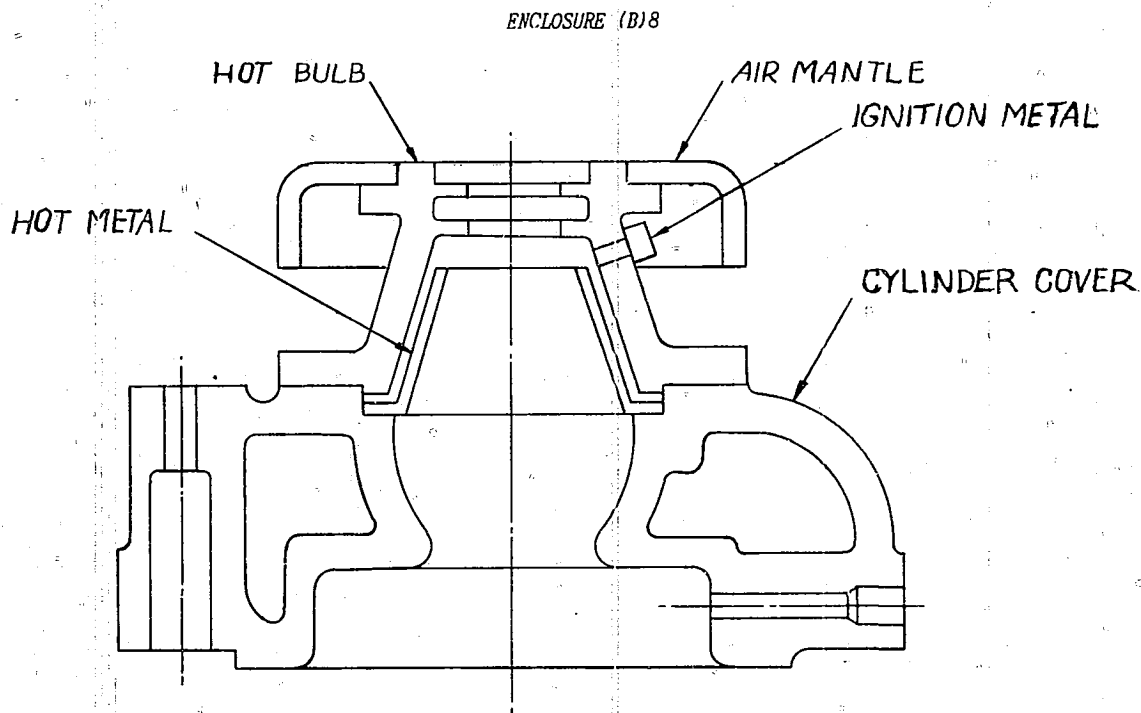
Figure 1(B)8
REDESIGNED HOT BULB

LUBRICATING OIL TANK   FUEL TANK

                    FILTER

DELIVERY OIL PUMP   SUCTION OIL PUMP

                    OIL
                    COOLER

WATER FEED PUMP   OIL   WATER BRAKE (Floude Type)

                                    CLUTCH

TEST ENGINE   FUEL PUMP   Water
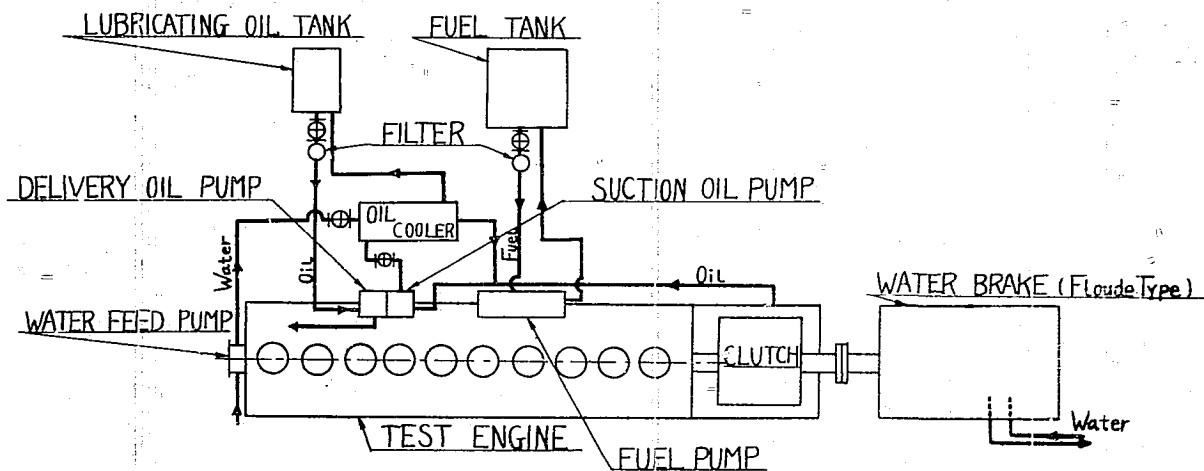
Figure 2 (B)8
TESTING APPARATUS
FOR DIESEL ENGINE NO. 51-10

ENCLOSURE (B)8

S O Y - B E A N   O I I   A N D   P I N E - R O O T   O I L .

SUMMARY

Practical operations of diesel engine No.51-10 were made
with soy-bean oil alone, pine-root oil alone and mixture
of both (mixing ratio of 5 : 5). The following results
were obtained.

1. Soy-bean oil had better properties than heavy oil
No.1. Therefore, diesel engine No.51-10 could be opera-
ted easily at full load with soy-bean oil.

2. By operating diesel engine No. 51-10 with pine-root
oil alone or mixed oil (soy-bean oil : pine root oil =
5 : 5), similar operating conditions were obtained to
those when heavy oil No.1 was used. However, starting
was impossible unless the fuel pump plunger and needle
valve were cleaned at the end of the preceding run. This
fact was caused by the formation of resinous matters in
the pine-root oil. Therefore, practical operations were
unsatisfactory using pine-root oil or mixed oil.

I. INTRODUCTION

A. History of Project

After practical tests of creosote oil, the above tests were made in
June, 1945.

These fuels were prepared in the First Fuel Depot. Only a small amount
of soy-bean was tested, but running characteristics with soy-bean oil
were very good. Therefore, investigations were carried out only for a
short period. As pine-root oil and mixed oil gummed up the fuel injec-
tion system, it was considered unsatisfactory. As a result, only two
or three experiments were made.

B. Key Research Personnel Working on Project

Eng. Lt. M. TOMITA.

II. DETAILED DESCRIPTION

A. Description of Apparatus

1. **Testing Apparatus.** This is shown in Figure 2(B)8.

2. **Fuels.** See Table IV(B)8.

B. Test Procedure

1. No design alteration was made on the main engine No.51-10.

2. Starting was accomplished by use of light oil.

3. Light oil was changed to testing fuel after starting.

ENCLOSURE (B)8

4.   Investigations were made at each power.

5.   Soy-bean oil and mixed oil heated to 50-60°C were employed.

C. Experimental Results

1.   Soy-bean Oil. Properties of soy-bean oil were better than those of heavy oil No.1. Therefore, diesel engine No.51-10 could be operated easily at any load with soy-bean oil. The experimental results at full load are shown in Table V(B)8.

2.   Pine-root Oil and Mixed Oil. Diesel engine No.51-10 could be operated with the same operating conditions as for heavy oil No.1; however, starting was impossible unless the needle valve and fuel pump plunger were cleaned immediately after the end of the previous operation. This was caused by the formation of resin in the needle valve and fuel pump plunger. No data were taken.

III. CONCLUSIONS

A.   Engine running characteristics using soy-bean oil were very good, and it was concluded that this oil was a good substitute for diesel engine fuel.

B.   It was determined that pine-root oil or mixed oil could not be used as a substitute fuel, unless they were thoroughly refined removing the resinous matters which gum up the fuel injection system.

Table V(B)8
XPERIMENTAL RESULT USING SOYA-BEAN OIL AT FULL LOAD

rpm	bhp	Regulating Condition		Fuel Consumption		Max. Pressure in Cylinder kg/cm^2	Temperature (°C)	
		Timing Handle	Full Handle	lit/hr	gm/bhp/hr		Exhaust Gas. Temp.	Fuel Temp.
1500	300	4/10	48/60	80.4	245	54	515	45

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WOOD GAS

SUMMARY

The substitution of wood gas for liquid fuel in a 75 hp hot bulb engine was examined, and the following results were obtained.

1.   When a mixture of wood gas and heavy oil No.1 (for ignition use) was employed, consumption of heavy oil No.1 was 20-35% of the heavy oil consumption when heavy oil No.1 was employed alone and operations were comparatively smooth.

2.   "Hot metal" was installed in the hot bulb shown in Figure 1(B)8 (same as the case of creosote oil) with the following results:

    a.   When the load was 2/10-4/10 of the full load, both wood gas and heavy oil No.1 had to be employed.

    b.   When the load was 6/10-8/10 of the full load, operation was possible using wood gas only.

3.   For starting, liquid fuel was necessary.

4.   Characteristics of the gas producer were not examined in detail, but improvements in some parts were considered necessary.

I.   INTRODUCTION

A.   History of Project

Since the end of 1944, many hot bulb engines could not be driven since the shortage of liquid fuel was imminent.

Therefore, the Naval Department of Material issued orders in October, 1944, to the Yokosuka Naval Arsenal to test hot bulb engines using wood gas. Experiments were made from March to August, 1945, and possibilities for practical use of wood gas in the hot bulb engine were discovered.

B.   Key Research Personnel Working on Project

Eng. Lt. S. WATANABE.

II.   DETAILED DESCRIPTION

A.   Description of Apparatus

The apparatus is shown in Figure 3(B)8 and Figure 4(B)8.

B.   Test Procedure

1.   When both wood gas and heavy oil No.1 (ignition fuel) were

employed:

    (a) Burning cloths were thrown into the gas producer from the firing hole to ingnite wood in the furnace.

    (b) Satisfactory gas was produced by blowing for a period of 10 to 15 minutes with a hand blower.

    (c) The engine was started with heavy oil No.1, fully opening the airvalve in the gas and air mixing apparatus.

    (d) In order to control load, the air valve and gas valve were opened slowly and then the fuel handle (for liquid fuel use) was regulated slowly.

    (e) Characteristics of the gas producer and operating characteristics of each load were investigated.

    (f) Another engine with a 3mm top clearance in the cylinder was examined. (No changes were made in the engine).

2. When wood gas without liquid fuel was used alone adjusting the top clearance in the cylinder to 3mm:

    "a", "b", "c", and "d" were the same as B,1
    "e" after operating in 1,d state for 10 minutes, liquid fuel was completely shut off.

    "f" characteristics of the gas producer and engine operating characteristics at each load using wood gas only were investigated.

C. <u>Experimental Results</u>

1. The experimental results for when both wood gas and heavy oil No. 1 were employed are shown in Table VI(B)8.

Comparatively smooth operation was obtainable for any load and comparable to the operation obtained when heavy oil No. 1 was used alone.

Consumption of heavy oil No. 1 was about 35% at 4/10 of the full load and about 18% at full load, as compared with consumption of heavy oil No. 1 when heavy oil No. 1 was used only. Consumption of wood: 1.35 kg per boiler horsepower hour at full load. Horse power was greatly influenced by the degree of opening of the air valve.

2. Using wood gas alone. Experimental results are shown in Table VII(B)8.

8/10 of full load operation was possible with wood gas alone, but 2/10-4/10 of full load operation was difficult when hot bulb temperature was low.

Comparatively smooth operation was possible at 6/10-8/10 of full load. Consumption of wood was 1.4 kg per boiler horsepower hour at 8/10 of full load.

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III. CONCLUSIONS

Wood gas could be substituted with satisfactory results in a hot bulb engine but its practical application was considered difficult for the following reasons:

A.   Practice and skill are necessary to control the ratio of gas and air mixture.

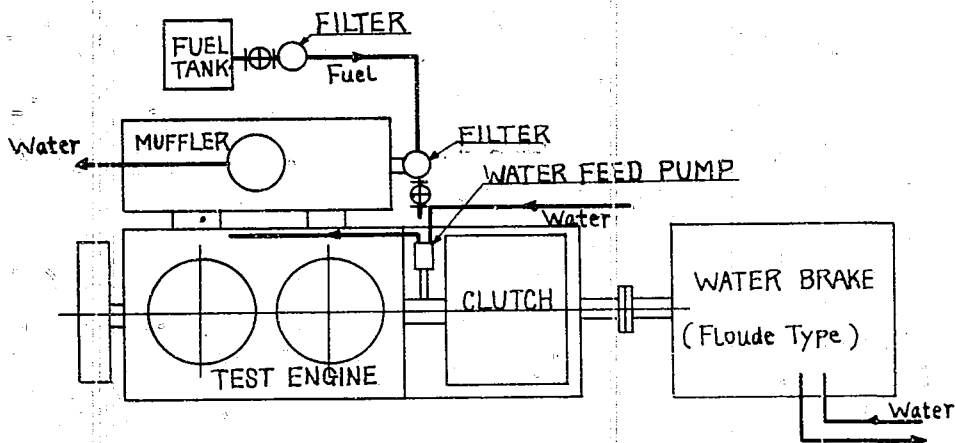B.   Exact setting and timing of the fuel injection system before operating is necessary.

Figure 3(B)8

TESTING APPARATUS FOR

75 H.P. HOT BULB ENGINE

ENCLOSURE (B)8

GAS PRODUCER

GAS AND AIR MIXING APPARATUS

COOLER

CENTRIFUGAL SEPARATOR

FILTER

GAS VALVE

SUCTION VALVE

MIXING TANK

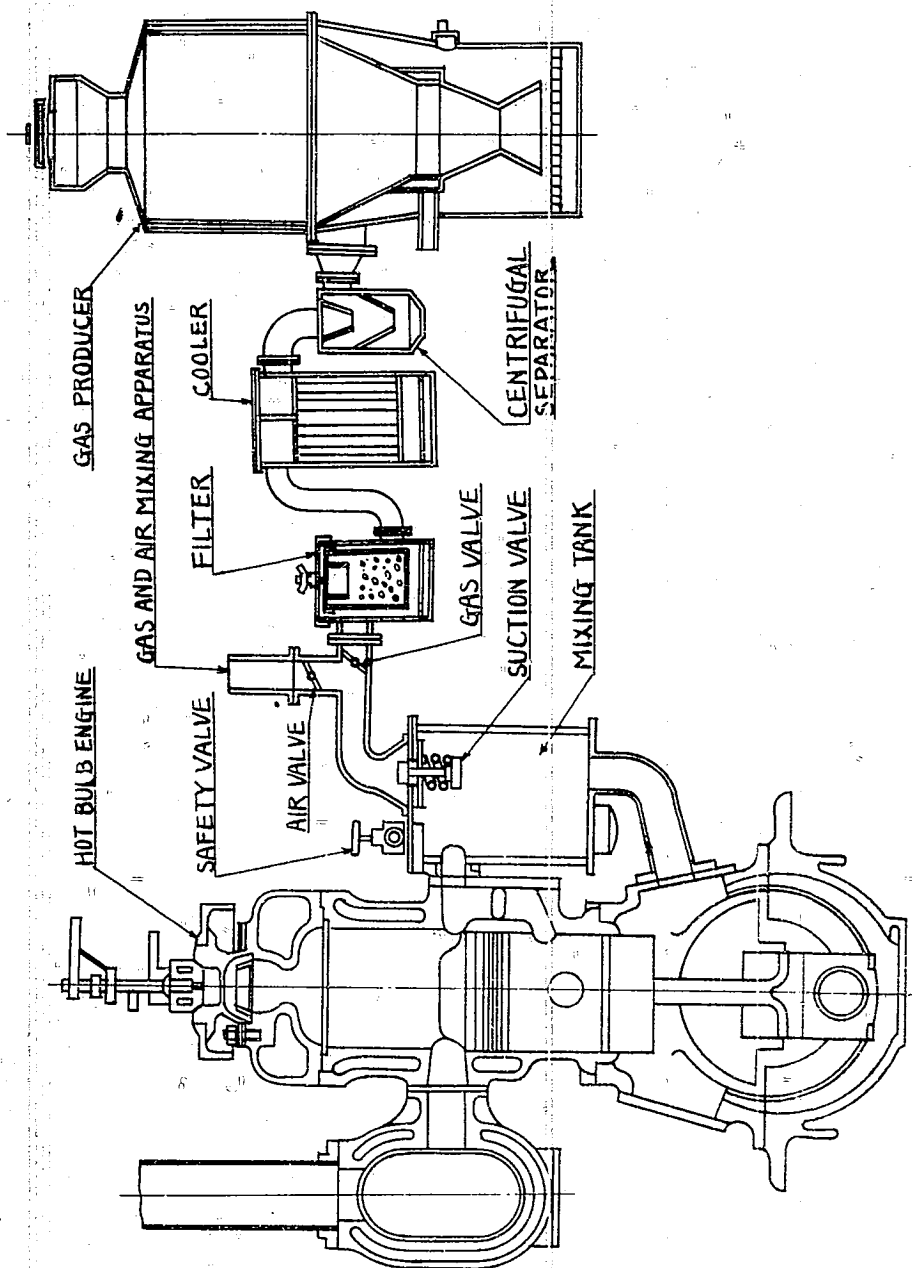HOT BULB ENGINE

SAFETY VALVE

AIR VALVE

Figure 4(6)8

GAS PRODUCING APPARATUS FOR 75 H.P. HOT BULB ENGINE

ENCLOSURE (B)8

Table VI(B)8
EXPERIMENTAL RESULTS USING WOOD GAS AND HEAVY OIL No. 1

Power Tested	rpm	bhp	Regulating Condition			Fuel Consumption				Pressure		Gas Temperature	
			Gas Valve	Air Valve	Fuel Handle	Liquid Fuel		Wood		Max. Pressure in Cylinder kg/cm^2	Gas Pressure (at inlet of engine) mm.H2O	Outlet of Gas Producer °C	At inlet of Engine °C
						lit/hr	gm/bhp hr	kg/hr	kg/bhp hr				
4/10 of full load	247	30	3	2.5	1.0	3.7	111	-	-	20	240	-	35
6/10 of full load	283	45	5	2.0	1.0	4.0	80	-	-	22	260	-	32
8/10 of full load	311	60	10	1.5	0.5	3.8	57	-	-	25	290	-	38
10/10 of full load	335	75	10	1.2	0.5	3.8	46	108	1.35	25	320	388	42

Note:- Colour of hot bulb--black.

Table VII(B)8
EXPERIMENTAL RESULTS USING WOOD GAS AT FULL LOAD

Regulating Condition				Wood Consumption		Pressure		Gas Temperature		Colour of hot bulb
rpm	bhp	Gas Valve	Air Valve	kg/hr	kg/bhp hr	Max. Pressure in Cylinder kg/cm	Gas Pressure (at inlet of engine) mm.H2O	Outlet of Gas Producer °C	At inlet of Engine °C	
335	60	10	10	112	1.4	24	320	395	42	black

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E N G I N E   T E S T   M E T H O D S

F O R   D I E S E L   F U E L   A T   O F U N A

by

CAPT. I. NORITAKE

Research Period: 1942-1945

ENCLOSURE (B)9

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B)9

I.   INTRODUCTION

An engine test plant for testing diesel fuel was installed at the First Naval
Fuel Depot in 1942, together with the engine test plant for aviation fuel and
lube oil.

The chemical properties and the cetane value of diesel fuel itself were ex-
amined by the 4th section of the Experimental Department. The samples were
examined by actual engine test, by the 2nd section of the same Department, and
their suitability for practical diesel engine use was determined.

One type of engine test was made in a mono-cylinder testing engine, another
in a full sized engine. If required, tests were made under actual running
conditions on ships or automobiles.

Work on substitutes for diesel fuel was also carried out because the supply
for this fuel became very scarce. See report "Engine Test of Substituted
Fuel for Diesel and Boiler", (Enclosure (B)6, (B)7, (B)8, and (B)14) in-
cluding tests of copra and copra oil, then creosote oil and soya-bean oil.

II.   DETAILED DESCRIPTION OF APPARATUS

A.   Mono-cylinder Engine Test

The C.F.R. engine test is the same as in U.S., and it will not be men-
tioned in this paper.

Several mono-cylinder engines were installed in this depot as shown in
the following list.

> Niigata Diesel engine
> Okiko diesel engine   } for prime movers of generators
> Ikegai semi-diesel engine

No. 31 type diesel engine--main engine for hydroplane carriers.

1.   The Froude type electric dynamometer was used to measure the
bhp delivered.

2.   The RPM or total revolutions during the test was measured with
tachometers and revolution counters.

3.   The tachometers were checked with stop-watches.

4.   A supply fuel tank was placed on a balance.

5.   The Maihak indicator was used for low speed engines, and the
Farnboros indicator for high speed engines to draw diagrams and to
measure the maximum pressure, mean effective pressure, etc., and to
determine the conditions of compression, combustion, expansion,
exhaust and suction stroke.

The Okill pressure indicator was also used but not often.

6.   The Orsat method was usually used to analyze the exhaust gas.

7.   The inlet and outlet temperatures of lube oil and cooling
water and also the temperatures of certain parts of the engine were
measured with mercury thermometers, thermocouples, and occassional-

ly measured by "Thermo-color". "Thermo-color" is a temperature indicating paint used in about six temperature ranges from 300°C to 1000°C. It indicates temperature with an accuracy of about ±10°C, and was used on such engine parts as nozzles and cylinder heads.

8. Pressure of the injected fuel, blast air, lube oil, etc., were measured with pressure gauges.

9. A five degree Lingerman chart was used to measure the color of smoke.

10. A triangular notch weir type flow meter was used to measure the rate of cooling water.

Each part of the engine is carefully inspected and then reassembled before operation. The clearance is adjusted and the engine is started by hand if small, and by compressed air if large. This test operation is continued for about an hour. Then a preliminary run is carried out until the entire engine and lube oil reach their proper working temperatures.

The functions of various accessories are checked during this stage to determine whether the engine has reached a normal running condition or not.

After everything is set in order, a test data sheet (cf. attached paper) is arranged and a recording trial is made. The men are then stationed in their respective positions, and the engine test is started carefully.

Tests of various loads are made, such as overload, full load, 8/10 load, 6/10 load, 4/10 load, 2/10 load, and minimum load.

An officer or an assistant engineer directs the test, one assistant handles the controls, and two or three men record the data by the director's signal.

All columns in the test sheet are filled, and from these data the characteristic curves are traced, and the thermal efficiency, etc., calculated.
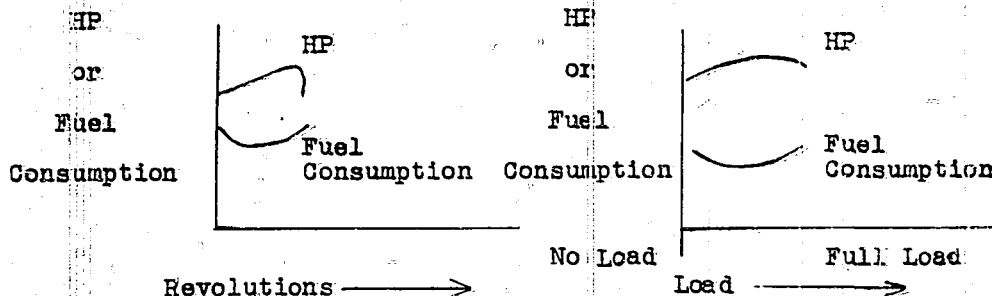
After the engine test is over, the engine is dismantled and conditions of the principal parts of the engine, such as frictional surfaces (valves, bearings, piston rings, etc.), nozzles, fuel, and lube oil filters, are examined.

Contamination, wearing, and decrease of tension of piston rings; carbon deposits on piston caps, nozzle valve tips, cylinder caps; scratches on cylinder walls, piston sides and fuel pump plunger; leakage of fuel pipe flanges and corrosion of engine materials are also carefully investigated.

ENCLOSURE (B)9

The combustion conditions in the cylinder are also examined from the indicator diagram obtained with a string-type indicator or a balanced pressure Farnsboro-type indicator.

B. Full Sized Engine Test

If the amount of oil sample prepared by the Research Department is small, or not suitable for long run tests, they are tested in mono-cylinder engines. But in the case of decisive tests, such as determining the applicability for actual use, full size engines are used, and when possible, they are tested with engines aboard ships or vehicles under practical conditions.

Only few full sized engines are installed in this depot, and most of the tests were usually carried out in the Yokosuka Naval Yard.

III. PROGRESS OF RESEARCH WORK

Investigation on the performance tests of high cetane diesel fuel for high speed diesel engines was planned, and a "61st" type high speed single cylinder diesel engine was installed but experiments were postponed owing to the shortage of gasoline which was made by cracking diesel fuel. As a result, a substitute fuel for diesel oil used in middle speed diesel engines was investigated. (See Enclosures (B)6 and (B)7.) Copra oil, soya-bean oil, creosote oil were next examined but no satisfactory results were obtained.
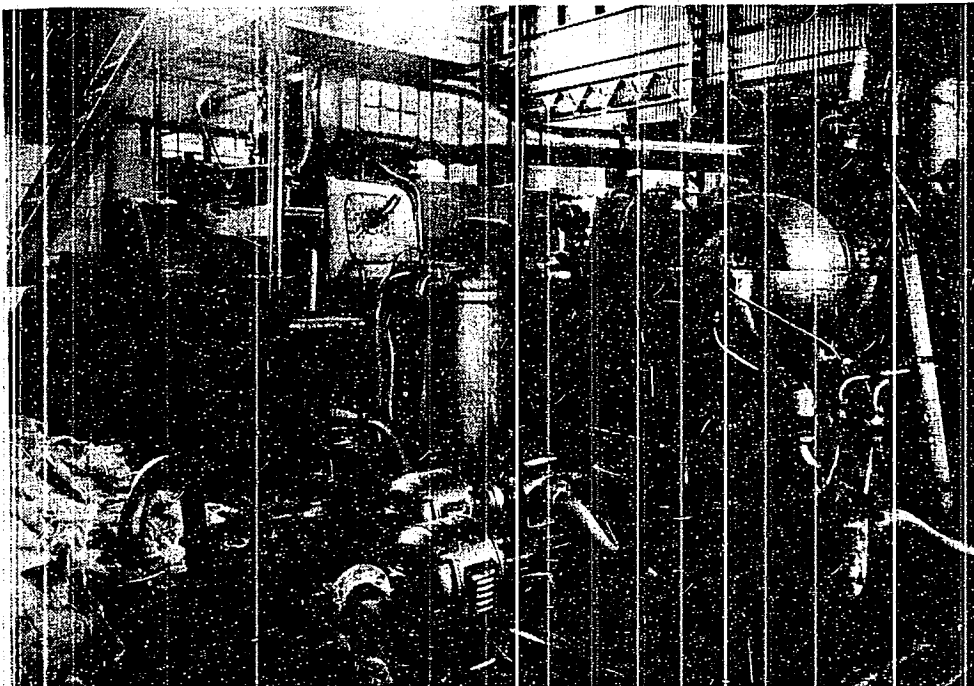

Figure 1(B)9
CLOSE UP VIEW OF NO. 31 TYPE
MONO-CYLINDER DIESEL ENGINE

ENCLOSURE (B)9

Table I(B)9
TEST ENGINES FOR DIESEL FUELS AND LUBRICATING OILS*

Name of Engine	Type of Engine	No. of Engine	Principal Dimensions			
			Bore	Stroke	rpm	ahp
No. 31 Diesel Engine*	2 cycle solid-injection vertical single cylinder	1	420	600	420	360
Okiko Diesel** Engine	4 cycle air-injection vertical single cylinder	1	220	300	450	25
Junkers Diesel Engine	2 cycle solid-injection vertical single cylinder opposed piston type	1.	65	900	1200	10
Niigata Diesel Engine (high speed)	4 cycle solid-injection vertical single cylinder	1	100	140	1800	10
Kaimuin Type Semi-Diesel Engine	2 cycle hot bulb type vertical 2 cylinder full scale engine	1	305	343	335	75
No. 61 Diesel Engine	2 cycle solid-injection vertical single cylinder	1	140	180	1600	62
Isuzu Diesel Engine	4 cycle solid-injection 6 cylinder, single row vertical	1	110	150	1600	100
Niigata Diesel Engine (low speed)	4 cycle solid-injection vertical single cylinder	1	220	300	450	25

*Principal accessories are listed on next page.

No. 31 Diesel Engine: One turbo-blower (3200 rpm, 190 hp, 185 .
                            m^3/min)
                          One water brake (500 to 1000 rpm, max. hp
                            600 Froude type)
    Marine engine was set in August 1942. Removed from Yokosuka
Naval Dockyard.

Okiko Diesel Engine: One electric dynamometer (450 rpm, 25 hp)
                          One air compressor (100 kg/cm^2, 15 hp)
    Generator engine – made by Osaka Machine Works Co. Ltd. Re-
moved from Tokuyama Naval Fuel Depot.

Junkers Diesel Engine: Opposed piston type – made by Junkers Co.
                            Ltd. (Japan agent Mitsubishi)
    Removed from Tokuyama Naval Fuel Depot without accessories.

Niigata Diesel Engine (high speed): One electric dynamometer
                            1   (2200 rpm, 10 hp)
    Generator engine – removed from Tokuyama Naval Fuel Depot.

Kaimuin Type Semi-Diesel Engine:
    Marine engine – made by Taguchi Machine Works.

No. 61 Diesel Engine:
    Aircraft engine – removed from Yokosuka Naval Dockyard.

Isuzu Diesel Engine:
    Automobile engine – made by Diesel Automobile Co. Ltd.,
Tsurumi Factory. Removed from Yokosuka Naval Dockyard in
July 1945.

Niigata Diesel Engine (low speed): Electric dynamometer (450 rpm,
                            30 hp)
    Generator engine – made by Niigata Machine Works Co. Ltd.
Removed from Tokuyama Naval Fuel Depot.

ENCLOSURE (B)9

Table II(B)9
BOILERS FOR TESTING FUELS*

Name of Boiler	Type of Engine	No.	Dimension		
			Heating Surface	Working Pressure	No. of Burner
Kan-pon Boiler (Main)	Ro-go type with air-preheater oil burnt 3 drum water tube	1	308.6	19	5
Kan-pon Boiler (Minor)	Ro-go type oil burnt 3 drum water tube	1	66	14	1
Cylindrical Boiler	Fire-tubes type single ended coal burnt	1	62.7	7	

* Notes on Boilers

   Kan-pon Boiler (Main):   One blower
                             Two feed pumps
                             Two fuel oil pumps

   Kan-pon Boiler (Minor): One blower
                           One feed pump
                           One fuel pump
        Formerly used for auxilary boiler for A-class cruiser.

   Cylindrical Boiler: Donkey boiler

ENCLOSURE (B) 10

P R E P A R A T I O N   O F   P U R E
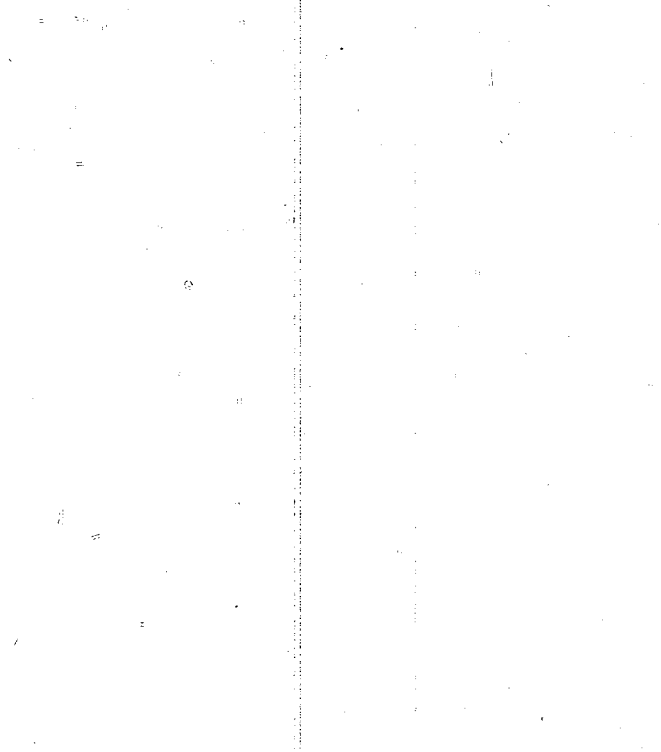
a - M E T H Y L N A P H T H A L E N E

by

NAVAL ENGINEER
C. MIYATA

Research Period: 1942-1943

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)10

SUMMARY

a-Naphthylamine was transformed by the diazo reaction to
a-Naphthonitrile and then reduced with hydrogen to
a-Methylnaphthalene in the presence of reduced nickel at
250-290°C. The yield of pure a-methylnaphthalene was
approximately 21% by weight.

I. INTRODUCTION

The lack of standard fuel for Diesel engines had become serious since 1941,
and, consequently, the study of the following method of preparation was under-
taken. The reaction was as follows:
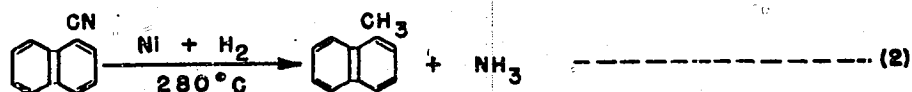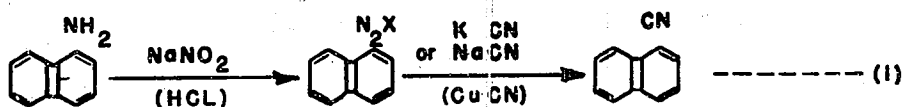
II DETAILED DESCRIPTION

A. Preparation of a-Naphthonitrile (Reaction 1)

To 14.3gm a-naphthylamine in 270cc water containing 10cc concentrated HCl
was added 15cc concentrated HCl and 135gm of broken ice.

Then 35cc of an aqueous solution containing 7gm $NaNO_2$ was added dropwise
with stirring.

The product was treated at 80°C with 100cc of an aqueous solution contain-
ing 25gm $CuSO_4.5H_2O$ and 28gm NaCN. The mixture was steam distilled and
yellow, and oily, crude a-naphthonitrile was obtained. The crude a-naph-
thonitrile was extracted with ether, dried with $CaCl_2$, and then redis-
tilled. The yield of pure a-naphthonitrile was 5.9gm (corresponding to
approximately 40% by weight). The properties of the a-naphthonitrile
formed were as follows:

B.P., 295-297°C, M.P., 35-36°C.

B. Preparation of a-Methylnaphthalene (Reaction 2)

The a-naphthonitrile was reduced in the presence of reduced nickel
(prepared from nickel nitrite by ignition at about 300°C and by reduction
with hydrogen at 300°C), at 270-280°C in a silica reaction tube (18mm X
1000mm). The colorless, oily product obtained (yield about 80% by weight)
was distilled at atmospheric pressure into the following fractions:

93

1st fraction :   233 - 240°C

2nd fraction :   240 - 250°C

3rd fraction :   250 - 285°C

The first fraction consisted mainly of a-methyl naphthalene, 3rd fraction was mainly a-naphthonitrile, and the second fraction was a mixture of a-methyl naphthalene and a-naphthonitrile.

The yield of crude a-methylnaphthalene (from first and second fractions) was about 78% by weight of a-naphthonitrile.

C.   Purification of a-Methylnaphthalene

An alcoholic solution of the first and second fractions was added to the same amount of picric acid. The a-methylnaphthalene picrate was crystallized by cooling from the alcoholic solution.

The picrate, (m.p. 140-141°C) was decomposed with concentrated NH_4OH (about 28%) to a-methyl naphthalene by warming, and, after steam distillation of a-methyl naphthalene, was extracted with ether, dried with calcium chloride, and then redistilled.

The yield of a-methylnaphthalene
                     from 1st and 2nd fractions: approx. 84% by weight.
                     from a-naphthonitrile: approx. 52% by weight.
                     from a-naphthylamine: approx. 21% by weight.

The properties of pure a-methylnaphthalene prepared from a-naphthylamine were as follows:

B.P. (760mm Hg) :   239 - 240°C

n_D^{25} :   1.6153

n_D^{20} :   1.6173

m.p. of picrate :   140 - 141°C

Complete data relative to these experiments are not available.

ENCLOSURE (B) 11

INVESTIGATIONS ON THE TREATMENT

OF LIGNITE TAR

by

NAVAL ENGINEER
DR. T. ITAKURA

Research Period: 1945

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)11

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B)₁₁

SUMMARY

By laboratory experiments it was confirmed that by using
a simple batch retort, a naval bunker fuel of satisfacto-
ry quality could be distilled from lignite crude tar, the
yield being 60 - 65%.

I. INTRODUCTION

It is possible to manufacture about 2% of tar oil from lignite by carbonizing
at a temperature of 400 - 450°C, for 20 - 25 hours. However, it is impossible
to use this tar in naval boilers because its melting point is too high. The
problem of obtaining a satisfactory boiler fuel from this tar was assigned as
an urgent problem, and the work was carried out very hurriedly by Nav. Eng.
Lieut., I. TANAHASHI, S. HIRANO, Nav. Eng., Y. FUJIEDA, during the period
May - August, 1945.

II. DETAILED DESCRIPTION

A. Test Apparatus

A simple batch retort with a goose-neck was designed; the details of
which are shown in Figure 1(B)11.

B. Test Procedures

About 10kg of crude tar oil were charged (60% of the retort volume) and
heated slowly to 200°C during a period of about two hours to avoid foam-
ing of oil. Next, the oil was rapidly heated to the peak temperature of
340°C, over a period of 4 hours. During this period the product oil was
almost completely distilled over, and during a subsequent period of 2
hours, coking occurred at moderate heating rate.

C. Experimental Results

A material balance for the overall operation is given by Figure 2(B)11.
All yields are weight per cent.

Physical and chemical properties of the products and raw materials are
given in Table I(B)11. The raw lignite tar was obtained from Aichi Pre-
fecture.

It was possible to remove 95% of the water included in the crude lignite
tar by warming to a temperature of 60 - 80°C.

It was possible to distill the dehydrated tar satisfactorily to coke in
the goose-necked retort by regulating the heating velocity in the initial
period to avoid foaming.

Corrosion tests with various metals showed that the heavy oil was only
very slightly corrosive to steel, iron, copper, and brass.

III. CONCLUSIONS

It was concluded that it was possible to manufacture a fuel oil from the lig-
nite tar oil, which was satisfactory for use in naval boilers.

ENCLOSURE (B)11

Table I(B)11
PHYSICAL AND CHEMICAL PROPERTIES OF PRODUCTS AND RAW MATERIALS

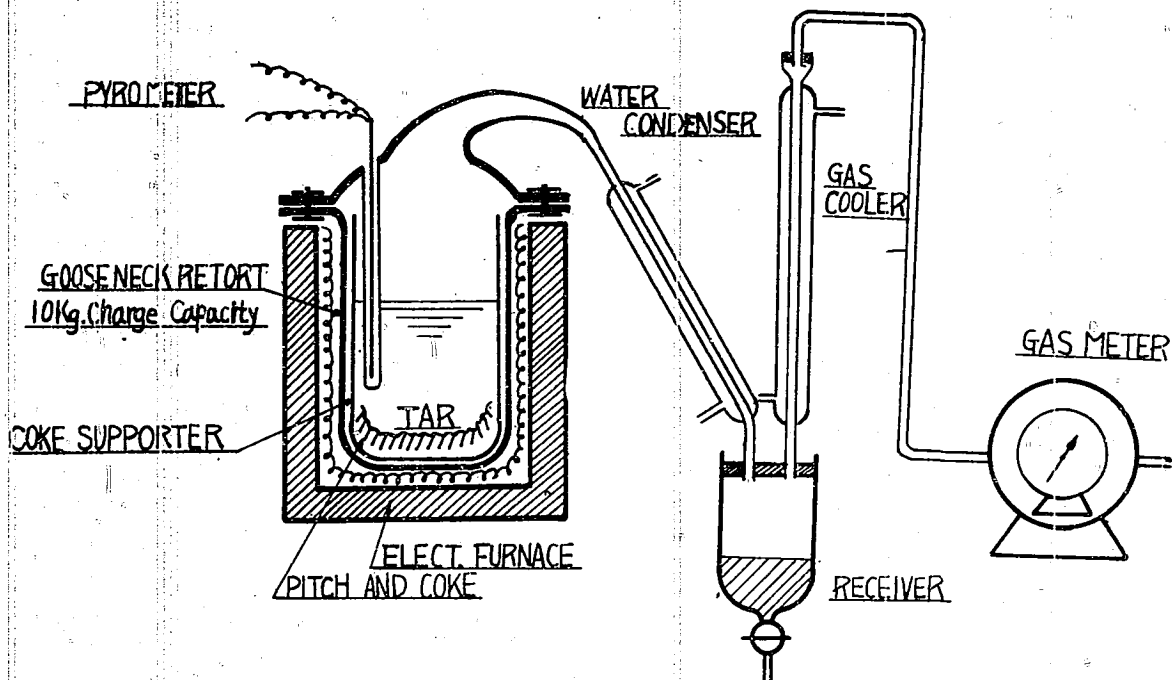|	Naval Boiler Fuel Specification	Raw Light Tar	Heavy Oil Distillate Product
Sp. Gr. (15/4°C)		0.9010	0.9137
Viscosity (R-1,30°C sec)	below 2000 secs (R-2,0°C)	97.0	44.0
Flash pt. (°C)	over 80	87.0	75.0
Pour pt. (°C)		24.0	4.0
Conradson's Carbon (%)		7.51	0.45
Calorific Value (Cals)	over 10,000	10,400	10,700
Impurity (%)	none	0.07	trace
Water Content (%)	below 1.0	26.0	0.9

Figure 1 (B)11
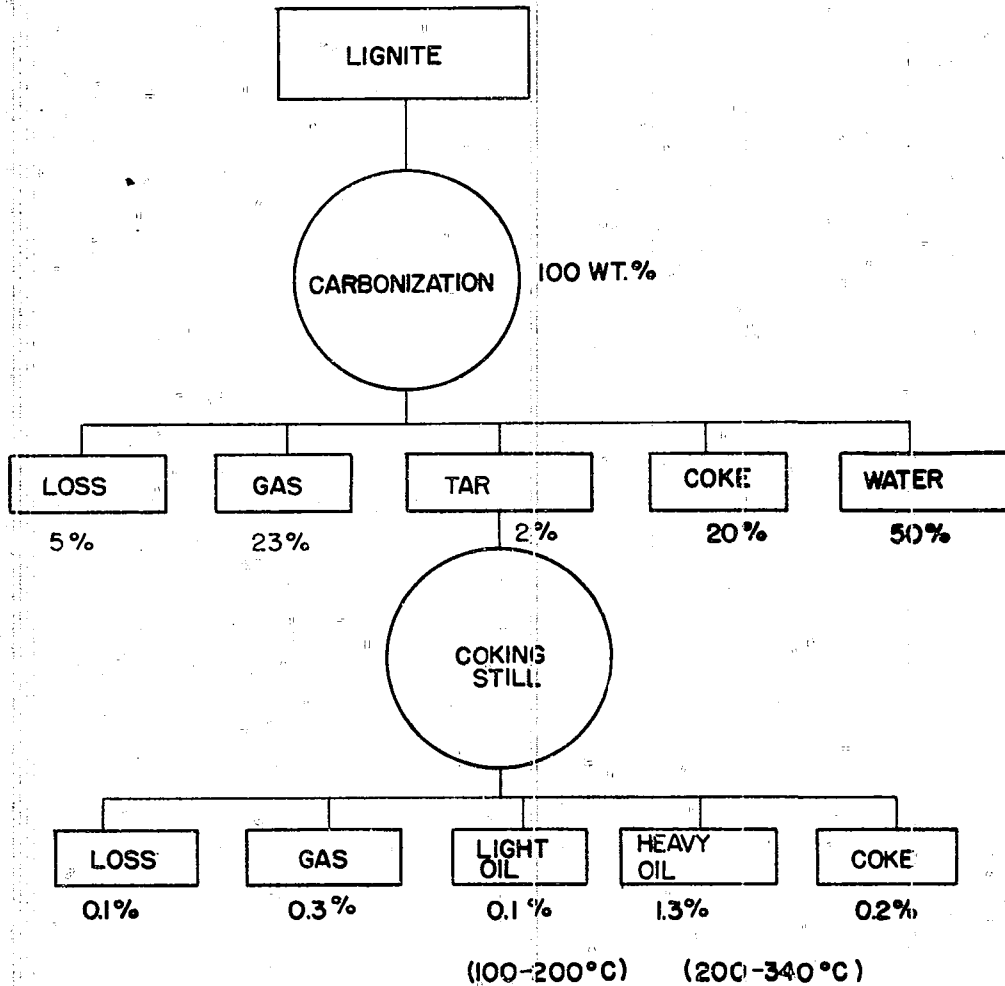DIAGRAM OF LIGNITE OIL DISTILLATION RETORT

ENCLOSURE (B)11

Figure 2 (B)11
MATERIAL BALANCE

ENCLOSURE (B) 12

S T U D I E S   O N   T H E   P O U R   P O I N T   D E P R E S S A N T

F O R   W A X - C O N T A I N I N G   F U E L   O I L S

by

CHEM. ENG. CAPTAIN DR. I. KAGEHIRA

CHEM. ENG. LIEUT. COMDR. A. WAKANA

ENG. LIEUT. I. HARA

Research Period: 1945

Prepared for and Reviewed with Authors
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)12

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B) 12

SUMMARY

From the results of studies on the pour point depressants
for the wax-containing fuel oils, it was found that
aluminium stearate was most effective. Fuel oils contain-
ing 5-10% of wax had a pour point of $+15°C$. By adding a
small quantity of aluminium stearate, such as 0.5 to 1.0%,
to this fuel oil, its pour point could be easily depressed
below zero degree C.

As the raw material for the manufacture of aluminium
stearate, saturated fatty acids whose carbon atom numbers
were above eighteen were found to be the best, and it was
recognized that the longer the carbon chain, the better
result was obtained; however, the effect of aluminium
soaps on the pour point of fuel oil depended mainly upon
the composition of the fuel oils.

Aluminium stearate was produced on a commercial scale and
it was used to some extent by some petroleum companies.
It was used (but not produced) by the Navy in the winter
of 1944-1945. The cost of aluminium stearate was approxi-
mately 1000 yen/ton in 1944.

I.   INTRODUCTION

A.   History of Project

In April 1943, it was found that a wax-containing fuel oil which was
fluid in the tropical zone sometimes suddenly lost it fluidity at lower
temperatures during loading in the oil tank.

As Sachanen already has pointed out, the solidification temperature of
oils varies with the temperature to which the oils were preheated, and
that the higher the preheating temperature, the greater the depression
of the solidification point, which, however, rises to its original
value in storage. It was necessary, therefore, to find some means of
depressing the pour point permanently to $0°C$. The following methods were
considered:

(1) Dewaxing
(2) Cracking of wax-containing fuel oils
(3) Dilution with low pour point fuel oil
(4) Addition of pour point depressant

Studies were directed only toward the use of pour point depressants. At
first the usual pour point depressants were examined, e.g. "Santo pour",
and it was found that they were superior for refined lubricating oils but
not effective for heavy fuel oils which contained the asphaltic
substance. Considering its colloidal properties, the depression of pour
point may be due to the prevention of wax crystal growth and monopole
soap which was prepared from Kapokseed oil by sulphonation, and, follow-
ing neutralization, was tested for its effect on the pour point. This
soap was fairly effective and hence it was concluded that more metallic
soaps, should be investigated. As a result, aluminium stearate was
found the best pour point depressant in June, 1943.

B.   Key Personnel Working on Project

Chem. Eng. Lieut. Comdr. A. WAKANA

ENCLOSURE (B)12

Eng. Lieut. Comdr. S. HARA

II. DETAILED DISCRIPTION

A.   Variation of pour point of wax-containing fuel oils with their pre-
heating temperature is as follows:

    1.   A wax-containing fuel oil was diluted with 10 volumes of di-
chlorethane and filtered at -21°C. Wax and dewaxed oil, thus ob-
tained, were mixed again in various proportions and the pour points
were measured. See Figure I(B)12.

    As shown in Figure 1(B)12, the pour point of dewaxed oil did not
change with the preheating temperature, but wax-containing oil
changed abnormally.

    2.   Normal heptane and sweated wax were mixed in various proportions
and the pour points were measured. As shown in Figure 2(B)12, the
variation of pour point was not observed.

    3.   The above mentioned solution of wax and normal heptane was mixed
with several amounts of asphalt obtained from Tarakan crude oil by
topping to 300°C at 1mm, and the pour points were then measured. As
shown in Figure 2(B)12, the abnormality of pour point was observed in
curves 2 and 3 of asphalt and wax-containing oil.

    4.   Sanga Sanga topped heavy oil and Tarakan crude oil were mixed in
various proportions, and to these mixtures prepared "Santopour" was
added. The results are shown in Figure 4(B)12. Prepared "Santopour"
had some effect, but it was far from excellent. One per cent of
monopole soap which was prepared from Kapok seed oil by sulphonation,
followed by neutralization, was added to the heavy fuel oil which had
a 19°C, pour point. The pour point was lowered to -18°C, but on re-
peating the pour point test it rose to 1°C. From this it seemed that
its effect was considerably changed due to change in crystal struc-
ture with heating and cooling.

B.   Effect of aluminium stearate on pour point of wax-containing fuel oil
is as follows:

Tarakan fuel oil which contained no wax had a pour point of 135°C.
To this a wax obtained from Sanga Sanga crude oil in South Borneo
and melting at 49°C was added in various proportions and their pour
points determined.

As shown in Figure 5(B)12, when the content of the 56°C wax was re-
stricted to 7%, and in the case of 49°C wax, to 11%, aluminium
stearate was distinctly effective in depressing the pour point of
oil. Also, the melting point of the wax had a marked effect on the
pour point.

C.   Effect of aluminium stearate on the pour point of wax-containing fuel
oil which was diluted with lower pour point light oil as follows:

The properties of sample used are shown in Table I(B)12 and Table II(B)12
As shown in Table III(B)12 and in Figure 6(B)12, it was observed that a
fuel oil having a pour point below 0°C and not subject to change with pre-
heating was obtainable by blending with 30% of light oil and 0.5% of alu-
minium stearate. By diluting with the lower pour point light oil, the

wax content of the fuel oil was reduced to a range where the pour point depressant was very effective.

D.   Determination of the necessary temperature to dissolve aluminium stearate completely in fuel oils was arrived at as follows:

0.5 grams of aluminium stearate was dissolved completely, in 30 grams of a light oil at 80°C. This solution was mixed with 70 grams of fuel oil heated at the following mixing temperatures and the pour points after preheating at 40°C. As shown in Table IV(B)12, mixing at 0-60°C, the pour point rose gradually with repeated pour point test, indicating that the mixing temperature should be above 80°C.

E.   Preparation of   Aluminium Stearate.

Aluminium soaps prepared from hydrogenated palm oil, soy bean oil, sardine oil, and rape oil were tested. The results are shown in Table V(B)12. Of these, aluminium soap of hydrogenated rape oil was the best.

Aluminium stearate was prepared from hydrogenated soy bean oil by the ordinary double decomposition method given in Figure 7(B)12.

III. CONCLUSION

The pour point of wax-containing fuel oil could be depressed to a considerable degree by the limitation of wax content to about 10% and by adding a small amount of aluminium stearate. With this method, the wax-containing fuel became usable in the winter season in Japan, but was utilized only by the oil companies, including Mitsubishi and Showa Petroleum Oil Companies. This method was not used by the Navy.

ENCLOSURE (B)12

Table I(B)12
PROPERTIES OF SAMPLE

Properties	Heavy fuel oil	Light oil
Specific gravity (d_4^{25})	0.8854	0.8364
Flashing point (°C)	78	41
Pour point (°C)	21	-14
Conradson carbon (%)	2.4	0.03
Viscosity at 30°C(R-1)	69.2	30.5
Water content (%)	1.1	0
Distillation test		
I.B.P.(°C)	95	110
5 (Vol %)	166	180
10	217	
20	238	199
30	250	210
40	269	220
50	283	228
60	318	232
70	332	241
80	349	253
90	323	263

ENCLOSURE (3)12

Table II(B)12-a
ANALYSIS OF HEAVY FUEL OIL

No	Fraction(°C)	Yield(weight %)	Pour Point(°C)
1	95-292	55	-10
2	292-297/4mm	37.2	
	oil part	8.4	+17
	wax part	28.8	+40
3	297/4mm -	6.3	+115
4	loss	1.3	

Table II(B)12-b
PROPERTIES OF ALUMINIUM STEARATE

Free fatty acid (%)	43.8
Combined fatty acid (%)	50.0
Ash (%)	9.9
Free H_2SO_4	0.5
Water content	13
Na_2SO_4	4.6
Pure Aluminium stearate (%)	51.6
Iron stearate	2.2
Weight of 1cc (gm)	0.25

ENCLOSURE (B)12

Table III(B)12
EFFECT OF ALUMINIUM STEARATE ON LOWERING POUR POINT FOR HEAVY FUEL OIL

Proportion of Mixing (wt %)			Pour Point (°C) at each preliminary temp.		
Heavy Fuel Oil	Light Oil	Aluminium Stearate	30°C	40°C	50°C
100	0	0	18	21	18
80	20	0	12	16	13
80	20	0.5	-5	15	1
70	30	0	-11	14	11
70	30	0.5	-17	-5	-14
60	40	0	10	12	4
60	40	0.5	-21	-18	-25
50	50	0	10	0	0
50	50	0.5	-31	-30	-32
0	100	0	-14	-14	-14

Table IV(B)12
DETERMINATION OF THE EFFECT OF MIXING TEMPERATURE ON POUR POINT
STABILITY FOR FUELS COMPOUNDED WITH ALUMINIUM STEARATE

Mixing temp. (°C)*		Test Number					
		1	2	3	4	5	6
	20	-11	-13	-11	-8	-7	-5
Pour Point (°C)	40	-14	-14	-13	-9	-6	-8
	60	-18	-17	-17	-15	-14	-10
	80	-23	-23	-24	-23	-23	-23
	Without Aluminium Stearate	+15	—	—	—	—	—
Time elapsed (Day)		0	0	0	3	4	4

*Preliminary temperature in each test was 40 °C.

ENCLOSURE (B)12

Table V(B)12
TESTS OF VARIOUS ALUMINIUM SOAPS

		Properties of Fatty Acid			Aluminium Soaps	Pour Point (°C) Preheating at Next Temperature (°C)			
	Fatty Acid	Iodine Value	Melting Point (°C)	Water Content (%)	Quantity Used (%)	20°C	30°C	40°C	50°C
1					0	+7	+16	+17	+15
2	Hydrogenated			0.8	1.0	-15	-22	-20	-23
3				10.1	1.1	-16	-21	-21	-21
4	soy			22.7	1.3	-18	-21	-20	-22
5				37.3	1.6	-17	-19	-17	-19
6	bean	14.4	62	1.5	0.5		-7	-13	-15
7		6.0	63.8	0.04	0.5		-6	-6	-16
8	oil	6.0	63.8	0.04	0.2		+17	+18	+15
9	Hydrogenated	14.3	51.3	0.04	0.5		-19	-14	-18
10	sardine	5.7	53.4	0.77	0.5		-15	-13	-16
11	oil	5.7	53.4	0.77	0.2		-3	+17	-4
12	Hydrogenated	18.9	59.1	0.31	0.5		-15	-16	-18
13	rape oil	18.9	59.1	0.31	0.2		-12	-1	-13
14	Hydrogenated palm oil	3.2	58.0	3.8	0.5		11	-5	-5

ENCLOSURE (B)12

NO	DEWAXED OIL	WAX
1	70	30
2	80	20
3	90	10
4	100	0
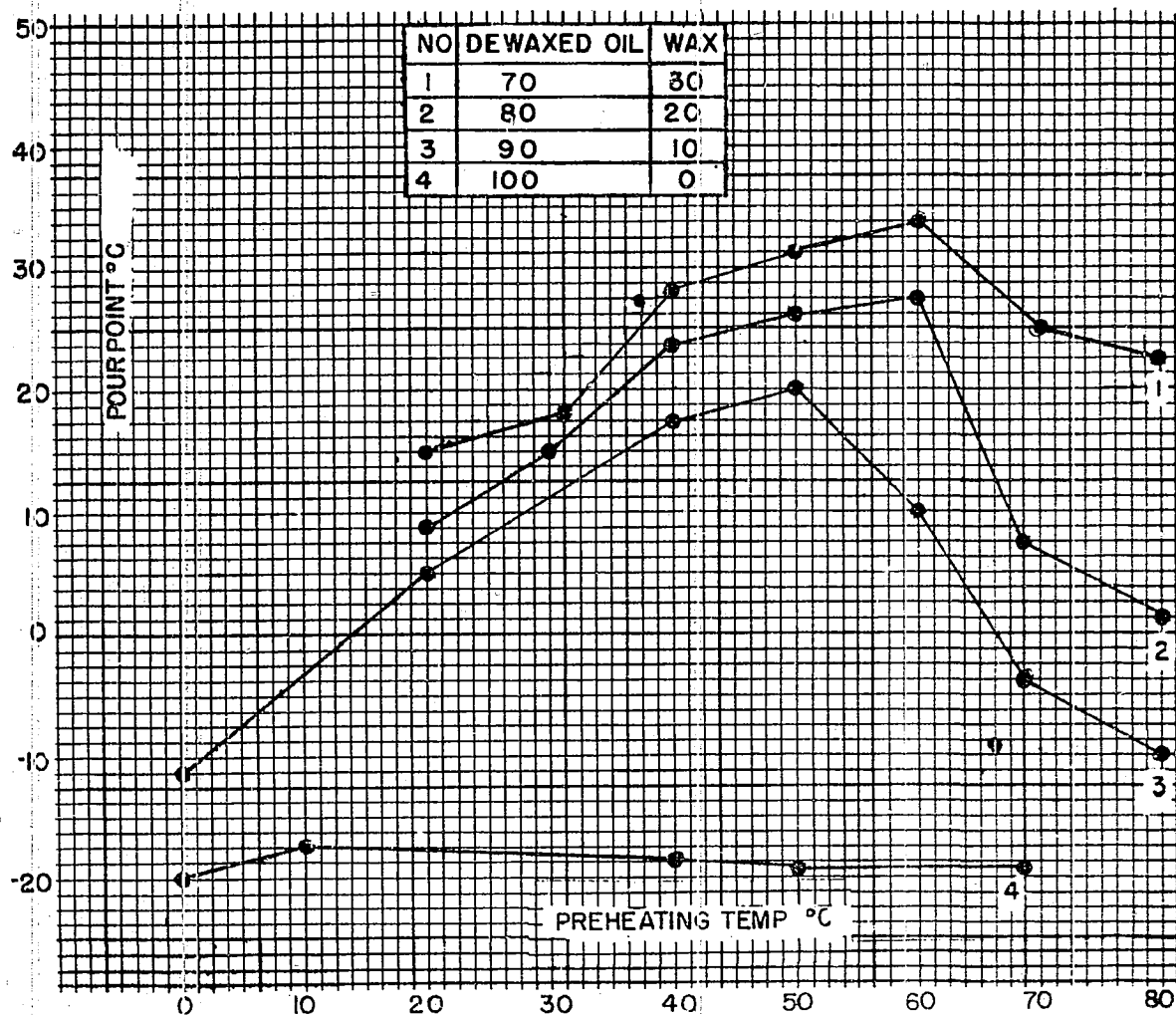
Figure 1 (B)12

RELATIONSHIP BETWEEN POUR POINT
AND PREHEATING TEMPERATURE

ENCLOSURE (B)12

NO	N-HEPTANE	REF WAX
1	100	50
2	100	30
3	100	20
4	100	10
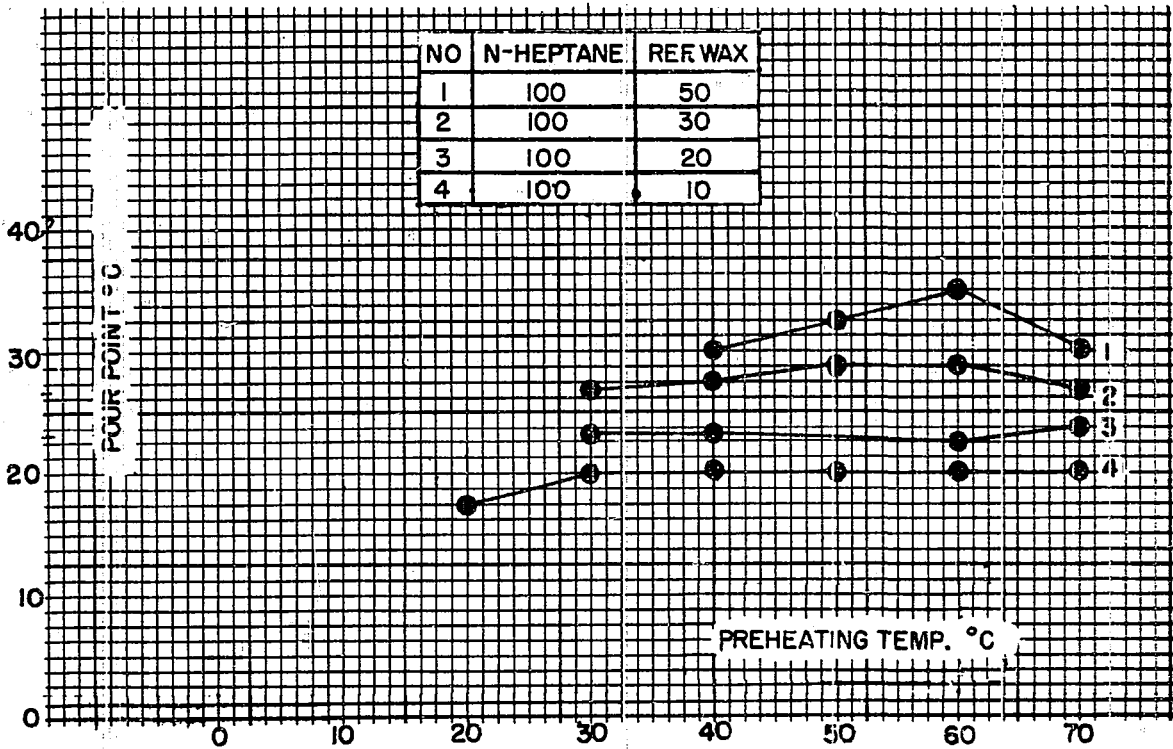
Figure 2 (B)12
RELATIONSHIP BETWEEN POUR POINT
AND PREHEATING TEMPERATURE

ENCLOSURE (B)12

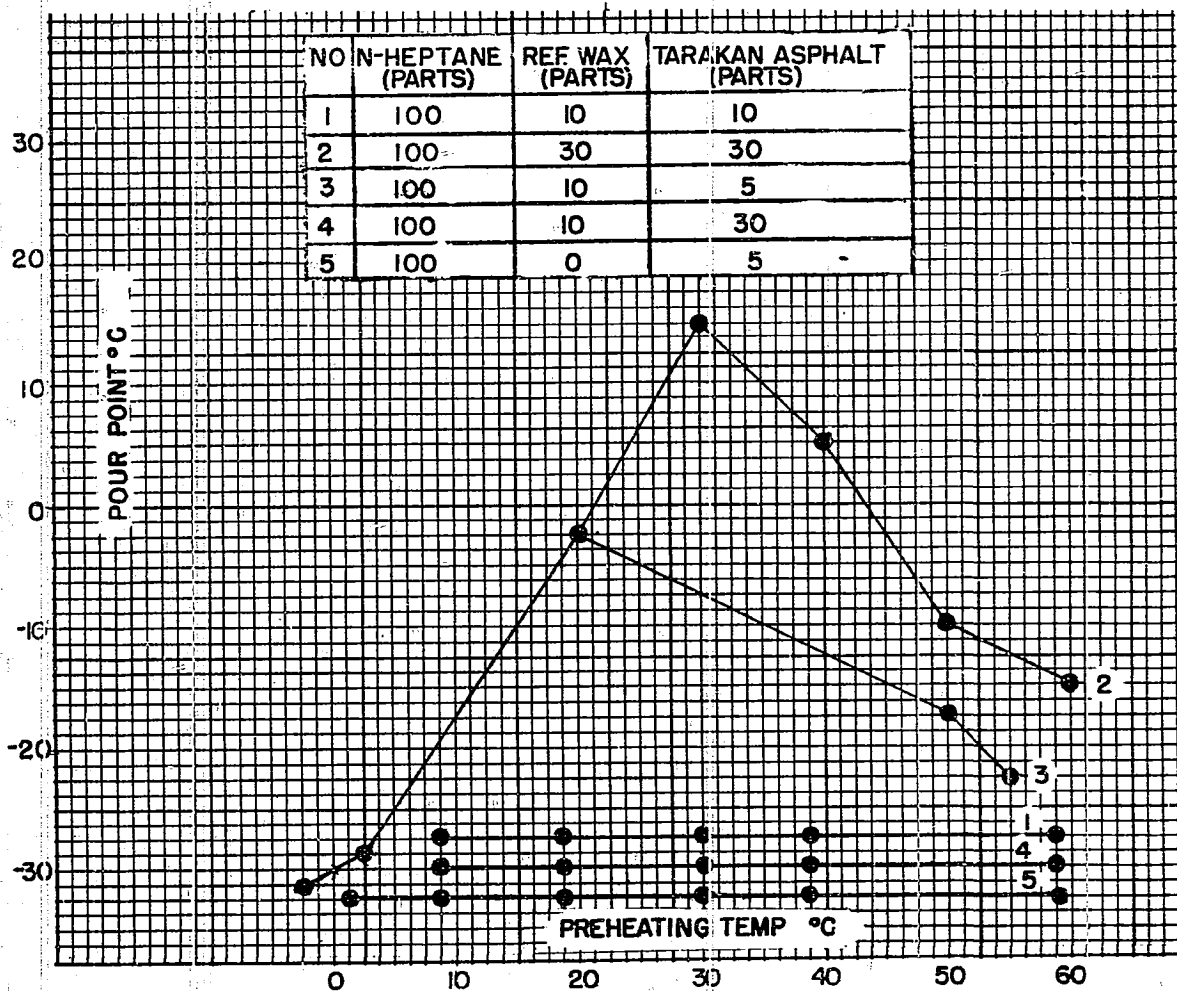| NO	N-HEPTANE (PARTS)	REF WAX (PARTS)	TARAKAN ASPHALT (PARTS)
1	100	10	10
2	100	30	30
3	100	10	5
4	100	10	30
5	100	0	5

Figure 3 (B)12
RELATIONSHIP BETWEEN POUR POINT
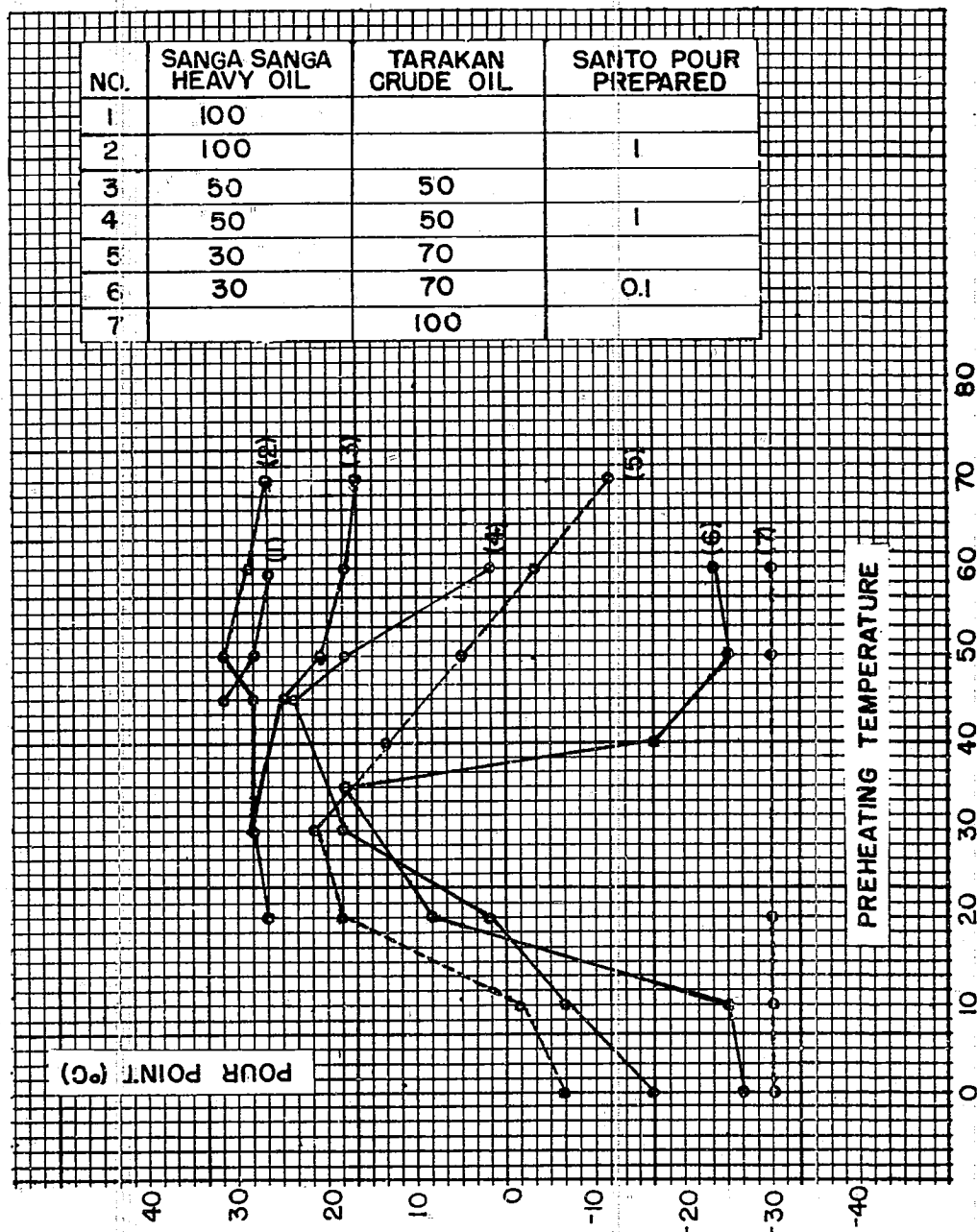AND PREHEATING TEMPERATURE

ENCLOSURE (B)12

NO.	SANGA SANGA HEAVY OIL	TARAKAN CRUDE OIL	SANTO POUR PREPARED
1	100		
2	100		1
3	50	50	
4	50	50	1
5	30	70	
6	30	70	0.1
7		100	

Figure 4 (B)12

RELATIONSHIP BETWEEN POUR POINT AND PREHEATING TEMPERATURE

PREHEATING TEMPERATURE

POUR POINT (°C)
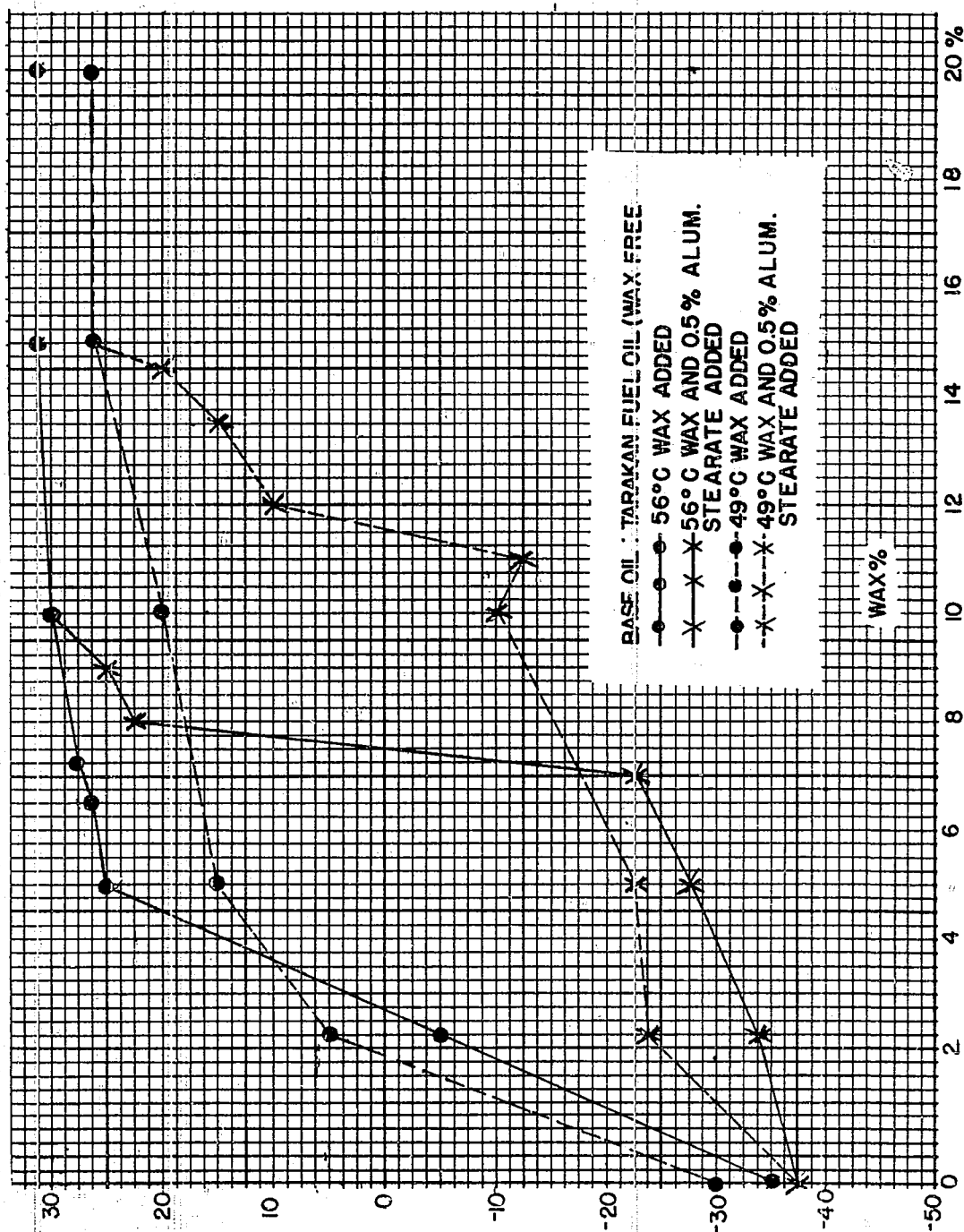
113

ENCLOSURE (B)12
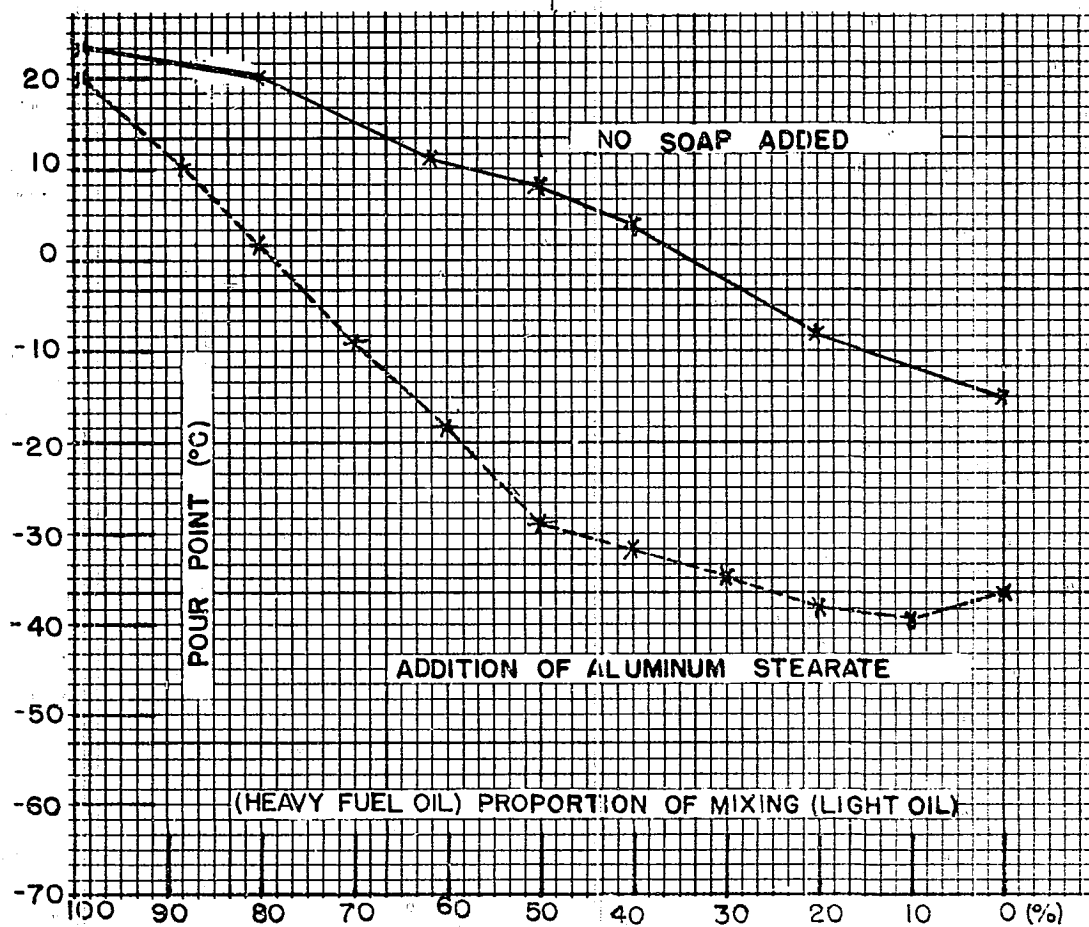

Figure 5 (B)12

EFFECT OF WAX ON POUR POINT

ENCLOSURE (B)12

Figure 6 (B)12
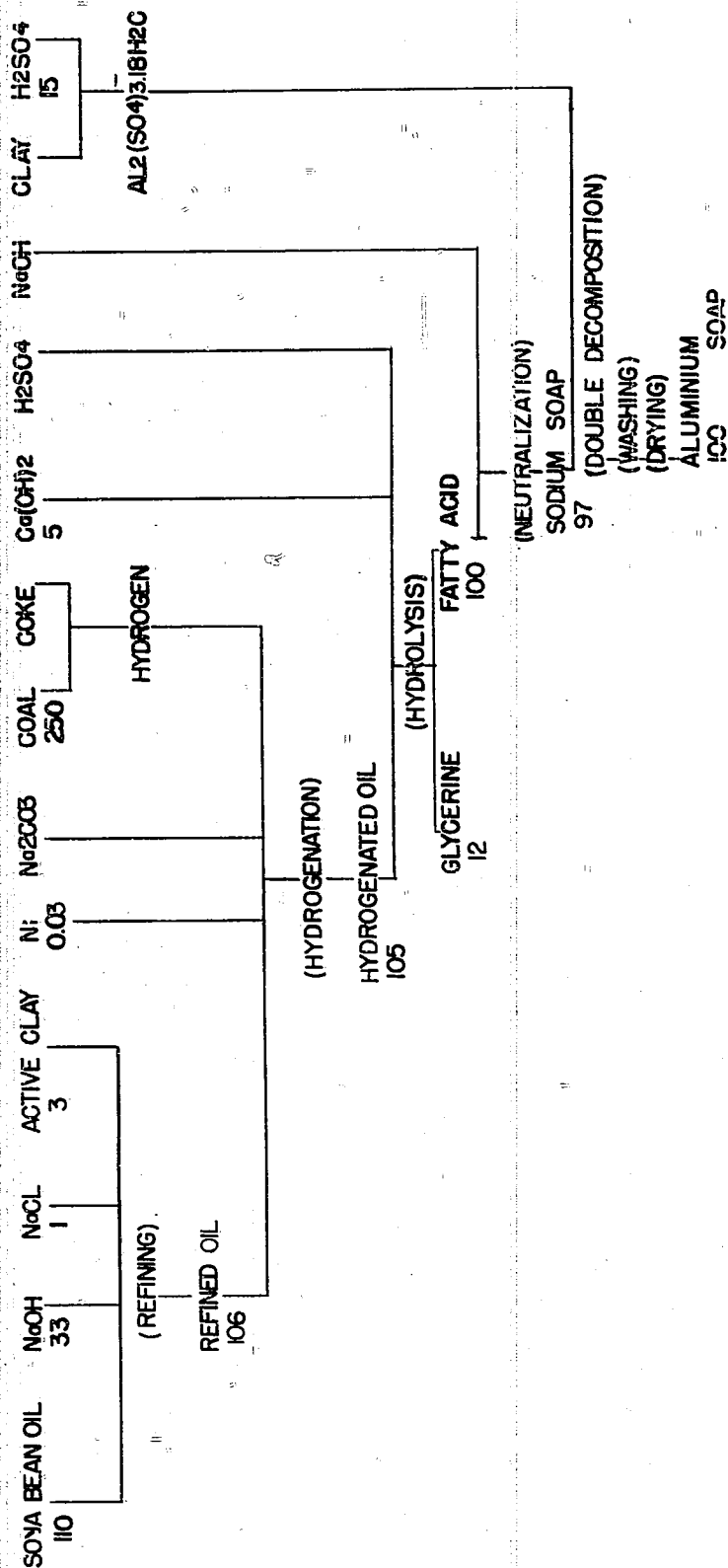EFFECT OF ALUMINIUM STEARATE
ON POUR POINT

ENCLOSURE (B)12

Figure 7 (B)12

PRODUCTION OF ALUMINIUM STEARATE

SOYA BEAN OIL 110 — NaOH 33 — NaCL 1 — ACTIVE CLAY 3 — (REFINING) — REFINED OIL 106

Ni 0.03 — Na2CO3 — COAL 250 — COKE — HYDROGEN — (HYDROGENATION) — HYDROGENATED OIL 105

Ca(OH)2 5 — H2SO4 — (HYDROLYSIS) — GLYCERINE 12 — FATTY ACID 100

NaOH — (NEUTRALIZATION) — SODIUM SOAP 97

CLAY — H2SO4 15 — Al2(SO4)3.18H2O — (DOUBLE DECOMPOSITION) — (WASHING) — (DRYING) — ALUMINIUM SOAP 100

ENCLOSURE (B) 13

S T U D I E S C N T H E S C L I D I F I C A T I O N

O F B U N K E R F U E L C O N T A I N I N G - W A X E S

by

ENG. COMDR.
H. FUJIMOTO

Research Period: 1943

ENCLOSURE (B)13

L I S T   O F   T A B L E S

A N D   I L L U S T R A T I O N S

ENCLOSURE (B)13

SUMMARY

This research was undertaken to clarify the solidifying
behavior of bunker fuel containing wax, which was obtained
from East Indies crude oil. The purpose of the research
was also to investigate the dopes for lowering the pour
point, and to revise the testing method for pour point de-
termination of bunker fuel.

The pour point of bunker fuel containing waxes differs
remarkable depending on the temperature at which the oil
was treated before the determination and a maximum pour
point is obtained when the oil was preheated to between
40°C to 60°C. The reason of this phenomena was accepted
to be the influence of asphalts contained in the fuel
which serves to change the crystallizing habits of the
waxes.

Aluminum stearate was chosen as the dope for lowering the
pour point, and it was found to have a marked effect on
bunker fuels having a maximum pour point below about 15°C;
in other words, containing less than 3% of waxes in the
fuel.

The pour points of bunker fuels were revised so as to ex-
press the maximum pour point by determining 5 points ac-
cording to the temperature to which the oil had previously
been heated such as 30°C, 40°C, 50°C, 60°C, and 70°C.

I.   INTRODUCTION

In war time the source of bunker fuel was displaced from California to East
Indies crude oil, and it was projected to prepare a low freezing bunker fuel
by deforming its paraffin wax using a cracking lant, since the capacity of
available dewaxing plants was not sufficient to supply the bunker fuel.

The topped residue of an East Indies crude, having a pour point of about
40°C, was cracked to lower its pour point using a Dubbs cracking plant at the
2nd Naval Fuel Depot. From the experiments reported herewith it was defined
that the maximum pour point of the cracked residue must be below 15°C and the
product, after adding 1% of aluminium stearate, was used as bunker fuel.

II.   DETAILED DESCRIPTION

A.   Experimental Method

Several typical hydrocarbons such as n-heptane, cyclohexane, benzene,
cetane, and deasphalted Tarakan crude oil were used as solvents and
paraffin wax having a melting point of 57°C was dissolved in them in
varying proportions. For each wax-containing solution, the relation
between the pour point of the solution and the temperature at which
the wax crystallized out from the solution by cooling was measured.
The crystallizing temperature was measured by finding the break in the
cooling curve of the solution as it was cooled from outside of the
vessel at constant speed. There was good agreement between the pour
point and crystallizing temperatures, as shown in Table I(B)13 for the
case of n-heptane solution.

It was concluded from these results that the pour point of the solution
is not the solidifying temperature of the solution but is that of the
wax deposited from the solution, which causes the whole system to solidify.

In the above experiments there was no influence of temperature history on the pour point determination, but when the oils contained some bituminous matter such as asphalt, the pour point was markedly influenced by the temperature history of the oil.

For example, the pour point of 3% and 5% wax solutions of deasphalted Tarakan crude is 21°C and 25°C, respectively, independent of the temperature to which the oils had been heated before the determination, but in the case of un-deasphalted Tarakan crude oil, the same solutions gave the following pour points according to the temperature preheated.

Preheated Temperature	20°C	30°C	40°C	50°C	60°C	70°C	80°C
3% Wax Solution	6	19	-3	-30	-25	-24	-24
5% Wax Solution	26	16	23	13	11	12	12

On the contrary, the crystallizing temperatures of the same solutions were not influenced by the preheated temperature as shown below:

Preheated Temperature	30°C	40°C	50°C	60°C	70°C	80°C
3% Wax Solution	21	24	22	24	23	22
5% Wax Solution	26	27	26	26	27	26

From the above experiments it was supposed that the paraffin waxes in those oils preheated to higher temperatures would be deposited out in crystallized form and remain in suspension which causes the low pour point. On the contrary, when the oils preheated to comparatively lower temperatures were cooled, the paraffin waxes dissolved in the oil would be deposited out in colloidal form and the whole system will solidify.

This consideration is also justified by microscopic observation of the solidified oils as shown in Fig. 1(B)13.

Figure	Composition	Pour Pt. (°C)	Preheated at (°C)	Photographed at (°C)
A	Tarakan Crude Oil+5% Wax	12	100	15
B	Tarakan Crude Oil+5% Wax	26	30	15
C	Deasphalted Tarakan Crude Oil+5% Wax	25	100	15

These preheating effects which influence the pour point of bunker fuels remain for a fairly long time as shown by the following experiment.

A bunker fuel having a maximum pour point of 8°C was preheated to 100°C for one hour and allowed to stand at room temperature of 25 to 30°C for varying time intervals, and the pour points of the oil were determined as follows:

ENCLOSURE (B)13

Pour Point	Time of Standing
-30°C	immediately after cooling
-25°C	1 day
-16°C	5 days
-18°C	11 days
-6°C	38 days

It was also observed that to eliminate the preheating effect on the oil it must be cooled to solidify and allowed to stand for at least one day at room temperature.

When 0.5% of aluminum stearate was added to some bunker fuels and the effects as a pour point depressant were tested, the following results were obtained at different preheating temperatures:

Example 1, Bunker fuel containing about 5% of wax.

Preheat temp. (°C)	20	30	40	50	60	70	80
Pour pt.	-16	-18	-21	-21	-13	-10	-13
Pour pt. with 0.5% Al-st.	7	7	15	12	-10		

Example 2, Bunker fuel containing about 3% of wax.

Preheat temp. (°C)	20	30	40	50	60	70
Pour pt. without Al-st.	-4	12	13	8	6	
Pour pt. with 0.5% Al-st.		-20	-19	-14		

Example 3, Deasphalted bunker fuel containing about 3% of wax.

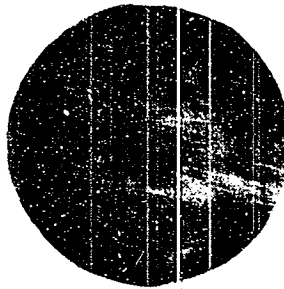| Preheat temp. (°C)	20	30	40	50	60	70
Pour pt. without Al-st.	17	18	19	18	19	17
Pour pt. with 0.5% Al-st.	-7	-5	-4	-5	-5	-6

III. CONCLUSIONS

It was concluded that aluminum stearate has a remarkable effect in lowering the pour points of bunker fuels containing less than about 3% wax, which corresponds to fuels having a maximum pour point below about 15°C.
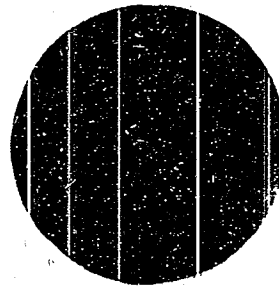

A   B   C
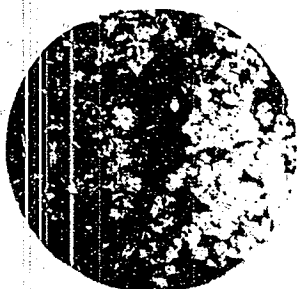
x50   x50   x50

Figure 1(B)13
MICROSCOPIC OBSERVATIONS OF SOLIDIFIED OIL.

Table I(B)13
POUR POINTS AND CRYSTALLIZING TEMPERATURES
OF SOLUTIONS OF WAX IN N-HEPTANE.

		Pour Point (^{O}C)	Crystallizing Temp. (^{O}C)
n-Heptane Only		below -60^{o}	-
Wax Solution %	1	-25	5
	3	5.5	14.2
	5	14.0	17.5
	10	21.0	23.1
	20	28.0	29.1
	30	32.0	34.1
	50	38.5	40.0
	70	45.0	46.5
	90	53.0	54.2
	100	57.0	58.8

ENCLOSURE (B) 14

P R A C T I C A L   T E S T S

O F   S U B S T I T U T E   B O I L E R   F U E L S

(C O P R A   A N D   C O P R A   P R E S S E D   R E S I D U E)

by

CAPTAIN I. NORITAKE

Research Period:
From June 1942 to October 1942

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)14

LIST OF TABLES
AND ILLUSTRATIONS

ENCLOSURE (B)14

SUMMARY

It is confirmed that copra and copra pressed residue are suitable as boiler fuels, and it is recommended that they be used by mixing with coal or coal briquettes, the ratio of mixing being as follows:

       Copra 70%, coal (in pieces-about 1" diameter) 30%
       Copra 50%, briquette (egg-shaped) 50%
       Copra pressed residue 50%, coal or briquette 50%

I.   INTRODUCTION

To utilize the products of South Sea Islands for fuel, copra and copra pressed residue were tested as the substitute for coal for marine and land boiler use. Samples were prepared beginning June, 1942, and the tests finished in October, 1942.

II. DETAILED DESCRIPTIONS

A.   Sample analyses are shown in Table I(B)14

B.   **Boiler Used**

Stationary type cylindrical boiler, fire tubes, return flame type.

       Working pressure: 7.0 kg/cm^2 (gauge)
       Tube size: 7.0cm diameter; 2 meters long.

C.   **Test Procedures**

    1.   **Tests of Lighting Fire**.

    2.   **Tests of Steaming at High Rate of Combustion (Hand-stoked)**.
These tests were compared with the tests using only coal or briquette as standards.

In the tests of lighting the fire, 4 kg of fire-wood and 100 kg of sample were used in each case and the ease or difficulty of lighting and flaming up, and the density of smoke were observed.

In the steaming tests, the rate of combustion was kept at 107.6 kg/m^2/hr, and keeping the working steam pressure constant, the evaporation, degree of smoke conditions, etc. were measured.

D.   **Experimental Results**

    1.   **Tests of Lighting Fire**. The fire was very easy to light when copra was used. Mixing the copra with briquette, the difficulty of lighting fire was considerably reduced. Consequently, the utilization of copra was very effective for quick steaming.

The copra pressed residue was also effective for the same purpose. (See Table II(B)14)

Note: It was advisable that the size of copra pressed residue be 50 mm^2 if a plate of thickness 15^{mm} was used as the sample, (50^{mm} x 50^{mm} x 15^{mm}).

ENCLOSURE (B)14

2.   <u>Steaming Tests</u>. It was advisable that the ratio of mixing copra or copra pressed residue with coal or briquette be as follows:

        Coal (in pieces) 30%, copra 70%
        Briquette 50%,   copra 50%
        Coal (in pieces) 50%, copra pressed residue 50%
        Briquette 50%,   copra pressed residue 50%

In the case of copra, evaporative power of boiler was nearly equal to coal or briquette alone, but when copra pressed residue was used, the evaporative power was decreased about 20%.

When the copra or copra pressed residue was used, less smoke, less clinker, and easier lighting was obtained. (See Table III(B)14)

3.   There was no danger of spontaneous combustion with copra or copra pressed residue in storage at the temperature of 100°C and below..

III. CONCLUSION

It is very easy to light the fire when copra is used together with coal. For steaming purposes, copra with coal is effective as this combination gives less smoke than coal alone.

When copra is mixed in the ratio of 3:7 for coal. 5:5 for briquette, the evaporative power of a boiler is nearly equal to that for coal alone.

From the standpoint of fire bed thickness, clinker, flame color, and length, it is preferable to use a mixture of ratio 5:5 for pressed copra residue with coal or briquette, but in this case the evaporative power decreases about 20% compared with coal or coal briquettes alone.

In summary, copra and pressed copra residue are suitable for boiler fuel when intermixed with coal or briquettes.

Table I(B)14
ANALYSIS OF SAMPLES

Property	Raw Copra	Copra Pressed Residue	Coal (in pieces)*	Coal Briquettes**
Moisture %	3.6	5.4	2	2.5
Volatile matter %	92	76	41	14.6
Fixed carbon %	2.5	14	50	70
Ashes %	1.6	4.8	7	13
Calorific value (cal)	7300	4300	7200	7600

    *   Grade C_2 (by Navy Specification)
    ** Egg-shaped briquette

ENCLOSURE (B)14

Table II(B)14
RESULTS OF LIGHTING FIRE TESTS

Fuel	Time required from lighting fire till steaming (A)	From lighting fire till working (B)	Temperature		Fuel consumption (B) (kgs)	Ease of lighting
			Room (^{o}C)	Feed water (^{o}C)		
Coal in pieces only	2^{h}-25'	3^{h}-50'	26.5	26.5	280	Slightly difficult
Coal 30% Copra 70%	1-0	2-20	27	29.5	290	Slightly difficult
Coal 40% Copra 60%	1-10	2-40	21.5	27	270	Very easy to light
Coal 50% Copra 50%	1-05	2-10	21.5	27	245	Very easy to light
Coal 30% Copra pressed residue 70%	1-20	2-25	13.5	14.5	400	Very easy to light
Coal 40% Copra pressed residue 60%	1-20	2-15	7.5	16	350	Very easy to light
Coal 50% Copra pressed residue 50%	1-30	2-30	7.5	10	360	Very easy to light
Briquette only	3-20	4-20	25	27.5	380	Most difficult to light
Briquette 30% Copra 70%	0-55	2-0	23.5	27	300	Easy to light
Briquette 40% Copra 60%	1-05	2-10	23	24	300	Easy to light
Briquette 50% Copra 50%	1-10	2-25	19	25	320	Easy to light
Briquette 30% Copra pressed residue 70%	1-10	2-30	8	31	340	Easy to light
Briquette 40% Copra pressed residue 60%	1-30	2-50	5	15	410	Easy to light
Briquette 50% Copra pressed residue 50%	1-40.	3-0	17	16	320	Easy to light

ENCLOSURE (B)14

Table III(B)14
RESULTS OF STEAMING TESTS

Fuel	Fuel consump- tion (kgs)	Rate of combus- tion (kgs/ m²/hr)	Quantity of feed evaporated (kgs/kg of fuel)	Temperature Room (°C)	Feed water (°C)	Flame colour	Length	Caking or non-caking	Smoke
Coal in pieces only	450	1076	8.3	30	27	yellow	long	non-caking	poor
Coal 50% Copra 50%	450	1076	7.4	28	25	yellow	long	non-caking	rather poor
Coal 40% Copra 60%	450	1076	7.8	29	25	light yellow	long	non-caking	poor
Coal 30% Copra 70%	450	1076	8.5	32	26	light yellow	longest	non-caking	fair
Coal 50% Copra pressed residue 50%	450	1076	7.2	16	14	yellow	short	non-caking	very good
Coal 40% Copra pressed residue 60%	450	1076	7.0	12	14	yellow	short	non-caking	good
Coal 30% Copra pressed residue 70%	450	1076	6.4	25	23	yellow	short	caked	very good
Briquette only	450	1076	9.3	31	25	light yellow	long	caked	rather poor
Briquette 50% Copra 50%	450	1076	8.9	31	25	light yellow	long	caked	fair
Briquette 40% Copra 60%	450	1076	8.3	33	26	light yellow	long	caked	rather poor
Briquette 30% Copra 70%	450	1076	9	32	25	light yellow	long	caked	rather poor
Briquette 50% Copra pressed residue 50%	450	1076	7	32	27	yellow	short	caked	best
Briquette 40% Copra pressed residue 60%	450	1076	6.7	33	26	yellow	long	caked	very good
Briquette 30% Copra pressed residue 70%	450	1076	6.6	32	26	yellow	long	non-caking	very good

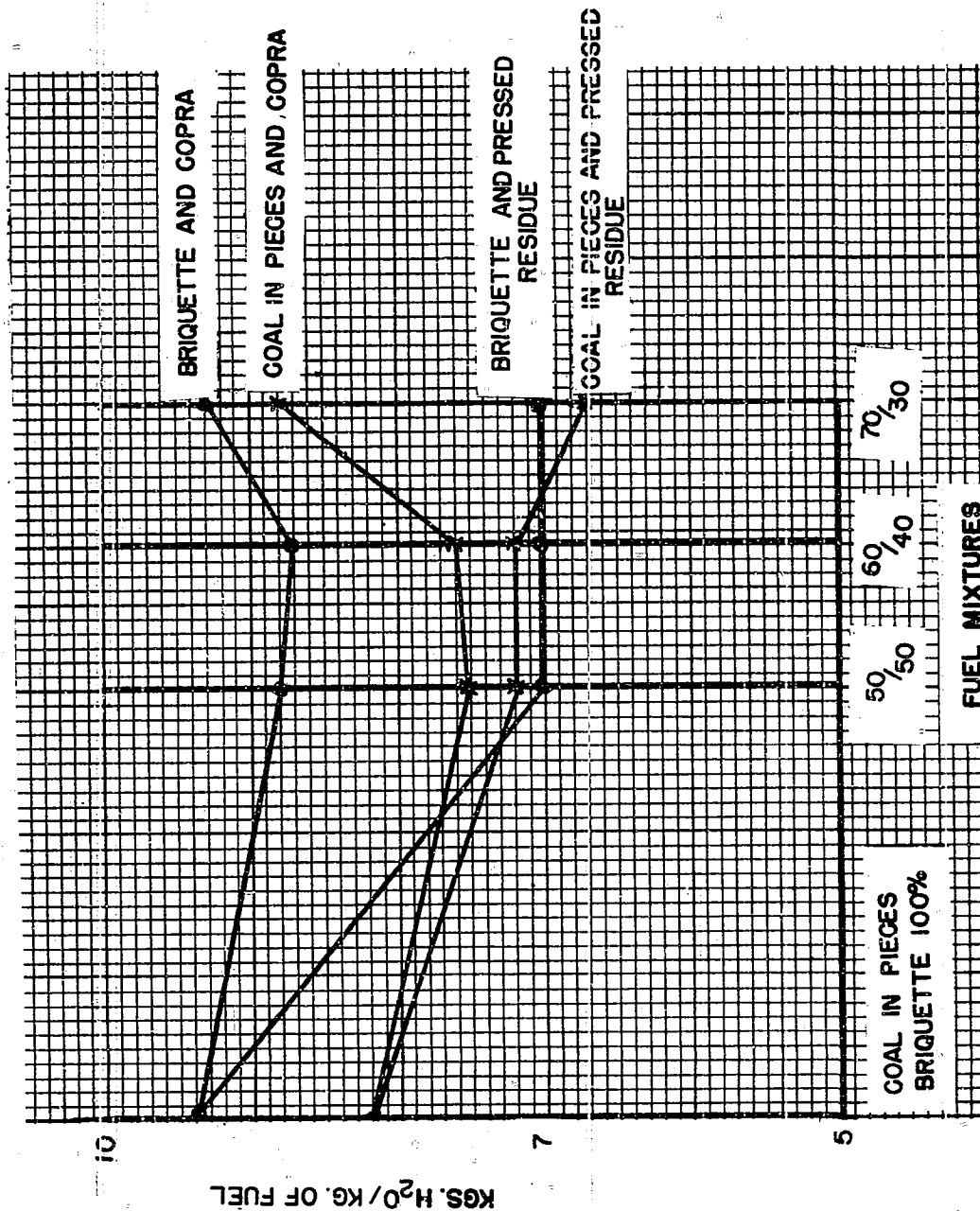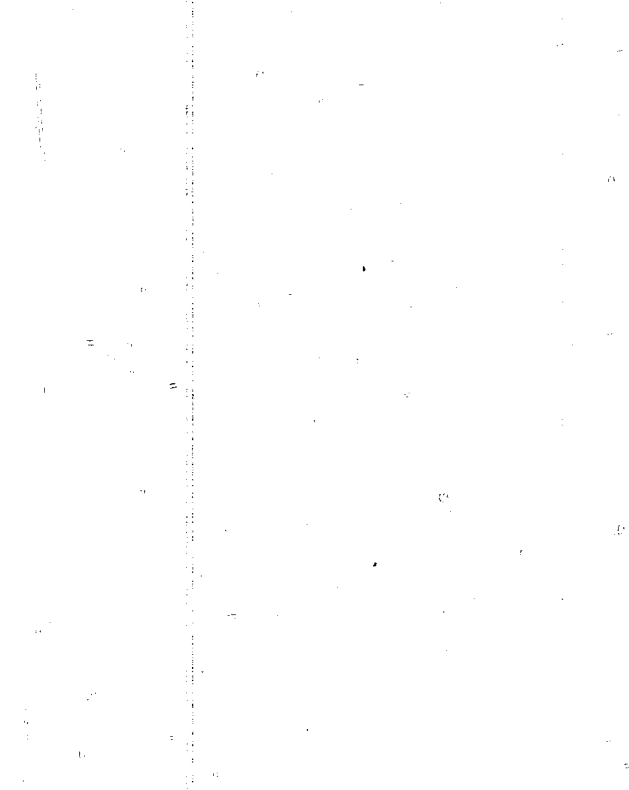ENCLOSURE (B) 14

Figure 1(B)14
EVAPORATIVE POWER

ENCLOSURE (B) 15

S T U D I E S   O N   B R I Q U E T T I N G

by

CHEM. ENG. LIEUT COMDR.
M.   KUMAMOTO

Research Period: 1941-1944

Prepared for and Reviewed with Author
by U. S. Naval Technical Mission to Japan

December 1945

ENCLOSURE (B)15

LIST   OF   TABLES

AND   ILLUSTRATIONS

ENCLOSURE (B)15

SUMMARY

A study was made of the suitability of pitchless briquettes for use as boiler fuels.

A briquette formed of the mixture of the caking coal and anthracite coal under proper conditions is suitable for this purpose. In this work it was found that the optimum conditions for briquetting were as follows:

Temperature, ^{o}C .... about $400^{o}C$
Compression, kg/cm^2 .... 47.7
Time, min. 3
Mixing ratio of the
Yubari coal to Phyong-
Yong coal 9:1

I.   INTRODUCTION

These studies were undertaken in an attempt to find an optimum condition for briquetting in which process the caking property of coal would be used. A briquette having a strength of about 20kg/cm^2 and not absorbing water was designed.

Date of beginning of this project was in April 1941 and the date of finishing was in March 1944.

Key Personnel Working on Project:

Chem. Eng. Lt. Comm., M. KUMAMOTO

II. DETAILED DESCRIPTION

A.   Description of Test Apparatus

1.   The test apparatus for briquetting is shown in Figure I(B)15.

2.   Lessing's apparatus was used for the determination of the decomposition temperature.

B.   Test Procedure

Sample coals were ground and sized under 60 mesh screen. The determination of the caking index at different temperatures was carried out by Compredon's method, and the decomposition temperature was determined by observing the evolved gas volume by Lessing's apparatus. The briquette was formed by keeping about 7gm of the coal powder at a definite temperature, pressure, and duration of time. After cooling the product was obtained.

The strength of the briquette was determined by measuring the hydraulic pressure in kg/cm^2 required to crush the briquette.

C.   Experimental Results and Summary of Data

1.   Nature of the Yubari and the Phyong-Yong Coal. The Yubari coal possesses high caking power and the Phyong-Yong coal is an anthracite.

The approximate percentage compositions of these coals are tabulated in Table I(B)15.

ENCLOSURE (B)15

The caking index at different temperatures and the decomposition temperature were investigated for the Yubari coal, and the results are shown in Table II(B)15 and in Figure 2(B)15.

The caking properties of this coal appear to start at 395°C and increase with increasing temperature, but increasing the temperature above 500°C did not appreciably increase the caking index. Decomposition, as observed by the evolved gas volume, began at 380°C and with further increase of temperature of the Yubari coal it decomposes. The results are plotted in Figure 2(B)15. Therefore, to obtain pitchless briquettes, caking coal must be kept at the temperature causing caking properties, or decomposition of coal will occur.

2. Experiment to Find Optimum Conditions for Manufacturing Pitchless Briquettes.

a. Effect of Temperature. The influence of temperature on the strength of briquettes formed under a definite condition (pressure=47.7kg/cm², time = 3 min.) was investigated and the results are shown in Table III(B)15.

The effect of preparation temperature on the strength of the briquettes is especially apparent above 380°C at which temperature decomposition starts.

b. Effect of Compression Ratio and Time of Compression. The effect of compression and time of compression were investigated, and these data are tabulated in Table IV(B)15 and V(B)15.

The maximum briquette strength (kg/cm²) is obtained at a compression ratio of 56kg/cm².

3. Preparation of Pitchless Briquettes from the Mixture of the Yubari Coal and the Phyong-Yong Coal. For the Yubari coal only, the optimum conditions for preparing pitchless briquettes were determined.

The strength of the briquette formed at different ratios of the Yubaru and the Phyong-Yong coals was investigated and the results are given in Table VI(B)15.

Although the strength of the briquette increases with increasing mixing ratio of the Yubari coal, the briquettes formed at a ratio of 10% of the Yubari to the Phyong-Yong coal was compared with the briquette which was produced at 5th Naval Depot, and the results are shown in Table VII(B)15.

III. CONCLUSIONS

Pitchless briquettes having suitable properties for boiler fuel were obtained by taking advantage of the caking power of the Yubari coal and the optimum conditions were as follows:

Temperature	400°
Compression (kg/cm²)	47.7
Time (min)	3
Mixing ratio of the Yubari coal and the Phyong-Yong coal	9:1

Mechanical and technical problems still remain before this procedure can be applied in mass production.

Table I(B)15
APPROXIMATE PERCENTAGE COMPOSITION OF COALS

	Coal Origin	Yubari	Phyong-Yong
Compo-sition	Moist.(%)	1.99	2.80
	Vol. M.(%)	41.20	7.66
	Fix. C.(%)	47.50	76.34
	Ash (%)	9.31	13.20

Table II(B)15
CAKING INDEX OF THE YUBARI COAL

Temp. °C	Caking Index
350	0
395	1
450	2
490	3
525	4
900	5

Table III(B)15
EFFECT OF TEMPERATURE ON STRENGTH OF BRIQUETTE

Temp. °C	Strength of Briquette kg/cm^2
280	6.5
300	10.0
320	12.5
340	15.5
360	17.5
380	20.0
400	31.0
420	47.5

ENCLOSURE (B)15

Table IV(B)15
EFFECT OF COMPRESSION RATIO ON THE STRENGTH OF BRIQUETTE

Briquetting Condition	Press kg/cm^2	Strength kg/cm^2
Temp. = 400°C	16	17.5
	24	23.5
	32	27.5
	40	41.5
Time 3 min.	56	75.0
	63	64.0
	72	57.0
	78	47.0

Table V(B)15
EFFECT OF TIME OF COMPRESSION STRENGTH OF BRIQUETTES

Briquetting Condition	Time of Compression Min.	Strength of Briquett kg/cm^2
Temp. = 400°C	3	35
	6	37
	10	caking
Compression = 47.7kg/cm^2	15	caking
	20	caking

Table VI(B)15
STRENGTH OF BRIQUETTE

Briquetting Condition	Mixing Ratio of the Yubari (%)	Strength of Briquette kg/cm^2
Temp.=400°C	10	20.5
	20	24.5
Time = 3 min.	40	31.0
	60	34.0
Compression 47.7kg/cm^2	80	38.0

Table VII(B)15
STRENGTH AND APPROXIMATE PERCENTAGE
COMPOSITION OF BRIQUETTES

Properties	A	B
Moisture	1.95	1.87
Vol. M, (%)	16.03	20.63
Fixed C. (%)	67.47	66.37
Ash (%)	14.55	11.13
Strength kg/cm^2	35.0	24
Composition	10% Yubari Coal 90% Phyong-Yong Coal	10% Saits Coal 80% Phyong-Yong Coal 10% Pitch

A   Briquett prepared and in our laboratory (10% Yubari Coal.)
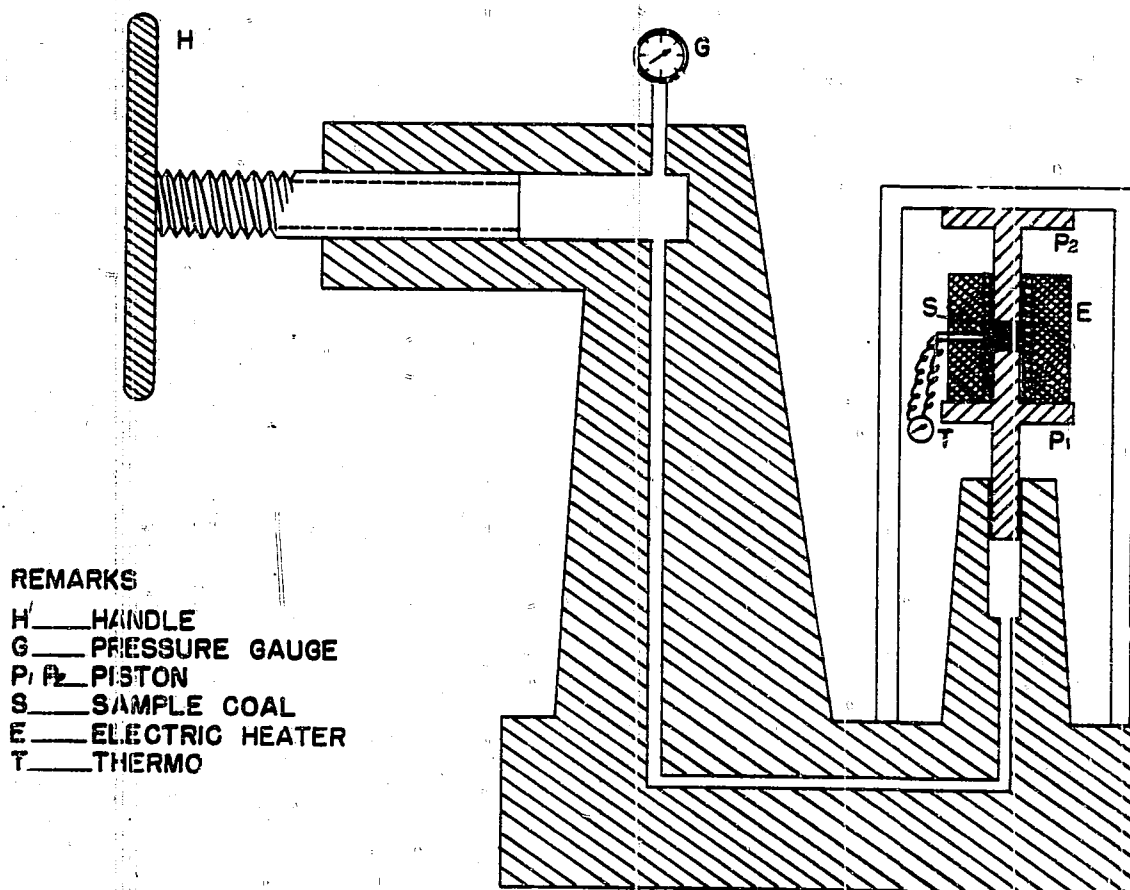B   Briquett produced in Fifth Fuel Depot.

ENCLOSURE (B)15

H

G

REMARKS
H____HANDLE
G____PRESSURE GAUGE
P₁ P₂_PISTON
S____SAMPLE COAL
E____ELECTRIC HEATER
T____THERMO

P₂

S

E

T

P₁

Figure 1 (B)15
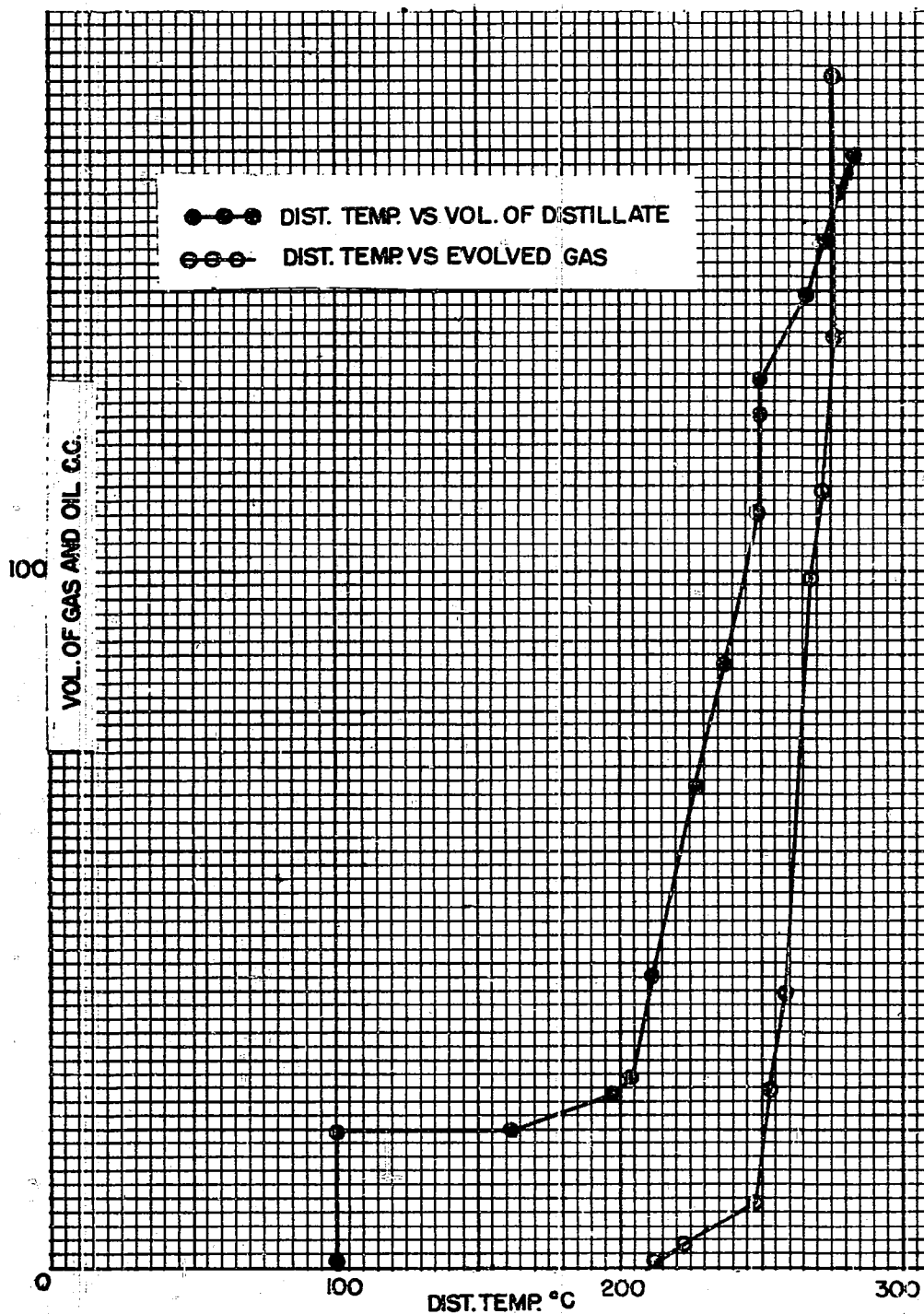TESTING APPARATUS FOR BRIQUETTING

ENCLOSURE (B)15

Figure 2 (B)15
RELATIONSHIP BETWEEN DISTILLATION TEMPERATURE
AND VOLUMES OF DISTILLATE AND EVOLVED GAS

ENCLOSURE (C)

ENCLOSURE (C)

LIST OF JAPANESE RESEARCH REPORTS PERTAINING TO
DIESEL & BOILER FUELS OBTAINED FROM THE FIRST NAVAL DEPOT, OFUNA

(Forwarded through ATIS to the Washington Document Center
Refer to ATIS No. 4578 and NavTechJap Document No. listed below)

NavTechJap No.	Title	Author	Year
ND26-0007.1	Economical Value of Combustion Apparatus of Pulverized Coal.	G. UEDA	May 1926.
7.2	Softening Agent of Boiler Water.	Y. YUEDA	July 1926.
7.3	White Smoke and the Combustion of Bunker Fuel Oil.	G. UEDA M. AKITA T. HIROYOSHI H. OGATA	July 1927.
7.4	Review on the Briquette Industry.	G. UEDA	Dec. 1927.
7.5	Emulsion in the Crude Oil and Bunker Fuel Oil.	T. EGUCHI	Dec. 1929.
7.6	Utilization of Burned Coal of Locomotives.	H. MIYASHITA	Apr. 1929.
7.7	Poisonous Matter in Coal Briquettes.	S. SUMIMOTO	Sept. 1931.
7.8	Properties of Various Bunker Fuels.	T. NAMIKAWA T. YOSHIHIRO	May 1932.
7.9	Studies on the Properties of Bunker Fuel Oil, Part I.	T. NAMIKAWA	June 1933.