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RUHRCHEMIE A.G.
STERKRADE - HOLTEN

Faragher, W. F.

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COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

SUPPLEMENTAL REPORT ON

RUHRCHEMIE A.G., STERKRADE-HOLTEN (Oberhausen-Holten) RUHR

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On behalf of:

BRITISH MINISTRY OF FUEL AND POWER

and

U.S. TECHNICAL INDUSTRIAL INTELLIGENCE COMMITTEE

22 October 1945 (from t.p.c.)

CIOS TARGET NO. 30/5.01.

FUELS AND LUBRICANTS

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413.

From typewritten copy:
Dates of trips: 5-8 July, 1945
21 July, 1945
19-23 August, 1945

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SUPPLEMENTAL REPORT
ON RUHRCHEMIE, A.G.
STERKRADE-HOLTEN, RUHR.

Introduction

Examination of documents evacuated from this plant as well as the information obtained by interrogation of certain key personnel, indicated that additional information was desirable on certain phases of research, plant operation and product testing and utilization.

The present account is in addition to and supplements that previously reported in the C.I.O.S. report dated 5 July 1945, "The Fischer-Tropsch Plant of Ruhrchemie, A.G., Sterkrade-Holten, Ruhr", compiled and edited by [illegible]

The process information reported was secured by interrogation of key personnel of Ruhrchemie by the [illegible]

1. At Sterkrade, 5-7 July 1945, by:

Dr. W.F.Faragher, (U.S., P.A.W.), Leader
Dr. W.A.Horne, (U.S., P.A.W.)
Dr. H. Schindler, (U.S., P.A.W.)
Capt. C.C.Chaffee, (U.S., Ordnance)

2. At Sterkrade, 19-23 August 1945, by:

Dr. W.F.Faragher, (U.S., P.A.W.) Leader.
Dr. W.A.Horne, (U.S., P.A.W.)
Mr. J.G.Allen, (U.S., P.A.W.)
Dr. G.S.Bays, Jr., (U.S., P.A.W.)
Mr. B.L.MacKusick, (U.S., P.A.W.)

The personnel securing information on product testing and utilization are listed on page 31.

RUHRCHEMIE AKTIENGESELLSCHAFT
STERKRADE-HOLTEN.

CIOS No. 30/5.01.

I Summary

A process has been developed by Ruhrchemie to convert n heptane into toluene, using a Cr_2O_3 Al_2O_3 catalyst. The development work was finished in October 1944 and a plant for the production of 24,000 tons of toluene per year was designed. Plant construction was abandoned however, on order of the German government when the plant was about 20% complete.

Information on the process was obtained by interrogating Dr. Walter [illegible] development work.

II Process Details

The charge stock consists of the C_7 fraction (boiling range 90-100°C) (194-212°F), from the Fischer-Tropsch systhesis of hydrocarbons (15-20% olefins) or a C_7 cut from crude oil. The vaporized and preheated (400°C) feed stock is passed into the reaction chamber where it is converted, yielding 90-92% by weight of liquid product which contains about 50% by weight of toluene. The reaction takes place at about 480-530°C (896-986°F). No external heating of the catalyst container is required, since the heat of combustion released during the regeneration of the catalyst is "stored" in the catalyst bed and is utilized during the aromatization reaction. The maximum temperature during regeneration is 550°C. The reaction chamber has a total volume of about 11 m^3, of which 8.8 m^3 is filled with catalyst. The on-stream time of each reactor was intended to be 30 minutes, and the design provided for 3 groups of 3 reactors. The space velocity is 0.15-0.20 (volume of liquid feed stock per volume of catalyst per hour). Details of the time cycle are given on the attached flow sheet (Figure I).

The catalyst consists of activated alumina with about 20% Cr_2O_3. (*)

Coke formation during the reaction period amounts to 2.0-2.5 g. of coke per liter of catalyst per hour, corresponding to 1.5-1.8% by weight of the feed stock: these details are given on an hourly basis since they were obtained in the pilot plant, the operating cycle which was 60 minutes instead of 30 minutes, as planned for the full-scale plant. The life of the catalyst is about two years. By that time, the reaction temperature has to be raised by about [illegible] and the yield of liquid product, as ascertained in an [illegible] test continued two years, decreases to [illegible] by weight of [illegible] stock, the toluene content [illegible].

Regeneration of the catalyst comprises two steps separated by a purging step using flue gas. The first regeneration step consists in burning off the carbon deposit with air, whereas the second step serves to reduce the six-valent chromium to three-valent chromium by passing hydrogen, preheated to 400°C., over the catalyst. Hydrogen is obtained from the process itself by separating the hydrogen liberated during the [illegible] of C_6, C_7 and C_4 hydrocarbons [illegible].

The total liquid product, containing 50% of toluene, is fractionated in a 60-plate column (45 theoretical plates). The crude toluene, which contains 3-5% of olefins, is acid-treated and rerun to produce nitration-grade toluene.

(*) The activated alumina is prepared by precipitation of a 5% Na aluminate solution with CO_2, as described in the section on synthetic lube oil at Ruhrchemie.

III. Development Work.

Laboratory work has been done on the aromatization of hexane, octane and nonane.

Preparation of benzene from hexane over the above-mentioned catalyst requires a reaction temperature of 480-500°C. (896-932°F) and gives a yield of 85% by weight of liquid product, of which 30% is benzene. Octane and nonane give the same yields of aromatic hydrocarbon but require lower temperatures since, [illegible] in that

Synthetic Lubricating Oil Manufacture.

I. Introduction.

Experimental laboratories for research in the field of synthetic lubricating-oil production were completed in 1937. During the same year, the construction of a plant for the manufacture of 1000 tons/month of automotive lubricating oil of 6-8°E. at 50°C. was started. The plant began ~~production in 1938; due to good operating practices, it~~ was able eventually to reach a capacity of 1500 tons/month. [illegible] primary charge stock included gas oil from other Fischer-Tropsch plants in addition to the feed stock made at the Ruhrchemie plant.

Development work was later carried out on the manufacture of aviation-grade lubricating oil (38°F. at 50°C.) and the construction of a plant was started in 1943. Due to repeated severe air attacks, it was decided to erect the plant underground near Willingen, west of Kassel, but [illegible] change was not accomplished. The plant was designed [illegible] capacity of about 1000 tons of finished [illegible]

II. Lubricating Oil (Automotive Grade)

a) Preparation of Feed Stock.

Information on the subject was secured mainly by the interrogation of Dr. Walter Schuff, manager of manufacturing of hydrocarbons by the Fischer-Tropsch process at the Holten plant. Dr. Schuff had held this position since 1939.

The starting material for the manufacture of synthetic lubricating oil by the Ruhrchemie process consists of olefins in the gasoline boiling range having one double bond at the end of the chain. The olefins are obtained by separately cracking the Fischer-Tropsch gas oil and "sweat oil" from the manufacture of wax derived from the Fischer-Tropsch synthesis. Gas oil, both from plants operating at atmospheric pressure and at 10-15 atm., is suitable, and the practice at Ruhrchemie consisted in supplementing their own production (10-15 atm) with purchased material from other Fischer-Tropsch plants. The gas oil has a boiling range of about 230-320°C. (446-608°F.). Cracking is carried out in a Dubbs unit at 500-520°C (932-968°F) at a throughput rate of 4.5 tons of oil per hour. Steam, at a rate of 1 ton per hour, is added to the vapors leaving the furnace and prior to entering the reaction chamber. The furnace outlet pressure is 4.5 atm. (50 [illegible] psig).

In addition to gas oil, the cracking of "sweat oil" from the manufacture of wax is practised. This material is obtained as follows: The primary synthetic product from the Fischer-Tropsch synthesis boiling above 320°C. (608°F) is vacuum-distilled, yielding a distillate (boiling from 320-380°C (608-716°F)) and a residue. The residue is distilled under vacuum and the resulting distillate is worked up for the manufacture of wax.

The oil obtained by sweating during the wax manufacture represents the charge stock for the cracking s[illegible] Cracking conditions are the same as for gas oil except that the temperature is kept at 480-500°C (896 932°F). The products from this source are blended with those obtained from gas oil, but cracking of the two charges is carried out separately.

The following cracking products result from both procedures:

Liquid olefins in gasoline boiling range	68% by wt.
Cracking Gas	30% " "
Loss	2% " "

The olefinic gasoline contains about 70% olefins. The boiling range of the material from the cracking of gas oil lies between 30° and 200°C (86-392°F), whereas the end-point of the corresponding olefins from "sweat oil" lies at 220°C. (428°F).

The cracking gas has the following composition:

C_3 & C_4	18% by wt. of charge.
C_2H_4	4% by wt. of charge.
C_1 & C_2 & inert gas	8% by wt. of charge.

b) <u>Polymerization.</u>

The feed stock is dried in a $CaCl_2$ tower to ensure that the water content does not exceed 0.015%. Polymerization is carried out in 7 autoclaves, each of which has a capacity of 2[illegible] m^3 and is filled with 18 m^3 of olefinic gasoline; the autoclaves are equipped with a closed coil for cooling and heating. The autoclaves are charged at room temperature and 1.2-1.5% (by weight of the charge) of $AlCl_3$ is added; the mixture [illegible] and the temperature is r[illegible] [illegible] following [illegible]

40°C	(104°F)	2 hours
60°C	(140°F)	3 hours
80°C	(176°F)	[illegible] hours
[illegible]	[illegible]	[illegible]

The first three steps are reached by control of the amount of cooling applied [illegible] [illegible] heating by steam.

A technical grade of $AlCl_3$ with an iron content of about 5% $FeCl_3$ is used, and no advantages were found to result from using a catalyst of higher purity.

The reaction product is transferred to settlers where the synthetic oil separates as upper layer from the catalyst-complex-oil lower layer. A settling time of 2-3 hours is required. A certain amount of the catalyst-complex oil mixture is left in the autoclave as solvent for the catalyst for the next charge.

The synthetic oil obtained in the above way contains some chlorinated hydrocarbons which are decomposed catalytically. For this purpose, the oil is treated with 1.5% of Tonsil (HCl activated clay) and 1.5% by wt. of ZNO at 180°C. (356°F) for 3 hours; the materials are added separately. The reaction mixture is subsequently cooled to 80°C (176°F) and filtered in a Kelly filter. The oily filter cake is extracted with gasoline to recover additional oil; and an extract oil containing 0.003% Cl and having a neutralization number of 0.04 is obtained.

c) <u>Finishing of Synthetic Lubricating Oil.</u>

The dechlorinated oil is distilled under atmospheric pressure yielding some gasoline, naphtha and Diesel oil. The residue is distilled under vacuum giving Diesel oil and spindle oil as distillates, whereas the residue is the synthetic lubricating oil.

The total yield of gasoline and Diesel oil resulting from both distillations is about 33% by weight of the olefinic feed stock; the yield of synthetic lubricating oil is 64% by weight and the loss [illegible] catalyst complex, amounts to 3%.

To prepare finished automotive lubricating oil, the residue from the vacuum distillation is contacted [illegible] of activated clay (Tonsil) at [illegible]

d) Disposal of Catalyst-Complex Oil

The lower layer obtained when the autoclave content, after polymerization, is allowed to settle consists of a catalyst-complex-oil mixture. To recover additional synthetic oil, the heavy oily layer is blended with Diesel oil in an autoclave and heated to 200°C (392°F) for 3 hours. The treatment results in the formation of an asphaltic mass which separates while hot from the solution of synthetic lubricating oil in Diesel oil. The lubricating oil solution must be dechlorinated in the same way as the original synthetic oil. The dechlorinated oil is then fractionated to recover the lubricating oil. This oil differs from the main product in its less favorable viscosity-temperature curve (pole height about 2) and high Conradson carbon residue (2-3%).

e) <u>Inspection Data of Synthetic Lubricating Oils.</u>

Inspection data of the spindle oil and automotive lubricating oil are given as follows; also included is a bright-stock which is obtained when the polymerization is carried out with 4-6% $AlCl_3$ at 15°C., followed by heating to 60°C.

	Spindle Oil.	Motor oil.	Brightstock
Density at 20°C.	0.845	0.855	0.865
Viscosity at [illegible]	2.3	7	38
Pole Height	1.75	1.75	1.82
Neut. No.	0.01	0.05	0.05
Sap. No.	0.04	0.10	0.10
Flash Point °C.	195	220	320
Pour Point °C.	-50	-45	-25
Loss by Evaporation (Test 1 hr.100°C)	45%	12%	2%
Conradson Carbon	01%	04%	20%
Petroleum Resins	2%	3%	5%
Hard Asphalt	0%	0%	0%
Iodine No.	abt 5	abt 5	abt 30
Cl %	0.01	0.01	[illegible] 0.01
[illegible]	[illegible]	[illegible]	[illegible]

Records of engine tests on the synthetic oils [illegible] been obtained from Dr. Schaub at Nuttler [illegible] available for study after microfilming.

The lubricating oil was delivered to the German Army (probably through the WIFO at Heiligenstadt) under the name of "Wehrmachtseinheitsöl" (Army All-Purpose Oil). The oil was apparently used as such for summer grade automotive lubricating and no inhibitor or other additive was used.

III. Improvement of Stability and Viscosity Index.

Due to the unsaturated character of the synthetic lubricating oil made by the Ruhrchemie process, the oil is not stable with respect to oxidation. Development work to improve the oil in this respect was carried out under the direction of Dr. Clar, who was interrogated on the subject.

The work was carried out entirely under laboratory conditions, using a number of oxidation and "cracking" tests as criteria for the quality of the oil and to evaluate the effect of inhibitors.*

* All tests used appear to be rather arbitrary and are mentioned mainly to permit a certain comparison of natural and synthetic oils of this type and to gage the effect of improving treatments.

The oxidation test consists in passing 15 liters of oxygen per hour through 200 g. of oil held at 160°C. (320°F); the test is continued for 6 hours. Increase in viscosity, expressed as percentage of the original viscosity, and saponification number are used as criteria of the oil quality. When lubricating oils from natural sources are subjected to this test, they do not show any increase in viscosity, whereas the Ruhrchemie oil increases its viscosity by 150% of the initial viscosity.

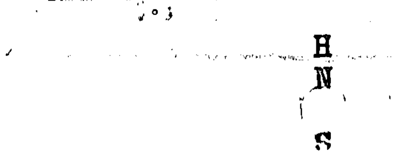
Another test used is termed the "heat of reaction" test. The oil is brought to 140°C (284°F) under N_2; oxygen is passed into the oil and the temperature rise during short time intervals is noted. Uninhibited synthetic oils show an abrupt rise in temperature shortly after oxygen introduction has started. Natural oils s[illegible] "heat of reaction" under these conditions.

A third test is used by Dr. Clar to estimate the thermal stability of synthetic oils. It consists in heating 500 g. of oil to 300°C (572°F) for three hours and determining the weight loss at the end of the test. The test is highly empirical and results are dependent on the shape of the distillation flask and other details. The following comparative results have been obtained:

Temperature.	Sample.	% Loss.
300°C.	Automobile oil from Natural oil (Greenring)	No cracking
300°C.	Synthetic oil (6-8°E at 50°C)	5%
330°C.	Automobile oil from Natural oil (Greenring)	5%
330°C.	Synthetic oil (6-8°E at 50°C)	40%

Since unsaturation appeared to be the main cause of the lack of stability of the synthetic oil, it was attempted to improve the stability by subjecting the polymerized oil to a second $AlCl_3$ treatment immediately following the polymerization. For this purpose, the oil was treated with 1% $AlCl_3$ at 180°C (350°F) for three hours. This process was, for a time, used in actual production, but was subsequently abandoned since the stability improvement was only temporary and since it was stated that the oil was satisfactory for its purpose without the additional treatment.

A permanent improvement in the stability of the synthetic oil was obtained by Dr. Clar by adding 0.2-0.5% by weight of phenthiazin



to the olefins before polymerization. The compound enters the reaction in an unknown manner and undesirable products formed by the addition of phenthiazin are removed during the treatment to which the polymerized oil is subjected in the course of the regular manufacturing procedure. Addition of phenthiazin to the finished oil is unsatisfactory, since it leads to the formation of gel-like material in the oil. The additive used by Ruhrchemie is the crude product obtained by melting 1 mol of diphenylamine with 2 mols of sulfur in the presence of $AlCl_3$ (2% by weight), stirring the mixture for 8 hours during which the temperature is raised from 90°C to 150 and decomposing with water.

Other compounds which have been used successfully in the same way as phenthiazin, but which were not considered for commercial production, are β thionaphthol and anthraquinonethiol.

The improvement in stability obtained by the phenthiazin treatment was indicated by the results of the laboratory tests. The viscosity increase in the oxidation test amounted to only 20% of that of the original oil, as compared to 150% increase for the uninhibited oil.

Another process designed to improve the stability of the synthetic oil is the addition of 0.3-0.5% by wt. of sulfur to the feed stock before polymerization and treating the polymerized oil with 1% by wt. of $AlCl_3$ at 250°C. (482°F) for 5 hours. It is stated that the sulfur is removed completely in the form of H_2S during the latter treatment. The finished oil does not contain sulfur, but it is claimed that its stability is greatly improved nevertheless.

Development work on the control of viscosity of the finished oil by changing conditions during the polymerization step was also carried out by Dr. Clar. By using a small amount of $AlCl_3$ and a comparatively high temperature, an oil of low viscosity is obtained, whereas reversal of these conditions leads to the production of oils of high viscosity. Using 1.5% by wt. of $AlCl_3$ and keeping the polymerization temperature at 100°C. from the start of the reaction (by preheating the olefinic charge) results in the production of an oil ~~with a viscosity of 4°E at 50°C. When 4-6% $AlCl_3$ is~~ used and the polymerization temperature is kept at 15°C. for 12-20 hours, followed by heating to 60°C for 2 hours an oil of 38°E at 50°C is obtained. These latter conditions were selected for the planned manufacture of aviation-grade bright stock, except that the total reaction was limited to 12 hours, based on the experience that the plant process generally works smoother than the corresponding laboratory procedure. Some work has been done on the polymerization of pure heptene-1; it was found that polymerization to lubricating oil can be effected by 1% of $AlCl_3$ without formation of any catalyst complex; the $AlCl_3$ remains granular and no loss by heavy polymers is experienced.

Experimental work also showed that an improvement in the viscosity index resulted when olefins with longer chains were polymerized, as compared to those with short chains or a mixed feed stock containing both long and short chains. Oils containing long chains (above C_{12}) were also found to be more resistant to oxidation.

IV. Planned Manufacture of Aviation-Grade Bright Stock (Syntol Process).

a) Preparation of Feed Stock.

Since the viscosity index of synthetic oils by the Ruhrchemie process depends on the chain length of the olefins polymerized, and since a higher viscosity index than that of the regularly manufactured synthetic motor oil was required for the aviation-grade oil, certain modifications in the process had to be made. It was intended to polymerize only olefins ranging from C_9 to C_{18}

and to supplement the material obtained by cracking with the olefins obtained directly by the "Recycle Process". The charge stock to the cracking plant was furthermore to be increased by C_{15} to C_{18} paraffins which remained unreacted in the OXO process.

The "Recycle Process" has been designed for the manufacture of olefins. It consists in using water gas as primary synthesis gas to which is subsequently added recycle gas from the synthesis. The water gas contains 87% of CO and H_2 (ratio of $CO:H_2$ 1:1.23-1.25) and one volume of water-gas is mixed with three volumes of recycle gas so that the ratio of $CO:H_2$ in the actual synthesis is 1:0.8. The catalyst used contains 100 parts cobalt, 15 parts MgO and 200 parts kieselguhr; the temperature of the synthesis is 200-220°C, and the pressure 10-15 atm.; the space velocity is 800 m^3 gas/10 m^3 catalyst/hour. The total yield (liquid products and liquefiable gas) amounts to 160 g/m^3 of "ideal synthesis gas" (CO and H_2). This yield includes a final conversion step, for previously unreacted gas, using an atmospheric Fischer-Tropsch unit.

The C_6 to C_{10} hydrocarbons from the "Recycle Process" contain about 20% of alcohols that must be removed before use in the Syntol process. The alcohols are converted to olefins and water by passing the hydrocarbon-alcohol vapors over activated alumina at 340-350°C (644-662°F) at a space velocity of 1 volume hydrocarbon-alcohol (calculated as liquid) per volume of catalyst per hour. (See Fig. II). The catalyst is prepared by precipitating a 5% Na aluminate solution with CO_2, removing the alkali by repeated washing, predrying, extruding and drying at 400°C (752°F). The C_9, C_{10} olefins are then separated by distillation and fed into the polymerization process together with the C_9-C_{18} olefins from the cracking process. The preparation is indicated on the attached flow sheet (Fig. III).

b) <u>Polymerization and Finishing</u>.

The polymerization procedure planned for the manufacture of aviation-grade bright stock does not vary from the practice followed in the manufacture of lubricating oil with respect to equipment and operations. The principal difference is the planned addition of phenthiazin to the olefinic feed stock, the temperature conditions and the polymerization time. In accordance with the laboratory work, it was intended to use 4-6% by wt. of $AlCl_3$, react the olefins for ten hours with the catalyst at 15°C and finish the reaction by heating for 2 hours at 60° C. Phenthiazin was to be added to the olefins before polymerization. Dechlorination, distillation and finishing were planned analogously to [illegible] natur[illegible] [illegible]

LABORATORY TEST FOR ACTIVITY OF FISCHER CATALYST.

The catalyst produced in the factory as well as the reduced catalyst, is tested continually for activity. The factory product is first reduced during two hours at 450°C with a mixture of hydrogen and nitrogen (3:1) at the rate of 300 liters per hour for each 4 g. of cobalt. The catalyst can also be reduced at 400°C with relatively pure hydrogen. By either method the final catalyst con[illegible] 40 50% of the cobalt [illegible] the oxide.

The test for activity is made in an aluminum-block furnace, designed especially for the purpose. The furnace is heated electrically or by gas flame to 185°C and controlled at this temperature to within 0.1°C by [illegible] regulator. [illegible] furnace.

The catalyst is put into a glass tube of 15 mm. inside diameter to a bed length of about 30 mm., corresponding to a weight of cobalt of about 4 g. After reduction the tube is put into the furnace, carefully avoiding oxidation, and treated with synthesis gas (4 liters per hour; CO/H_2 = 1.0/1.8-1.9). During the 500-hour test, the activity of the catalyst is measured each 48 hours (approximately). Contraction of the gas volume and yield of liquid products are measured and serve as measures of activity. The liquid products are expressed as cubic centimeters of liquid per normal cubic meter of synthesis gas. Liquid products comprise oil that condenses at room temperature in the receiver and the liquid that is removed from the activated carbon adsorber by steaming at 150°C. and 15-20 mm. Hg. Water formation can also be used in appraising the catalyst activity.

As is shown in the drawing (Fig. IV) the contractions of the gas volume can be determined by turning the three-way cock so that the feed passes through the by-pass to the flow meter.

$$\% \text{ contraction} = \frac{c}{a} \times 100$$

a = feed gas volume
b = tail-gas volume
and a-b = c

No accelerated test that could be used to predict catalyst life had been developed, nor was any standard-ized test used for evaluating experimental catalysts

TABLE I.

TEST DATA FOR COMMERCIAL COBALT CATA

Hours from start	Temp	[illegible] %	Condensed oil cc	Total C_5 + [illegible]
4	1[illegible]	70	-	-
18	"	72	98	-
56	"	72	89	-
80	"	69	94	114
128	"	70	70	-
176	"	65	77	95
223	"	66	76	-
272	"	60	75	120
319	"	67	69	-
368	"	66	62	125
416	"	66	73	-
464	"	66	67	105
511	"	64	56	-
559	"	65	60	111
607	"	63	63	-
655	"	60	66	114
703	"	58	62	
758	"	61	64	

Catalyst treated for 20 hours with H_2/N_2 = 3/1.

767	185-188	70	-	-
785	"	70	75	-
849	"	63	68	-
896	"	65	65	119
945	"	64	60	-
992	"	61	63	104
1041	"	62	59	-
1089	"	61	62	115
1137	"	61	63	-
1185	"	63	63	117
1233	"	61	60	-
1287	"	61	60	100
1329	"	60	57	-
1376	"	63	58	108
1425	"	60	52	-
1469	"	57	58	94
1517	"	54	49	-
1565	"	59	49	88
1613	"	56	47	-

(1) Condensed oil and C_5 + from activated carbon adsorber.

OXO PROCESS.

Some additional information on the Oxo-Process as developed by Ruhrchemie, has been obtained from [illegible], manager of the Oxo Plant.

The economic estimate attached as Table II, as well as the design data for the commercial unit were calculated from a pilot unit in which the reactor was 5 meters length and 35 mm. internal diameter. The design of this pilot unit [illegible] the commercial plant.

The pilot unit had a charge capacity of [illegible]0 kg. of olefin mix[illegible]

The Oxo stage charge gas was water gas $CO:H_2$ = 1:1.1 to 1.2 and was recycled until the composition reached $CO:H_2$ = 1:2. [illegible]

There are also attached two schematic flow sheets of the process, Figures VI and VII.

TABLE II.

ESTIMATE OF THE WORKING COSTS FOR 12,000 TONS PER YEAR OF FATTY ALCOHOLS.

(Based on a supply of 12,000 tons per year [illegible] in from the Ruhrchemie, [illegible]ade [illegible]

	RM	
Material Input:		
12,000 T.olefin at 0.40 RM/Kg.	800,000	
6,000,000 Nm^3 water gas. 10 atm.at 0.04 RM/Nm^3	240,000	
3,000,000 Nm^3 hydrogen 10 atm.at 0.075 RM/Nm^3	[illegible]	
Operating Costs:		
Operating wages & salaries incl.social security tax (150 men [illegible]		
Energy:		
Steam.		
78,000 T/Y, 80 atm. at 4.00 RM/T.	312,000	
97,000 T/Y, 18 atm. at 3.50 RM/T	339,500	
100,000 T/Y, 2.5 atm. at 2.55 RM/T (vacuum and heating)	255,000	906,500.
Electricity.		
10,160,000 KWH @ 0.03 RM/KWH (gas compressors, pumps)		304,800.
Water.		
1,344,000 m^3 at 0.075 RM/m^3		100,800.
Accessory Material.		
Catalyst Cost		72,000.
Operating Material.		
Oil etc.		24,000
		1,889,900.

	RM	RM
	[illegible]	
Repairs & Maintenance		
1% of the Plant cost of 11,000,000 RM	[illegible]	
Auxiliary Operating [illegible]		
Insurance, T[illegible] other costs	10,000	
Laboratory Costs		
[illegible] Wages [illegible] Salaries	[illegible]	
General Operating Expenses including Management		
[illegible] Wages & Salaries	10[illegible],[illegible]90	2,661,070
Sum of Operating and Material costs.		7,926,070.
Interest on Capital.		
13.5% of 11,000,000 RM.		1,485,000.
General Expenses.		
Taxes		120,000.
		9,531,070.
Credit for by-product		144,000.
		9,387,070

100 kg. Fatty Alcohol costs therefore 78.23 RM.

(Dr. Landgraff, Oberhausen-Holten)

4 March 1943.

THE DIRECT SYNTHESIS OF HIGHER ALCOHOLS FROM WATER GAS.

The direct synthesis of alcohols was being studied in the small unit shown schematically in Fig. VIII. A mixture of fresh water gas and recycle gas is compressed in two stages to 10 to 100 atmospheres. The gas then passes downflow at a space velocity of 100-150 N liters per liter of catalyst per hour, over 5 liters of a promoted iron catalyst. The catalyst is contained in an heated tubular reactor the tubes being 12 mm. inside diameter. The product from the reactor passes through an electrically heated hot separator at 110°C, thence to a cold water condenser. After the pressure on the remaining gas is released, it passes through an activated-carbon adsorber. Part of the dry gas is discharged from the [illegible], the remainder passing to the gasometer for rec[illegible]

The gas flow is started with the reactor temperature at 200°C. The temperature is then raised degree by degree until until the desired conversion is attained. This temperature is in the range of 220-240°C.

The catalyst is a cerium or vanadium promoted iron catalyst which is prepared in a similar manner to the Ruhrchemie precipitated iron catalyst. The composition of the cerium catalyst was stated to be:-

100	parts	by weight of	Iron
5	"	"	Copper
10	"	"	Cerium
50	"	"	Kieselguhr

At the higher pressure (100 atm), the olefin content of the reaction product is small and the oxygen-containing products are of shorter chain length. Medium pressure (10 atm) favors the formation of higher molecular compounds with a higher proportion of olefins.

From one normal cubic meter of gas, 80-100 gms. of a mixture of alcohols, esters and olefins (to about C_{18}) are obtained in a single pass operation. The product (C_3) from the separator, condenser and active carbon adsorber is combined and cut into fractions by distillation. The alcohol content of the total product averages 50-60%. The alcohol content of the benzene fraction (80-200°C) was lower than that of the gas-oil fraction (200-320°C).

The alcohols formed are all primary and predominantly of iso-structure. By caustic fusion of the 200-320°C. fraction, soaps can be directly prepared.

Experiments had been discontinued when the laboratory was completely destroyed by bombing. Dr. [illegible] ... [illegible] project, supplied the [illegible]

IRON FISCHER CATALYST.

Introduction.

The dense sintered iron catalyst used by others was objectionable to Ruhrchemie for [illegible]

The temperature of favorable action was too high to be satisfactory in the standard converters, because of the high steam pressure necessary for the control of temperature; and the catalyst charge for the converter was too heavy for the converters in use. It was desired that no change of converter design be included at the time, so research was started to obtain an iron catalyst free from the two objections enumerated. It was not expected that a catalyst superior to the cobalt catalyst would be discovered, but the shortage of cobalt made necessary to attempt to equal the results [illegible] by taking [illegible] iron.

The iron catalyst contains also copper, [illegible] oxide and potassium hydroxide [illegible] Kieselguhr is used as support.

The solution employed contains iron, copper and calcium oxide in the proportions 100:5:10.

Since the precipitation of the calcium oxide is not complete, the finished catalyst has the following proportions: iron: copper: calcium oxide: kieselguhr, 100:5:8:30.

The dissolved nitrates are precipitated by adding a solution of sodium carbonate.

Materials.

<u>Iron</u> - Iron Turnings. They must be free from such metals as chromium, molybdenum, nickel, vanadium, etc., and also be clean of oil and dirt.

<u>Copper</u> - Waste metal in the form of clippings of sheets, wire, etc. is used. Copper oxide of corresponding purity can be used.

<u>Lime</u> - Calcium carbonate, quick lime or hydrated lime are equally good.

Kieselguhr - A light, voluminous product is best, calcined at 700°C.

Potassium Hydroxide - [illegible] product.

Nitric Acid [illegible]

Solution Preparation

The preparation of the solution of mixed nitrates is carried out in an acid resistant vessel provided wi[illegible] heating and cooling coils and with an effective [illegible]. The components are dissolved in the nitric acid. The copper is dissolved first, then the iron, [illegible] [illegible]tion of the qua[illegible] [illegible] the basis of [illegible]

2 Fe requiring 8 HNO_3

3 Cu requiring 8 HNO_3

[illegible]

The dissolving of the copper is begun in the cold. As the metal dissolves with strong evolution of oxides of nitrogen, the temperature rises (high heat of reaction). By heating, the temperature is brought toward the end to 60-70°C.

Next, the dissolving of the iron is effected by adding the turnings gradually. The rate of addition is determined by the rate of evolution of oxides of nitrogen. The temperature of the solution rises to about 80°C., and as the reaction slackens toward the end, is held at this level by heating.

The calculated amount of calcium oxide in the form of calcium carbonate, quick lime or hydrated lime, is then added. This component should in all cases be finely divided. It must be added slowly in order to avoid local over-neutralization.

The solution is next heated to boiling and held at that temperature for several hours before cooling to room temperature. Prepared in this way, the solution contains little free nitric acid. The solution is stable and no deposit forms even if it is boiled for a long time. The content of iron, copper and calcium oxide is within the following ranges:-

Iron	115.0-125 g. per liter.	
Copper	5.0-7.0 g. " "	
Calcium oxide	11.0-13.0 g. " "	

Total nitric acid is between 510-450 grams. If the iron and lime are free from insoluble impurities, the solution can be used directly. Otherwise, the solution must be filtered, a difficult operation because of the gelatinous character of the usual solid material. Filters if used, must be of material not attacked by the solvent. Before precipitation, the concentration [illegible] brought to [illegible] g. per liter.

The sodium carbonate solution is prepared by dissolving soda ash to a concentr[illegible] The solution is not filtered.

Precipitation and Impregnation

Precipitation is effected by introducing, as quickly as possible, the nitrate solution, heated to 90°C., into the boiling soda ash solution while stirring intensively.

The quantity of soda ash used is such that, at the end of the precipitation, the pH is 6.8, determined hot with indicator strips (Folienkolorimeter). If necessary, either nitrate solution or soda-ash solution is added to produce the desired pH. Total time of precipitation must not exceed five minutes.

The contents of the vessel are then stirred for half a minute; evolution of carbon dioxide is over in this time. Then the calculated amount of kieselguhr is stirred into the mixture.

For the purpose of separating rapidly the mother liquor from the catalyst, the suspension is filtered by using pumps of large capacity. Washing with hot condensate (70-80 C), is continued until the cake will yield a finished catalyst containing 0.4-0.6% of sodium nitrate, based on the iron content. More complete washing is unnecessary and in fact lowers the desired content of calcium oxide. In general, 200-220 cu.m. of wash water per ton of iron in the cake is sufficient to give the desired result.

Impregnation follows the washing. Potassium hydroxide is used to give the desired content of alkali. Repeated experiments proved that impregnation in the filter by pumping through the cake a potassium hydroxide solution of the proper concentration does not give a uniform product. The reason is [illegible] the cake during the operation.

To obtain a satisfactory impregnation, it is therefore necessary to paste the cake and to add the caustic to this mass. The quantity of potassium hydroxide is so gaged that the filter cake (moist) contains 3.0-3.5% of potassium hydroxide, based on the iron. This result is in general reached if the solution used in the suspending has a concentration of 6. [illegible] g. KOH per liter. After impregnation, the catalyst is again put in the iron filter press. The cake obtained [illegible] dried [illegible] 110°C. and subsequently shaped [illegible]

Reduction

Reduction with hydrogen or with a mixture of hydrogen and nitrogen follows at a temperature of 300°C (maximum). Higher temperatures cause over reduction and an inactive catalyst. Time for reduction is usually 30 minutes after the temperature is reached. This statement applies when H_2 and N_2 are used in the proportion of 3:1. Times are much shorter when hydrogen only is used.

Reduction is most satisfactory when the mass is disposed in layers of 25 cm. depth and when the gas flow is high (about 2000 cu.m. per hour per square meter of cross section). A content of more than 5-8% of iron (metallic) in the finished reduced catalyst must be avoided. Metallic iron is determined by the use of mercuric chloride by the normal procedure. Higher contents of iron give an inactive catalyst. Further, the iron soluble in 2% solution of acetic acid shall be 60-70% of the total iron. This determination is made by boiling the reduced catalyst for about two hours with reflux, using a protective inert gas.

After reduction, the catalyst is treated in the usual manner with nitrogen (cold) and then saturated with carbon dioxide. Contrary to the behavior of cobalt catalysts, much heat is liberated when the iron catalyst is saturated with carbon dioxide. The saturation must, therefore, be conducted slowly.

METHANIZATION CATALYST AND PROCESS

Introduction

The methanization of coke-oven gas [illegible] oxides of carbon [illegible] methane [illegible]

1) $CO + 3H_2 = CH_4 + H_2O$

2) $CO_2 + 4H_2 = CH_4 + 2H_2O$

Volume contraction is considerable due to the water formation and condensation. The catalyst contains nickel, magnesium oxide and [illegible]

Catalyst Preparation

For the preparation of 1 kg of nickel containing catalyst, 24 liters of a solution of nitrates containing 42.0 g/l. of nickel and 6.2 g/l. of magnesium oxide and 40 liters of a solution of sodium carbonate (80.0 g/l) are separately heated to boiling. The hot soda solution is added slowly to the nitrate solution with efficient stirring (centrifugal stirrer). When precipitation is complete, 0.5 kg. of kieselguhr is added and mixed well by stirring.

The hot mixture is then filtered rapidly in a filter press and washed with 120 liters of hot water.

The moist filter cake is shaped in an extruder and dried on a belt heated by an open flame. The catalyst is next brought to proper size (3-5 mm) in a special mill (Kornmühle) and a vibrator. This preparation is shown in Figure IX.

The granular mass (called Grünkorn) is reduced for one hour at 350°C. with a mixture of hydrogen and nitrogen (3:1) at a space velocity of 6000-8000 (calculated at operating conditions). The reduced catalyst is swept by the stream of hydrogen and nitrogen until the temperature has fallen below 100°C., then is purged with nitrogen and saturated with carbon dioxide. The catalyst should now contain 60% of metallic nickel (based on total nickel)

Process Operation

The flow scheme for this process is shown in Fig. X. The preheated gas is introduced into the decomposing vessel (kept at 425-450°C), where the organic sulf compounds are decomposed, ~~and the oxides of nitrogen reduced~~. After cooling, the decomposition products (H_2S, NH_3, etc) are removed by luxmasse and activated carbon. The purified gas passes to the synthesis reactor where the carbon monoxide, the carbon dioxide and the heavy hydrocarbons are converted to methane at 160-230°C. It is important that the operation be started at as low a temperature as possible. During the process, the temperature must be controlled to within 1-2°C. Increase of temperature is made only to compensate for decrease in activity of the catalyst. The water formed contains some ammonia and is removed from a separator beyond the condenser.

The decomposer is a cylindrical vessel (heated externally); the converter, a well-constructed tubular boiler. The catalyst fills the tubes (20-28 mm diameter), the cooling water being around the tubes. Control of the pressure of the generated steam provides good temperature control.

OXIDATION OF PARAFFIN WAX WITH NITROGEN OXIDES.

The oxidation of paraffin wax was carried out with the intention of producing high molecular weight fatty acids, [illegible] chain length of the hydrocarbon [illegible] acids were to serve as substitute for [illegible], after further processing [illegible].

The raw material [illegible] wax, refined or unrefined, which [illegible] with an initial boiling point [illegible], with less than 10% over at 450°C. The average molecular weight is 600, corresponding to an average chain length of 40-45 carbon atoms. The solidifying point is about [illegible]°C, and the melting point about [illegible]. The wax is treated in an enamelled iron kettle with nitrosyl sulfuric acid at 120-125°C. Oxides of nitrogen ([illegible] of NO_2, drawn from the ammonia oxidation plant) are bubbled through the wax while it is continuously stirred. The gas flow is 65 cu.m. per hour. For [illegible] charge of wax, [illegible] kg of nitrosyl sulfuric acid ([illegible]) is used. The nitrosyl sulfuric acid is made by saturating concentrated sulfuric acid with the gas from the ammonia oxidizer. The oxidation time depends upon the acidity desired, but is usually 10-12 hours. The acid number is then 70-75, and the saponification number 80-85. The oxidation is on the average, 50%, at these values. Stirring is discontinued; the greater part of the acid settles is withdrawn and re-used. The product is withdrawn to a washing vessel and washed with boiling water with as little agitation as possible, until the water is free from sulfates. The dried product, at this stage, is called OP3, and is suitable directly for use in a number of ways. The material is nearly white and is very hard. The solidifying point is 80° and the clear melting point about 90°C.

The paraffin wax is separated from the acids by treating melted OP3 in a kneading machine with concentrated caustic potash (30% minimum) or caustic soda, being sure to use at least 50% excess of caustic. The kneading machine must be provided with a means for heating for the temperature is maintained at 100°, until all water has been evaporated. The mass is cooled while kneading to effect a disintegration.

The mass is discharged and broken up in any desired machine. Extraction of the paraffin wax is then effected in an extractor, the best solvent being a gasoline fraction from the Fischer-Tropsch plant (b.p. 80-100 C). The extracted wax is recharged to the process. The soap is treated with dilute sulfuric acid, washed and dried. A simplified flowsheet is attached as Fig. X

The finished wax is designated as OP 32. It is a yellow to brown hard material, solidifying at 80°C. and melting (clear) at 90 100°C. [illegible] id number is 145-150 saponi[illegible]

If desired, OP 32 can be bleached with nitr syl sulfuric ac[illegible] and nitric [illegible]

METHANE ACTIVATION.

A Roumanian by the name of Slatineanu worked for two years at Ruhrchemie, Sterkrade-Holten, on the acti vation of methane at high pressure. He claimed to be able to combine methane and water to produce alcohols, as well as to produce ammonia and fatty acids from wa gas and nitrogen. The catalyst tried was the usual Fischer-Tropsch cobalt catalyst prepared at Sterkra operating at 5-60 °C and ab[illegible] 1500 atm. No useful [illegible] were ever obtained

After being released by Ruhrchemie, Slatineanu was employed by the Concordia Company, Oberhausen. Here he duplicated the equipment used at Ruhrchemie, but st obtained no positiv results. H claimed t'at he was unable to repro[illegible] [illegible] [illegible] [illegible] [illegible] for his failure

Dr. Sexauer of the Concordia Company wi[illegible] [illegible] details on the subject, but they seem [illegible]

[illegible]

Dr. Vel[illegible] July 8t[illegible],1945 [illegible] Ruhrch[illegible]

[illegible]

Capt. [illegible] U.S., [illegible]

[illegible]

Mr.H.L.West, British, Ministry of Fuel and Power.
Major L.Rosenfeld, British, " " " " "

3. Dr.Hageman and Dr.Schaub were interrogated at Sterkrade-Holten on August 23rd,1945 by:

W.F.Faragher, U.S., Petroleum Administration for War.
W.A.Horne,Junr., " " " "

2. Ruhrchemie A.G., Fischer Tropsch Products.

Dr.Velde - July 8th,1945.

Motor Gasolines boiling up to 150-160°C. (302-320°F.) were shipped by Ruhrchemie to the Zentralburo as blending agents. The only specification was for Reid Vapour Pressure which was:

Summer 0.55 Kg/cm^2 max. (7.8 lb/sq.inch)
Winter 0.80 Kg/cm^2 " (11.4 " " ")

Octane numbers (C.F.R. Research) for atmospheric pressure products were 60-61 and for 10 atm. pressure products about 45-50. The latter products had lower Octane Numbers due to their lower olefine contents.

Diesel [illegible] les were manufac[illegible]red as [illegible]

	Aero Diesel Oil for Junkers Engines.	Normal Diesel Oil (known as Special Diesel Oil N [illegible])
Sp. Gr.	~ .700	~ 0.7[illegible]
Pour Point, °F	40	-4
Cetane Number	70	80+
Viscosity at 20 C. (68°F)	ca. 1.06 centistokes.	1.1 centi[illegible]
Flash Point	[illegible]7°C.(98.6°F.)	-
Boiling Range	170-230°C. (338-446°F)	180-270°C (356-518
Production tonnes/month	?	400 45

It was stated that the cetane numbers of diesel oil fractio[illegible] the same boiling range from atmospheric pressure and medium pressure (10 atm.) synthesis are almost identical.

<u>Waxes.</u> Two grades were produced for industrial use separated by vacuum distillation at atmospheric pressure:

(a) Melting Point 50-52°C. (122-125.6°F.) - Acid Free,
Colour - White.

(b) " " 90-92°C. (194-197.6°F.) - Acid Free,
Colour - Light Yellow.

3. Ruhrchemie A.G., Engine Test Laboratory at Nüttlar.

On the occasion of the first visit to Nüttlar, Dr.Schaub, who was in charge of the engine test laboratory at Sterkrade-Holten and who had been evacuated to Nüttlar, was not located and the Nüttlar laboratory was examined in his absence. It was a small wooden hut in which was installed a 4-cylinder automobile engine which was in running order for lubricating oil tests and a Four Ball Testing machine. No other equipment was installed but a number of crates containing various engine components were located. No documents of any value were located in the laboratory. A visit to Schaub's house, however, revealed a number of reports and documents dealing with fuels and lubricants, and these were removed. A complete list of these documents, with titles given in English and German is reproduced in Appendix I.

In the second visit to Nüttlar it was learned that it was intended to install most of the test engines evacuated from Ruhrchemie at Sterkrade-Holten in a slate quarry at Nüttlar but this was not actually done because of the speed of the Allied advance on the Western Front and the engines were being returned to Sterkrade Holten. Dr.Schaub was located [illegible]

4. Interrogation of Dr.Schaub July 21st,1945.

Dr.Schaub was in charge of the engine test laboratory at Sterkrade-Holten, having been engaged in 1938 for the express purpose of developing engine testing of Ruhrchemie products. Born on April 22nd,1911, he obtained his Doctor's degree at the Technische Hochschule, Berlin, having worked on the cold starting of diesel engines, using, for example, gasoline. Previous to being employed by Ruhrchemie, he had been engaged on engine testing by Daimler-Benz.

Dr.Schaub claimed that he had never been a Party Member and proved very co-operative. However, throughout the interrogation he complained of not being able to refer to his reports and documents which had been removed by the previous team. From memory, Schaub gave the following details of the laboratory of which he was the leader.

Equipment. The equipment of the engine laboratory at Sterkrade-Holten consisted of 12 test engines, as follows:-

- 2 I.G. Pruf Motors for gasoline testing.
- 1 C.F.R. engine.
- 1 Supercharged 500 cc. 4-stroke N.S.U. (NECKARSULM) engine.
- 2 N.S.U. engines (not supercharged).
- 2 Triumph 2-stroke engines (similar to the Puch but with a different crankshaft).
- 2 4-cylinder Opel and Daimler-Benz engines.
- 1 H.W.A. (Deutz) diesel engine for cetane ratings.
- 1 F.K.F. Stuttgart diesel engine for fuel testing (developed by Kamm of Stuttgart but not considered by Schaub to be very good).
- 1 Four-ball machine.
- 1 Almen machine.

1 Z.F. (Zahnradfabrik - Friedrichshafen) gear test machine (bombed).

1 large cold chamber 5 x 9 metres (no chassis dynamometer).

1 small cold chamber for engine testing, with external brake. This used a Linde plant for cooling and a temperature of -40°C. could be obtained

1 [illegible] small cold chamber cooled by dry [illegible] for gear oil tests.

Personnel. The total staff in the laborato[ries] of Ruhrchemie was about 500, Dr.Tramm being the chief chemist. [The] large staff was due, in part, to the fact that the Ruhrchemie [he]ld the Fischer Tropsch patents and licensed other pr[illegible] [illegible] engaged [illegible]

Operation.

(a) General. It had been learned previously that Dr.Hagemann, one of the directors of Ruhrchemie, had been intimately concerned with the OKH. Questioned on this, Schaub stated that Hagemann was the leader of a group of the OKH which dealt with fuels, lubricants and rubber. Because of this connection, the Ruhrchemie engine test laboratory was one of the main places for engine testing for the OKH, other places being the Erprobungsstelle, Rechlin and the Army Test Station at Kummersdorf, the latter being the chief place for testing vehicles, having a large cold chamber. Nearly all the engine test facilities, except the supercharged engine, were used for work on lubricants and fuels for the OKH.

Schaub claimed that he did not have any detailed knowledge of the changes in quality of Army products and suggested that Tramm would be better informed.

(b) Fuels and Fuel Testing. The I.C. and C.F.R. engines were used to test Ruhrchemie gasolines. Questioned on the change made during the war in the method of test, namely from the Research Method to the Motor Method, Schaub considered that the reason for the original adoption of the Research Method was due to a certain amount of influence or pressure by the Benzol Verband, and it was eventually found, by correlation tests, that the Motor Method under-rated benzol blends less than the Research Method over-rated them. The Air Ministry had always used the Motor Method and its adoption by the Army allowed greater uniformity.

Alcohol blends were stated to have been mainly used for civilian purposes and not to any great extent by the Army.

Certain tanks with Maybach engines did require a special fuel of 78 O.N. C.F.R.M.M. as against the more usual supplies of 72 O.N.

Schaub claimed to have developed a small super-charged, fuel test engine based on a 500 cc. 4 stroke motor cycle engine (the N.S.U.) which was alleged to correlate well with the B.M.W. engine after initial difficulties with the piston and bearings due to the increased temperatures and loads. Other engines developed and [illegible] the N.S.U. are the I.G. and [illegible]

[illegible] fuel [illegible] were used mainly for [illegible]

A very small amount of work had been carried out on [illegible] and the only [illegible] Schaub could quote [illegible]

(c) Lubricating Oils. In the early part of the the Army had tried to use the same oils summer and winter (Einheitsöl) both for engines and gears, but this had to be dropped due to experience on the Russian front and summer and winter qualities were introduced. Schaub was, however, of the opinion that the original programme could have been carried through. On the Russian front a system of fuel dilution had been developed for cold starting, using either Kerosene or gasoline, the latter being preferred. There was, however, no definite programme. Tramm developed an air bubble viscometer and every driver was supposed to measure the viscosity of his oil and dilute with fuel accordingly. This was not successful and was superseded by instructions, with tables, which gave the quantity of fuel to be added (% by vol. of gasoline) for a given outside temperature.

Questioned on synthetic lubricating oils, Schaub explained that the various synthetic aviation oils produced by Ruhrchemie had been given code numbers of SS.2000 to SS.2010. All of these oils had viscosities of about 3°E at 100°C. and 10 to 12° E at 50°C. With increasing code number the Pole Height had decreased from 1.8 to 1.5. Schaub mentioned that all the Ruhrchemie synthetic oils increased in viscosity in use - much more so than mineral oils - due to further polymerisation. This he gave as the reason for mixing mineral oils with the synthetic products in, for instance, the aviation oil S3. He also claimed that the latest Ruhrchemie production was superior to any other synthetic oils and superior to natural products, having overcome the disadvantage of increased viscosity in use. It was presumably for producing this product that the plant at Willingen was intended. Schaub also mentioned that he felt that if they had had the influence of the I.G. they could have been able to get into production much more easily than had been the case.

Questioned on the use of synthetic oils by the Arm Schaub stated that no I.G. synthetics were used for this purpose; Ruhrchemie production did, however, find a use in this field. Deurag, Rhenania and D.A.P.G. blended synthetic oils with natural oils and possibly used Oppanol (a V.I. improver) to give the Pol Height of 1.8 required by the Army. Schaub did not, however, favour the use of Oppanol because its efficacy disappeared with use due to depolymerisation. He had heard by hearsay that Oppanol was used in gear oils; more data on this subject [illegible] be obtained from Dr Tramm. Schaub had no knowledge [illegible] ... oils used by the Army.

(d) Engine Tests for Lubricating Oils. Schaub knew of the Intava DKW 2-stroke ring sticking test but he did [illegible] see how an engine operating with petroil lubrication could [illegible] expected to correlate with the BMW 132 single cylinder test [illegible] with full scale engines. Of the engine tests developed by Ruhrchemie other than the N.S.U. fuel rating unit mentioned [illegible] Schaub instanced the following work [illegible] ... fresh in his memory.

(i) Triumph Motorcycle Engine.

This engine is a two-cylinder side-by-side two stroke engine with a common combustion chamber, similar to the "Puch" engine but with a modification in the arrangement of the crankshaft. The manufacturers claimed that this engine needed a special lubricant due to piston seizure or scuffing in the arduous use in Army motor cycles. In the test set-up the engine was run with reduced cooling air so that it overheated and gave seizure or scuffing after about 10-15 mins. Instead of using the normal lubrication system, the oil was fed directly by an adjustable supply to the cylinder, the connecting rod roller bearing being lubricated by excess. By introducing the oil near the top of the piston at bottom centre, and by careful regulation of the feed, it was claimed that reproducible results could be obtained in a short time. Using this method Schaub claimed that he was able to prove that Ruhrchemie synthetic oils were the best of a series of about 6 oils circulated, under code numbers, for test. These same oils were also subjected to road tests in motor cycles fitted with the Triumph engine, the route including some steep hill climbing in Alpine country. It was found that the laboratory test agreed with the road tests.

(ii) In order to evaluate oils for their ability to lubricate and reduce wear in engines Schaub had developed a ring wear test using the 500 cc. N.S.U. engine. This test, which enabled results to be obtained in 9 to 10 hours was carried out and assessed by the loss in weight of the piston ring. Some trouble had also been experienced due to sludge centrifuging out in the crankpin and blocking the oil channels. In order to overcome this difficulty on the test engines and at the same time to provide a means of estimating the propensities of the oil to deposit sludge a special provision was made. One of the webs of the crank was drilled and screwed on the oil inlet side and [illegible] put in position. This bolt acted as a trap [illegible] weight, [illegible]ved as [illegible] deposited. It [illegible]

Documents. Schaub stated that the originals of most of the documents seized from [illegible] by the previous party [illegible] be found at [illegible] when [illegible] with their Ruhrc[illegible] [illegible] from [illegible]. It [illegible] that the [illegible] in [illegible] that [illegible]

Interrogation of [illegible]

On this occasion Hagemann and Schaub were requested to prepare a report on the wartime activities of the Ruhrchemie engine laboratories. A translation of this report is reproduced in Appendix 2, and includes references to the reports listed in Appendix I. It reveals that a considerable amount of work was carried out on behalf of the Heereswaffenamt (HWA) in the Ruhrchemie Engine Laboratories and that Schaub and Hagemann are very knowledgeable concerning the work. On the other hand when detailed questionnaires on fuels and lubricants were handed to them with a request that they should prepare detailed answers, they were unco-operative and gave answers which were so brief as to be practically valueless or else disclaimed all knowledge. It is clear that Schaub and Hagemann must be interrogated further on this subject. The questionnaires and answers thereto are, however, included in this report as Appendix 3, for the sake of completeness.

APPENDIX I

DOCUMENTS EVACUATED FROM THE RESIDENCE OF DR. SCHAUB OF RUHRCHEMIE A.G.

Doc. No.	Rep. No.	TITLE	Author	Date
		RUHR-BENZIN REPORTS		
[illegible]		Ruhrbenzin results a propos the Co-operati[illegible] Tests in the H.W.A. Test Engine (Diese[illegible]).	[illegible]	[illegible]
[illegible]		Report on Tests to clarify discrepancies in Octane No. Determination of Ruhrbenzin Fue[illegible]	[illegible]	[illegible]
[illegible]		Supplement to the Report: Position [illegible] tests with C_3, C_4 (liquefied Gases)	[illegible]	[illegible]
[illegible]		Interim report on the tests to date w[illegible] Test Engine from the F.K.F. Stuttgart.	[illegible]	[illegible]
[illegible]		Progress report No.2. Lubric[illegible] on the Opel 1.3 ltr. Engine.	[illegible]	[illegible]
6.	-	Report on test with mixtures of liquefied Gas (Gasol) and Gasoline.	Schaub	4.12.39.
7.	-	Progress report No.3. The importance of Engine conditions in the testing of Lubricating Oils.	Schaub	19. 1.40.
8.	P101.	An Apparatus for measuring the vapour lock of Gasoline.	Velde Schaub	20. 6.40.
9.	P102.	Supercharged tests with the NSU 501.OSL Engine.	Schaub	5. 9.40.
10.	P103.	Comparison of SS oil with other Diesel Oils with respect to Nozzle Coking.	Schaub	5.10.40.
11.	P104.	Tests with fuels of different density.	Schaub	9.12.40.
12.	P105.	The Development of an Engine Test Method for Aero Engine Oils in the NSU 501.OSL Engine.	Schaub	14.12.40.
13.	P106.	The Testing of some Aviation Oils in the NSU Aviation Oil Test Engine.	Schaub	20.12.40.
14.	P107.	Testing synthetic Aviation Oils of Low Pole Height.	Schaub	24.12.40.

ITEM NO.	REPORT NO.	TITLE.	AUTHOR(S)	DATE
[illegible]	[illegible]	SECRET Report on Engine Testing of [illegible] Synthetic Aero Engine Oils.	Schaub	10. [illegible] .41
[illegible]		Evaluation of Fuels for Vapour Lock troubles in an engine	Schaub Velde	[illegible]
[illegible]	[illegible]	Report on the Engine testing of the synthetic Aviation Oil K1860 (Japan[illegible])	Schaub	15. 5. 41
[illegible]	[illegible]	The Development of an Engine Test for Lubricating Oils in relation to Pisto[illegible]	Schaub	6. 5. 41
[illegible]	[illegible]	SECRET. Report on Engine Tests of Synthetic Aviation Oil K.1880.	Schaub	7. 7. 41
[illegible]	[illegible]	Testing various Wehrmacht Standard Oils for Piston seizure in the Triumph Engine	Schaub	[illegible]
21	[illegible]	Comparison of Supercharge Tests in the NSU Engine of Ruhrbenzin and the BMW 132 Engine of the Tec.Prufstand, Oppau.	Schaub	6. 9.41.
22.	-	Extract from a report on Tests with Gear Oils by the Rheinmetall-Borsig A.G.	Schaub	30.10.41.
23.	P114.	Engine Tests of the Aviation Oil K.1929.	Schaub	7. 1.42.
24.	P116.	Influence of Viscosity and various additives on the behaviour of synthetic Oils in Engine Tests in relation to Piston seizure.	Schaub	12. 1.42.
25.	P115.	Development of a Test for Engine Oils relative to Piston Seizure.	Schaub	15. 1.42.
26.	P117.	Testing 4 Engine Oils for Piston Seizure.	Schaub	29. 1.42.
27.	P118.	Ease of Ignition of R.C.H.Cetane.	Schaub	30. 3.42.
28.	P119.	SECRET. Oil Testing in a NSU Engine.	Schaub	25. 4.42.
29.	P120.	Dilution of Engine Oils for Winter Operation.	Schaub	22. 5.42.

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[illegible]IOF NO	[illegible]EPT NO	TITLE.	[illegible]UTHOR	D[illegible]TE
[illegible]		Report on Lubrication abilit[illegible]		[illegible]
[illegible]		[illegible] Engine Tests		
[illegible]		On the Question of the D[illegible]termination [illegible] Asphalt Contents in Aged Lub. Oils.		
[illegible]		Wor[illegible]ing [illegible]ut a method for tes[illegible]ing [illegible]		
[illegible]		The beha[illegible] of [illegible] Aviation an[illegible] Autom[illegible]tive En[illegible] [illegible]	[illegible]	
15	[illegible]	[illegible]		
16	[illegible]	Avi[illegible]tion [illegible]il Blend [illegible]1951 fr[illegible]m RCH [illegible] and a low [illegible]	[illegible]	[illegible]
17	[illegible]	Evalu[illegible]tion of [illegible]he "WA T[illegible] (ME96 [illegible])	[illegible]	[illegible]
38.	-	Preliminary Report[illegible] Engine Oil Test No. 3370 (ME96 - Ester Oil)	Schaub	1. 7.42.
39.	-	Analytical investiga[illegible]ion of an Ester oil from I.G.Farben.	Rottig	28. 8.42.
40.	P125a.	Testing Engine Oil 3370.	Schaub	8. 4.43.
41.	P126.	Influence of viscosity on Oil Consumption.	Schaub	19. 9.42.
42.	P127.	On the lubrication effect of thin Engine Oils (Winter Oils).	Schaub	21. 9.42.
43.	P128.	Aviation Oil 3344 from the Main Plant.	Schaub	6.10. 42.
44.	P129.	Aviation Oil 1979 from the Main Laboratory.	Schaub	4. 1.43.
45.	P130.	The Effect of Addition of Oppanol on the behaviour of Engine Oil.	Schaub	27. 2.43.
46.	P131.	The Influence of Oppanol addition on wear.	Schaub	11. 3.43.

RUHRCHEMIE REPORTS.
(continued)

[illegible] N	RPT. [illegible]	TITLE	[illegible]UTHOR(S)	[illegible]ATE
[illegible]	[illegible]	Aviation [illegible]il [illegible]lend K1951/2 made from [illegible] new Bright Stock and Nerag [illegible]	Schaub	[illegible]
[illegible]	[illegible]	Investigation of Engine Oil 3698	Schaub	12. [illegible]
[illegible]	[illegible]	[illegible] of Engine Oil from Nerag (N[illegible]	[illegible]	[illegible]
	[illegible]	Investigation of a Nerag [illegible] winter oil (new Reference [illegible] N[illegible]	Schaub	[illegible]
	[illegible]	Investigation [illegible] 3 [illegible] [illegible]	Schaub	[illegible]
[illegible]	[illegible]	Starting I.C. Engines at Low Temperatures	Schaub	[illegible]
	[illegible]	Investigation of the [illegible] new Research Laboratory	Schaub	[illegible]
[illegible]	[illegible]	Testing Engine Oil 3993 in relation to Piston Seizure.	Schaub	17. 9.43
55.	P140.	Knock measurement of Synthesis-Benzin dependent on the Ignition system.	Schaub	1.11.43.
56.	P141.	On the pumping behaviour of lubricants at low temperatures.	Schaub	29.11.43.
57.	P143.	Cranking Test with Rumanian Oil.	Schaub	29.12.43.
58.	P144.	Testing an Aero Engine Lubricant SS1060 for Piston seizure.	Schaub	7. 3.44.
59.	P145.	The foaming of Lubricating Oils.	Schaub	17. 3.44.
60.	P146.	Testing the Aviation Oil sample K2015 of "Molaj".	Schaub	17. 6.44.
61.	P147.	Starting I.G.Engines at low temperatures 2. Intermin Report.	Schaub	27. 6.44.
62.	P148.	Testing Gear Oils for heat stability.	Schaub	29. 8.44.
63.	P149.	Preliminary Tests with the 4 Ball Apparatus.	Becker & Schaub	26. 9.44.

CIOS NO.	REPT. NO.	TITLE.	AUTHOR(S)	DATE
64	F150.	Cold Testing [illegible] AK7-200.	[illegible]	?.9.44
65.	F151.	The Evaluation of [illegible] Wear in an Engine.	[illegible]	15.11.44
66	F152	Ageing Behaviour of the Avi [illegible] (with [illegible] bright stock [illegible]		
67	F153	Comparison of Synthetic Residue and Distil[illegible] Oil of simila[r] Viscosity for Clarifica[tion] the effect of Bright Stock Components [illegible]		
68	F154	Testing various E.P. additions to Current Synthesis Oil, com[b]ine[d] with [illegible] on Various [illegible] ability.	Schaub	2.11.44.
69.	F155.	Tests with Fuels of Different [illegible]	Schaub	16.?1.44.
70.	F156.	Report on the incomplete [illegible] Test	Schaub	1?.?.45.
71.	P157.	Report on the Vapour Lock Correlation Test of the OKH.	Schaub	14.2.45.

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CIOS NO.	REPT. NO.	TITLE.	AUTHOR(S)	DATE
72.	75.	On the attack of Anti-Freeze materials on Metal and Rubber. (Staatlichen Material-prufungsamt, Berlin-Dahlem).	Schikorr & Alex.	
73.	52.	The State of Knowledge on Mixture Formation in I.C. and Diesel Engines. (T.H. Dresden).	Zinner.	
74.	96/1941.	Test on the Use of Power Gas in the Pure Diesel Process (T.H.Dresden).	Dreyhaupt.	
75.	94/1941.	Bomb Tests on Mixture Formation and Combustion with Gasoline Injection (T.H.Graz).	Bianchi	
76.	58.	Knock Processes in Multi-Cylinder Engines (T.H.Munich).	Schmidt & Regel.	
77.	99/1941.	Tests with a Carburettor Engine with Self Ignition (T.H.Stuttgart).	Ernst & Dorr.	

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CIOS NO.	DEPT. NO.	TITLE.	AUTHOR(S)	DATE
79	74.	Tests on the Engine Behaviour of Synt[illegible] I.C. [illegible] ([illegible] [illegible]tuttgart).	Kamm	
[illegible]	[illegible]	Engine Method [illegible] ([illegible] Stuttgart)	Ernst [illegible]	
8[illegible]	86.	[illegible]he Position of 2 Str[illegible]ke [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	2 Meeting of the W[illegible] [illegible]stroke [illegible]		[illegible]
[illegible]	[illegible]	2. Meeti[illegible] [illegible] the W[illegible]rki[illegible]g Group [illegible]		[illegible]
[illegible]	[illegible]	Power [illegible] Engines	D[illegible]	[illegible]
		New Oil [illegible] Bearing	Huber & [illegible]	[illegible]
		Investigation of the Exhausting of the Combustion Chamber of High Speed Diesel and I.C. Engines.	Bisang.	
86.	Vol.5.	Contribution to the Exploration of the Combustion Process in High Speed Diesel Engines.	Kneule.	1938
87.	Vol.29.	Cylinder and Piston Ring Wear.	Beck.	1939
88.	Vol.31.	Measurement of Knock Resistance in I.C.Engines.	Schutz.	1939
89.	Vol.33.	Investigation of Knock Clatter of I.C.Engines with an Electro-Acoustic Measuring Apparatus.	Schmidt & Generlich.	1939
90.	Vol.34.	Mechanical Losses of the High Speed Diesel Engine and their Determination with the Towing Test (Schleppversuch).	Ullman.	1939
91.	Vol.52.	Comparative Investigation of Bearing Shell Materials.	Heidebrock & Doring.	1941.

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CIOS NO.	REPT. NO.	TITLE.	AUTHOR(S)	DATE
92 [illegible]	[illegible]	Injection of Fuels in the Diesel [illegible] Ignition Delay Measurement b[illegible] means Photo Cells in various [illegible]	[illegible]	[illegible]
93	Vol.54.	Detection of Lubricating Film brea[illegible] by Measuring the Electrical Res[illegible] between [illegible]	[illegible]	
94 [illegible]	[illegible]	Fuel and Engine [illegible] the [illegible] Automotive [illegible]	[illegible]	
95	Vol.57	Fuel Preparati[illegible]		
96 [illegible]	[illegible]	The Lub[illegible]icant [illegible] Special [illegible]		
97	Vol.60	The Operation with Liqui[illegible] Flushed [illegible] Engine [illegible]	[illegible]	[illegible]
98.	Vol.61.	The Scavenging Process on the Basis of a new Conception of Expansion [illegible]	Schultz [illegible]	[illegible]
99.	Vol.62.	Increased Loading of 4-stroke Diesel Engines. The Scavenging Process.	Riedel.	1941
100.	Vol.63.	Ignition Delay and the Evaluation of Fuels Ignition Delay Measurement of Diesel and I.C.Engine Fuels.	Ernst Widmaier.	1941
101.	Vol.76.	Influence of Air Swirl on the formation of Fuel Stream in the Swirl Chamber.	Sauberlich.	

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CIOS NO.	REPT. NO.	TITLE.	AUTHOR(S)	DATE
102.	2363.	Method for Cetane Number Determination of Diesel Fuels.	Lange.	18.11.41.
103.	2337.	SECRET. Behaviour of Aviation Fuels at High Altitude.	Cinssmann.	18. 4.42.
104.	2485.	Sludge Formation in Aero Engine Oils.	Baier et al.	20.7.42.
105.	2525.	Circulation of Lubricating Oil in an Engine with Low Temperature Resistant Aero Engine Oil.	Muller & Baier.	12. 2.43.
106.	2363.	Determination of Cetane Number of Diesel Fuels (with the Inertia Indicator according to Dr.Neumann).	Starke.	1. 4.44.

[illegible]RTS BY THE PHYSIKALISCHE-TECHNISCHEN REICHSANSTALT

[illegible]ION NO	[illegible]	TITLE.	AUTHOR(S)	DATE
[illegible]		Development [illegible] [illegible]meter.	[illegible]	[illegible]

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[illegible]		[illegible] for (Clarification of) Terminology [illegible] [illegible] on Aviation Fuel Problems.	[illegible]	[illegible]

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		Evaluation of Fuels in relation to [illegible] [illegible] Troubles (Dresden).	Hager & v.Eberan.	
		Mixture Formation in Otto Engines at [illegible] ing Fuel Vapour Tension and Starting [illegible] at Low Temperatures (Dresden).	Werminghof v Schiaev [illegible]	
[illegible]		Tests to Determine the Pressure Stability of Lubricating Oils (Doctor Thesis, Berlin)	[illegible]	
[illegible]		Investigation of the Lubricating Ability of Oils (Munich).	Kadmer.	May 1944.
114.	-	Gear Tests at 150°C. Oil Sump Temperature (Stuttgart).	Wellinger.	5. 8.44.
115.	392.	Investigations on the Development of Self Ignition-Operation in a mixture Compressing Engine (Stuttgart).	Ernst & Dorr.	29. 3.41.
116.	-	Tests on the Heat Stability of Gear Lubricants in respect of the new Uncompounded Gear Oils.	Wellinger.	9. 5.44.

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117.	VB532b.	Establishing the Limiting Flow Temperature of Lubricating Oils.	Paul & Richter.	30. 6.43.
118.	VB540a.	Devélopment of a Test Method for Determining the Low Temperature Behaviour of Lubricating Oils.	"	13. 3.44.
119.	VB541a.	Investigation of the Heat Stability of Wehrmacht 8E Gear Oil.	"	13. 3.44.
120.	VB542a.	E.P.Oil (Hypoid Oil for Highly Loaded Operation).	Richter,Paul & Urlass.	14. 3.44.

CIOS NO.	REPT. NO.	TITLE.	AUTHOR	
		INTAVA.		
121	[illegible]	Testing Aero Engine Oils in the DKW Eng[illegible]	[illegible]	
		Evaluation of Test [illegible] the BMW Oil Test [illegible] relation to Oil Coke [illegible]		
		RHENANIA - OSSAG.		
[illegible]		Pump Type Apparatus [illegible] Indicating the [illegible] [illegible]	[illegible]	
[illegible]	[illegible]	Investigation of G[illegible] at Low Temperatures	Zogb[illegible]	
		Pump Circulation T[illegible] at Low [illegible] (Wehrmacht Gear Oil [illegible] Winter)	[illegible]	
[illegible]	[illegible]	Preliminary Test for [illegible] at Low Temperatures	Zogbaum	
[illegible]	[illegible]	Testing Wehrmacht Gear Oil 8r [illegible] ability at Low Temperatures.	Zogbaum	
128.	11.	Standardizing the Modified Pump Type Apparatus and Construction of a Curve for Pumpability at Low Temperature.	Zogbaum & Zander.	[illegible] 1.43.
129.	14.	Testing the Reference Batch of Wehrmacht 8R Gear Oil for Pumpability.	Zogbaum & Schauer.	[illegible] 1.44.
130.	18.	Comparison of the Old Model Pump Type Apparatus with the new Model.	Zogbaum.	[illegible]4
		I.G.FARBEN, OPPAU.		
131.	-	The I.G.Prufdiesel for Measuring the Ease of Ignition of Fuels.	[illegible]	[illegible] 42.
132.	-	Origination and Object of Use of the Test Engine K.	-	[illegible] 42.
133.	-	Drawings from I.G. Oppau Rept. No.478.	-	
134.	-	" " " " " " 542.	-	
135.	-	" " " " " " 518.	-	

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[illegible]	[illegible]	SECRET. A contribution to the Testing of Knock Behaviour of Aviation Fuels in Small Engines.	[illegible]chakov	25.[illegible].41
		The carrying out of Octane Number Determination according to the Oppau Method.	[illegible]	[illegible]

JUNKERS (?)

		Influence of Lubricant and Fuel on Deposit Formation and Gas Ring Wear (in a [illegible] cylinder Diesel Engine, Jumo 205).	[illegible]	[illegible]

DAIMLER BENZ.

		Cranking Tests [illegible] Winter Oils.	[illegible]	[illegible]
		Cranking Tests at - 20 [illegible] New Wehrmacht Winter Oils.	"	[illegible]
		Standards for Cranking Tests for Evaluation of the Startability of Engine Oils at Low Temperatures.	"	[illegible]

ADAM OPEL A.G.

142.	S.713.	Cold Starting Tests with Wehrmacht all-the-year-round Oil. (Standard Diesel of the Wehrmacht, HWA526).	Gorissen.	15.1.43.
143.	Z.804.	Cold Starting Tests with Wehrmacht all-the-year-round Oil. (Mayback Engine HL62TR).	"	31.1.41.
144.	-	Cold Starting Tests with Wehrmacht all-the-year-round Oil. (BMW 2 Ltr. Engine Type 326).	"	14.7.41.

RHEINMETALL BORSIG.

145.	-	Testing 14 Uncompounded Gear Oils.	Heimann.	15.2.42.

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146.	-	Notes on the Meeting of the Working Committee (Knock Measurement in the I.G. and CFR Engines)	-	23.6.44.
147.	-	Special Committee for Standardising Engine Testing of Diesel Fuels by DVM.	-	22.9.42.
148.	-	Standard Method for Diesel Fuels.	-	18.1.41.
149.	-	Heating Oil Quality.	-	16.9.38.

CIOS NO.	REPT. NO	TITLE.	AUTHOR(S)	DATE

MISCELLANEOUS REPORTS.

15[illegible]		Technical Report on Standardizi[illegible] Engine Testing of Diesel Fue[illegible] (Klockner Humboldt Deutz).		
		Instruction f[illegible] Determining [illegible] Cumpability [illegible]		
		Instru[illegible]		

ORIGINAL GERMAN TITLES OF DOCUMENTS EVACUATED

FROM THE RESIDENCE OF DR.SCHAUB OF RUHRCHEMIE,A.G.

	Bericht uber Messergebnisse der Ruhrbenzin am HWA-Prüfmotor.	Schaub	[illegible]
	Bericht über Versuche zur Klarung von Unstim[illegible]keiten bei der [illegible] Bestimmung von [illegible] Kraftstoffen.	[illegible]	[illegible] 38
	Nachtrag zum Beri[illegible] [illegible] von 10.8.39.	[illegible]	[illegible]
	Zwischenbericht über die bisherigen Versuch[illegible] Prüfmotor des Forschungsinstitute für Kr[illegible] [illegible] und [illegible] Stuttgart.	Schaub	[illegible]
	Zwischenbericht Nr.2. [illegible] Opel 1.[illegible] ltr. Motor	Schaub	[illegible]
	Bericht über [illegible] Mischungen von [illegible] und Benzin.	Schaub	[illegible]
	Zwischenbericht Nr.3. Die Bedeutung der Motorischen Bedingungen bei der Erprobung von Schmierölen.	Schaub	19. 1.40.
8. P101	Ein Gerat zur Messung der Dampfblasenbilding von Benzin.	Velde Schaub	20. 6.40.
9. P102.	Überladeprüfung am NSU 501 OSL - Motor.	Schaub	5. 9.40.
10. P103.	Vergleich von SS-Stoff mit anderen Dieselölen in Bezug auf Düsenverkoken.	Schaub	5.10.40.
11. P104.	Versuche mit Kraftstoffen verschiedener Dichte.	Schaub	9.12.40.
12. P105.	Die Entwicklung eines motorischen Prüfverfahrens für Flugmotorenschmieröle im NSU 501 OSL-Motor.	Schaub	14.12.40.
13. P106.	Motorische Prüfung einiger Flugole im NSU-Flugol-Prufmotor.	Schaub	20.12.40.
14. P107.	Motorische Prüfung synthetischer Flugöle mit niedriger Polhöhe im NSU - Motor.	Schaub	24.12.40.
15. P108.	Geheim. Bericht über die motorische Prüfung synthetischer Flugmotorenschmieröle der Ruhrchemie.	Schaub	10. 1.41.

16.	-	Zur Beurteilung von Kraftstoffen hinsichtlich der Dampfblasenstörung am Motor.	Schaub & Veld	19. 2.41.
17.	P109.	Bericht über die motorische Prüfung des synth. [illegible] Flugöles KI860 [illegible]	[illegible]	[illegible]
18.	P110.	Die Entwicklung einer motorischen Prüfung [illegible] Schmieröle [illegible]	Schaub	[illegible]
19.	P111.	Geheim. Bericht über die motorische [illegible] des synthetischen [illegible]	[illegible]	[illegible]
	P112.	Prüfung verschiedener Einheitsöle [illegible] Wehrmacht im Triumph Motor hinsichtlich des [illegible]	[illegible]	[illegible]
		Überlade-Vergleichsmessungen im NSU-Motor der Ruhrbenzin A.G. und im BMW 132 Prüfmotor der [illegible]	[illegible]	[illegible]
		Auszug aus einem Bericht der Rheinmetall [illegible] A.G. [illegible] Versuche mit [illegible]	Schaub	[illegible].41
23.	P114	Motorische Prüfung [illegible] Flugöle [illegible] 1220	[illegible]	[illegible]
24.	P116.	Motorische Prüfung synthetischer Öle zur Beobachtung des Einflusses der Viskosität und verschiedener Zusätze auf das Verhalten beim Kolbenfressen.	Schaub	12. 1.42.
25.	P115.	Entwicklung eines Verfahrens zur Prüfung von Motorenölen hinsichtlich des Kolbenfressens.	Schaub	15. 1.42.
26.	P117.	Prüfung von 4 Motorenölen auf Kolbenfressen.	Schaub	29. 1.42.
27.	P118.	Zündwilligkeit von RCH-Cetan.	Schaub	30. 3.42.
28.	P119.	Geheim. Ölprüfung im NSU-Motor.	Schaub	25. 4.42.
29.	P120.	Verdünnung des Motorenöles für Winterbetrieb.	Schaub	22. 5.42.

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30.	-	Bericht über die Schmierfähigkeitsuntersuchungen (Lediney)	Lediney	3. 8.38.
31.	-	Humboldt - Deutzmotoren-Versuche.	?	20. 1.39.
32.	-	Zur Frage der Bestimmung des Asphaltgehaltes in gealterten Schmierölen.	?	30. 4.42.

33 F121. Zusarbeitung eines Verfahrens zur Prüfung von Motorenölen hinsichtlich Ringstocken, Alterung und Verschleiss. — Schaub — [illegible]

[illegible] Das Verhalten verschiedener handelsüblicher Flug ung Kraftwagenmotorenöl in Bezug auf das Kolbenfressen. — Schaub — 13.6.42.

[illegible] [illegible] Verdünnung der Motorenöle für Winterbetrieb [illegible] Einfluss auf das Kolbenfressen. — Schaub — [illegible]

[illegible] [illegible] Flugölmischung E1951 aus RCH-Brightstock und [illegible] niedrig viskosen mineralischen Komponenten. — Schaub — 10.9.42

[illegible] [illegible] Erprobung des Versuchsöles [illegible] (MM96 [illegible] der I.G.) — Schaub — [illegible]

[illegible] Vorbericht Motorenöl [illegible] 3370 (MM [illegible] Esteröl). — Schaub — [illegible].42

[illegible] Analytische Bearbeitung eines [illegible] I.G.-Farben. — Rottig — 28.8.42.

40 F125a. Erprobung des Motorenöles 3370. — Schaub — 8.4.43.

41. P126. Der Einfluss der Zähigkeit auf den Ölverbrauch. — Schaub — 19.9.42.

42. P127. Über die Schmierwirkung von Dünnflussigen Motorenölen (Winteröle). — Schaub — 21.9.42.

43. P128. Flugöl 3344 von der Grossanlage. — Schaub — 6.10.42.

44. P129. Flugöl 1979 von Hauptlabor. — Schaub — 4.1.43.

45. P130. Die Wirkung von Oppanolzusatz auf das Verhalten von Motorenöl. — Schaub — 27.2.43.

46. P131. Der Einfluss von Oppanolzusatz auf den Verschleiss. — Schaub — 11.3.43.

47. P132. Flugölmischung K1951/2 aus inhibiertem RCH-Brightstock und Neragöl. — Schaub — 8.4.43.

48. P133. Untersuchung des Motorenöles 3698. — Schaub — 12.4.43.

49. P134. Unteruschung des Motorenöles der Nerag (N.1) — Schaub — 12.4.43.

50. P135. Untersuchung eines normalen Wehrmacht-Winteröles der Nerag (RCH-Kurzbezeichnung: N.2) — Schaub — 4.5.43

RUHRCHEMIE REPORTS
(continued)

51.	P136.	Untersuchung von 3 Winterölen der I.G.Farbenindustrie A.G. Ludwigshafen Ma46, Ma48 und Ma[illegible]	Schaub	5. 5.43
52.	P137.	Anlassen von Otto Motoren bei Tiefen Temperaturen.	Schaub	29. 6.43.
53.	P138.	Untersuchung des Motoröles E[illegible] vom Forschungslabor RCH.	Schaub	6. 7.43
54.	P139.	Prüfung des Motorenöles 3993 in Bez. auf Kolbenfressen.	Schaub	7. 9.43
55.	P140.	Die Klopfmessung von Synthese-Benzinen Abhängig von der Zündeinstellung.	Schaub	1.11.43
56.	P141.	Über das Pumpverhalten von Schmierstoffen [illegible] tiefen Temperaturen.	Schaub	29.11.43.
57.	P143.	Durchdrehversuche mit Rumanienöl.	Schaub	20.12.43
58.	P144.	Prüfung eines Flugmotoren-Schmierstoffes SS1060 auf Kolbenfressen.	Schaub	7. 3.44.
59.	P145.	Die Schaumbildung bei Schmierölen.	Schaub	17. 3.44.
60.	P146.	Prüfung der Flugölprobe K2015 der Molaj.	Schaub	17. 6.44.
61.	P147.	Anlassen von Otto-Motoren bei tiefen Temperaturen 2. Zwischenbericht.	Schaub	27. 6.44.
62.	P148.	Prüfung von Getriebeölen auf Hitzebestandigkeit.	Schaub	29. 8.44.
63.	P149.	Vorversuche im Vierkugelapparat.	Becker & Schaub	26. 9.44.
64.	P150.	Kalteprüfung von Getriebeölen im Schaltgetriebe AK 7-200.	Schaub	29. 9.44.
65.	P151.	Die Beurteilung von Schmierstoffen nach dem Verschleiss im Motor.	Schaub	15.11.44.
66.	P152.	Alterungsverhalten der Flugölmischung K2025 (mit RCH-Brightstock, nicht inhibiert).	Schaub	19.10.44.
67.	P153.	Vergleich von synth.Rückstans-und Destillatöl gleicher Zahigkeit zur Klarung der Wirkung des Brightstock-anteils.	Schaub	21.10.44.

RUHRCHEMIE REPORTS
(continued)

[illegible] Erprobung verschi[illegible]er Hochdr[illegible]ckzusätze zu normalen synthe[illegible] mit Unt[illegible] Über ver[illegible] — Schaub [illegible]

[illegible] 1155 [illegible] — Schaub 16 [illegible]

[illegible] Versuch[illegible] — Schaub [illegible]

[illegible]

[illegible] KRAFTFAHRT FORSCHUNG

[illegible] Motor[illegible] — Schm[illegible] & [illegible]

[illegible] Stand [illegible] der Gemisch[illegible] — [illegible]

[illegible] Versuche zur [illegible] Diesel[illegible] — Dreyhaupt.

75.94/1941. Bombenversuche üb[illegible] Gemischbildung und Verbrennung bei Benzineinspritzung (T.H.Graz). — Bianchi.

76. 58. Klopfvorgänge an Mehrzylindermotoren (T.H.München) — Schmidt & Regel.

77.99/1941. Versuche an einem Vergasermotor mit Selbstzündung (T.H.Stuttgart). — Ernst & Dorr.

78. 74. Versuche über das motorische Verhalten synthetischer Ott[o]-Kraftstoffe (T.H.Stuttgart). — Kamm.

79. 54. Motorisches Verfahren zur Prüfung von Dieselkraftstoffen (T.H.Stuttgart). — Ernst & Gross.

80. 86. Der Stand der Zweitaktforschung. — (Various) 6. 6.40.

81. 91. Gemischbildung und Verbrunnung (Diesel). — " 1.10.40.

82.103/1941. 2.Tegung des Arbeitskreises fur Zweitaktfragen. — " 20. 5.41.

83.111/1942. 2.Tagung des Arbeitskreises fur Fragen der Motorischen Verbrennung. — " 10.10.41.

84.Heft 3. Leistung und Wirtschaftlichkeit gasgetriebener Fahrzeugmotoren. — Rixmann. 1938

DEUTSCHE KRAFTFAHRT FORSCHUNG
(continued)

[illegible] Heft 4. Frischolschmierung beim Pleuel-Gleitlager (Huber & Eiberger) [illegible]
Untersuchungen an Fahrzeugdieselmotoren. ([illegible] & [illegible])

Untersuchung der Ausstrahlung des Verbrennungsraumes schnellaufender Diesel-und Ott[illegible] — [illegible]

86. Heft 5. Beitrag zur Erforschung des Verbrennungsvorganges im schnellaufenden Dies[illegible] — Knoul[illegible] — 1938

87. Heft 29. Zylinder und Kolbenringverschlei[illegible] — Beck. — 1939

88. Heft 31. Messung der Klopffestigkeit an Otto Motoren. — Schmitz. — 1939

[illegible] Heft 33. Untersuchung der Klopfgeräusche von Ottomot[illegible] mit elektroakustischen Messgeräten. — Schmidt & [illegible] — [illegible]

[illegible] Heft 34. Die mechanischen Verluste des schnellauf[illegible] Dieselmotors und ihre Ermittlung mit dem Schleppversuch. — Ullman. — 1939

91 Heft 52. Vergleichende Untersuchungen an Lagerschalenwerkstoffen. — Heidebroek & Doring. — 1941

92. Heft 53. Das Aufspritzen des Kraftstoffes im Dieselmotor. — Blume. — 1941
Zundverzugsmessung mittels Photozellen in verschiedenen Wellengebiten. — Stallechner.

93. Heft 54. Nachweis der Schmierfilmdurchbrechung durch Messen des elektrischen Übergangwiederstandes zwischen Kolbenring und Zylinder. — Poppinga. — 1941

94. Heft 55. Kraftstoff und Motor beim Anlassen von Fahrzeug-Dieselmotoren. — Bixmann, Schaub & Conrad. — 1941

95. Heft 57. Kraftstoffaufbereitung durch die Einspritzdüse. — Oschatz. — 1941

96. Heft 59. Das Schmiermittel im Zahnradgetriebe unter besonderer Berucksichtingung der Grenzreibung. — Pietsch. — 1941

97. Heft 60. Der Betrieb gemisch-Gespülter Zweitaktmotoren mit Flüssiggas. — Schmidt. — 1941

98. Heft 61. Der Spülvorgang auf Grund einer neuen Auffassung der Expansionsströmung. — Schultz-Grunow & Weighardt. — 1941

99. Heft 62. Aufladeborgang von Viertaktdieselmachinen der Spülvorgang. — Riedel. — 1941

Heft ... Zündverzug und Bewertung des Kraftst... Zündverzugsmessungen an Diesel-und Ottokraftstoffen. — Trost ...

Einfluss der Luftbewegung auf die Ausbildung des K... der Mittelkammer.

REPORTS BY THE ERPROBUNGSSTELLE ...

Verfahren zur Cetanz... Dieselkraftstoffe ...

Geheim. Verhalten ... beim ...

... — Beier et al

Schmierölförderung im "Motor bei Kältebeständigen Flugmotorenölen. — ...ller & ...

Cetanzahlbestimmung von Dieselkraftst... (mit ... nach Dr. Neumann) ...

REPORTS BY THE PHYSIKALISCH-TECHNISCHEN REICHSANSTALT.

107 - Entwicklung und Prüfung eines Kälteviskosimeters. — Willenberg. 1944

DVL REPORTS.

108 - Vorschläge für die Beschlussfassung. — Phillipovich. 13.5.42.

109 - Aussprache über Kraftstoffprobleme der Luftfahrt. — 17.6.41.

REPORTS FROM TECHNISCHE HOCHSCHULE.

110 - Kraftstoffbewertung hinsichtlich Dampfblasenstörung (Dresden) — Hager & v.Eberan. 30.3.44.

111 - Gemischbildung im Otto-Motor beim Anlassen, Kraftstoff-Dampfspannung und Anlassverfahren bei Tieftemperaturen (Dresden) — Werminghoff, v.Schieszl & Hanse. 1.12.43

112 - Versuche zur Bestimmung der Bruckbestandigkeit von Schmierölen (Doktor-Arbeit:Berlin) — de Jong. -

113 - Untersuchung der Schmierfähigkeit von Oelen (München) — Kedmer. May 1944

REPORTS FROM TECHNISCHE HOCHSCHULE (continued)

114. - Zahnradversuche bei Oelsumpftemperaturen von 150°C. (Stuttgart) — Welling [illegible] .5.3.44

Untersuchungen zur Entwicklung der Selbstzundung betriebs im gemisch verdichtenden [illegible] (Stuttgart). — Ernst [illegible]

Versuche uber die Hitzebeständigkeit der [illegible] schmiermittel unter Einbeziehung [illegible]. — Well[illegible]

REPORTS BY OTHER COMMERCIAL COMPANIES.

DEUTSCHE [illegible]

[illegible] Herstellung der [illegible] — [illegible]

[illegible] Entwicklung von Versuchseinrichtungen und Verfahren zur Bestimmung des [illegible] — 13.3.44

[illegible] Untersuchung der Hitzebeständigkeit von Getriebeölen [illegible] — " — 13.3.44

120. VR542a. Hochdruck Öle (Hypoidöle fur Hochbelastete Antriebe). — Richter, Paul & Urlass — 14.3.44

INTAVA

121. 10. Prüfung von Flugmotorölen in DKW-Motor. — Wenzel. — 20.3.41.

122. 30. Auswertung der Versuche im BMW-Ölprüfmotor hinsichtlich Ölkohlebildung. — Wenzel. — 30.9.43

RHENANIA - OSSAG

123 - Pumpapparatur zur Kennzeichnung des Kälteverhaltens von Motoren-und Getriebeölen. — Rossig. — 25.4.44

124 3 Untersuchung von Getriebeölen auf Pumpfähigkeit in der Kälte. — Zogbaum & Deberitz — 1.7.42

125 5 Umpumpversuche in der Kälte (Getriebeöl der Wehrmacht-Winter). — Hofmann. — 25.9.42

RHÉNANIA - OSSAG
(continued)

1[illegible]7. Vorversuche für Pumpfähigkeit von Getriebeölen in der Kälte. — Zogbaum & [illegible]eberitz — 30.4.43.

[illegible] Prüfung [illegible]on [illegible]etriebeolen der [illegible]ehr[illegible] [illegible] auf Pumpfähigkeit in der Kä[illegible]. — Zogbaum [illegible]

[illegible] Eichung der [illegible]geänderten Pumpappar[illegible] und Anlagung einer Kälteenpumpfähig[illegible]keits Kurve. — Zogbaum & Zander. — [illegible]

[illegible] Prüfung der als Eichöl zurück-gestellten Getriebeöle [illegible] [illegible] auf Pumpfähigkeit. — Zogbaum & [illegible] — [illegible]

[illegible] Pumpapparatur alte [illegible] [illegible] [illegible]

I.G.FARBEN, OPPAU.

[illegible] Der I.G.Prüfdiesel zur Messung [illegible] [illegible]willigkeit von Kraftstoffen — [illegible]

[illegible] Entstehung und Verwendungszweck des Versuchsmotors K. — 27.2.42.

133. - Drawings from I.G.Oppau Rept.No.487. — - — -

134. - " " " " " " 542. — - — -

135. - " " " " " " 518. — - — -

136.474.Geheim Ein Beitrag zur Prüfung des Klopfverhaltens von Flugkraftstoffen in Kleinmotor. — Witschakowski. — 25.8.41.

137.489.Die Durchführung von Oktanzahlbestimmungen nach dem Oppauer Verfahren. — Singer. — 22.1.42.

JUNKERS(?)

138.2037.Einfluss von Schmierstoff und Kraftstoff auf Ruckstandsbildung und Feuerringverschleiss (im Einzylinder-Diesel-Motor Jume 205). — Sauermilch. — 12.5.43.

DAIMLER-BENZ.

139. - Durchdrehversuche mit neuen Winterölen der Wehrmacht. — Hohensee. — 21.9.42.

DAIMLER-BENZ (Continued)

14[illegible]. Durchdrehversuche mit neuen Winterölen der Wehrmacht bei -20°C.

Richtlinien für Durchdrehversuche [illegible] Beurteilung [illegible]

ADAM OPEL A.G.

Kaltstart Versuche mit Einheitsöl der Wehrmacht [illegible] Kw.526).

Kaltstart Versuche mit Einheitsöl der Wehrmacht (Maybach [illegible] TR).

Kaltstart Versuche mit Einheitsöl de[illegible]

RHEINMETALL BORSIG.

[illegible]

MISCELLANEOUS REPORTS.

146. - Niederschrift über die Sitzung des Arbeitsausschusses "Klopfmessungen im I.G. - und C.F.R.Motor". - 23. 6.44.

147. - Sonderausschuss zur Normung der motorischen Prüfung von Dieselkraftstoffen beim DVM. - 22. 9.42.

148. - Einheitliches Verfahren fur Dieselkraftstoffe. - 18. 1.41.

149. - Heizölbeschaffenheit. - 16. 9.38.

150. - Technischer Bericht zur Normung der Motorischen Prüfung von Dieselkraftstoffen (Klockner-Humboldt-Deutz). - 11. 4.42.

151. - Arbeitsvorschrift zur Bestimmung der Pumpfähigkeit von Heizölen. - -

152. - Gebrauchsanweisung für den Kathoden-Doppelstrahl-Ossillographen (Quarz-Indikator). Nier, -

APPENDIX 2.

Wartime Activities of the Ruhrchemie Engine Laboratories at Sterkrade-Holten.

Report by Dr [illegible]

Auto-Engine Fuels

1. Knock Rating.

The knock properties of Fischer Tropsch product were continually under examination. The station took part in collective work on the improvement of the precision and repeatability of knock rating methods with the I.G. and C.F.R. engines. Special investigation of the varying behaviour of synthetic benzine in I.G. and C.F.R. engines was instituted after the engine method had been adopted. This work has not been completed. It has been shown, however, that synthetic benzin is less sensitive to change [illegible] on the reference fuels.

Under investigation during: 1939 - 1944
Research Reports [illegible]

2. Vapor Locking.

Little is known about the relation between the formation of bubbles of vapor (vapor locking), under actual running conditions and the usual laboratory test methods (Reid Vapor Pressure and 15% evaporated temperature). Research was, therefore, carried out at the station on vapor locking using commercial automobile engines under various working conditions. Based on this work, apparatus was evolved which duplicated practical conditions as exactly as possible. It is described in ATZ, 1941, Number 22. In the same connection, various engine factors were examined, e.g., fuel consumption, delivery-pump performance, etc. The research showed that fuel behaviour cannot be wholly necessary to construct a curve corresponding to the various working conditions. Under certain conditions a satisfactory enough agreement with the earlier evaluations can be obtained, i.e., according to the Reid V.P. or to a point on the boiling range curve. These comparison trials are not yet concluded.

Under investigation during: 1939 - 1944
Research Reports : P101 & P157

3. <u>The Influence of Fuel Density on the Adjustment of the Fuel-Air Mixture in the Carburettor.</u>

Brief trials were made bearing on [illegible]'s. [illegible] mixtures [illegible] high [illegible] relative [illegible]

Under investigation in: 194[illegible]
Research report: [illegible]104.

<u>The Influence of Tetra Ethyl Lead on [illegible] and Ageing during [illegible]</u>

This was examined i[illegible] small number of trials [illegible] the results showed that lead [illegible] conditions of [illegible] [illegible]

[illegible]

The Influence of Boiling [illegible] Fuel Behaviour [illegible]

At the request of the [illegible] was carried out to determine whether raising the F.B.P. would entail any considerable disadvantages as regards wear and oil-dilution. The work is still incomplete. Results up to now show no appreciable differences on increasing the F.B.P. from about 180° to 215°.

Under investigation in: 1944.
Research report: P155 of 26/11/44.

B. <u>Aviation Fuels.</u>

For the examination of synthetic fuels a small scale engine installation was developed. An NSU four-stroke engine of 500 ml. swept volume was used. Mixture formation was by injection of the benzine into the inlet manifold. It was attempted to get an evaluation corresponding to that with the BMW 132 N-engine of the RLM, as regards performance, using the smallest possible quantity of fuel. Numerous comparison trials with the DVL and the I.G.Oppau Technical Station showed that an adequate agreement had in fact been attained.

Complete agreement, however, was shown to be too much [illegible]

[illegible] investigation during: 1939-1941 (development of the [illegible]ing installation)

[illegible] P102 Sept 1940). P113 " 1941)

The development of this installation permitted the examination and further development of synthetic aviation fuels obtained by catalytic cracking and polymerisation of Fischer Tropsch products. Fuels were obtained with a performance curve of the technical iso octane type i.e. with [illegible] in the [illegible]

Diesel Fuels.

The station co-operated in work on the improvement in cetane number measurement methods with the HWA engine (throttle method). Work on the special action of [illegible] ignitable Ruhrchemie diesel fuel on diesel engine combustion did not give any special results.

D. Lubricating Oils - Engine Lubricating Oil.

The development of suitable engine test methods was a prerequisite for further development in the quality of Ruhrchemie synthetic tubes. In order to give as comprehensive a picture as possible, lubricating oil testing covered the following points:

(i) Ageing
  (a) Increase in viscosity.
  (b) Other chemical changes.
  (c) Sludge formation.
(ii) Ring sticking.
(iii) Wear and lubricating properties
(iv) Piston seizure.
(v) Oil consumption.
(vi) Cold behaviour.
  (a) Cranking resistance.
  (b) Pumping behaviour.

* A lecture by Dr. Schaub at the DVL meeting of June 1941 "The Performance Test in the NSU Engine of the RCH-Oberhausen-Holten".

(i) Oil Testing.

To decrease the expense and time involved ~~and also because of the unavoidable straying in the~~ results of individual runs, it was decided to work with short runs in small scale engines. Thus the ageing behaviour was examined in a ten hour run with a NSU-501-OSL engine (air-cooled) at high and constant temperature. The thermal demands made on the oil were higher in this [illegible] with the RLM ring sticking test in [illegible] [illegible] can be seen from [illegible]

Under investigation	1939 1942.
Research reports:	F105, [illegible], [illegible], 10?, [illegible]
[illegible] by:	[illegible]

Chemical Change and Sludge Formation.

These were examined as under (i). The quantity of sludge was observed by centrifuging out it to the crank-web. The repeatability of result was not [illegible] There are no comparison tests with full size [illegible] apart from those with the RCH synthetic oil.

(ii) Ring-sticking Tests.

A test corresponding to that with the BMW engine was developed for the NSU-501-OSL engine. Although straying was still considerable, sufficiently good agreement was achieved with the BMW engine for our purpose. This is confirmed by results from different Luftwaffe testing stations (Rechlin & Travemünde).

(iii) Wear Test.

This test was combined with the ageing and sludge tests in a short 10 hour run. Only after a large number of trials was it possible to get more or less reproducible results from which conclusions could be drawn as to lubricating oil behaviour. Wear was estimated by weighing the piston rings. It was measured with run-in as well as new rings. With the latter, the absolute value is many times higher, as might be expected. The evaluation of the oil is the same, however. Experiments with a separately driven engine gave only a slightly lower wear than with a machine under load.

... far as comparison is possible, there is no fundament ... from the DVL results (experiments of Krieh ... engine).

... 1942 - 1944.
P105, P106, P107,
P108, P118, P1..
P121, ...

... Piston Seizure.

This test was developed using a high ... two stroke engine (Triumph BD 250 ml ... air ... led). Evaluation followed from an intermedi... series of results where the unknown ... with certain standard oils. Comparis... different oils gave good agreement ... carried out by another station for ... test is also comparatively reproducible ... trained personnel.

Under investigation from: 1940 - 1942.
Research reports: P110 May 1941,
P115 Jan 1942
Suggested by: HWA.

(v) Oil Consumption.

Measurement of oil consumption was combined with the ageing and wear tests by weighing the lubricant used during the test.

(vi) Cold Behaviour.

(a) Cranking Resistance. For cold tests a large cold chamber (base area about 6 x 9 m) and a small one (base area about 2 x 3 m) were erected. Cooling was brought about by a constant blast of cold air (-55° C.) from a Linde plant. The small chamber was especially suitable for engine tests. It was possible to cool an engine from room temperature to -40° in 5 hours. Engine behaviour could be observed from outside (measurement of r.p.m. engine temperatures actuation of the ignition adjustment and of the injection-quantity etc.). The engine could be started from outside by dynamometer. The insulating cover consisted of a bell shaped box, which could easily be removed or put into place during engine assembly.

Under investigation from: Nov.'42 - Summer '43.
Research reports: P137 June 1943.

(b) Pumping Behaviour. To examine this a special installation was constructed. The delivery rate, delivery pressure, suction and other quantities of interest were observed for a oil-pum driven a constant r.p.m. Observations could [illegible] de [illegible] different temperatures (down [illegible] [illegible] solid [illegible]

Investigation: 1943
Research reports: P141.
Requested by: [illegible]

The following problems [illegible] using the methods described above:

1. The testing and development of a syntheti aviation engine oil possessing good ageing and cold behaviour as well as the outstanding performance of synthetic oils with respect to ring-sticking wear, consumption and piston-seizure. In the course of [illegible] work an oil was made which possessed the following properties. [illegible] results agreed with those of R and Travemünde [illegible] (BMW 132 [illegible] engine and full size Argus engine):

Ring-sticking behaviour was more favourable than with well-known mineral or fatted oils (Rotring, ASM) and as good as with the synthetic aero oils used in Germany. Wear behaviour was better than with the mineral reference oil (Rotring) and as good as with the voltolised ASM aviation oil. As regards piston seizure, this RCH synthetic lubricating oil was better than any other product tested. The setting point was below -40°C. Good cold behaviour (cranking resistance and "pumpability") was confirmed by trials at Rechlin. The original weak point of synthetic oils, namely, a tendency to thicken during running was so far overcome that, during the RLM ring-sticking tests, absolutely no increase in viscosity was observed, in spite of the length of run. The latter was very long because of the good ring-sticking behaviour (tests at Rechlin and Travemünde). As regards sludge formation and engine-deposits, the oil also showed outstanding qualities.

Between the years 1939 and 1944, the pole-height was decreased from about 1.8 to 1.5 (1.52). At the same time there was a general tendency of the viscosity (at 50°) to decrease (from 22°E to 10°E).

[illegible] Investigation period: 1939 - 194[illegible].
Research reports: P106, P107, P108, P1[illegible]9, P111, P1[illegible]9.

[illegible] the behaviour of RCH synthetic [illegible]

[illegible] reports: P1[illegible], P1[illegible], P15[illegible].

[illegible] experiments of [illegible] carried out in connection with the questi[illegible] oils compared with residual oils [illegible] origin ([illegible] synthesis). The [illegible] not found to have any fundament[illegible] problem as of interest in view of [illegible]

[illegible] Investigation: 1944.
[illegible] reports: P1[illegible]

The Behaviour of Oils from Various Sources in the RCH Piston Seizure Test (see above)

The synthetic RCH lubricating oils behaved remarkably well, even better than fatted mineral aviation oils. Viscosity had no apparent influence, and in any case it could not be large. The usual mineral motor oils lie close together in a comparatively small range and their quality is adequate, except in high rating two stroke engines.

Research reports: P110, P112, P115, P117, P122, P129.

5. General research was carried out on the relation between wear and oil consumption on the one hand and viscosity on the other hand. This was done to ascertain what disadvantages might arise on lowering the viscosity to improve cold starting behaviour. As expected, it was shown that viscosity influenced consumption but not wear, which appeared to be practically independent of it.

Investigations: 1942.
Research reports: P126, P127.
Requested by: RLM.

6. The action of Oppanol was examined in connection with wear, oil consumption and cold behaviour (effect of viscosity index). The use of Oppanol is advantageous, at least with oil which is not too strongly used.

Investigation: Winter 194[illegible]/1943.
Research reports: P1[illegible], P1[illegible].
Requested by: [illegible]

7. The effect of lubricating oil dilution was investigated, also in connection with cold behaviour. Investigations were made under practical running conditions in the cells at the testing station. It was demonstrated that the use of motor fuels need not cause damage, because they rapidly volatilise, while the use of diesel oil can be dangerous in certain circumstances. Oil dilution is not favourable [illegible] piston-seizure.

Investigation: 194[illegible] (first half)
Research reports: P1[illegible].
Requested by: [illegible]

8. Extensive work was done on the cold behaviour of oils from various sources (Rumanian oil, oil with added Oppanol). The cold chamber was used and at the same time an attempt was made to find a connection between practical results and laboratory tests (Schweiger viscometer). The straying of results at low temperatures (near the setting pt.) was too great to allow definite conclusions to be drawn.

Under investigation during: 1943 - 1944.
Research reports: P130, P141, P143
Requested by: [illegible]

9. Fundamental research on the low temperature pumping behaviour of oils from various sources, was carried out in the apparatus developed by MCH and described above.

Investigation: 1943.
Research report: P141.

10. A complete record of work on engine-wear done at the station over a period of years is collected in Research Report P151.

11. At the request of the OKH, various oils were examined as to their general behaviour. The origin of these oils is unknown to us.

Research reports: P125a, P133, P135, P136, P139, P142.

12. A few experiments were carried out in connection with foaming. They showed the poor reproducibility of the results without indicating the explanation of this behaviour. None the less, differences between individual oils could be recognised. RCH-oils behaved well as regards foaming.

Research report: P150.

13. Gear Oils.

Work on the development of a synthetic RCH gear oil was in the preparatory stage. Some endurance tests for the examination of the heat stability of normal gear oils were carried out at a large gear testing station of the ZF firm, Friedrichshafen. Further, investigations were made using well-known lubricating oil testing machine (the Almen-machine and four ball apparatus). The development of a practical test in a motor-cycle back axle cone drive was also under way.

Investigation: 1944 (2nd half)
Research reports P148, P149.
Requested by: O.K.H.

14. Various.

Mechanical methods for the improvement of cold starting with auto engines at very low temperatures were tested in the small cold chamber. Benzine injection was used in this work.

Under investigation from: 1943- 1944.
Research report: P137, P147.

(Signed) ... Schaub.

Date: 23.8.45.

In the above report the following abbreviations are employed:-

BMW .... Bayerische Motoren-Werke.
DVL .... Deutsche Versuchsanstalt für Luftfahrt, Berlin, Aldershof.
RLM .... Reichsluftfahrtministerium.
HWA .... Heereswaffenamt.
E-Stelle .... Erprobungstelle.
VI .... Viskositätsindex.
ATZ .... Automobiltechnische Zeitschrift.
ZF Friedrichshafen. Zahnradfabrik Friedrichshafen.
RCH .... Ruhrchemie.

APPENDIX 3.

ANSWERS TO QUESTIONNAIRE BY HAGEMANN AND SCHAUB. DATED 23. 8. 45.

AVIATION FUELS.

Fuel Rating Methods.

[illegible] (a) small scale engine
(b) full scale s.c. aero engines?
(c) multicylinder aero engines.

Ruhrchemie used only small scale engines for testing aviation fuels (See accompanying report on work of the RCH research station). These engines have the advantages of cheapness and simplicity and in addition only require small test samples. Agreement with the official BMW 132 single cylinder engine was satisfactory, especially when bearing in mind the differences which exist between different aero engines of the same size in fuel evaluation.

Question 2. What relative importance is attached to rich mixture and weak mixture performance?

3. How is rich mixture performance measured?

4. How is weak mixture performance measured?

Answers. The use of rich mixtures is of especial importance with the aromatic aviation fuels common in Germany for they gave a much better performance with rich mixtures than with weak mixtures. The use of weak mixtures is important in reducing fuel consumptions. Fuel behaviour at rich and weak mixtures is measured by determining a performance curve.

Question 5. What work is in hand for the development of fuels having improved weak mixture characteristics?

Answer. Ruhrchemie always stressed the importance of iso-paraffinic fuels because of their favourable behaviour at weak mixtures. We therefore aimed at the manufacture of such a fuel by the Fischer-Tropsch synthesis and some success was achieved as instanced by catalytic cracking of Fischer-Tropsch products and polymerisation and hydrogenation of C_4 and C_5 fractions.

Question 6. To what extent is the C.F.R. Research, or similar method used, and why?.

Answer. This test is used as a preliminary evaluation of Knock-rating. Final evaluation was by the BMW single cylinder or other such tests.

Question 7. What degree of inter-correlation is obtained between small scale engines, single cylinder full scale aero engines, and multicylinder main engines?

Even aero engine single cylinders do not agree on fuel evaluation so that the agreement between small scale engines and aero engines is not good although it is considered satisfactory. We have no first hand knowledge of tests in multicylinder aero engines.

Question 8. What flight tests have been carried out to [illegible] the antiknock requirements of fuels?

Answer. No information available

Question 9. What reference fuels are used (a) under 100 octane number, or corresponding rating?
(b) over 100 octane number?

Answer. (a) I.G. Test benzine and Technical iso-octane.
(b) ~~I.G. Test benzine~~ and Technical iso-octane - leaded.

2. GERMAN AVIATION FUELS.

Question 1. To what specifications are C-3, B-4, and A-3 fuels produced?

Answer. Not known.

Question 2. What is the reason for the high aromatic content of the German C-3 fuel, and for its excessive margin of rich mixture performance? For what planes is this type of fuel specified?

Answer. Of the fuels originally developed and made available in Germany, the aromatic type hydrogenation products from bituminous coal had the best anti-knock value, particularly at rich mixtures, consequently this type of fuel was adopted by the Luftwaffe.

Question 3. From what components are C-3 fuels blended at the blending points?

Answer. Not known.

Question 4. What trouble has been experienced with fuels containing small amounts of water?

Answer. Not known.

Question 5. ~~What difficulties have been experienced with a high~~ aromatic fuels? (Effect on synthetic rubber, etc.)

Answer. No exact knowledge available. Believed to have poor behaviour at weak mixtures.

6. How important is gum stability considered? What gum inhibitors are used?

7. What trouble has been experienced with vapour lock due to excessive fuel volatility, and also to dissolved air? How were these troubles overcome?

8. To what extent are cracked fuels used for aviation purposes?

9. What work has been done on the development of safety type fuels?

Answers. No information is available.

Question 10. What engine studies have been carried out on the effect of engine factors, such as valve overlap, etc., on fuel performance, particularly at weak mixtures?

Answer. The results of tests are contained in a lecture by Dr. Schaub entitled "The Supercharged test in the N.S.U. engine of the Ruhrbenzin A.G., Oberhausen-Holten" given at a D.V.L. meeting in June 1941. Apart from this we have no other experience.

Question 11. What general methods are used for cold starting, and to what extent were special priming fuels used, and of what components did these consist?

Answer. Easily vapourised fuel was used and also lubricating oil dilution. Engine preheating was used at very low temperatures.

Question 12. To what extent was "run-out" fuel used in an effort to combat cold corrosion?

Answer. No information is available.

3. ANTI-KNOCK ADDITIVES.

Question [illegible] What factors decided the amount of lead to be incorporated in aviation fuels?

Answer. No precise information is available. Probably exhaust valve corrosion and sparking plug trouble are the deciding factors.

Question [illegible] What attempts have been made to [illegible] TEL beyond the present amount?

Answer. No information is available.

Question [illegible] What experience has been obtained on spark plug fouling, exhaust valve corrosion, etc? What effect has TEL on overhaul periods? Has any connection been found between type of oil, and cylinder head deposits?

Answer. No information is available as regards aero engines.

Question 4. What difficulties have been experienced with lead deposition in storage and what inhibitors, if any, were developed to cure this? Was any special test devised to evaluate lead stability.

Answer. No information is available at Ruhrchemie.

Question 5. What laboratory methods are used to determine lead content of a fuel?

Answer. Ruhrchemie use the ZB method due to Ullrich.

Question 6. What work has been carried out on alternative anti-knock agents?

Answer. No information is available.

Question 7. What work has been done on the development of new lead evacuants, and in what percentage of theoretical are they used?

Answer. Ruhrchemie has no experience in this matter. Experiments by the RLM and HWA using increased addition of ethylene bromide or chloride were, as far as is known to RCH, unsuccessful in practice.

Question 8. What experience has been obtained with water injection, or other supplementary booster fuel?

Answer. No information is available.

Question 9. Has any trouble been experienced due to cold corrosion as a result of the use of leaded fuels, and what steps were taken to combat such effects?

Answer. No information is available.

4. DETONATION RESEARCH

Question 1. What work has been done, and is in hand, on the rationalisation of factors controlling detonation, and on the fundamentals of combustion, e.g. Muhlner experiments?

Answer. See the accompanying research report.

Question 2. What experimental work has been carried out on pure hydrocarbons?

Answer. None by Ruhrchemie.

Question 3. What work has been done to investigate pre-ignition, and on the development of pre-ignition ratings of fuels?

Answer. See the accompanying research report.

5. GAS TURBINE FUELS

Question 1. What specifications are laid down for (a) Gas Turbine Fuels. (b) Flying bomb fuels. (c) Rocket fuels?

Answer. No information is available.

Question 2. What special requirements are necessary for these fuels and how have these requirements been met?

Answer. No information is available.

Question 3. What developments are under way in connection with fuels for these types of engine?

Answer. No information is available.

6. MOTOR FUELS.

Question 1.	What specifications were adhered to for military purposes, particularly in respect of knock rating, gum content, stability and vapour pressure, and what methods of test were applied. What changes in specification have occurred during the war, with dates of such changes?
Answer.	The army specification was:- Research O.N. 74, later motor O.N. 72; permissible gum-content - 10 mg./ml. ~~(evaporation method) ; Reid vapour pressure - 0.65 atm.~~ (Summer), 0.75 atm. (Winter).
Question 2.	Were any difficulties experienced when vehicles were operated on fuels with the higher lead concentration, such as the new tank fuel which was introduced towards the end of 1944 (2.5 - 2.75 ml./I.G.)? Was there any reason for eliminating entirely added aromatics from some of these blends? Was any change made either in composition or proportion of lead evacuants added to the Ethyl mix?
Answer.	RCH has no experience in this connection.
Question 3.	What were the compositions of the various types of automotive gasolines, and of the main basic components? What happened to the Fischer-Tropsch gasoline, and what was the source of the large quantities of unsaturates normally included in the blended gasoline?
Answer.	The composition depended on the availability of the following blending components: hydrogenation benzine, synthetic benzine, lime and foreign mineral oil benzine, benzol, alcohol. No fixed blending proportions were maintained.
Question 4.	What effect did the cessation of Roumanian supplies have on the general position for motor spirit, and to what extent was Roumanian gasoline used in motor and aviation fuels?
Answer.	The loss of Roumanian benzine caused a big increase in the proportion of benzol used in fuels. Large quantities of straight run and cracked benzine blends were used as motor fuels with the addition of TEL or benzol. An asphalt base straight run benzine component was worked up into an aviation fuel.

Question 5. Was the general idea to work to a given octane number in blending these fuels, using Benzol and/or TEL as the adjusting agents, reducing the latter when more Benzol was available?

Answer Yes.

Question To what extent has Methanol and Ethanol been used as a <u>blending agent for internal civilian consumption</u>, for use in non-military vehicles in occupied territories, and for military purposes? What factors have lead to the small use made of these blending agents for the latter purpose?

Ethanol production was severely restricted by food requirements. Since methanol was only used in conjunction with ethanol this limited the availability alcohol blends. Alcohol was used only for civil purposes and for army vehicles on the home front.

Question What quality of Aromatic blended component was used? i.e. was all the toluene extracted from the [illegible] and what happened to the higher aromatics?

Answer. Toluol was removed from motor-benzol by careful fractionation. The higher aromatics remained in the fuel.

Question 8. What disposal arrangements were made for Esthonian shale gasoline, and was any difficulty experienced in its use as a motor gasoline constituent? What tests, if any, were made to establish its suitability as a flying bomb fuel, particularly from the point of view of corrosion?

Answer. No special regulations for Esthonian shale gasoline are known. RCH has no information as to any difficulties attending its use as a motor gasoline constituent or ~~its suitability as a flying bomb fuel.~~

Question 9. To what extent have alternative fuels such as producer gas, acetylene, etc. been used for civilian and military purposes? What technique has been employed with these fuels?

Answer. No precise information is available.

Question 10. What methods, if any, are used to determine Road Octane Numbers, and how do the results correlate with test engine data?

Answer. Measurements of road octane numbers have not been carried out in Germany in recent years.

Question 11. What bench tests are carried out on fuels and lubricants performance, and what type of operation (e.g. full power continuous, or ov[illegible]) [illegible] data best with actual operation?

Knock rating tests were carried out with numerous auto-engines at the request of the HWA. They led to the introduction of the Motor O.N. for motor-fuels because of its better agreement with test-results. The accompanying report contains details of the various tests used at the station for fuels and lubricating oil. Continuous drive was generally preferred in the trials. Comparisons with actual running trials seemed too difficult and costly and were only carried out in rare cases, e.g. [illegible] piston seizure test.

Question 12. How is wear in an engine measured?

Answer. Wear was measured by the loss in weight of the piston rings. Other methods, e.g. cylinder measurement and iron-content of the lubricating oil were not so accurate.

7. DIESEL FUELS (AUTOMOTIVE, AVIATION AND MARINE)

Question 1. What is the status of research on aircraft diesel engines?

Answer. No precise information is available.

Question 2. What specifications are laid down for aviation diesel fuels, and why?

Answer. Cetane number 50, pour point -35°C. (because of use at high altitudes). The other requirements were normal.

Question 3. What work is in hand on special fuels for aviation diesels?

Answer. An aviation diesel fuel corresponding to the above specifications was made by blending a naphthenic German gas oil (Reitbrook) with a low-boiling synthetic component made by RCH.

Question 4. From what components and how is K.1 fuel made?

Answer. No information is available.

Question 5. To what extent is the cetane number considered an adequate measure of ignition qualities? How are they measured? What is the cetane number requirements of average aviation, automotive, and marine diesel engines?

Answer. Recent developments have limited the applic ation of Cetane number. In particular, the cold starting behaviour of fuels, having different boiling ranges and with additives to accelerate ignition, is often quite different from what the cetane number would indicate. The specified cetane numbers are:-

Motor engines	:	Ca 40
Aero "	:	ca 50
Marine "	:	unknown

Question 6. What work has been done on combustion and ignition accelerators, and to what extent are they used?

Answer. No special investigations have been made by Ruhrchemie. The effect of ignition accelerators on cold starting behaviour was small.

Question 7. What work has been done on cold starting aids, and what is the normal cold starting procedure?

Answer. Measures taken to improve cold starting behaviour varied according to the type of combustion process employed in the engine. Pre-heating of the inlet-air, cooling water and oil was employed as well as glow-plugs (Glühkerzen) and lubricating oil dilution.

Question 8. What filtering systems are used for diesel fuels?

Answer. Felt-filters to a large extent.

Question 9. How is low pour point obtained, especially in conjunction with high cetane number?

Answer. By blending as under (3)

Question 10. What general research has been carried out on combustion in diesel engines?

Answer. None has been done by Ruhrchemie.

Question 11. What types of diesel fuels are used in (a) submarines?
(b) motor ships of all types?
(c) land vehicles?

Answer. No information is available.

Question 12. What is the composition of [illegible] fuel heavier than water?

Answer. No information is available.

Question 13. What is the reason for use of very light diesel fuels almost in the kerosine range, for some types of small motor vessels?

Answer. The shortage of heavy diesel fuels and a relative surplus of Otto fuels.

Question 14. What importance is attached to boiling range, and has any relationship been worked out between specific gravity, aniline point and boiling range, with cetane number? What importance is attached to aniline point?

Answer. Diesel fuels in the lower boiling range have a relatively good starting performance. A sufficiently accurate estimate of cetane number can be made, in the case of fuels of similar origin, from the specific gravity and boiling range. Aniline point estimation is thus no longer considered necessary and has not been examined during recent years.

Question 15. To what extent are diesel fuels from petroleum, brown coal, shale, and Fischer Tropsch processes used?

Answer. Suitable fractions from mineral oil, brown coal, shale and the Fischer Tropsch synthesis were all used.

Question 16. What is the significance of the phenol content present in some diesel oils?

Answer. Phenol is present in brown coal diesel fuel. The proportion allowed to remain caused no running troubles. Removal of the last traces would be tedious and would involve the use of special processes

8. FUEL OILS

Question 1. What types and to what specifications are used for

(a) heavy industrial?
(b) light industrial?
(c) Marine?

2. What experimental work has been carried out on [illegible] bustion of fuels under boilers?

3. What main types of fuel oil burners are [illegible]?

4. To what extent are fuels of non petroleum [illegible]

5. Are coal suspensions used to any extent?

6. Has any difficulty been experienced on the compa[illegible] of the various fuel oils from different sources?

7. Has any trouble been [illegible] of gases in fuel oils?

Answers. [illegible] have no information on [illegible]

QUESTIONNAIRE NO. 2.

LUBRICANTS.

1. AVIATION.

Question 1. What general types of aviation oils are used, from what sources are they obtained, and why were these sources chosen?

Answer No precise information is available.

Question 2. What refining methods are used for aviation oils? To what extent are solvent refined oils incorporated in aviation oils?

Answer. No precise information is available.

Question 3. To what extent are synthetic oils used in the blending of aviation oils, and what advantage, if any, result?

Answer. Highly viscous synthetic products (V 100°C = 6°E.) were blended 50/50 with a mineral oil component of low viscosity. The synthetic component gave a decided improvement in ring-sticking behaviour according to statements by RLM.

Question 4. To what extent is Voltol used in aviation oils? What are the reasons why it is or is not extensively used? What effect has Voltol on V.I. or pole height.

As far as is known to Ruhrchemie, voltolised oils were only permitted for use in certain engines (aero-diesel). They could not be used in Otto-engines because of a pronounced tendency to cause ring-sticking. This disadvantage was not so apparent in aero diesels.

Are the advantages of the incorporation [illegible] detergent type additives recognised [illegible] been developed for use in aviation oils?

These dopes were not used by Ruhr[illegible] [illegible] other precise information is available.

Are viscosity temperature [illegible] of the O[illegible] oils?

No information is available

Have additives of any other type been used in aviation oils, if so, what are they, and what results are obtained by their use?

Answer. No exact information is available.

Question 8. What trouble have been experienced with (a) oil frothing, (b) ring sticking (c) bearing corrosion.

and what remedies have been found?

Answer. No constructive measures against frothing and ring sticking are known. There is an unmistakeable difference in the ring-sticking behaviour of different oils. RCH synthetic oil was better here than mineral or voltolised oil. Our investigations indicated that synthetic oils behaved well as regards frothing. This field has not been thoroughly investigated yet, however.

Question 9. Have any particular combinations of bearing metals given trouble with any particular oils, if so, how were the troubles overcome?

Answer. No information is available.

Question 10. What engine tests are carried out on an oil before it is accepted for aviation use, and by what methods are the merits of a given oil assessed? If small scale engines are used for oil testing, how do they correlate with main engine performance.

Small scale engine trials only were used by Ruhrchemie. These gave a good evaluation (see accompanying report). The official tests in the BMW single cylinder and in different full size engines included general behaviour especially ring-sticking, sludge formation and thickening The agreement of these tests with the RCH small scale engine tests has been very good.

Has any connection been found between condition of and [illegible] leaded fuels, and type of oil?

Answer. No.

What laboratory tests are considered most important and has any laboratory procedure been evolved which ties in closely with actual behaviour in an engine?

No laboratory tests are known which give clear and certain indications of actual running behaviour. The most important laboratory tests are considered to be viscosity, pour point, acid value and saponification value.

Question 13. How many hours running are normally carried out between overhauls?

Answer. No information is available.

Question 14. To what extent are oil filters and/or centrifuges used on aircraft engines, and what types are used?

Answer. No precise information is available.

Question 15. Has any trouble been experienced with sludge deposition in oilways, etc., and if so, what remedies have been applied?

Answer. According to the RLM, difficulties did arise. Remedy measures are not known. Synthetic oils had only a small tendency to sludge formation.

Question 16. Has any trouble been experienced with scuffing of reduction gears and what remedies have been applied?

Answer. No information is available.

Question 17. What lubrication system and lubricant are used on the flying bomb, including ancillary equipment, gyros, etc.?

Answer. No information is available.

Question 18. What type of aviation oils are used in jet propelled aircraft, I.C. turbines, rocket propelled missiles, etc., and what special properties are required? What temperature extremes are met in such devices? By what methods are low pour point oils obtained required? Is more than one [illegible] necessary?

Answer. No information is available.

Question 19. Are diluents employed with aviation oils. If so, to what extent, and why? What diluents are used?

Answer. Dilution, employing ordinary fuel, was used to improve the cold starting performance of aero engines.

2. AUTOMOTIVE

Question 1. To what specifications are lubricants for petrol engines and high speed diesel engines produced, and what relative importance is assigned to the various properties?

Answer. They are produced according to the HWA delivery specifications (not available here at the moment). The viscosity and pole height were regarded as being specially important.

Question 2. What are the chief sources of motor oils? What crudes are used, what refining methods, and to what extent are synthetic oils incorporated?

Answer. Since the highest grade components were placed at the disposal of the Luftwaffe, motor oil had to be mixed with 10-35% of synthetics to bring its quality to an adequate level.

Question 3. Are engine tests carried out before approval, and if so, what are they?

Answer. When a new type of oil was put into use engine tests were made, as far as was thought necessary. The following properties were examined: ring-sticking, wear, aging, sludge formation and piston seizure. A small scale engine was used as described in the accompanying report.

[illegible] What laboratory [illegible] are used and [illegible]

A[illegible] No particular laboratory [illegible] from the usual inspection [illegible]

To what extent is [illegible] oils? Is it more commonly [illegible] oil and if so [illegible] cleanliness, [illegible]

A[illegible] [illegible]

[illegible] (a) petrol engines [illegible]

Answer. No

[illegible] Is trouble experienced with ring sticking in [illegible] engines and if so what [illegible]

Answer. No.

Question 8. What type of filters are used in mechanically propelled vehicles? If chemical type filters are used, is any trouble experienced with them?

Answer. Mainly slit-filters are used. Chemical filters were not employed.

Question 9. What mileage is normally recommended between sump drainings?

Answer. ca. 3000 km. (not known exactly)

Question 10. What inspections are carried out on used oils, and how do the various types of oil compare on used oils conditions?

Answer. No special inspection techniques are known to Ruhrchemie.

Question 11. What additives are used as pour point depressors, V.I. improvers, anti-oxidants, antiwear additives, anti-corrosion additives, and film strength improvers?

Answer. Paraflow was used to lower the pour point and Oppanol to improve V.I. Other additives are unknown.

Question 12. To what extent are fatty oils used in motor lubrican[illegible] What kind of fatty oils are used, and what adv[illegible] have they?

Answer. Fatty oils were not used.

[illegible] Were any lubrication difficulties experienced wit[illegible] producer gas equipment (both [illegible] and coal type[illegible] bottled ga[illegible] [illegible] tylers [illegible] vehicles.

Answer. [illegible]

3. MARINE

[illegible] 1 What lubricating oils a[illegible] [illegible]fied for use with marine diesel equipment?

2 What oils are used in steam turbine driven vessels? Are additives of any kind incorporated (anti-corrosion etc.)?

3 To what extent are compounded cylinder oils used, and what are the compounding agents employed?

4. To what specifications are stern-tube greases manufactures, and what compounding agents are employed.

5. For what uses are aqueous emulsions of oil, with the addition of montan wax, employed?

Answers. No precise information is available.

4. TRANSMISSION LUBRICANTS.

Question 1. What lubricants are recommended and specified for tank gear boxes, and car and truck gear boxes of normal and synchromesh types?

Answer. The use of a standard gear oil (mineral oil raffinate with a high pressure additive) was stipulated by the HWA for all gears and rear-axles.

Question 2. To what extent are voltolised oils and compounded oils used for tank gear boxes ? What compounding agents are employed ?

Answer. Voltolised and compounded oils have not been in recent use.

Question 3. To what extent are additives of the nitrogen type, chlorine type, etc., used in oils for gear boxes ?

Answer. The nature of the high pressure additive is unknown to RCH.

Question 4. In what proportion are straight tooth, spiral & Hypoid, and worm gears used in rear axles, and what oils are specified in each type ?

Answer. See answer to question (1). The gear manufacturers were permitted to use special (hypoid) oils for running-in purposes.

Question 5. What additives are used in extreme pressure oils ?

Answer. No precise information is available. "Etr 1" was used, among other additives.

Question 6. To what extent are compounded oils (fatty oil compounded) used for rear axle lubrication ?

Answer. No information is available.

Question 7. What type of oil seals are used ?

Answer. None.

Question 8. What temperature extremes are encountered in the different types of axle ?

Answer. Reputedly 250°C. (in tanks).

5. HYDRAULIC, RECOIL and BUFFER OILS.

Question 1. To what extent are pure mineral oils used for this purpose ? What specifications apply with particular reference to V.I., pour point, etc ? From what crudes are they made and by what refining methods ?

2. To what extent are non-mineral oils used for this purpose ? How much castor oil is used for this purpose ?

Question 3. What solvents such as diacetone, alcohol, methyl carbinol, etc. are used ?

4. To what extent are water and glycerol used in hydraulic fluids ?

5. What work has been done on non-inflammable hydraulic oils ?

6. What oils seals are used, and has any trouble been experienced as a result of interaction between seals and fluids ?

To what extent are compounded mineral oils used, and why ?

Answer. No exact inf[illegible]

6. RAILROAD <u>LUBRICANTS.</u>

Question 1. What oils are used for steam cylinder lubrication (satd. and superheat) valves axle boxes, etc., and what compounding agents are used, and why ?

2. What type of crudes are preferred for this purpose ? What asphaltene content is usual in such oils ?

3. Are any special oils used in the lubrication of diesel locomotives, and what additives, if any, are employed ?

Answer. No information is available.

7. <u>INDUSTRIAL LUBRICANTS.</u>

Question 1. What types of oil are used in steam turbine lubrication ? Are any troubles experienced with corrosion, emulsification, and if so, how are they combatted ? What additives are used, if any ? What is the average life of a steam turbine oil ?

2. What types of oils are used for transformers ? What electrical tests, if any, are carried out ? Are any additives employed ?

3. To what extent are mineral, non-mineral, compounded oils, and aqueous emulsions used in quenching ? What types are preferred for small and large objects ?

Question 4. What types of cutting oils are used ? To what extent are sulphurised and compounded oils used ? Are corrosion inhibitors added, and if so, what are they ?

5. What types of slushing oils are used ? What additives are employed to give anti-corrosion properties ?

6. From what sources are textile oils refined ? What research has been done on carcogenicity ?

7. What oils are used for clock and instrument lubrication, especially for aviation [illegible] compounding agents are used ?

8. What is "Radiol", and for what uses is it employed ?

[illegible] What us the composition of [illegible] machine oils ?

Answer. No information is available.

8. GREASES.

Question 1. To what extent are barium, lithium and aluminium soap greases used ?

Answer. No precise information is available.

Question 2. What fats are used for greases, and what substitutes have been employed ?

Answer. Fatty acids for the first runnings in the air-oxidation of paraffins are used as substitutes.

Question 3. To what extent are waxes, especially montan wax, used in grease manufacture ?

Answer. Montan wax is used as the standard army chassis grease (Abschmierfett). Experiments aiming at substitution by the synthetic Ruhrchemie wax acids OP3 and OP32 were in progress.

Question 4. What types of greases are used for high temperature applications ?

Answer. Fats saponified with NaOH were in use, as far as is known to Ruhrchemie.

Question 5. For what reason and to what extent are greases used in shock absorbers [illegible] aeroplane landing gear ?

Answer. No information is available.

Question [illegible] What material is employed [illegible] [illegible] ?

[illegible]

[illegible].

[illegible] To what extent are aqueous [illegible] in industrial lubrication ?

Has this type of lubricant ever been employed in engines of any type ?

They have been repeatedly used in industrial lubrication in recent years and with good results, as far as is known (e.g. with air compressors).

Question 3. By what processes is Voltol made ?

Answer. No information is available.

QUESTIONNAIRE No.3.

Special Products

1. BITUMENS.

Question 1. To what extent are bitumens of petroleum origin used in road construction, and to what extent are hot application, cut-back, and bituminous emulsion application used ?

Question 2. What advances, if any, have been made in bitumen emulsion manufacture, and what crude sources are preferred for this purpose ?

3. Are emulsions of any other pitch residues used for any purpose ?

4. What work has been done on soil stabilisation, and to what extent has this process been used for airfield runways, etc.? What types of emulsions have been found most suitable, and how are they made ?

To what extent are bitumens and residues used for:

(a) Paper impregnation ?

(b) Roofing ?

(c) Insulation ?

(d) Paint applications ?

What filters, if any, are used ?

Answer. No information is available.

2. EXTRACTS AND POLYMERS.

Question 1. Are lubricating oil extracts produced by either acid treatment or solvent extraction being used as substitutes for:

(a) Linseed oil in paints and putties ?

(b) Plasticisers in rubbers and P.V.C. compositions ?

Are they being used for any other purposes ?
What are the user requirements ?

2. To what use are the phenol extracts from solvent extraction or lubrication oils put ?

3. How are olefine polymers such as those of ethylene, propylene and particularly of butenes and butadiene being utilised ?

4. To what extent are polymers [illegible] manufacture of lubricants ?

Answer. No information is available.

3. WAXES.

Question 1. To what uses are waxes produced from petroleum, brown coal oils, and Fischer Tropsch processes being applied, and what particular properties are demanded by the user ?

Answer. Paraffin waxes from petroleum, brown coal and the Fischer Tropsch process are used in the following industries, among others:

(a) In the manufacture of floor polishes etc.
(b) " " " " shoe creams etc.
(c) " " " " cable insulation materials.
(d) " " " " candles.
(e) " " " " artificial flowers.
(f) For sizing paper.

As well as these direct uses paraffins are worked up on a large scale in the cerisin industry.
Three types of paraffin wax resulted from the Fischer Tropsch synthesis namely slab paraffin wax, R.B. hard wax, catalytic paraffin wax (Kontakt-parafffin).

Their properties are as follows:-

	Slab Paraffin Wax.	RB Hard Wax.	Catalytic Paraffin Wax.
Colour	White	White to ivory	Ivory to yellowish
Solidification Pt.	50/52°C.	90 C	90°C. (Brown
Melting Point.	50/52°C	100°C	100°C
Acid & Sap. values.	0	0	0
Components boiling below 450°C.	–	10	–

Question 2. What types of waxes (with specifications) are used candle manufacture, paper impregnation, insulating,

Answer. In candle manufacture slab paraffin and, to a small extent, RB Hard Wax are used.

Question 3. To what extent is slack wax from solvent dewaxing processed into a usable wax, and how is this What proportion is used as a cracking stock

Answer. No information is available.

Question 4. What results have been obtained with the use of montan wax, and synthetic substitutes in grease manufacture?

Answer. Wax acids, obtained by the oxidation of RB hard wax, were tried as synthetic substitutes in grease manufacture. Two types were investigated, designated as OP3 and OP32. They have the properties shown below:

	OP3	OP32
Colour	White to ivory	yellow to ivory
Solidification Pt.	80-82°C.	80-82°C
% Unsaponifiables	50	3-5
Acid value	70-80	140-150
Sap. value.	75-85	145-155

The wax acids were tried out in the manufacture of sodium soap greases as well as with industrial greases, e.g. hot-bearing greases. They were also tried in the standard army chassis grease (Abschmierfett) Greases developed from these wax acids fulfilled all that was required of them and were remarkable for their specially high water resistance.

Question 5. What work has been done on micro-crystalline waxes?

Answer. No information is available.

RUST PREVENTIVES

What rust preventives of the solvent type suitable for spray application, are used, and what is their composition. [illegible] inhibitors?

What corrosion preventives of the petrolatum type brush or swab application, of the transparent hard drying type, and of the permanent [illegible] type are used? Are any spe[illegible] What solvents are employed?

Are "fly-away" corrosion preve[illegible] and what is their composition?

Have any special compounds been p[illegible] cold corrosion in stored engines?

Are any corrosion preventive additives [illegible] red for addition to turbine oils, trans[illegible]

Answer. [illegible]

5. CABLE OILS.

Question 1. To what extent are oil filled cables used; what oil specifications are laid down; what are the best sources for oils of this type?

2. Are any blending agents or additives employed (e.g. resins)?

3. To what extent are oil impregnated insulated types used? What oils are used, and what specifications have been laid down?

4. What methods of test are used to determine di-electric strength, and s.i.c. for such oils?

Answer. No precise information is available.

6. COOLANTS AND DE-ICING FLUIDS.

Question 1. What coolants are used in automotive engines, both for normal operation and low temperature, and in aviation engines? Are corrosion inhibitors added? Are soluble oil emulsions ever employed?

Answer. Water and water-Glysantin mixtures. The use of oil emulsions is unknown to Ruhrchemie.

Question 2. What fluids or compounds have been developed for de-icing of aircraft, and what additives are used? For what purposes are lithium and [illegible] these compounds?

Answer. No information is available.

7. MISCELLANEOUS.

Question 1. Have detergents of the ester salts type been developed and how are they made?

Answer. No precise information is available.

Question 2. What developments have been made in products used for pest control?

Answer. No precise information is available.

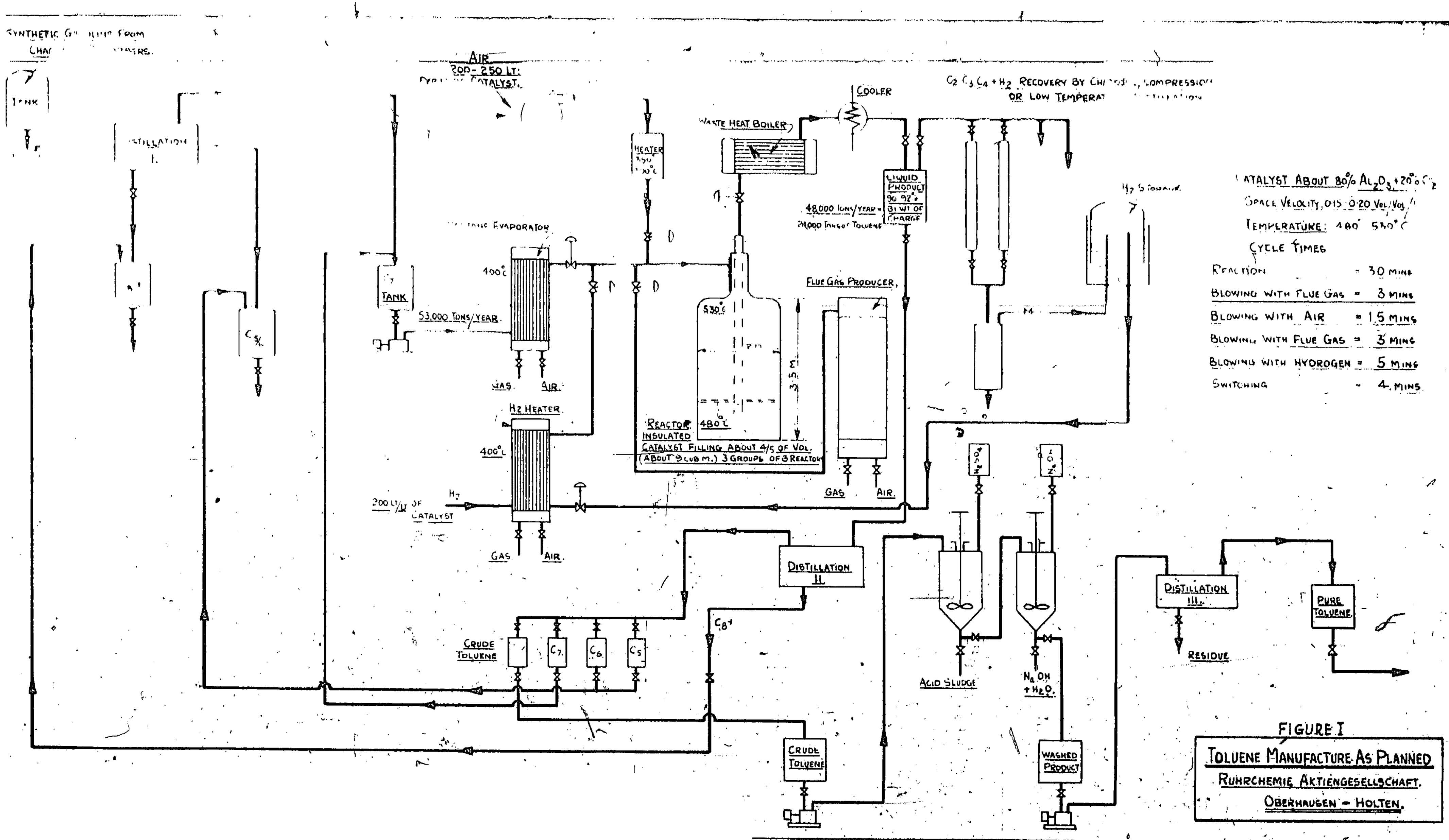


FIGURE I

TOLUENE MANUFACTURE AS PLANNED
RUHRCHEMIE AKTIENGESELLSCHAFT.
OBERHAUSEN - HOLTEN.

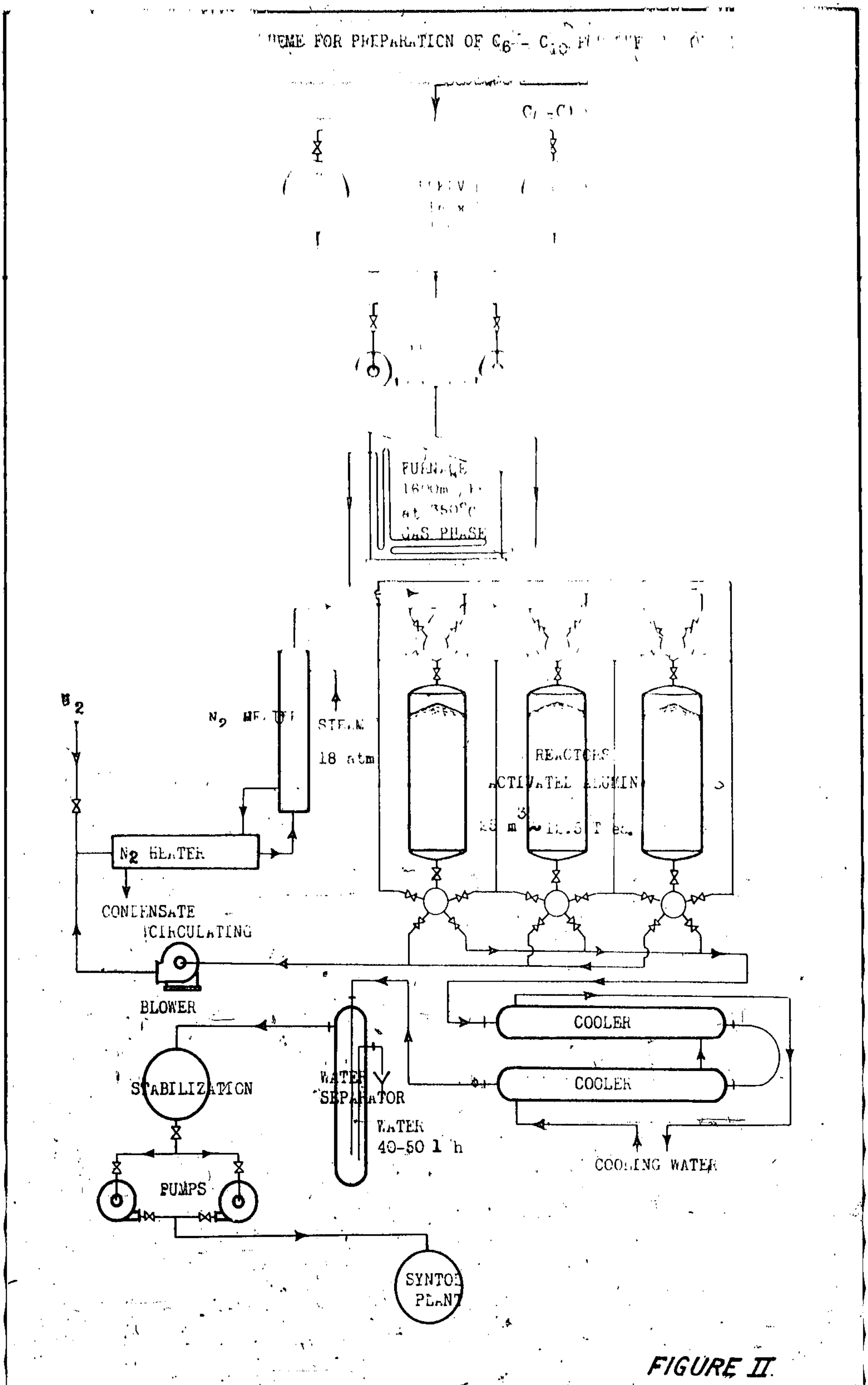

FURNACE
GAS PHASE
REACTORS
N_2
N_2 HEATER
STEAM
18 atm
CONDENSATE
BLOWER
COOLER
COOLER
STABILIZATION
WATER SEPARATOR
WATER
40-50 1 h
COOLING WATER
PUMPS

FIGURE II

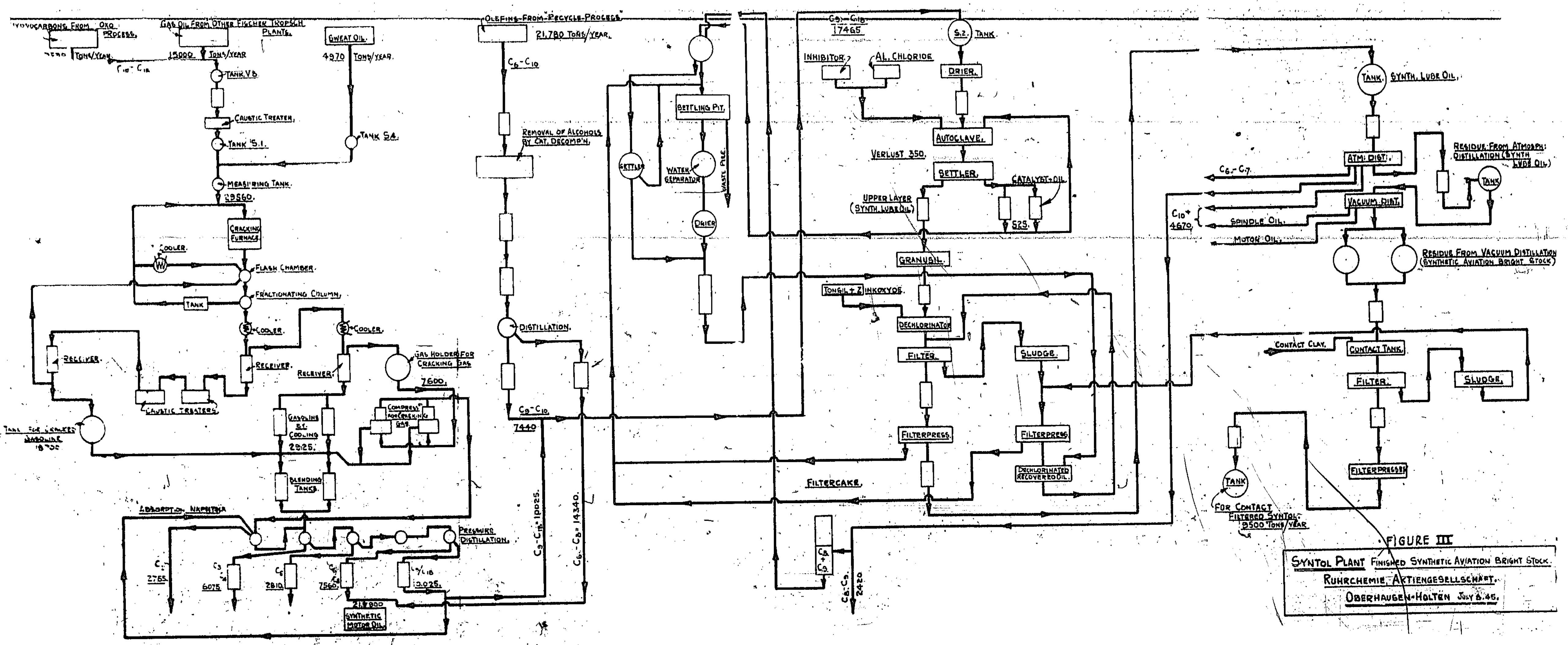


FIGURE III

SYNTOL PLANT FINISHED SYNTHETIC AVIATION BRIGHT STOCK.

RUHRCHEMIE, AKTIENGESELLSCHAFT.

OBERHAUSEN-HOLTEN JULY 6.45.

APPARATUS FOR CATALYST ACTIVITY

3 way valves

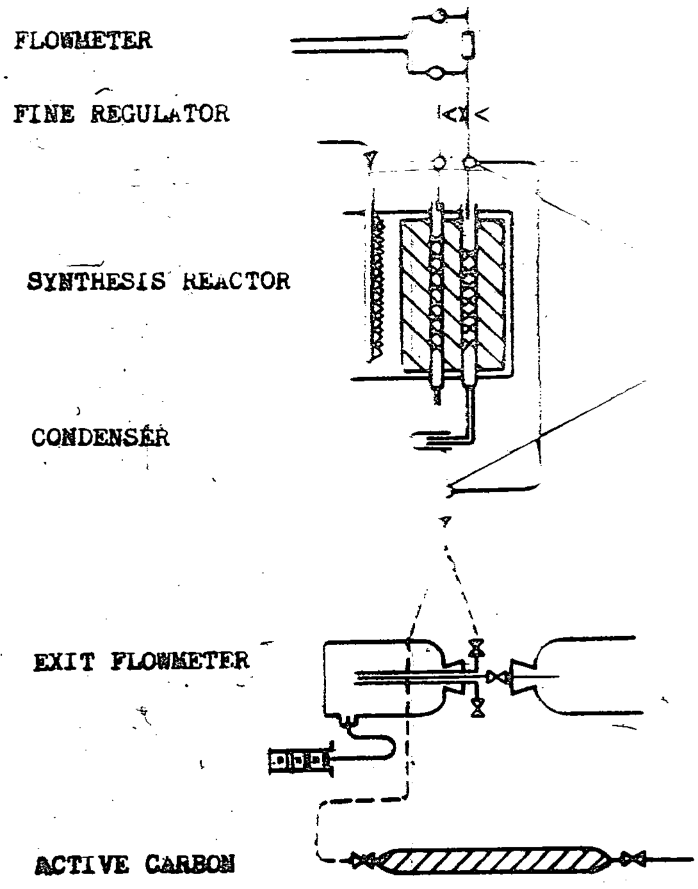


FIGURE IV.

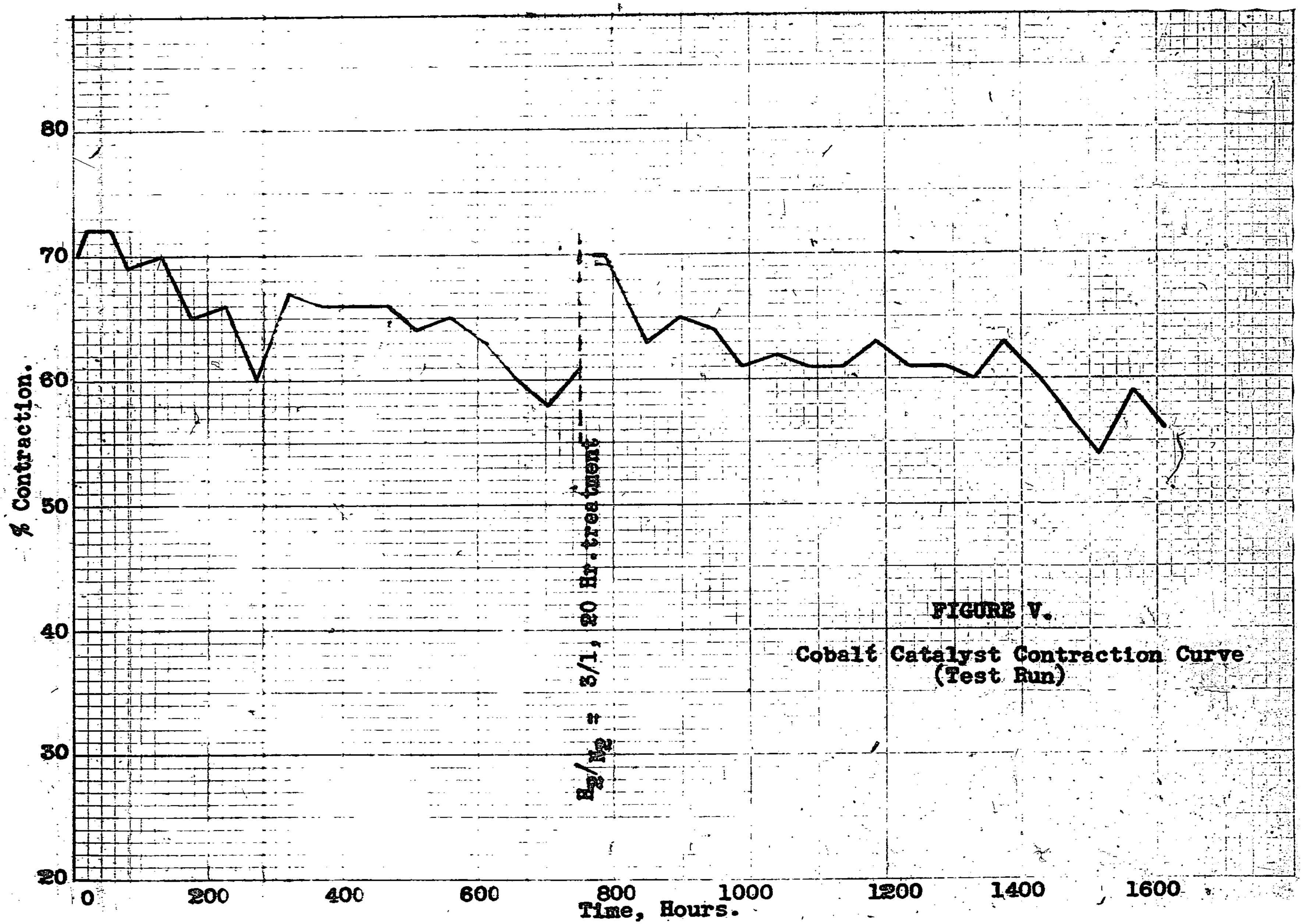


FIGURE V.

Cobalt Catalyst Contraction Curve
(Test Run)

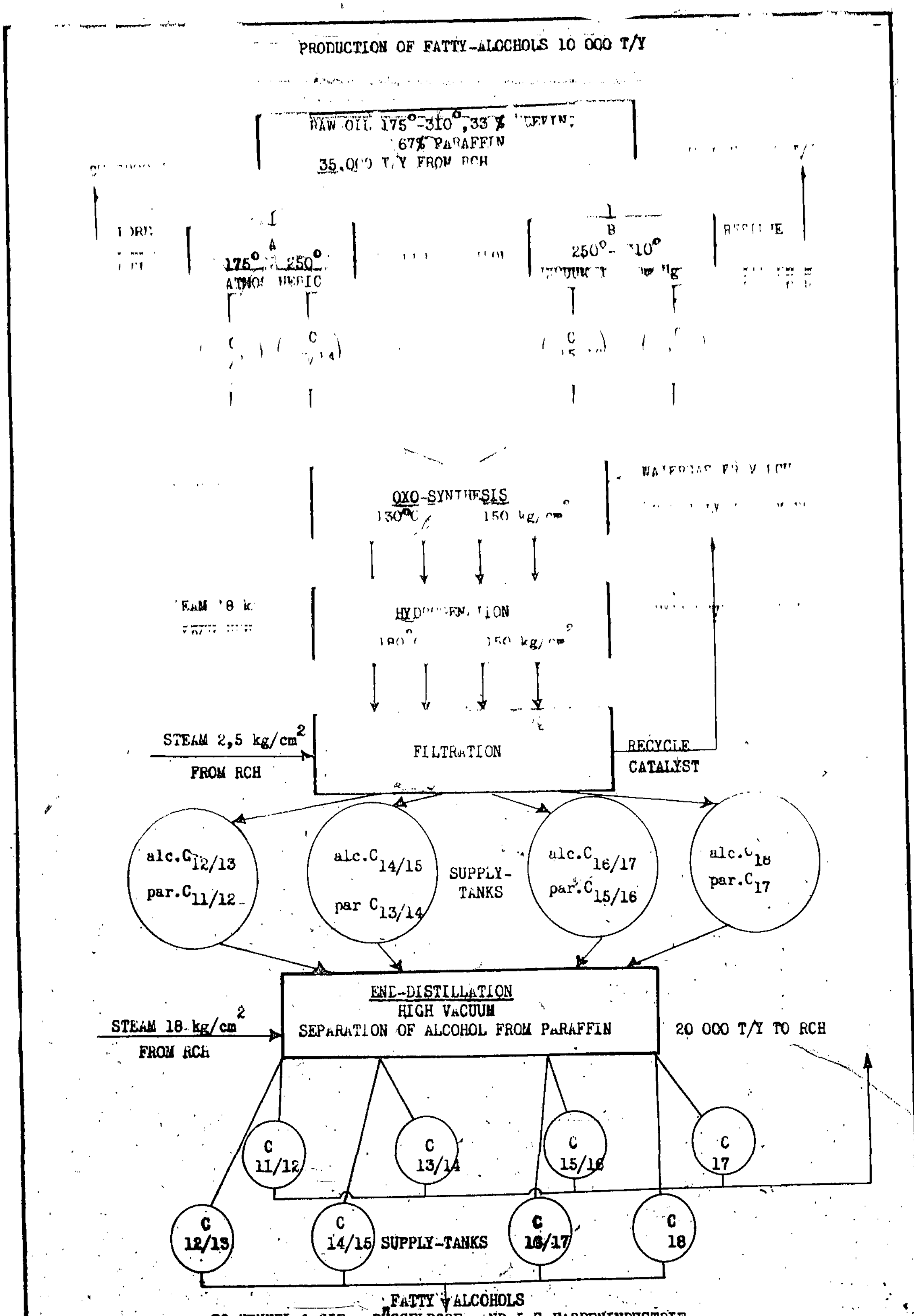

PRODUCTION OF FATTY-ALOCHOLS 10 000 T/Y
67% PARAFFIN
A
B
OXO-SYNTHESIS
HYDRO
STEAM 2,5 kg/cm2
FROM RCH
FILTRATION
RECYCLE
CATALYST
alc.C12/13
par.C11/12
alc.C14/15
par C13/14
SUPPLY-
TANKS
alc.C16/17
par.C15/16
alc.C18
par.C17
END-DISTILLATION
HIGH VACUUM
SEPARATION OF ALCOHOL FROM PARAFFIN
STEAM 18 kg/cm2
FROM RCH
20 000 T/Y TO RCH
C 11/12
C 13/14
C 15/16
C 17
C 12/13
C 14/15
SUPPLY-TANKS
C 16/17
C 18
FATTY ALCOHOLS
TO HENKEL & CIE., DÜSSELDORF, AND I.G.FARBENINDUSTRIE

FIGURE VI.

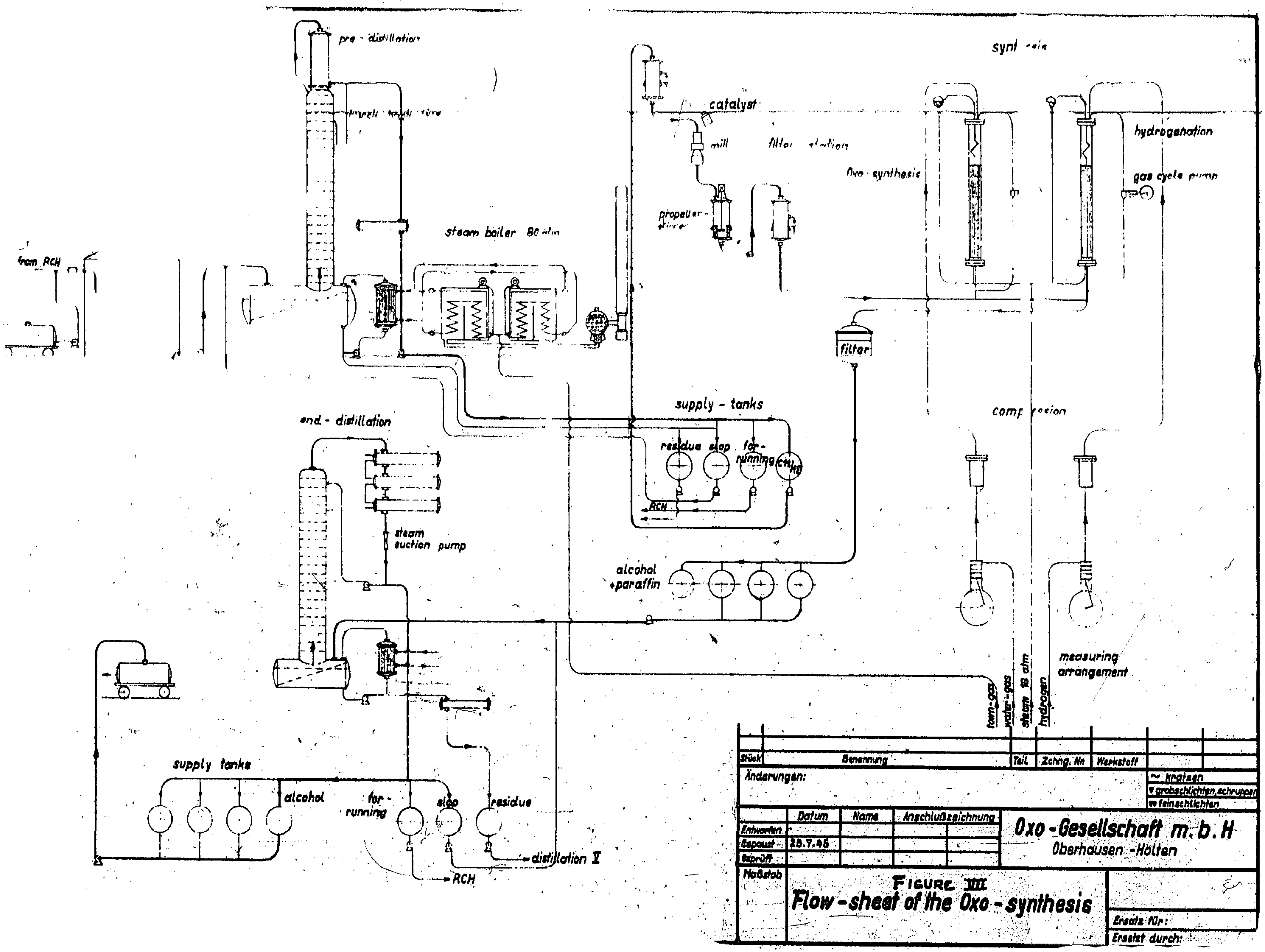
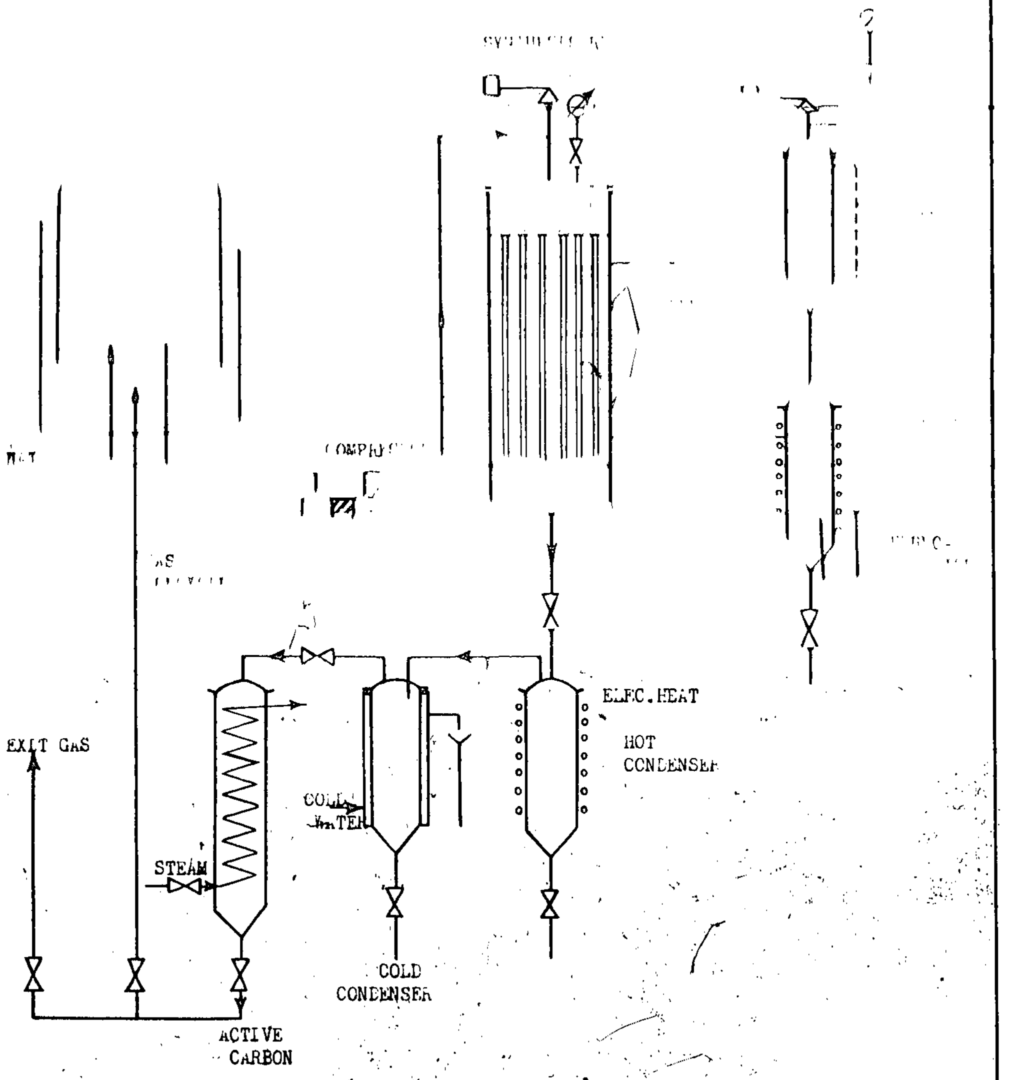


FIGURE VIII
Flow-sheet of the Oxo-synthesis



DIRECT SYNTHESIS
OF
ALCOHOLS

FIGURE VIII.

FLOW SCHEME FOR NICKEL CATALYST PREPARATION

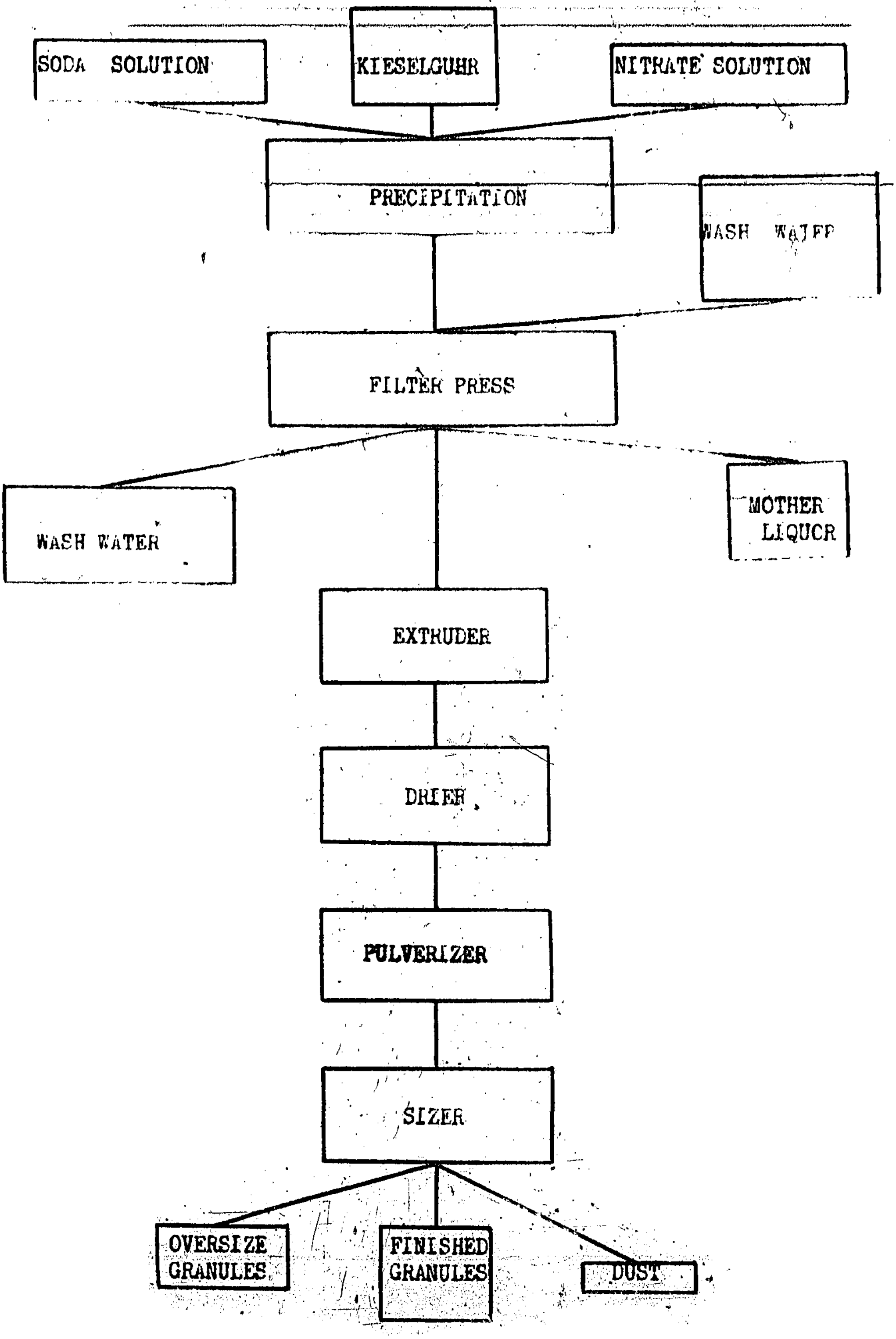
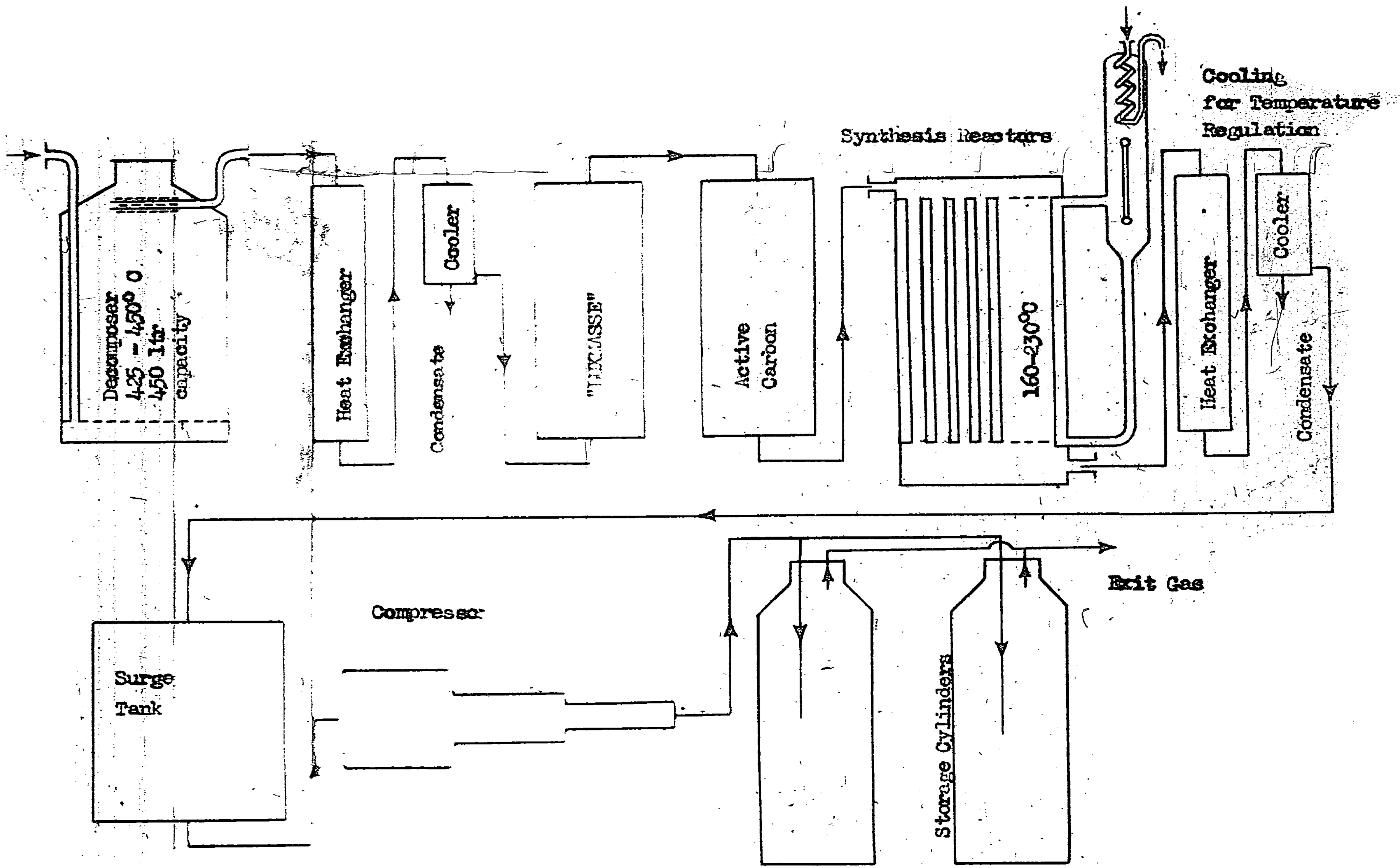


FIGURE IX.



Flow Scheme for Methanization

FIGURE X

FLOW SCHEME FOR OXIDATION OF PARAFFIN

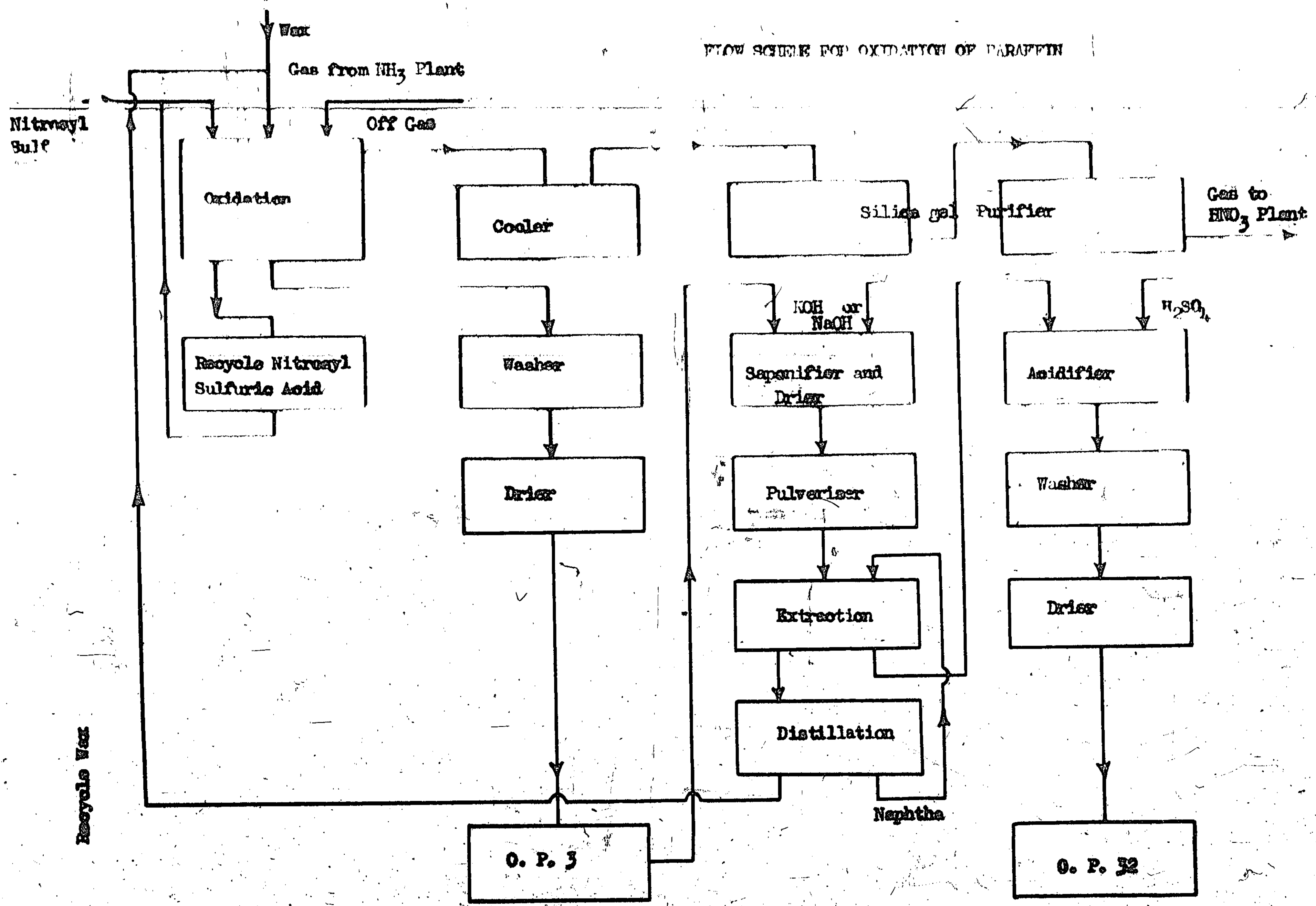


FIGURE XI.