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STUDIES ON THE MANUFACTURE OF AERO-ENGINE OILS FROM RESIDUAL OILS BY SOLVENT EXTRACTION

by

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LIST OF TABLES AND ILLUSTRATIONS

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SUMMARY

A. As the operation of the propane dewaxing process is greatly influenced by cooling temp., cooling rate and filter-aids, these factors were investigated for deasphalted Osage residual oil in 3 volumes of propane. The results obtained were as follows:

1. At -40°C cooling temperature, and a cooling rate of 1°C per min., the pour point of the dewaxed oil was -18°C~-22°C, and at a cooling rate of 5°C per min., the pour point was the same.

2. At -35°C cooling temperature and a cooling rate of 1°C per min., the pour point of the dewaxed oil was -15°C~-19°C, and at a cooling rate of 5°C per min., the pour point was -12°C~-15°C.

3. As a filter-aid, Japanese acid clay was not suitable. Addition of 3% of diatomaceous earth was effective in increasing the filtering capacity by 5%. Acetone was more effective and promoted the filtering capacity by 10%. Phenol, when 1% by weight was added had no effect on the filtering capacity, but 5% by weight decreased the filtering capacity by 20%.

4. Aero-engine oils were prepared in the laboratory from the natural residual oil boiling over 250°C at 5mm Hg by successive propane deasphalting, phenol extraction, acetone-benzol dewaxing, and topping of the raffinate in vacuo. Yield of aero-engine oils are tabulated below.

Yields of Aero-Engine Oil from Crude Oils

Crude oils	Yields %(wt) of total crude
Iran	3.0
Arabia	2.0
Burma	2.0
KADO	10.0
CHOKAIZAN (Japan)	2.3
YAMOKI (Japan)	2.5
OMONOGAWA (Japan)	0.9
RIRIKU (Sumatra)	2.2

Note: Viscosity of these products was 115~125 S.U.S. at 210°F and viscosity-index was 90~95.

B. The solvent extraction process, which uses amyl alcohol and furfural as solvents, for the production of aero-engine oil was studied and the following results were obtained:

1. Deasphalting and dewaxing were accomplished by treating the residual oils with 3 volumes of amyl alcohol at -20°C. (optimum condition of operation)

2. In the furfural extraction of the deasphalted and dewaxed oil, it was found best to treat with 4 volumes of furfural at 60°C~120°C.

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3. Yields of aero-engine oils from residual oils, when treated by above method, are tabulated below.

Yields of Aero-Engine Oil by Amyl Alcohol-Furfural Process

Crude	Yields of Aero-Engine Oil
OMONOGAWA (Japan)	2.1 (wt)% of total crude
OHA (Sakhalin)	4.8 (wt)% of total crude
Rhodessa (U.S.A.)	7.2 (wt)% of total crude
Posalika (Mexico)	3.8 (wt)% of total crude

Note: Viscosity of these products was 115~125 S.U.S. at 210°F and viscosity-index was 90~95.

I. THE PROPANE - PHENOL PROCESS

A. Introduction

1. The Term of Study was from April 1937 to March 1943. In this solvent process, especially in the propane dewaxing, there were various factors controlling the dewaxing effect which were not known in Japan. The author studied this problem with a view to developing its industrial application in Japan. The investigation of the preparation of aero-engine oils by the propane-phenol process was carried on, intermittently, when crude oil was available from 1937 - 1943.

2. Key Research Personnel Working on Project.

Eng. Capt. Dr. I. KAGEHIRA

B. Detailed Description of the Propane-Phenol Process

1. Propane Dewaxing. Osage deasphalted oil was used for this experiment. The properties of this oil are as follows:

Properties of Osage Residual Oil

Density (25/4)	0.9205
Viscosity in S.U.S. at 100°F	2460
Viscosity in S.U.S. at 210°F	118.5
Viscosity-index	60
Conradson's carbon residue (%)	5.2
Pour point (°C)	+11

This residual oil was deasphalted with 5 volumes of liquid propane at 45°C and the yield and properties of the deasphalted oil are tabulated below:

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Properties of the Deasphalted Oil

Yield from Osange residual oil (wt%)	71.4
Density(25/4)	0.9087
Viscosity in S.U.S. at 100°F	1282
Viscosity in S.U.S. at 210°F	96.3
Viscosity-index	87
Conradson's carbon residue (%)	2.43
Pour point (°C)	+27

This deasphalted oil was subjected to propane dewaxing and the results shown in Table I(B)4 were obtained.

The effect of use of filter-aids on filtering capacity at -40°C with 3 volumes of liquid propane is shown below:

Effect of Filter-Aids

Filter-Aids	Increasing of Filtering Capacity (%)
Japanese acid clay alone	non effective
With 3% of diatomaceous earth	+50%
With 5% of acetone	+100%
With 5% of phenol	-20%

2. Propane-Phenol Extraction of Various Residual Oils to Produce Aero-Engine Oil. Several residual oils were subjected to the following procedures and the yields of aero-engine oil were determined.

a. Deasphalting. In deasphalting, liquid propane obtained by the hydrogenation of cracking plant gas and having the composition tabulated below was used.

Composition of Liquid Propane

C_3H_8	80%
C_3H_6	0.5%
C_4H_{10}	15%
C_4H_8	0.5%
the others	4.0%

Experiments were carried out with 5 volumes of liquid propane, stirring the mixture for 30 min. at 45°C and then allowing to stand for 1 hr. at the same temperature.

b. The apparatus for the propane deasphalting and propane dewaxing procedures was made from iron and is shown in Figure 1(B)4.

c. In the next procedure, solvent extraction by phenol was carried out. The deasphalted oils were treated three times with 5—6 volumes of dehydrated phenol. Each time the mixture was agitated for 30 min. at 45°C and settled for 1 hr. at 45°C, separating the raffinate and the extract. Apparatus for this procedure was a common separatory funnel having a capacity of 3-5 liters.

d. The raffinates were mixed with 5 volumes of acetone-benzol solution in which the volume ratio of components was 35:65, respectively. The mixtures were cooled at -15°C~-20°C and filtered to remove waxes. From these dewaxed solutions, the solvents were distilled off, and dewaxed oils were obtained. The dewaxed oils were topped to a suitable viscosity; that is, in general, up to 250°C~280°C under a vacuum of 5mm Hg. The topped residual oils were refined by treating with 5% of dried acid clay by weight.

e. The yields of aero-engine oils thus obtained from several residual oils are tabulated below:

Yields of Aero-Engine Oils From Various Crudes

Crudes	Yield of Oil Wt% to Total Crude
Iran	3.0
Arabia	2.0
Burma	2.0
KADO	10.0
CHOKAIZAN (Japan)	2.3
YAMORI (Japan)	2.5
OMONOGAWA (Japan)	0.9
RIRIKU (Sumatra)	2.2

Note: Viscosity of these products was 115~125 S.U.S. at 210°F and viscosity-index was 90~95.

II. THE AMYL ALCOHOL~FURFURAL PROCESS

A. History

The term of study was from April 1937 to November 1940. From many deasphalting methods, the author chose the amyl alcohol method, since in Japan, amyl alcohol is available as a by-product of alcohol fermentation and is easier to obtain than other solvents. It was recognized that amyl alcohol has not only a deasphalting action, but also a dewaxing action.

For solvent extraction, the furfural process was chosen, since it is suitable for naphthenic oils, as indicated by the author's studies on Japanese crude oils, and K. P. Likhushin's conclusions relative to Balanchamy's crude oil. Consequently, the process utilizing these two methods was called the amyl alcohol~furfural process.

B. Key Research Personnel Working on Project

Chem. Eng. Lieut. Comdr. S. IIMURA

C. Experimental Results

1. Properties of Japanese crudes and their distillates are tabulated in Table II(B)4. The determination of wax content was carried out by filtering at -30°C with 4~6 volumes of acetone-benzol solution.

2. It was recognized from Table II(B)4 that the lubricating oil fraction had, in general, high densities and low viscosity-indexes.

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a. Ultimately, Japanese crude oils are of naphthenic or mixed-base character.

b. Experiments were carried out to choose a suitable solvent for Japanese crude oils. Oha deasphalted and dewaxed oil was used for this purpose. Three volumes of each solvent was added and the consolute temperatures were measured. After standing for 30 min. at 20°C below the consolute temperature, the raffinates and extracts were separated. The raffinates were treated with 1-2% of dried acid clay by weight. The effects of 4 solvents are tabulated in Table III(B)4. According to Table III(B)4, comparatively higher yield of raffinate, based on viscosity of product, was obtained in the furfural extraction.

3. Deasphalting and Dewaxing with Amyl Alcohol. Omonogawa residual oil was used as the raw material and its properties are tabulated below.

Properties of Omonogawa Residual Oil

Yield to total crude, (Vol%)	27.0
Density(15/4)	0.9461
Viscosity in S.U.S. at 210°F	122.5
Flash point (°C)	238.5
Pour point (°C)	+29.0
Conradson's carbon (%)	6.45

The solvent analysis of the components of Omonogawa crude was carried out by Engler's method. (See Figure 2(B)4 The results are tabulated below.

Results of Solvent Analysis by Engler's Method

Resins	24.0% (wt)
Asphaltenes hard	5.5% (wt)
Asphaltenes soft	29.5% (wt)
Waxes hard	12.4% (wt)
Waxes soft	4.0% (wt)
Oily parts	24.2% (wt)
Total	99.6% (wt)

4. Mechanism of Cooling Treatment by Amyl Alcohol. The Omonogawa residual oil was dissolved in 2~3 volumes of amyl alcohol (Boiling point, 130°C~132°C). The solution was gradually cooled to 0°C, -5°C, -10°C, -15°C and -20°C respectively and filtered at the same temperatures.

Analytical data by Engler's method of each soluble and insoluble part are tabulated in Table IV(B)4 (See also Figure 3(B)4)

The deasphalted and dewaxed oils were refined by treatment with furfural at suitable temperatures.

The results obtained are tabulated in Table V(B)4

The best results were obtained using a solvent ratio of 3:1 at -20°C for deasphalting.

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D. Source of Amyl Alcohol

Commercial amyl alcohol was used in the experiments. The properties of this amyl alcohol are tabulated below.

Properties of Amyl Alcohol

Density(20/4)	0.838
Refractive index(n_D^{25})	1.398
Acid value	3.1
Ester value	30.4

E. Results Obtained Using the Amyl Alcohol-Furfural Process on Various Crude Oils.

1. Description of Experimental Apparatus. The oil and amyl alcohol were mixed in a 5 liter beaker and cooled by ice and salt. The oil layer and asphalt layer were separated by decantation. The deasphalted and dewaxed oil was then agitated with furfural in a 5 liter beaker and the mixture was poured into a separatory funnel.

2. Results of Omonogawa Oil. Omonogawa residual oil was used as the raw material and its properties are tabulated below.

Properties of Omonogawa Residual Oil

Yield for total crude, (Vol%)	27.0
Density(25/4)	0.9461
Viscosity in S.U.S. at 210°F	122.5
Flash point (°C)	238.5
Pour point (°C)	+29.0
Conradson's carbon (%)	6.45

The properties of Omonogawa deasphalted and dewaxed oil by treatment with 3 volumes of amyl alcohol at -20°C are tabulated below.

Properties of Omonogawa Deasphalted and Dewaxed Oil

Yield to total crude (Vol%)	14.9
Density(25/4)	0.9649
Viscosity in S.U.S. at 100°F	4041.2
Viscosity in S.U.S. at 210°F	121.3
Viscosity-index	-52.8
Flash point (°C)	177.0
Pour point (°C)	-5.0
Conradson's carbon (%)	4.70

The deasphalted and dewaxed oil was subjected to the furfural extraction as follows:

To secure as complete a selective extraction as possible, the extraction was carried out first by high solvent ratios at lower temperatures and then by low solvent ratios at higher temperatures. Results of this procedure are tabulated in Table V(B)4.

The No.3 raffinate was then treated with 3% (Vol) of Conc. H_2SO_4 to remove residual resins. The properties of the refined raffinate are tabulated below.

Properties of the Refined Raffinate

Yield for Omonogawa residual oil (Vol%)	7.5
Density(25/4)	0.8758
Viscosity in S.U.S. at 100°F	594.1
Viscosity in S.U.S. at 210°F	69.5
Viscosity-index	99.3
Pour point (°C)	-14.0
Conradson's carbon (%)	0.101

Fifty percent of this refined raffinate was distilled off so as to obtain an oil of suitable viscosity for aero-engine oil. Properties of the product are tabulated below.

Properties of Refined Product

Yield from the original residual oil (Vol%)	2.05
Density(25/4)	0.8881
Viscosity in S.U.S. at 100°F	1811.8
Viscosity in S.U.S. at 210°F	121.4
Viscosity index	93.0
Pour point	
Conradson's carbon (%)	0.27
Acid value	0.04
Saponification value	0.06
Viscosity ratio after British Air Ministry Oxidation Test	1.22

The extracts were refined with 5%(wt) of conc. H_2SO_4. The properties of the refined extracts are tabulated in Table VI(B)2. These oils were useful as a mobile oil for a car.

3. Oha Crude Oil. Properties of the Oha crude oil and its distillates are tabulated in Table VIII(B)4.

Oha 45% topped residual oil was treated with 3 volumes of amyl alcohol at -23°C—-25°C. The properties of the Oha 45% residual oil and and the raffinate are tabulated in Table IX(B)4. As reference, the properties of the various fractions of Oha crude are given in Table VIII(B)4.

The raffinate was extracted with furfural under various conditions and refined by treating with dried acid clay. The results obtained are tabulated in Table VI(B)4.

4. Kettleman Hills Crude. The procedure and results are tabulated in Table XI(B)4, and it was observed that an aero-engine oil having a viscosity-index of 85 could be prepared from Kettleman Hills crude.

5. Rhodessa Crude Oil. The results and the conditions of the treatment are tabulated in Table XII(B)4. Good results were obtained.

6. Posalika Crude (Mexico). Posalika crude in Mexico was of paraffinic character, but rich in sulphur. The properties of the crude and the topped residue are tabulated in Table XIII(B)4.

This residual oil was treated by the amyl alcohol-furfural process. The conditions, procedures, and properties of the product are tabulated in Table XIV(B)4.

The distribution of sulphur in each stage of the procedure for Posalika crude is indicated in Figure 4(B)4.

III. CONCLUSIONS

Investigations were carried out on the propane-phenol extraction method, especially on the propane dewaxing process, and it was concluded that this process could be successfully operated with 3 volumes of liquid propane and a cooling rate of 1~5°C/min. at -40°C, especially when 5% of acetone or 3% of diatomaceous earth by weight was added.

As another solvent extraction process, the amyl alcohol-furfural process was examined and the best operating conditions for various residual oils were determined.

It was concluded that the optimum conditions were to treat with 3 volumes of amyl alcohol at -20°C for deasphalting and dewaxing of the residual oil and with 4 volumes of furfural at 60°C~120°C, for the extraction of deasphalted and dewaxed oil.

Comparing the above two processes, the propane-phenol process is better, since the deasphalting by liquid propane is completely accomplished and the heat stability of phenol is better than that of furfural.

Two propane-phenol plants are installed in Japan, one at the Second Naval Fuel Depot, and the other at the Third Naval Fuel Depot.

No large application of the amyl alcohol-furfural process has been made.

Table I(B)4
RESULTS OF PROPANE DEWAXING

Cooling Temp.*	Cooling Rate	Pour Point Dewaxed Oil
-40°C	1°C/min	-18 to -22°C
	5°C/min	-18 to -22°C
-35°C	1°C/min	-15 to -19°C
	5°C/min	-12 to -15°C

*In three volumes of liquid propane.

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Table II(B)4
PROPERTIES OF JAPANESE CRUDES AND THEIR DISTILLATES

Oil Field	Oil Cell	Crude Density (15/4)	Yield (Vol%)				Properties of a fraction boiling 220-330°C/7mm Hg			
			120-200°C/760mm	200°C-280°C/760mm	280°C/760mm-230°C/7mm	220°C-330°C/7mm	Residue	Density (15/4)	Viscosity Index	Viscosity Gravity Constant	Wax Content (wt%)
NIIGATA	No description	0.837	33	22	33.8	6.2	5.1	0.9642	- -	- -	34.47
	NISHIYAMA	0.855	7.2	29.4	33.6	27.0	2.8	0.9095	59.7	0.8535	11.32
	AGARAI	0.853	44.5	19.3	13.6	16.8	5.7	- -	4.9	- -	7.92
AKITA	FUKUURA	0.843	6.7	27.5	33.0	22.4	28.4	0.9467	-30.4	0.8965	- -
	ICHIBA	0.838	33.2	26.6	17.6	13.9	6.7	0.9253	10.4	0.800	6.45
	AKITA	0.971	- -	15.0	33.7	22.7	28.6	0.947	-25.8	0.8951	- -
AKITA	YUSHIAGE	0.930	1.2	27.1	37.9	28.4	5.4	0.9571	-67.8	0.9100	- -
	OGATA	0.942	1.8	28.0	29.3	26.4	14.5	0.9511	-26.1	0.8997	- -
	AKITA	- -	7.0	33.7	30.4	21.9	6.0	0.9364	12.3	0.8851	3.76
NIIGATA	TAINAI 3-4	0.843	26.0	36.2	11.5	10.2	16.1	- -	- -	- -	5.72
NIIGATA	KATAKAIDA	0.877	25.1	22.4	17.8	19.2	15.5	0.9523	-39.1	0.9004	6.20
HIYAMIZU	KATAKAIDA	0.877	33.5	21.3	19.7	13.6	11.9	0.9535	-36.3	0.9010	5.02
	KATAOKA	- -	43.9	18.0	19.7	13.1	5.3	0.9273	31.1	0.8158	10.1
KUBIKIRI	TAINAI 1	0.877	30.2	20.7	17.5	9.6	2.0	0.9490	-39.7	0.8977	1.36
	TSUJI	0.879	43.0	21.0	15.2	12.0	3.8	0.9300	62.4	0.8364	5.65
	MINAMIKUBE 2	0.780	69.0	20.0	20.6	7.1	3.3	- -	- -	- -	4.83
	CHUBUKI	- -									

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Table III(B)4
EFFECTS OF FOUR SOLVENTS ON OHA TREATED OIL

Solvent	Consolute Temp. (°C)	Yield (Vol%)	Density 60°F/60°F	Viscosity in S.U.S. at 100°F	Viscosity in S.U.S. at 210°F	Viscosity Index	Conradson's Carbon (%)
Oha deasphalted and dewaxed oil		100.0	- -	942.2	68.6	33.6	- -
Nitro benzene	20	18.0	0.8776	675.6	67.8	78.6	0.18
Phenol	70	13.3	0.8885	807.9	77.2	90.8	0.49
Chlorex	25	30.0	0.9077	1034.3	80.3	91.9	0.81
Furfural	140	25.0	0.8993	1093.5	85.2	79.5	0.96

Table IV(B)4
ANALYSIS OF FRACTIONS SEPARATED FROM OMONOGAWA RESIDUAL OIL BY AMYL ALCOHOL AT VARIOUS TEMPERATURES

		Asphaltenes (%)		Resins (%)	Wax (%)		Oily Parts (%)
		Hard	Soft		Hard	Soft	
Amyl alcohol	at 0°C	8.37	38.13	21.78	11.50	2.10	15.85
(Boils at 130-132°C)	at -5°C	2.48	5.71	76.21	1.95	1.00	10.71
	at -10°C	0.97	2.91	74.59	3.74	1.40	14.53
Solv.Ratio 2:1	at -15°C	2.75	17.10	31.54	5.90	0.58	37.90
	at -20°C	0.26	4.90	43.53	0.53	2.85	41.60
Amyl alcohol	at 0°C	10.12	24.05	43.73	11.10	0.16	7.04
	at -5°C	1.73	31.40	58.98	1.06	0.56	4.76
(Boils at 130-132°C)	at -10°C	0.35	41.17	45.00	1.65	0.72	10.39
Solv.Ratio 3:1	at -15°C	1.79	12.96	32.48	12.27	1.42	32.75
	at -20°C	0.73	8.10	34.78	2.00	4.10	46.60

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Table V(B)4
PROPERTIES OF PRODUCTS OF FURFURAL TREATMENT OF AMYL ALCOHOL TREATED OIL

			Yield (Vol%)	Density 15/4	Pour Point (°C)	Viscosity in S.U.S. at 100°F	Viscosity in S.U.S. at 210°F	Viscosity-Index	Conradson's Carbon (%)
Exp. No.1	1st stage	Lwr alcohol treatment at -20°C (solv. ratio 2:1)	6.75	0.9675	+8.0	- -	200.2		5.21
	2nd stage	Furfural extraction solv. ratio 6:1 at 60°C	2.95	0.9100	-16.0	1452.2	92.4	65.3	1.01
		Furfural extraction 1) solv. ratio 6:1 at 60°C 2) solv. ratio 3:1 at 80°C	2.03	0.8745	-13.5	1010.2	82.7	81.7	0.62
		Furfural extraction 1) solv. ratio 6:1 at 60°C 2) solv. ratio 3:1 at 80°C 3) solv. ratio 1:1 at 100°C	1.81	0.8887	-15.0	940.1	80.4	87.6	0.52
Exp. No.2	1st stage	Lwr alcohol treatment at -20°C (solv. ratio 3:1)	5.19	0.9099	+4.5	- -	189.2	- -	5.35
	2nd stage	Furfural extraction solv. ratio 6:1 at 60°C	2.24	0.9069	-16.5	1198.4	84.3	66.1	0.96
		Furfural extraction 1) solv. ratio 6:1 at 60°C 2) solv. ratio 3:1 at 80°C	1.47	0.8918	-15.0	838.7	76.8	85.6	0.41
		Furfural extraction 1) solv. ratio 6:1 at 60°C 2) solv. ratio 3:1 at 80°C 3) solv. ratio 1:1 at 100°F	1.07	0.8844	-13.5	742.2	74.2	91.2	0.31

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Table VI(B)4
RESULTS OF FURFURAL EXTRACTION RAFFINATES

Conditions of Procedure	Density (15/4)	Pour Point (°C)	Viscosity in S.U.S. at 100°F	Viscosity in S.U.S. at 210°F	Viscosity Index	Conradson's Carbon (%)
6:1 solvent ratio at 60°C	0.9099	-17	871.6	73.7	71.7	1.49
6:1 solvent ratio at 60°C followed by 3:1 solvent ratio at 80°C	0.8996	-15.5	69.2	71.2	89.2	0.79
6:1 solvent ratio at 60°C followed by 3:1 solvent ratio at 80°C followed by 1:1 solvent ratio at 100°C	0.8820	-14	803.8	78.3	95.3	0.62
EXTRACTED OILS						
Corresponds to raffinate No.1	1.017	25	- -	311.4	- -	11.0
Corresponds to raffinate No.2	0.9410	-14	1705.8	91.4	41.0	3.6
Corresponds to raffinate No.3	0.9156	-16.5	800.7	71.1	70.9	2.36

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Table VII(B)4
PROPERTIES OF THE REFINED EXTRACTED OILS

	Density 15/4	Viscosity in S.U.S. at 100°F	Viscosity in S.U.S. at 210°F	Viscosity Index	Conradson's Carbon (%)	Pour Point (°C)	Acid Value	Saponification Value
Extracted oil No.1	1.017	5404.2	119.1	-74.5	12.78	2.5	0.51	1.56
Extracted oil No.2	0.9201	777.3	67.1	56.3	1.24	-17.5	0.03	0.6
Extracted oil No.3	0.9000	539.4	60.9	73.8	0.35	-12.5	0.56	0.40

Table VIII(B)4
PROPERTIES OF DISTILLATES OF OHA CRUDE

	Boiling Point (1mm Hg)	Density (15/4)	Viscosity in S.U.S. at 100°F	Viscosity in S.U.S. at 210°F	Viscosity-Index	Mean Molecular Weight
1	I.D.~182	0.9258	141.8	38.3	-646	354
2	182~190	0.9340	391.5	48.1	-26.55	- -
3	190~200	0.9341	559.3	53.5	-71.03	363
4	200~210	0.9356	821.9	59.6	-16.17	- -
5	210~220	0.9364	1106	68.6	- 3.16	420
6	220~230	0.9365	1625	80.7	4.08	- -
7	230~240	0.9358	1904	89.0	14.57	423
8	240~250	0.9360	2421	101.8	21.38	- -
9	250~260	0.9385	3257	126.7	40.70	501
10	260~270	- -	3770	131.4	30.38	- -
11	270~280	0.9442	5789	172.1	30.02	509
12	280~290	0.9471	7656	198.5	29.83	- -
13	290~300	0.9496	10290	236.7	32.57	517
14	300~310	0.9536	14380	289.3	34.56	- -
15	310 320	- -	20090	344.6	-39.45	607
16	320 330	0.9533	8409	155.8	-51.08	- -

ENCLOSURE (B)4

Table IX(B)4
PROPERTIES OF OHA 45% RESIDUAL OIL AND THE RAFFINATE

		45% Residual Oil	The Raffinate
Density (15/4)		0.9733	0.9884
Viscosity	at 100°F	- -	4652.5
in S.U.S.	at 210°F	305.4	134.5
Viscosity index		- -	5.5
Pour point (°C)		- -	+9.5
Conradson's carbon (%)		7.82	5.16

See page 95 for Table X(B)4.

Table XIII(B)4
PROPERTIES OF POSALIKA CRUDE AND ITS TOPPED RESIDUE

	Posalika Crude	Residue (350°C—)
Density	0.867/24.5°C	0.9516/20°C
Viscosity in S.U.S. at 210°F	- -	158.7
Pour point (°C)	+1.5	+14.0
Sulphur (°C)	1.43	2.43

Table X(B)4

PROPERTIES OF RAFFINATES OF OHA RESIDUAL OIL EXTRACTED WITH FURFURAL

	Deasphalted and Dewaxed Oil with 3 Vols of Amyl Alcohol at -20°C	Raffinate with 6:1 Solv. ratio at 60°C	Raffinate with 8:1 Solv. ratio at 60°C	Raffinate with 6:1 Solv. ratio at 100°C	Raffinate with 9:1 Solv. ratio at 60°C	Raffinate with 9:1 Solv. ratio at 80°C	Raffinate with 12:1 Solv. ratio at 60°C	Raffinate with 6:1 solv. ratio at 60°C followed by 3:1 solv.ratio at 80°C
Density(15½)	0.9287	0.9204	0.9142	0.9149	0.9149	0.9053	0.9019	0.9018
Viscosity in S.F.S. at 130°F	- -	1713.6	1467.5	1545.2	1508.2	1613.0	1227.3	1113.6
Viscosity in S.F.S. at 210°F	238.5	96.8	92.2	100.1	94.4	91.2	92.7	85.2
Viscosity Index	- -	56.2	65.1	75.6	65.8	73.8	84.6	77.4
Conradson's carbon (%)	5.66	2.03	2.06	3.27	1.99	2.11	2.16	1.62
Pour point (°C)	+9.5	-13	-14	-13.5	+12	-15.5	-16	-15
Yield (Vol%)	100	39.4	20.0	6.7	27.9	17.3	8.7	20.0
RAFFINATES TREATED WITH DRIED ACID CLAY								
Density(15½)		0.9122	0.9101	0.9054	0.9138	0.9051	0.9085	0.8968
Viscosity in S.F.S. at 130°F		1565	1350.2	1421.6	1486.0	1280.2	1317.8	993.8
Viscosity in S.F.S. at 210°F		91.4	89.1	94.9	92.2	89.6	88.4	79.5
Viscosity Index		53	62.6	73.8	61.9	72.9	66.4	74.2
Conradson's carbon (%)		1.33	1.08	1.22	1.52	1.15	1.33	0.64
Pour point (°C)		-14	-15	-12	-14.5	-15	-16	-15.5

ENCLOSURE (β)4

Table XI(B)4
PROPERTIES OF PRODUCTS OBTAINED FROM KETTLEMAN HILLS CRUDE
BY ARTL ALCOHOL--FURFURAL PROCESS

	Residual Oil (Raw Material)	Deasphalted and Dewaxed Oil with 3:1 solv. ratio at -20°C	Furfural Extraction Raffinate with 1) 6:1 solv. ratio at 60°C 2) 3:1 solv. ratio at 60°C 3) 1.5:1 solv. ratio at 80°C	Refined Oil by 5% Acid Clay
Yield (Vol%)	100	53.7	14.1	8.9
Density(15/4)		0.9631	0.8970	0.8858
Viscosity in S.U.S. at 100°F	- -	- -	1331.4	766.9
Viscosity in S.U.S. at 210°F	180.4	194.2	97.0	74.3
Viscosity index	- -	- -	85.0	85.9
Pour point (°C)	+ 32.5	+4.5	-15.0	-14.5
Conradson's carbon (%)	7.97	5.75	1.15	0.26

ENCLOSURE (B)4

Table XII(B)4
PROPERTIES OF PRODUCTS OBTAINED FROM RHODESSA CRUDE
BY ANTL ALCOHOL--FURFURAL PROCESS

	Rhodesia Crude	Dewaxed and Deasphalted Oil with 3 Vols of Anyl Alcohol at -20°C	Raffinate from Furfural Extraction with 3:1 solv. ratio 3:1 at 80°C	77% topped Residual Oil of Raffinate
Yield (Vol%)	100	54.3	27.6	7.2
Density 15/4	0.8818/30°C	0.9078	0.8763	0.9118
Viscosity in S.U.S. at 100°F	- -	606.4	352.1	1961.5
Viscosity in S.U.S. at 210°F	81.5	61.9	57.6	125.8
Viscosity index	- -	84.2	110.5	91.5
Pour point (°C)	+35	-23	-13	-20
Conradson's carbon (%)	3.98	1.90	0.24	0.84
Oxidation test				1.3
Viscosity ratio				1.79
Carbon (%)				

ENCLOSURE (B)4

Table XIV(B)4
CONDITIONS, PROCEDURES, AND PROPERTIES OF PRODUCTS
FROM POSAITA RESIDUAL OIL

	Posalta Crude	Dewaxed Oil With 3 Vols. of amyl alcohol at -20°C	Raffinate from furfural-extraction 1st with 2:1 solv. ratio at 50°C 2nd with 4:1 solv. ratio at 80°C 3rd with 2:1 solv. ratio at 90°C	60% Residual Oil (Product)
Yield (%)	100	51.8	7.8	3.8
Density($^{15}/_{4}$)	0.9516	0.9430	0.8807	0.8980
Viscosity in S.U.S. at 100°F	- -	1300.3	487.9	1528.2
Viscosity in S.U.S. at 210°F	158.7	85.5	64.2	112.3
Viscosity Index	- -	99.4	102.5	96.3
Pour point (°C)	+14	-5.5	-9.0	-19.5
Conradson's carbon (%)	5.5	3.5	0.31	0.59
Sulphur (%)	2.43	2.21	0.53	0.81

ENCLOSURE (B)4

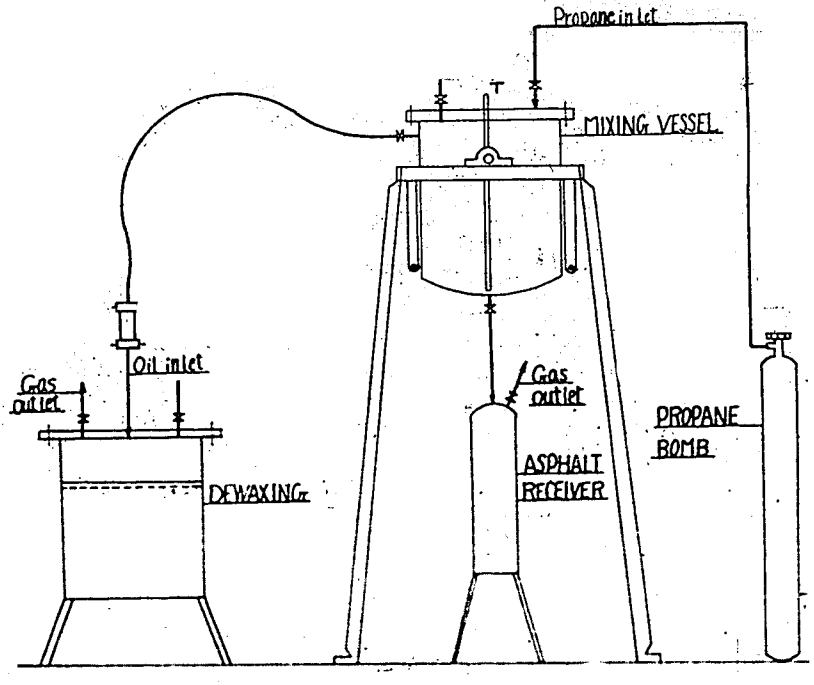

Figure 1(B)4
APPARATUS OF PROPANE DEASPHALTING AND DEWAXING

ENCLOSURE (B)4

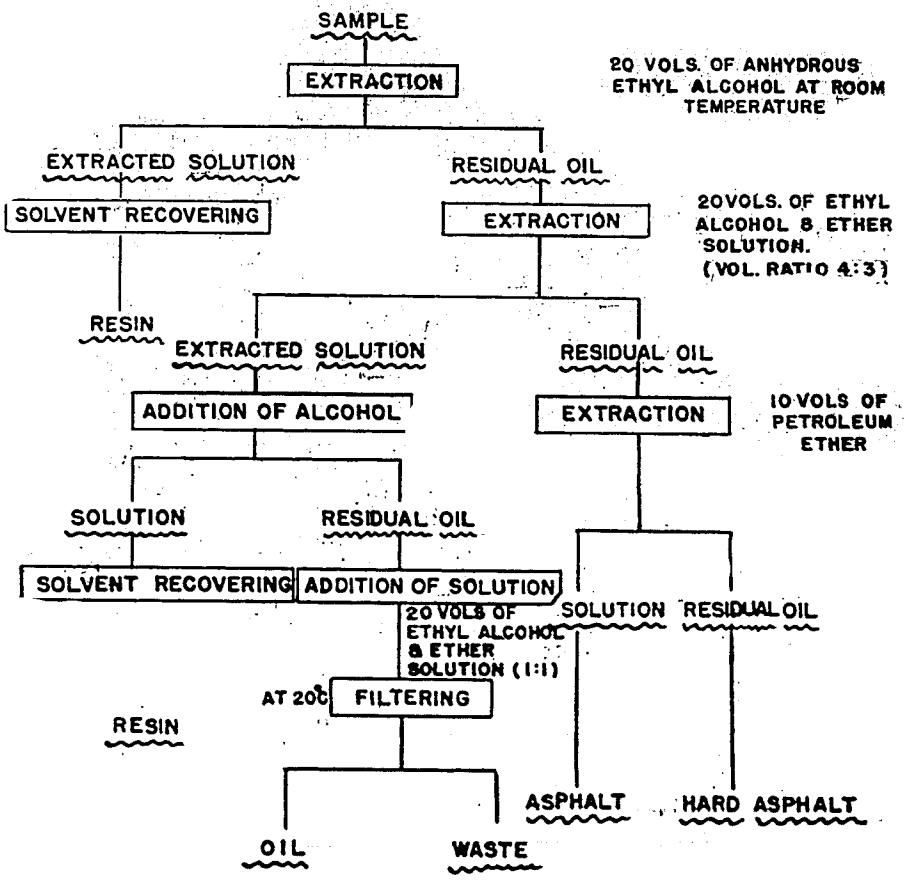

Figure 2(B)4
SOLVENT ANALYSIS BY ENGLER

ENCLOSURE (B)4

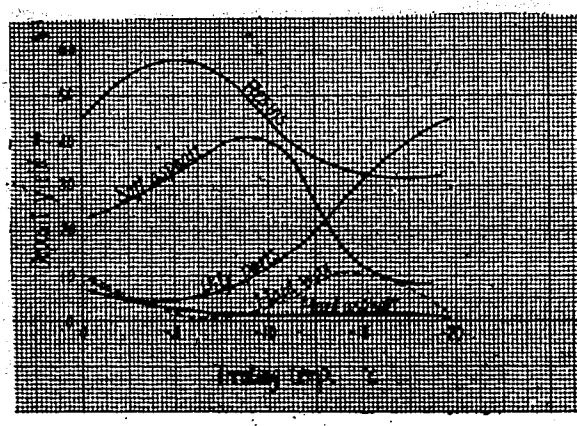

Figure 3(B)4
MECHANISM OF COOLING BY AMYL-ALCOHOL

ENCLOSURE (B)4

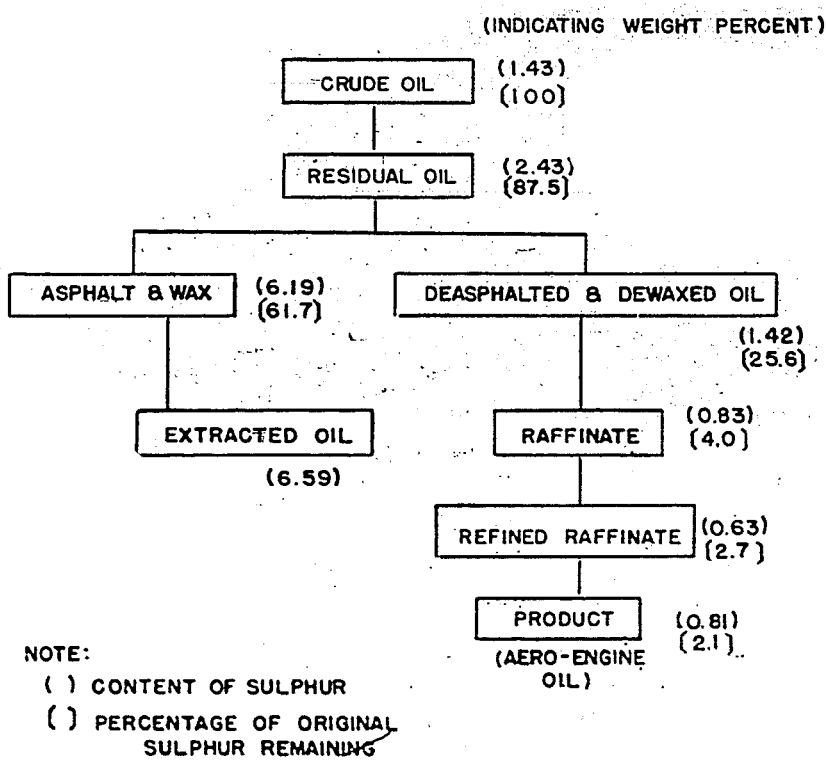

Figure 6(b)3
DISTRIBUTION OF SULPHUR IN EACH STEP OF PROCESS FOR MIXED CRUDE