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TECHNICAL REPORT No. 187-45

GERMAN DIESEL FUELS

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SUMMARY

Review of the work done in Germany during the past few years to produce a satisfactory diesel fuel for high-speed engines, and the research conducted by scientists to investigate possibilities of further improvements. Study of additives such as: nitrates, nitrites, peroxides, alcohols, etc., and of various processes such as "nitration" and "ozonisation" to raise the cetane rating of fuels.

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GERMAN DIESEL FUELS

1. German Diesel Fuel Specifications.

Slow speed stationary diesel engines were operated on such liquid fuels as were available. These fuels included petroleum residues, petroleum crude, coal and lignite tars and crude shale oil. No specifications could be maintained as the fuels for these types of engines were inadequate at all times and became increasingly scarcer as the war progressed. So much so that attempts, only partly successful, were made to use these local supplies, alone or mixed with other diesel fuels, in automotive engines. The results are reported in the 1944 quarterly reports of the "Reichs Minister für Rüstung und Kriegsproduktion" (Department of Planning and War Production), Fuels and Lubricants Section, under direction of Dr. Bokemüller of the Daimler Benz Company in Gaggenau (Baden).

Diesel fuel specifications were prepared for the various armed forces. A comparison of the requirements of the "Wehrmacht", the "Luftwaffe" and the "Kriegsmarine" are tabulated on Table I. Small differences are apparent in this tabulation between the requirements of the various branches.

The German Navy (Kriegsmarine) in particular was definitely opposed to the use of any additive in diesel fuels for fear of corrosion, and never did use specification KI of the Luftwaffe for fear of vaporlock.

In addition to these diesel fuels most generally used and recognized there came out, from time to time, certain fuels known as "Sonder Diesel Kraftstoff", "Leicht Diesel Kraftstoff", "Speziell Diesel Kraftstoff" prepared to order for a definite purpose or for certain experiments. Some were blends of various types of diesel fuels, others were blends of diesel fuels and gasolines. The latter could be classified in the United States as "tractor fuels".

2. Sources of Diesel Fuel in Germany.

Note: Whenever a production process is mentioned, such as Fischer-Tropsch synthesis, or hydrogenation, the reader is referred to the reports on these various processes prepared by the U. S. Naval Technical Mission in Europe.

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2. Sources of Diesel Fuel in Germany. (Cont'd)

(a) Natural Petroleum Distillates.

Crude oil was obtained from the Polish, Rumanian, Austrian and German fields, to serve as a base for the German fuels and lubricants industry. Although the quantity of these oils was continually decreasing under the impact of Allied air and land offensives, a surprisingly large amount was still on hand almost up to the end of hostilities.

(b) Synthetic Distillate known as Kogasin II.

The high boiling fractions distilled from the Fischer-Tropsch low pressure, low temperature, catalytic process for obtaining hydrocarbons from solid fuels has the following typical analysis (1945) and was used as blending product for the preparation of Diesel fuels:

		<u>DISTILLATION</u>	
Gravity	.76		
Color	15 Saybolt	I.B.P.	192°C
Odor	Sickly-Characteristic of F.T. products.	200°C	3.5 percent
Cetane No.	90 and better	210°C	17 percent
Bromine No.	13.8	250°C	82 percent
Iodine No.	13	260°C	91 percent
Aromatics	Nil	270°C	95 percent
Unsaturation	15 - 20 percent	E.P.	276°C
Flash Point (PM)	195°F	Recovery	97 percent
Fire Point	215°F		
Ash Content	Nil		
Comradson Carbon	Nil		
Viscosity	2.8 centiskokes @ 68°F		
Sulfur	.01 percent		
Aniline Point	90°C		

(c) Synthetic Distillate known as Kogasin I.

The lighter fractions distilled in the Fischer Tropsch process, with boiling range below 225 degrees centigrade, known as Kogasin I, and with a cetane number from 35 to 60, according to the cut, have also been used as one ingredient in various mixtures, for the production of Diesel fuels. Some work, mentioned below has been done to improve their suitability.

TABLE I.

TABLIFICATION OF DIESEL FUEL SPECIFICATIONS

	wehrmacht Diesel Kraftstoff	Sonder Diesel Kraftstoff	Luftwaaffe K1	KRIEGSMARINETREIBOEL	Ignite Oil
Appearance	The fuel must be clear, free from all solid matter.				90 Max.
Gravity @ 15°C	.810 to .865				.84 to .87
Viscosity Engler @ 20°C	← 1.10 to 20 →				For U-Boats to 2.60
Pour Point	← Winter: -30°C Max. →	← Summer: -10°C Max. →	← 150°C Max. →	Must flow freely and without separation @ 0°C	
Filtering ability	← Winter: 200 cc min in 60 Sec @ -25°C →	← Summer: " " " " @ -50°C →	← 50°C min →	No such specifications	
Flash point P.M.	← 55°C min →	← 21°C min →	← 50°C min →	← 55°C min →	← 1.5% Max. →
Neutralisation No	← 1 mg Max. →				← Acid by Zero →
Zinc Corrosion	← Not over 4 mg of weight reduction →				
Water	← 5% Max →				
Ash	← .05% Max →				
Sulphur	← 1% Max. →				← 1.3% Max. →
Conradson Carbon	← .05% Max. →				← 6% Max. →
Lower Heat Value	← Or 2% coke and gum by the Hagemann Hammerich method →				
Ignitability	← 45 Cetane Min. →	← 50 cetane Min. →	← 9900 Kcal/kg. min. →	← No specifications (in practice 50 - 55) →	
Volatility	← 80% Min distilled at 360°C, 95% Min @ 350°C →				← 60% Min, distilled @ 350°C →
Compatibility	← All Diesel fuels must mix together without precipitation →				

NOTES:

1. The Kriegsmarine specified also an "Emulsibility Test" which was the following: 10°C of the Diesel fuel was shaken in a 50cc closed tube with 10cc of water for 30 seconds. There must be no emulsion and the separation of oil and water should start within a minute after the shaking. After 1/2 hour separation must be complete (with in 1cc of mixture). Then 1cc of a 10/10 NaOH solution is added and the fuel and water are shaken again 1/2 minute. The coloring of the liquid within the next 24 hours must be at the utmost a very pale pink. If too dark the entire test is repeated with sea water.

2. All Kriegsmarine Diesel Fuels, called "TREIBOEL", except "SDK2 (Sonder Diesel Kraftstoff 2) which is actually a "Tractor Distillat", had to be colored to a minimum of 4 - 5 Oswald. For oils which were too light in color a mixture of 13 mg of Sulan brown R and 1 mg of Japan black were added per 1 kg of fuel (colors made by I.G. Farben-Industrie).

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2. Sources of Diesel Fuel in Germany. (Cont'd)

(d) Distillates obtained from the Low-Temperature Carbonisation of Coal and Lignite (Schwelteer).

Low-temperature carbonization of lignite produces about 3 percent of an oil containing as much as 20 percent of "creosote" and, according to the refining process, varying in cetane rating from 38 to 48. Its composition makes it a rather poor diesel fuel, and it is not generally used without further treatment.

(e) Distillates from the Hydrogenation Process.

The oil obtained from the hydrogenation of coal, coal tar and lignite constitutes a good diesel fuel, whether it is the middle oil from the sump phase, or the residue of distillation from the gas phase. Typical analysis of these hydrogenation diesel fuels cover a wide variety according to their boiling ranges:

Gravity	.850 to .885
Aniline Point	31 to 53°C
Aromatics and Unsaturation	38 to 49 percent
Boiling Index**	255 to 265
Cetane Rating	30 to 45
Four Point	Below -35°C and as low as -70°C
Viscosity E @ 40°C	1.45 to 1.81 ^o

They are used either pure or mixed with Kogasin II.

** The Germans refer to "Boiling Index" as the sum divided by ten of the temperatures at which 10 percent, 20 percent, 30 percent, etc... of the liquid have distilled, including the end point, but not the initial boiling point. Some also divide by nine the sum of the 10 percent, 20 percent, etc... fractions but exclusive of both I.B.P. and E.P.

(f) Oils from High-Temperature Carbonization of Coal.

In the Ruhr where large quantities of coal are coked for the metallurgical industry, a tar-oil is available, of high gravity and low ignitability which is not suitable as diesel fuel for high-speed engines. It can however, be processed and mixed with other products, as will be described below.

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2. Sources of Diesel Fuel in Germany. (Cont'd)

(g) Shale Oil.

The distillation of shale yields about 3.5 percent of an oil suitable as a Diesel fuel after further treatment and mixed with other products, in a manner similar to the treatment of coal tar mentioned above. This will be described further. A typical analysis of shale oil, such as produced at Dotternhausen (near Rottweil) is:

		<u>DISTILLATION</u>	
Gravity	.916		
Cetane Rating	35		
Neutralization Index	0	I.B.P.	124°C
Ash	.02 percent	10 percent	240°C
Water	.09 percent	20 percent	250°C
Sulphur	4.4 percent	50 percent	282°C
Saponification No.	2.63	70 percent	315°C
Conradson Carbon	.15 percent	90 percent	340°C
Asphalt	0.06 percent	E.P.	371°C
		Recovery	96 percent

3. Preparation of the Diesel Fuel Blends.

It is of interest to relate the manner in which all fuels, for aircraft as well as for ground forces, were prepared for consumption in war-time Europe.

The utmost secrecy was maintained at all times inside and outside Germany regarding sources of fuels and preparation of blends. Producers were ordered to ship certain quantities of products to locations designated by a number and were not informed of the disposition or ultimate destination of these products. Blending was accomplished upon the orders of certain organizations, without any knowledge of the identity of the products blended. People who had complete knowledge of the fuels and lubricants situation were, for automotive engines, the personnel of the "Zentral Büro für Mineral Oel" in Berlin and for aviation engines, the personnel of the "Oberkommando der Luftwaffe." Under these, the "Wirtschaftliche Forschung Gesellschaft" or WIFO, assisted by the "Reichs Amt für Wirtschafts Ausbau" in Berlin, took care, at strategic points throughout Europe, of the storage, blending and distribution of fuels and lubricants.

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3. Preparation of the Diesel Fuel Blends. (Cont'd)

WIFO Depots, such as the huge WIFO No. 1 at Hizacker, on the Elbe south of Hamburg, were equipped not only to store fuels and lubricants in underground tanks and in barrels, but also to make control analysis in a well-equipped laboratory, and to carry on a certain amount of research independently from the manufacturers. This set-up explains some of the difficulties encountered in the attempt to get a complete picture of the liquid fuel situation in Central Europe.

For diesel fuels the usual types of blends were prepared in WIFO depots. For the more elaborate mixtures only, necessitating preliminary treatment, did the manufacturer take a hand in the process.

From the point of view of ignitability alone, Kogasin II from the Fischer-Tropsch process is an ideal product. It has been demonstrated however that, used alone, it is far from being an advantageous diesel fuel. Tests have proven that, compared with a diesel fuel of petroleum origin having a cetane rating of 47 and a specific gravity of .856, Kogasin II with 86 cetane rating and .770 specific gravity, when used in engines adapted to low cetane fuel, the only engines available at this time, showed:

- (1) an increase in consumption of around 5 percent (based on equal heat value),
- (2) an increase in exhaust gas temperature of about 25 percent.

This was attributed to the fact that Kogasin II does not have enough "body", as it is referred to. It ignites too fast but burns too slowly and must be blended with some of the other products listed above. Therefore Kogasin II was used mostly to upgrade the ignitability of other fuels.

Typical blends used as Diesel Fuels, with the specifications indicated above, and obtained by simple mixing, were, for instance:

- 45 percent Fischer-Tropsch Kogasin II
- 50 percent Light petroleum gasoil
- 5 percent Spindle oil distillate or, as alternative:

- 75 percent of this 45 - 50 - 5 blend
- 25 percent of a slightly heavier petroleum gasoil.

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3. Preparation of the Diesel Fuel Blends. (Cont'd)

When the mixture involves tar oils from the carbonization of coal, or shale oil, serious complications arise from the fact that these oils contain high percentages of asphalt, gum and carbon-forming elements which rapidly clog the injection nozzles, especially in small high-speed engines. Furthermore these components have a tendency to segregate out of the liquid, when Kogasin II is added and to settle in storage tanks. Originally inhibitors were used to prevent this condition, either 2 cubic centimeters of cresol for 100 centimeters of fuel, or 0.02 grams of mono-benzyl-amido-phenol in weak alcohol solution per 100 centimeters of fuel.

It became therefore necessary to refine the mixtures, and Dr. H. Köibel of the "Rhein-Preussen Company" in Homberg, Ruhr, developed several processes for that purpose. The initial process consisted of a 20 percent liquid sulfuric acid wash at atmospheric temperature followed by a caustic wash with fullers earth filtration. Later aluminum chloride was substituted for the sulfuric acid wash, followed by neutralization and filtration. The latest method, covered by Deutsche Reichs Patent No. 730853 dated 28 January 1943 for the "cleaning of mixtures of tar oils and aliphatic hydrocarbons" consists of a treatment by sulfur dioxide SO₂, in gas form, at atmospheric pressure. On the following tabulation can be seen a typical picture of the changes taking place in the fuel by the use of this process.

	Kogasin II	Tar Oil	Mixture of Diesel Fuels		Petroleum gas-oil (for comp)
			Before Treatment	After Treatment	
Spec. gravity	.760	1.060	.862	.855	.857
Color	Water Clear	Black	Brown; not translucent	Yellow; Translucent; Fluorescent.	Yellow
Boiling Index	218°C	260°C	260°C	260°C	275°C
Cetane Rating	.96	20	60	60	50
Flash Point P.M.	48°C	114°C	70°C	70°C	90°C
Pour Point	-20°C	Zero	-20°C	-20°C	-30°C
Lower Calorific value	10500 Cal	9980 cal	-----	10100	10100
Conradson Carbon	.03 %	.26%	no data	.004%	.05%

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3. Preparation of the Diesel Fuel Blends. (Cont'd)

	Kogasin II	Tar Oil	Mixture of Diesel Fuels		Petroleum gas-oil (for comparison)
			Before Treatment	After Treatment	
Hard Asphalt (Hagemann & Hammerich)	Zero	2.5%	.46%	.03%	.06%
Insoluble in Benzine	Zero	4.8%	.87%	.05%	.11%

Proportions of carbon and hydrogen in these mixed Diesel fuels are:

87-90 percent C, to 9-12 percent H with a fraction of one percent of sulfur compared with following proportions in the Kogasin:

C - 85 percent
H 15 percent
No sulfur

The proportions of Kogasin II in the mixtures vary according to the results desired. It has been found that the cetane rating increases practically in proportion to the quantity of Kogasin in the mixture; thus 35 percent tar oil and 65 percent Kogasin has a cetane rating of 57 while a 50-50 mixture has a cetane rating of 52.

The refining process is said to be inexpensive, as the loss of SO₂ is extremely small, the bulk being used over and over again. The amount of heavy tar, asphalt, and carbon precipitated out of the fuel during the treatment is about 10 percent of the total in weight. The phenolic products eliminated can be recovered and marketed.

The refined mixture, known as diesel fuel "R" is clear, stable, mixes readily with all other diesel fuels, and is even less corrosive (zinc test) than petroleum gas oil. Diesel motor tests have shown that it compares advantageously with petroleum diesel fuel as to exhaust gas temperature, low CO content of these gases, and consumption per horsepower.

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3. Preparation of the Diesel Fuel Blends. (Cont'd)

For production of a low pour point diesel fuel with high cetane rating, distillates of paraffinic nature can be treated by liquid SO_2 followed by a butane extraction, to remove most of the waxes that cause a high pour point. This process is very similar to the Edeleanu process, but was not used extensively in Germany on account of the low yield. For example 200 kilograms of distillate from the liquefaction of brown coal, treated as above, will yield only 60 kilograms of diesel fuel of $-31^{\circ}F$ pour, 53 cetane; or 88 kilograms of diesel fuel of $-5^{\circ}F$ pour, 44 cetane.

(a) Use of Gasoline in Diesel Engines.

At various times during the war the Germans experienced a serious shortage of adequate diesel fuel. These shortages were partly due to the necessity of concentrating production efforts upon the preparation of high-test aviation gasoline. It was necessary at these times to operate diesel engines on gasoline and gasoline blends which were or could be made available locally. Regardless of the type of gasoline blend used, an addition of 5 percent of motor oil to the fuel was prescribed, to protect the fuel injection pumps and not to improve the ignitability. There is a basic difference between diesel injection pumps, lubricated and sealed by the fuel itself and gasoline injection pumps, used currently on aircraft engines, lubricated by a supply of motor oil. Naturally the situation being temporary, no change over of the injection system was made. The only difficulties mentioned in connection with the use of gasoline in diesel engines were the excessive overheating of the engine and some tendency to vapor-lock in hot weather. In certain cases additives were needed to reduce the octane rating and bring the fuel more in line with a diesel fuel. Chlorpicrin was used as one of these additives. A cetane rating of 35 was aimed at. It can be obtained either by fractionating properly the Fischer-Tropsch gasoline, or by blending a gasoline of as high as 60 octane with a high cetane diesel fuel. Naturally low aromatic gasolines such as "Ruhrbenzin" were selected in preference to higher grades.

An attempt was made to use benzol. Ignition was possible only by mixing ethyl nitrate vapour with the air used for combustion; the engine stopped as soon as this addition of vapour was cut off.

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3. Preparation of the Diesel Fuel Blends. (a)(Cont'd)

The ethyl nitrate was kept in a brass container in a water bath, as its boiling point is 194°C. The vapour circuit had to be absolutely tight as ethyl nitrate vapours are toxic. Approximately .3 cubic centimeters of nitrate was used per one liter cylinder. An attempt to spray liquid ethyl nitrate in very small quantity into the cylinder resulted in a serious explosion.

During the diesel fuel shortage of 1941-42 tests were conducted at the Leuna plant of I.G. Farben for the use of a 50-50 mixture of diesel fuel and Leuna gasoline produced from the hydrogenation of brown coal tar, and having a cetane rating of 35. No difficulties were noted except a slight reduction in power in trucks and locomotive diesels or in small construction engines. In large, slow-speed diesels vapor-lock difficulties developed.

4. Diesel Fuel Additives.

In Germany as well as in the United States considerable research work was carried forward to raise the "ignitability", the cetane rating, of diesel fuels. Additives were used, either without further treatment, in various proportions, or were added to the fuel in conjunction with some treatment such as "nitration", "ozonisation".

For convenience, the work done with various additives and the results obtained are summarized in table form.

Used as additive	Proportion in volume	Original Diesel fuel	CETANE RATING		Remarks
			Original	Resultant	
<u>NITRATES & NITRITES</u> Ethyl Nitrate	.5 to 1%	Petroleum Gas-Oil	45	53-59	Boils at 195°C; this is too low Vapour very toxic.
Ethyl Nitrate	1 to 5%	do	do	up to 72	Above 1% strongly corrosive in injection system

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4. Diesel Fuel Additives. (Cont'd)

Used as additive	Proportion in volume	Original Diesel fuel	CETANE RATING		Remarks
			Original	Resultant	
Amyl Nitrate	1 to 5%	Petroleum Gas-Oil	45	Up to 70	Quite corrosive in injection system
Iso Amyl Nitrite	1 to 5%	do	do	do	Much less corrosive than nitrate
Methyl nitrate		do	do	do	Not corrosive but boils at 122°F, too low
PEROXIDES					
Dimethyl-Peroxide	1 to 3 %	Petroleum Gas-Oil	45	-	Strong action but boiling point is 55°F
Ethylene-Peroxide	do	do	do	60	No special data
Acetone-Peroxide	do	do	do	do	Extremely explosive crystals - harmful only when dissolved.
Diethyl-Peroxide	do	do	do	do	Very effective
Diethyl-Peroxide	3%	Lignite Gasoline	25	31	Very effective
Diacetone Diperoxide	1 to 2%	Gasoil	45		Very effective
Diacetone Diperoxide	3%	Lignite Gasoline	25	34	
Diacetone Diperoxide	do	F.T. Kogasin No. 1	64	70	

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4. Diesel Fuel Additives. (Cont'd)

Used as additive	Proportion in volume	Original Diesel fuel	CETANE RATING		Remarks
			Original	Resultant	
Monoxy-Diethyl Peroxide	1 to 2%	-	-	-	About same action as ethylene peroxide but not quite so soluble in fuels
Dioxy-Diethyl Peroxide	Less than 1%				Appears to act satisfactorily but not soluble enough
Tetraline Peroxide	3%	Lignite Gasoline	25	39	These results are questionable
Tetraline Peroxide	do	F.T.K. Gasin #1	64	89	These results are questionable
Di-Benzoyl Peroxide	do	Lignite Gasoline	25	28	These results are questionable
Di-Benzoyl Peroxide	Less than 1%	Gasoil	45	up to 54	
Acetyl Benzoyl Peroxide	2%	Lignite Gasoline	25	30	
Acetyl Benzoyl Peroxide	1.2%	Gasoil	45	55	

This tabulation shows that the number of chemicals either of the nitrate or nitrite type, or of the peroxide type, that can effectively be used as additives to diesel fuels is somewhat restricted even though many may upgrade the ignitability to a considerable extent.

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4. Diesel Fuel Additives. (Cont'd)

A further limitation is found in the solubility of some of these additives.

(a) Solubility of Peroxides in Various Fuels.

An important aspect of the addition of chemicals into diesel fuels is their solubility in the various types of oils at different temperatures. This in several cases, limits their use. In general it can be said that the solubility of peroxide additives increases as the percentage of un-saturated and aromatic hydrocarbons in the oil increases, while their solubility decreases proportionally to the percentage of paraffinic components.

Following tabulation gives the solubility of several peroxides at a temperature of 68°F (20°C):

Peroxides	Petroleum Gasoil	Kogasin I from Fischer-Tropsch	Lignite Gasoline	Launa Gasoline (Hydrogenation of Lignite Tar)
DiAcetone di Peroxide	2.4%	4.2%	5.4%	4.2%
DiBenzoyl di Peroxide	1.2	.8	3.4	.8
Acetyl Benzoyl di Peroxide	2.2	8.2	15.4	-
Tetraline di Peroxide	1.8	4.8	16.1	3.
Diethyl di Peroxide	7 Vol.	6 Vol.	50:50	5 Vol.

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4. Diesel Fuel Additives. (Cont'd)

(b) Effect of Peroxides on Ignitability.

Further tests were conducted at the Technische Hochschule of Munich, in a test engine where the compression ratio could be modified from 10:1 to 18:1, for the purpose of determining, with several diesel fuels and various peroxide additives, how low the compression ratio could be brought, in each case, before ignition would fail to occur.

The characteristics of the tests were as follows:

Air Temperature	86°F
Cooling Water	158°F
R.P.M.	470 / 5
Injection Angle	17° before Top Dead Center
Torque	5 Kg/m
Injection Pressure	14.5 Atm.
Injector	Bosch DL 120 S 5 P 6, 5 outlets.

Below are the results, indicated in "Degrees of ignition delay, measured on the indicator diagrams", for various fuels at various compression ratios. The sign = means that no measurement was available, the sign - means "ignition fails to occur".

The reference fuel in all these tests is a petroleum gas-oil from Persian crude with a cetane rating of 45.

1st Series. The fuel selected for the tests was a widely used type of brown coal tar oil referred to as "diesel fuel B" from the low-temperature distillation of lignite from Middle Germany (probably Saxony) with 2 percent of the additives indicated:

Compression Ratio	18	16	14	13	12	11	10
Reference Fuel	9	10	12	=	15	=	20/21
Diesel Fuel B without Additive	14	15/16	20	26/27	-	-	-
Diesel Fuel B With 2% of:							

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4. Diesel Fuel Additives. (b)(Cont'd)

Compression Ratio	18	16	14	13	12	11	10
Di Methyl Peroxide	9	10/11	13	=	18	=	28
Di Ethyl Peroxide	10	11/12	13/14	=	19	25	-
Di Acetone Peroxide	11	12/13	15	=	21	27	-
Monoxydi Ethyl Peroxide	12	13	15/16	=	22/23	26/27	-
Hydrogen Peroxide	12	14	17	=	25/26	28	-
Monoperparaldehyde	13	15	19	29/30	-	-	-
Acetyl Benzoyl Peroxide	13/14	15	20	26	-	-	-

Tetralin, Dibenzoyl, Dioxy-Diethyl, etc.. show practically no difference in ignition delay.

2nd Series. Same diesel fuel "B" but with only 1 percent of peroxide additives:

Compression Ratio	18	16	14	13	12	11	10
Dimethyl Peroxide	10/11	12	14/15	=	20/21	28	-
Di Ethyl Peroxide	11/12	13	17	=	24/25	-	-
Di Acetone Di Peroxide	12	13/14	17	=	25	-	-
Ethylidene Peroxide	12/13	14/15	18	=	29	-	-
Acetylbenzoyl Peroxide	14	16	20/21	27	-	-	-

These two series of tests show the effect of even small percentages of certain peroxide additives in bringing back the ignition delay of a Diesel fuel towards the ignition delay of the reference fuel of petroleum origin. In other words it can be seen how certain additives permit the use of a synthetic diesel fuel which could not be adequately consumed without these additives at the compression ratio available in certain diesel engines.

The next series of tests shows the influence of peroxide additives on the stability of diesel fuels. For every compression ratio the ignition delay is shorter when peroxides were added to the fuel before its prolonged storage.

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4. Diesel Fuel Additives. (b)(Cont'd)

3rd Series. A similar diesel fuel (brown coal tar) from low-temperature distillation of lignites, with 2 percent additives except as noted, and after ten months of storage.

Compression Ratio	18	16	14	12	11	10
Diesel Fuel alone	13	14	16/17	22	29/30	-
Di Aceton Di Peroxide	10	11	12/13	16	-	26
Di Ethyl Peroxide	11	12/13	14/15	18/19	23	-
Di Ethyl but only 1%	12	13	15	19	24/25	-
Acetyl Benzoyl Peroxide	12	13/14	16	21	27	-
Tetralin Peroxide	12	13/14	16	21/22	-	-
Di Benzoyl Peroxide	12	13/14	16	22	-	-

The fourth series of tests reported on the next tabulation shows that some "ignition accelerator" must be added to the diesel fuel obtained from low temperature coal tar before it can be used as diesel fuel.

4th Series. A Diesel fuel from the low-temperature distillation of coal, which does not ignite satisfactorily in the engine at compression ratio of 18:1 or below, and even at 18:1 has a 27° ignition delay, with 2 percent of various peroxide additives, or 1 percent as noted.

Compression Ratio	18	16	14	13	12
Diesel fuel without additive	27	37/38	-	-	-
Diesel fuel with: Diethyl Peroxide, 2%	16	18	23	30	37
Diethyl Peroxide but only 1% added	16	18	28/29	-	-
Di Acetone Peroxide, 2%	17	19/20	26	34/35	-
Di Acetone Peroxide but only 1% added	18	22	34	-	-
Mono oxy Di Ethyl Peroxide, 2%	17/18	21/22	30	-	-

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4. Diesel Fuel Additives. (b)(Cont'd)

Compression Ratio	18	16	14	13	12
Acetyl Benzoyl Peroxide	18/19	22/23	31	-	-
Tetralin Peroxide	19	23	40	-	-

A final set of tests was made to see the action of the peroxide additives on a diesel fuel of petroleum origin. The same "reference fuel" is tabulated as for the first series of tests. Results show that the additives improve the ignitability of the diesel fuel beyond the quality of the reference fuel.

5th Series. Same additives in 2 percent concentration in a petroleum gas-oil (origin not known):

Compression Ratio	18	16	14	12	10	9
Reference Fuel	9	10	12	15	20/21	25
Gas-oil without Additives	9/10	11	13/14	17/18	26/27	-
Gas-oil with 2% of Di Ethyl Peroxide	6/7	7	9/10	11/12	16/17	22/23
Acetyl Benzoyl Peroxide	7/8	8/9	10	12/13	18	25/26
Di Aceton Di Peroxide	7/8	9	10/11	14/15	19/20	29/30
Mono OxyDiethyl Peroxide	8/9	9/10	11/12	14/15	21	29/30
Tetralin Peroxide	8/9	9/10	11/12	15	21/22	-

In addition to the better ignitability of diesel fuels containing peroxide additives, a much smoother operation and a much cleaner exhaust could be noticed.

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4. Diesel Fuel Additives. (Cont'd)

(c) Effect of Other Type Additives on Ignitability.

Two additives, tried at the Technische Hochschule of Munich are worth mentioning. One is "chlorpicrin" which is "trichlor nitro methane"; added in proportion up to 4 percent it increases the cetane value materially. For instance a Kogasin II, of 92 cetane, goes up to 116 cetane by nitration and to 170 with addition of chlorpicrin after nitration. The other additive is "Lupanol", a "tetra nitro methane" which in concentrations up to 3 percent has a marked influence on ignitability.

In 1942 the Technische Hochschule in Munich conducted experiments with other organic additives. It was found that the following chemicals reduce the ignitability:

- Esters
- Cyclic hydrocarbons (like pseudocumol, cymol)
- Cyclic aldehydes (like benzoic aldehyde)
- Alcohols of low-molecular weight.

The following chemicals, on the other hand, increase the ignitability:

- Straight-chains aldehydes, in large proportion (as much as 20 percent).
- Alcohols of high molecular weight.

For alcohols in particular the following tabulation illustrates the results, and shows that, from n-Octyl alcohol up an appreciable increase in cetane rating can be noticed.

Alcohol Added	Porportion	CETANE RATING		
		of Gasoil	After addition	Difference
D1 Aceton-Alcohol	20%	45	36	-9
n - Propyl Alcohol	20%	46	37	-9
C3	40%	46	28	-18
n - Hexyl Alcohol	20%	46	38	-8
C6		do		
n - Octyl Alcohol	20%	do	47	+1
C8	40%	do	51	+5

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4. Diesel Fuel Additives. (c)(Cont'd)

Alcohol Added	Porportion	CETANE RATING		
		of Gasoil	After addition	Difference
n - Nonyl Alcohol	20%	46	48	+2
C ₉	40%	do	49	+3
n-Decyl Alcohol	20%	do	51	+5
C ₁₀	40%	do	58	+12

(d) Effect of NITRATION on Ignitability.

Best results with high molecular alcohols were obtained when a "nitration" treatment was given the mixture, in the following manner. First a Fischer-Tropsch Kogasin I was selected and the fractions boiling below 212°F were removed. The balance had a cetane rating of 39. This was mixed with 50 percent of various alcohols, and the mixture subjected to a nitration process by bubbling gaseous concentrated nitric acid through the liquid. The results were as follows:

Percentage of NO ₂ Absorbed	Increase in Cetane
.12	0
.31	0
.67	3
1.20	7
1.58	10.5
2.08 (Saturation)	18

In most of these experiments a precipitation of pitch took place, and the oil had to be filtered after the reaction.

These fuels are not corrosive unless they are from coal origin and contain phenols.

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4. Diesel Fuel Additives. (Cont'd)

(c) Effect of OZONISATION on Ignitability.

The Technische Hochschule of Munich conducted a considerable number of tests in 1940-42 along the line of ozonisation of Diesel fuels for the purpose of raising the cetane rating. It was found that the length of contact of the diesel fuel with the ozone was important, and that the ignitability was raised regardless of the oil, for instance Ruhrbenzin (gasoline) was as susceptible to the ozonisation treatment as Kogasin. Taking a Ruhr gasoline of 47 cetane the following increases were noted:

After 3 hours ozonisation, the cetane was						
"	6	"	"	"	"	58
"	9	"	"	"	"	74
"	12	"	"	"	"	106
"	20	"	"	"	"	114
"	24	"	"	"	"	130
"		"	"	"	"	140

Results of various experiments conducted in 1941-42 are summarized in the following tabulation:

PRODUCT, ADDITIVE and TREATMENT	CETANE RATING
Pure Fischer-Tropsch Kogasin I (Average)	64
Same Kogasin I with 10% CS ₂	68
Same Kogasin I with 3% Di Acetone Di Peroxide	70
Same Kogasin I with 5% Nitro Benzol	72
Same Kogasin I with 3% Amyl Nitrite	74
Same Ozonised for 5 hours (1 liter)	82
Same Kogasin I with 3% Ethyl Nitrate	85
Same Kogasin I with 3% Tetralin Peroxide	89
Same Kogasin I with 3% Lupanol	96
Same treated in contact with nitric acid	98
Same ozonised 8 hours (1 liter)	100
Same ozonised 10 hours (1 liter)	100
Same ozonised 15 hours then extracted	106
Same extracted with methyl alcohol then ozonised 15 hours (1 liter)	134
Same extracted with methyl alcohol then ozonised 8 hours (1 liter)	148

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4. Diesel Fuel Additives. (e)(Cont'd)

<u>PRODUCT, ADDITIVE and TREATMENT</u>	<u>CETANE RATING</u>
Same extracted with methyl alcohol then nitrated	96
Kogasin I extracted, nitrated and ozonised (1 liter in 8 hours)	101
Kogasin I - simply ozonised at rate of 1 liter in 15 hours	113
Kogasin II - pure	92
Kogasin II - Nitrated	116
Kogasin II - Ozonised 5 hours	121
Pure cetane	100
Cetane treated with nitric acid	104
Cetane treated with nitric acid at 194°F	132
Cyclo-hexane	11
Cyclo-hexane treated with nitric acid at 130°F	26

The above tabulation is self-explanatory. A comparison of the results with those obtained by the mere addition of a chemical permits an evaluation of the effect of a treatment such as nitration, ozonisation, or a combination of the two processes.

(f) Object of German Research with Additives.

It is to be noted that the study of "diesel fuel additives", conducted in various German scientific activities was concentrated upon one single feature; an increase in ignitability. Extensive studies of the performance of these additives in various oils, their stability, their corrosive action, before and after combustion, were apparently not made. Neither have the investigators come in contact with any studies of real value about additives that would improve the entire process of combustion regardless of the ignitability. The reason seems to be that, up to this date, additives have not been considered as the proper method to improve a diesel fuel. The Germans efforts were rather to concentrate upon the preparation of the proper blends of oils, natural or synthetic, which would operate satisfactorily without the use of additives.

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5. The Significance of Cetane Increase.

At the Technische Hochschule of Stuttgart, considerable work was done to determine, at various temperatures, the "critical compression ratio" of a diesel engine; that is, the compression ratio below which ignition of the diesel fuel cannot be entertained. The two charts show some of the results. In Figure 1 critical compression ratios are plotted against air temperatures for fuels of various ignitabilities and for ignition accelerating vapours in the air used for combustion. Figure 2 shows the correlation between cetane ratings and critical compression ratios at normal temperature (65°C) for various additions of ethyl nitrate.

Thus it would appear that an increase in cetane rating by permitting a reduction of the "critical compression ratio" at every temperature makes it possible to build an engine that develops more power per pound or, conversely, to obtain a greater output from an engine built for a given compression ratio.

In reviewing these laboratory efforts to raise the cetane rating of oils used as diesel fuels the following questions have been justifiably asked. "How high should the cetane rating of a fuel be raised? What can be gained? What seems to be the desirable cetane limit in the light of today's knowledge? What is the diesel engine manufacturer's position with regards to extremely high cetane ratings?"

The German scientists and manufacturers interviewed seem to agree on the answer summarized below. For the present high speed diesel engine 50 cetane rating is satisfactory. For the engine of tomorrow the discussion revolved around the question of "efficiency versus compression ratio".

An examination of Figure 3 shows, in the range of the Otto gasoline engine, an increase in efficiency with an increase in compression ratio, the latter being made possible by an increase in the "octane rating" of the fuel. A further examination shows, in the range of the diesel engine, a somewhat smaller increase in efficiency with decreasing compression ratio. Such decrease, as shown above, is made possible by use of a fuel having a high ignition quality.

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5. The Significance of Cetane Increase Cont'd

Therefore an increase in cetane rating, in ignitability instead of being used to further an "increase in compression ratio" as used in an entirely opposite direction, namely to make a smoother running with a "lower" compression ratio, and all the simplification in weight, material, lubrication friction losses, that such a reduction entails. The principle appears to be perfectly sound especially when friction losses are considered and will undoubtedly guide manufacturers on both sides of the ocean towards the construction of a lighter more economical engine that may eventually permit an engine intermediate between Otto and diesel types.

6. Conclusions.

During the war it can be said that the Germans had no high quality diesel fuel as such, but blends of synthetic and natural products, each playing a definite part in the performance of the fuel. They explored the field of chemical additives but did not use them in practice. They developed certain treatments that resulted in cetane ratings of fantastic proportions. Gasolines had to be used at times when other diesel fuels were scarce. No innovations were found in the way of producing, storing or handling diesel fuels. The processes of nitration and ozonisation of diesel fuels and blends and the treatment of tar oil blends with gaseous SO₂ for purification are of major importance and may well contribute to an improvement in, or extension of American diesel fuel supplies, with their further exploration and adoption.

Prepared by:

R. J. BENDER,
Lieutenant USNR.

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APPENDIX I

THE FKFS TESTING STAND

The Technische Hochschule of Stuttgart had a department, at times 450 employees strong, for technical developments in the science of engines. It was called the "Forschungs Institut für Kraftfahrwesen und Fahrzeugmotoren an der Technische Hochschule Stuttgart" located at Unter Turckheim near Stuttgart in a group of buildings of the Daimler-Benz Factory. There a testing motor was developed, used for gasoline as well as for Diesel research, the FKFS Motor, having the following characteristics.

For diesel tests, in particular four (4) types of combustion chambers are available:

- Direct Injection
- Pre-combustion chamber
- Air-cell system
- Fuel-cell system

The compression ratio can be varied from:

- 4.5:1 up to 25:1
- Bore 100m/m
- Stroke 130m/m
- Cylinder Volume 1000 cm³ (1 liter)
- Speed Up to 2500 RPM normally, for short periods 3000 RPM corresponding to a piston speed of 42.6 feet-per second

- Cooling water temp 80° C
- Lubricating Oil Vol. from 3 to 6 quarts
- Oil temperature up to 100° C
- Oil pressure 3 Atm
- Valve lift (both) .15 m/m
- Inlet valve opens 10° BTDC
- Exhaust valve closes 12° ATDC

Injection and ignition timing controllable
Injection pressures:

- Direct injection 180 Atm
- Pre-comb. chamber 90 Atm
- Air-cell 90 Atm
- Fuel Cell 110 Atm

DEUTSCHES REICH



REICHPATENTAMT
PATENTSCHRIFT

№ 730853

KLASSE 12r GRUPPE 1a

SI 57006 IVd/11r



Dr. Herbert Käbel in Moers



ist als Erfinder genannt worden.

Steinkohlen-Bergwerk „Rheinpreussen“ in Homberg, Niederrhein
Verfahren zur Reinigung von Gemischen aus Teerölen und aliphatischen Kohlenwasserstoffen

Patentiert im Deutschen Reich vom 14. Januar 1938

Patenterteilung-bekanntgemacht am 24. Dezember 1942

Gemäß § 2 Abs. 2 der Verordnung vom 28. April 1938 ist die Erklärung abzugeben, wenn es sich um ein Verfahren handelt, daß sich der Schutz auf das Land Österreich erstrecken soll.

Die vorliegende Erfindung bezweckt die Herstellung von Dieselmotoren aus Gemischen von Teerölen, besonders Steinkohlenteeröl, mit Kohlenwasserstoffen der Paraffinreihe und betrifft ein Verfahren zur Reinigung dieser Gemische.

Es ist an sich bekannt, schwer zündende Teeröle durch Zusatz von zündwilligeren, vorwiegend aliphatischen Gasölen für den Verbrauch in Dieselmotoren nutzbar zu machen. Diese nichtraffinierten Mischungen scheitern jedoch in kurzer Zeit asphaltartige Stoffe aus, die eine motorische Verwendung und eine Lagerung unmöglich machen. Es ist bereits ein Verfahren bekannt, nach welchem solche Asphaltstoffe durch längeres Erhitzen unter Rückfluß aus Teeröl-Gasöl-Mischungen ausgeschieden werden. Die Wirkung dieser Wärmebehandlung soll dadurch erhöht werden, daß die Erhitzung des Ölgemisches in Gegenwart von Spalt- oder Hydrierungskata-

lysatoren oder im Beisein von Salzen des Aluminiums oder Magnesiums vorgenommen wird. Weiterhin soll die Erhitzung des Ölgemisches unter Druck von Vorteil sein.

Die nach dem angeführten Verfahren hergestellten Dieselmotoren genügen jedoch nicht den Ansprüchen, die an Dieselöl für schnell laufende, empfindliche Motoren gestellt werden müssen, insbesondere besitzen derartige Dieselmotoren eine zu hohe Verkokungsneigung, die zu Düsenverstopfungen und zum Verkleben von Kolbenringen führt.

Die Erfindung vermeidet diese Nachteile und erzielt einen einwandfreien Dieselmotorenstoff durch Reinigung von Gemischen aus Teerölen und vorwiegend aliphatischen Kohlenwasserstoffen der Siedelage 180 bis 300, indem die Gemische mit gasförmigem Schwefeldioxyd bei gewöhnlichem Druck behandelt und von den hierbei ausgeschiedenen

Stoffen abgetrennt werden. Durch diese Behandlung werden der größte Teil der phenolischen Anteile sowie Asphaltstoffe, Pech und Harze abgeschieden und abgetrennt. Die Anwendung von Wärme ist hierbei nicht unbedingt erforderlich. Das Schwefeldioxydgas wird zur Raffination weiterer Gemische wieder verwandt. Das so gereinigte Ölgemisch kann auf die übliche Weise durch Waschen mit Wasser oder Lauge, gegebenenfalls auch mit Bleicherde, weiter behandelt werden. Man erhält so einen hellen, lagerbeständigen Dieselloilstoff, der frei ist von Asphalten, Harzen und phenolischen Ölen und der nur eine geringe Verkokungsneigung zeigt. Es ist ein wesentliches Merkmal des Verfahrens der Erfindung, daß das zur Raffination verwendete Schwefeldioxyd chemisch nicht mit dem Ölgemisch reagiert, so daß auf diese Weise nur ein ganz geringer Verlust an Raffinationsmitteln eintritt. Man kann so mit geringen Mengen an Raffinationsmitteln große Mengen dieser Ölgemische, z. B. durch Umpumpen des Gases, reinigen. Bezüglich der Wirkungsweise wird angenommen, daß die Paraffinkohlenwasserstoffe die als Dieselloilkraftstoff erwünschten Bestandteile des Teeröls als eine Art selektives Lösungsmittel in Lösung haben, während die unerwünschten Inhaltsstoffe unter der Einwirkung von Schwefeldioxyd als unlöslich ausgeschieden werden.

Nach einem weiteren Erfindungsmerkmal ist es für die Ausführung des Verfahrens von großem Vorteil, bei der Kohlenoxydhydrierung entstehende Paraffinkohlenwasserstofföle der Siedegrenzen 180 und 360 zu verwenden. Diese Kohlenwasserstofföle zeichnen sich durch ihren hohen Wasserstoffgehalt bzw. durch ihre geringe Dichte aus und überwiegen in diesen Eigenschaften jedes natürliche Erdöl der gleichen Siedegrenzen. Aus Grund des hohen Wasserstoffgehaltes besitzen diese Kohlenwasserstofföle für die unerwünschten Inhaltsstoffe des Teeröls nur ein sehr geringes Lösungsvermögen, so daß die Ausscheidung dieser Stoffe mittels Schwefeldioxyds besonders leicht und schnell vor sich geht. Außerdem bietet die in Frage stehende Kohlenwasserstofffraktion des Benzinsgasolherodes, bekanntlich ganz erhebliche motorische Vorzüge, die sich in restloser Verbrennung und hoher Zündwilligkeit auswirken.

Es ist zwar bekannt, zwecks Herstellung von Dieselloilen Teeröle mit Kohlenwasserstoffölen der Kohlenoxydhydrierung zu vermischen. Ganz abgesehen davon, daß derartige Mischungen infolge von Ausscheidungen und Düsenverstopfung praktisch gänzlich unbrauchbar sind, bezieht sich die Erfindung

nicht auf die Zumischung dieser Kohlenwasserstofföle an sich, sondern auf ihre besondere Wirkung als selektives Lösungsmittel im Verein mit dem Schwefeldioxyd. Dieses selektive Lösungsvermögen ist begründet in dem eigenartigen Aufbau dieser Kohlenwasserstofföle, deren Wirkung auf Teeröle im Verein mit gasförmigem Schwefeldioxyd nicht bekannt war und überraschend ist.

Es sind zahlreiche Verfahren bekannt, nach denen Mineralöle und Teeröle mit flüssigem Schwefeldioxyd unter Druck behandelt werden. Bei diesen Verfahren handelt es sich jedoch um Extraktionen in der Flüssigphase. Demgegenüber unterscheidet sich die Arbeitsweise der Erfindung grundsätzlich nach Zweck und Ausführung. Weiter ist bekannt, Öle, die durch spaltende Hydratung von Kohlen, Teeren und Mineralölen erhalten werden, mit sauren Gasen zu behandeln, um diese von festen Teilchen zu befreien. Diese Arbeitsweise ist jedoch ausdrücklich auf die Entfernung fester Teilchen beschränkt. Das Verfahren nach der Erfindung bezweckt jedoch die Reinigung von Teerol-Paraffinkohlenwasserstoff-Gemischen, die frei von festen Bestandteilen sind; es wird daher von dem erwähnten bekannten Verfahren nicht be- rührt, zumal die erwähnte Wirkung des erfindungsgemäßen Verfahrens nicht zu erwarten war. Man hat auch versüht, Mineralöle, wie Petroleum und Paraffinole, mit gasförmigen Schwefeldioxyd zu reinigen, jedoch nicht Gemische von Teerölen mit Paraffinkohlenwasserstoffen, die durch die oben geschilderten Löslichkeitsverhältnisse sich in bezug auf die Ausscheidung von Asphalt, Harz und Pechstoffen gänzlich anders verhalten. Das geht daraus hervor, daß sich durch getrennte Behandlung von Teerol einerseits und Paraffinkohlenwasserstoffen andererseits mit Schwefeldioxydgasen keine Reinigungswirkung erzielen läßt.

Man hat auch schon Diesellole verschiedener Herkunft durch Behandlung mit ozonhaltigen Gasen zu reinigen versucht; ganz abgesehen davon, daß man hierbei die Mitwirkung aliphatischer Kohlenwasserstofföle nicht erkannte, zeigen Vergleichsversuche, daß die Reinigungswirkung von ozonhaltigen Gasen auf ein Gemisch von Teeröl und aliphatischen Kohlenwasserstoffölen sehr viel schlechter ist als die erfindungsgemäße Arbeitsweise mit Hilfe von Schwefeldioxyd.

Der mit dem Verfahren nach der Erfindung gegenüber dem Bekannten erzielte technische Fortschritt besteht in der Herstellung von Dieselloilstoffen aus Gemischen von Teerölen mit aliphatischen Kohlenwasserstoffölen, die frei sind von Asphalt, Harz, Pech und Harzbildnern, arm an phenolischen

Ölen, und die dem aus dem Destillat gewonnenen. Die Anwendung mit Wasserstoff stellt den wesentlichen Vorteil dar, nämlich Aufwänden an Kohlenwasserstoffen ohne Ausrüstung, welche sonst verwendet werden kann. Die ab gewonnenen Brennstoffe haben eine noch weit höhere Verbrennung sowie ein kohlenwasserstoffreiches Gas über einen weiten motorischen Belastungsbereich. Infolge der geringen Verkokungsneigung ist die Gefahr der Düsenverstopfung und Kohlenringverkrustung weitgehend herabgemindert gegenüber gleichartigen Dieselmotoren, die nach den erwähnten bekannten Verfahren hergestellt sind.

Beispiel

Ein Steinkohlenteeröledestillat aus der Hochtemperaturverkokung (180 bis 320°, Dichte 0,95 bis 1,05 bei 15°) wird mit einem nach der Benzinsynthese aus Kohlenoxyd und Wasserstoff hergestellten Kohlenwasserstofföl

gemischt. Das Gemisch wird durch eine leichte physikalische Destillation von dem von dem Öl sehr verschiedenen Destillat bei einer bestimmten Temperatur getrennt. Die Phenolmenge ist von 2,7 auf 1,2 Volumenprozent gesunken. Die Verkokungsneigung (nach Ringelmann und Hammerich, Öl und Koks, S. 22, 1936) ist von 0,320 auf 0,064 herabgemindert worden. Das mit der beschriebenen Weise behandelte Ölgemisch wird mit verdünnter Natronlauge und Wasser nachgewaschen und einer 1%igen Bleichmittelbehandlung unterzogen.

Die mit Schwefeldioxydbehandlung erzielte Wirkung geht aus den chemischen und physikalischen Daten des Ölgemisches vor und nach der Behandlung hervor:

	Vor der Behandlung	Nach der Behandlung mit SO ₂
Dichte bei 15°	0,862	0,855
Phenolgehalt in Volumprozent	2,9	1,2
Verkokungsneigung:		
Benzinunlösliches	0,320	0,064
Hartasphalt	0,108	0,030
Koks	0,212	0,034
Farbe	schwarzbraun undurchsichtig	gelb, klar durchsichtig

PATENTANSPRÜCHE:
 1. Verfahren zur Reinigung von aus Teerölen der Siedelage 180 bis 360° und vorwiegend aliphatischen Kohlenwasserstoffölen gleicher Siedelage bestehenden Gemischen, dadurch gekennzeichnet, daß die Gemische mit gasförmigem Schwefel-

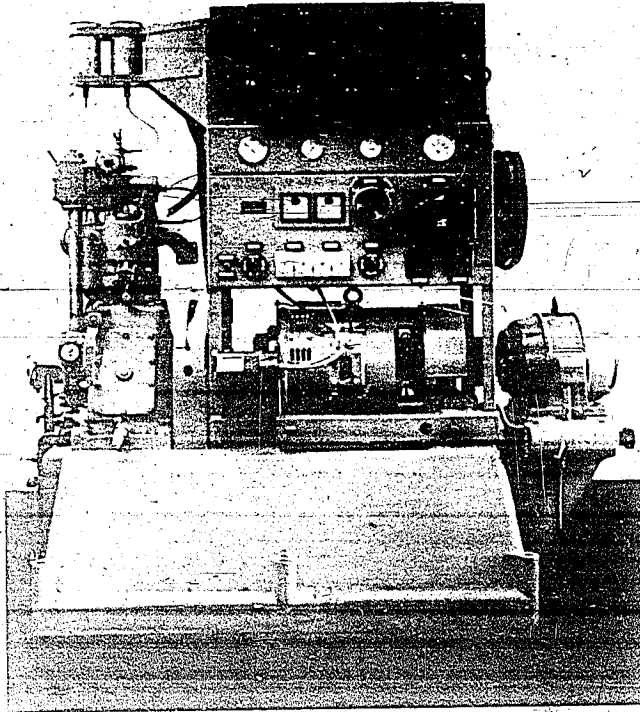
dioxyd bei gewöhnlichem Druck behandelt und von den hierbei ausgeschiedenen Stoffen abgetrennt werden.
 2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß man von Gemischen ausgeht, die außer Teeröl aliphatische Kohlenwasserstofföle enthalten, die durch Kohlenoxydhydrierung gewonnen werden.



FEDERAL INSTITUTE FOR RESEARCH AND TESTING
DEPARTMENT OF METROLOGY
TECHNICAL DIVISION
BREMEN

Betriebsanleitung für den Kraftstoffprüfmotor.

Bild 1



Hersteller	Göppel	Typ		Erstellt für	Ersetzt durch
Platz		Tag			

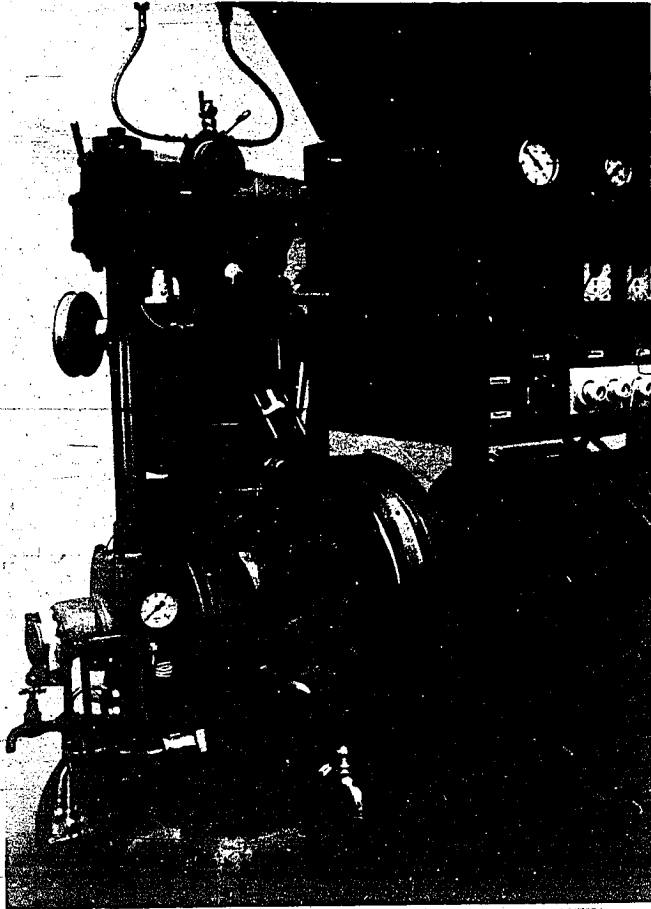
Se. 146. A 6 Albert Metz, Stuttgart.



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FÜR KRAFTFAHRZEUGE
U. FAHRZEUGMOTOREN
TECHN. HOCHSCHULE
STUTTGART

Betriebsanleitung für den
Kraftstoffprüfmotor.

Bild 2



Überprüfte Verweidung ist stropfer- und absaugenrichtig

Bild 2

FKFS Kraftstoff-Prüfmotor.

Bearbeiter: GROSS

Tag:

Erstellt für

Erstellt durch

Prüfer:

32

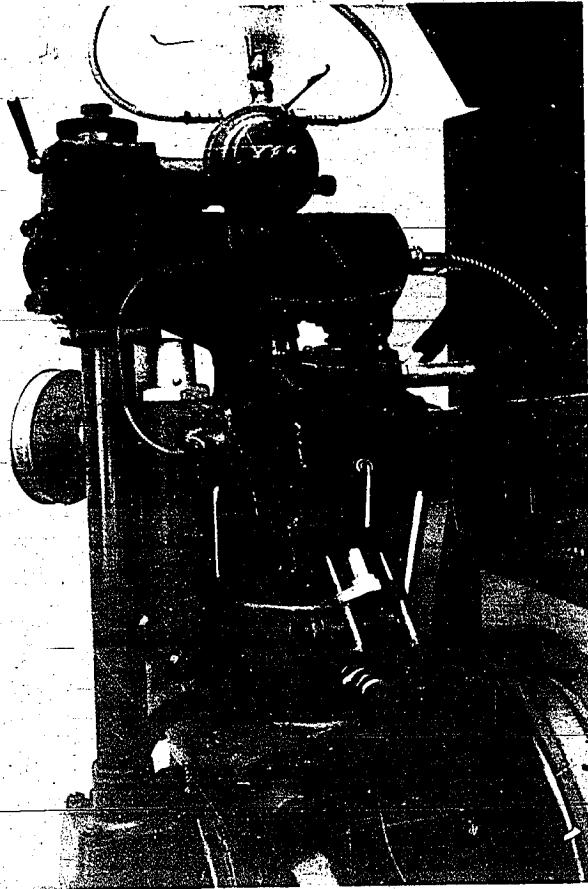


Bild 3
Zylinderaufbau.

Bearbeiter:

GROBE

Tag:

Ersatz für

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Prüfer:

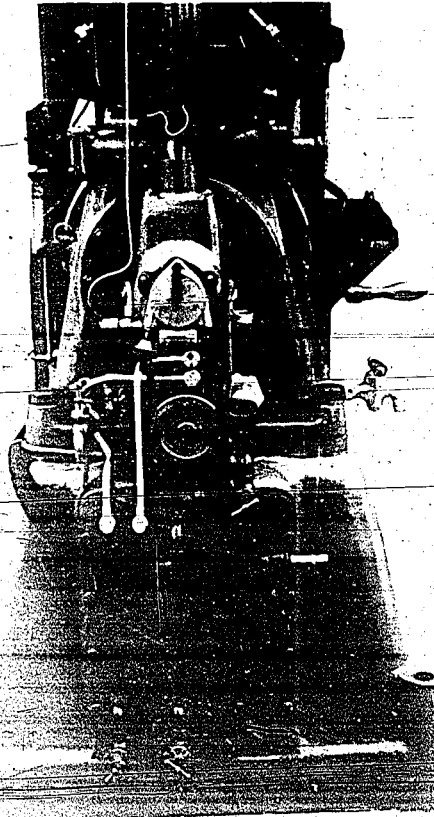
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FORSCHUNGSINSTITUT FÜR
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Betriebsanleitung für den Kraftstoffprüfmotor

Bild 4



Bearbeiter:
Prüfer:

GEORG

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Pag:

Ersatz für

Ersatz durch



Betriebsanleitung für den Kraftstoffprüfmotor.

Bild 8

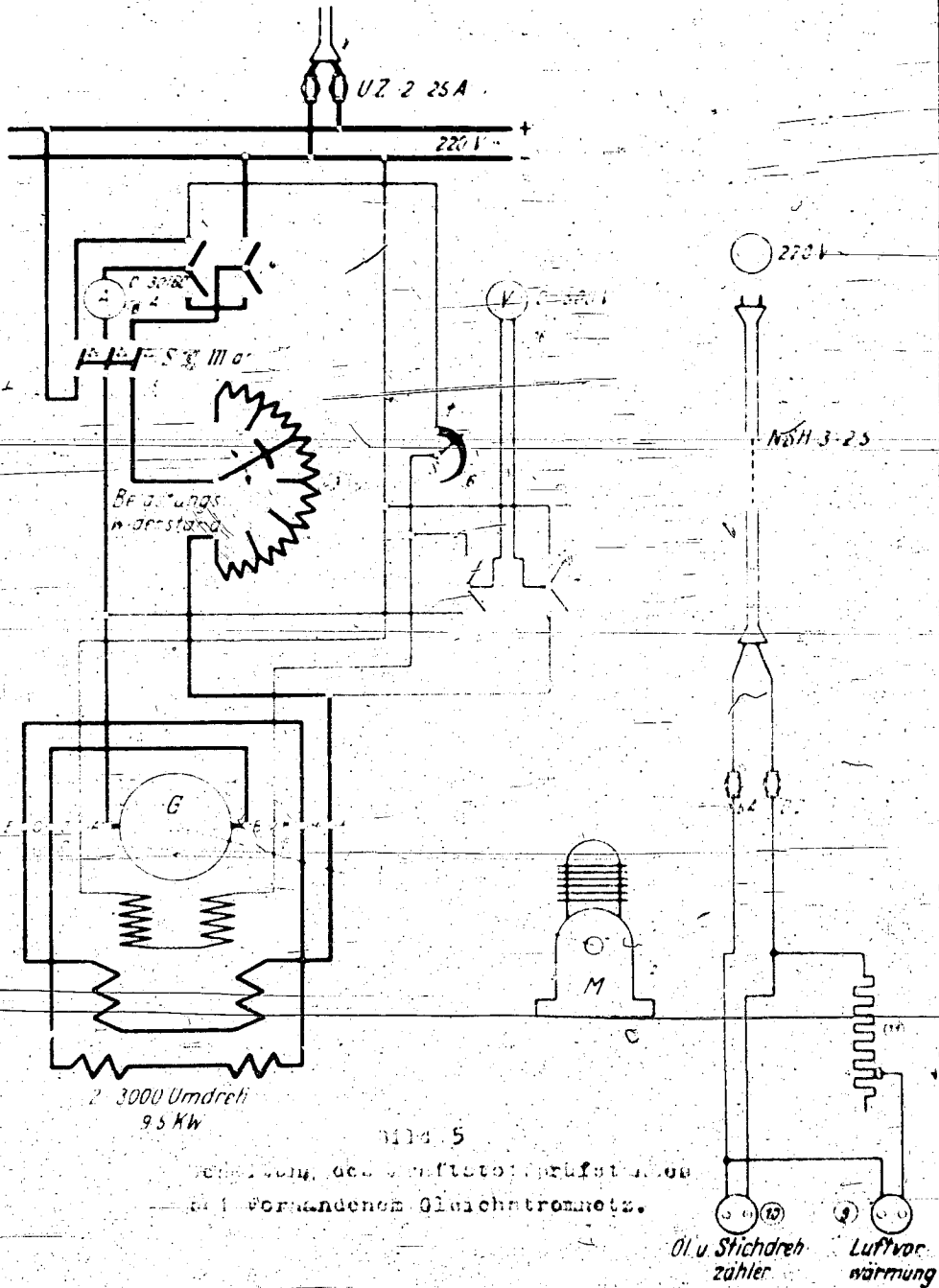


Bild 5

Verbindung des Kraftstoffprüfmotors an
ein vorhandenes Gleichstromnetz.

Hersteller	Typ	Erstellt von	Erstellt am
Prüfer	Tag		

35



HERGESTELLT IN ÜB-
ER EINGETRAGEN
VOM PATENTAMT
AM 10. SEPTEMBER
1933

Betriebsanleitung für den Kraftstoffprüfmotor.

3116 6

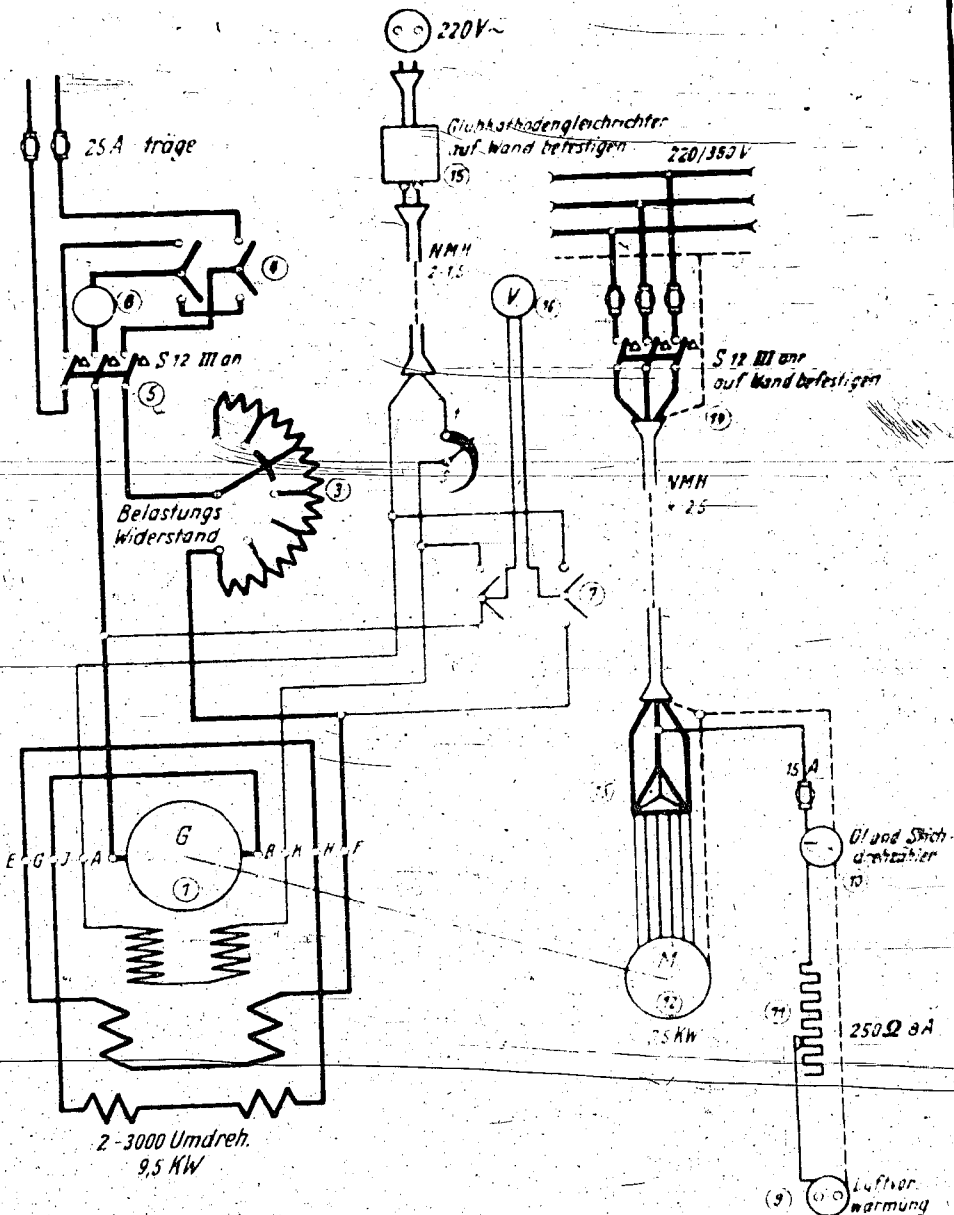


Bild 6

Schaltung des Brennstoffprüfstandes bei
vorhandenem Drehstromnetz.

Dauerhersteller: **Gröpp**

Tag: _____
Tag: _____

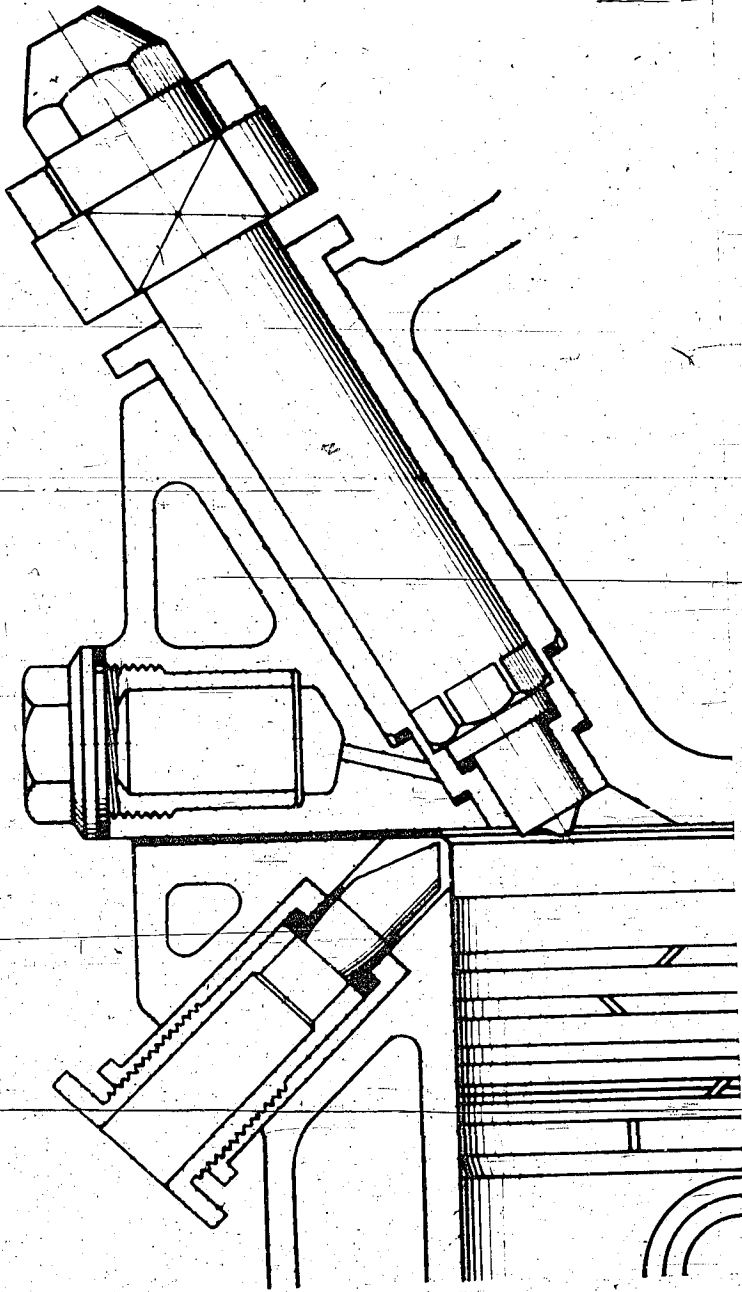
Gezeichnet von:

Freigelegt durch:



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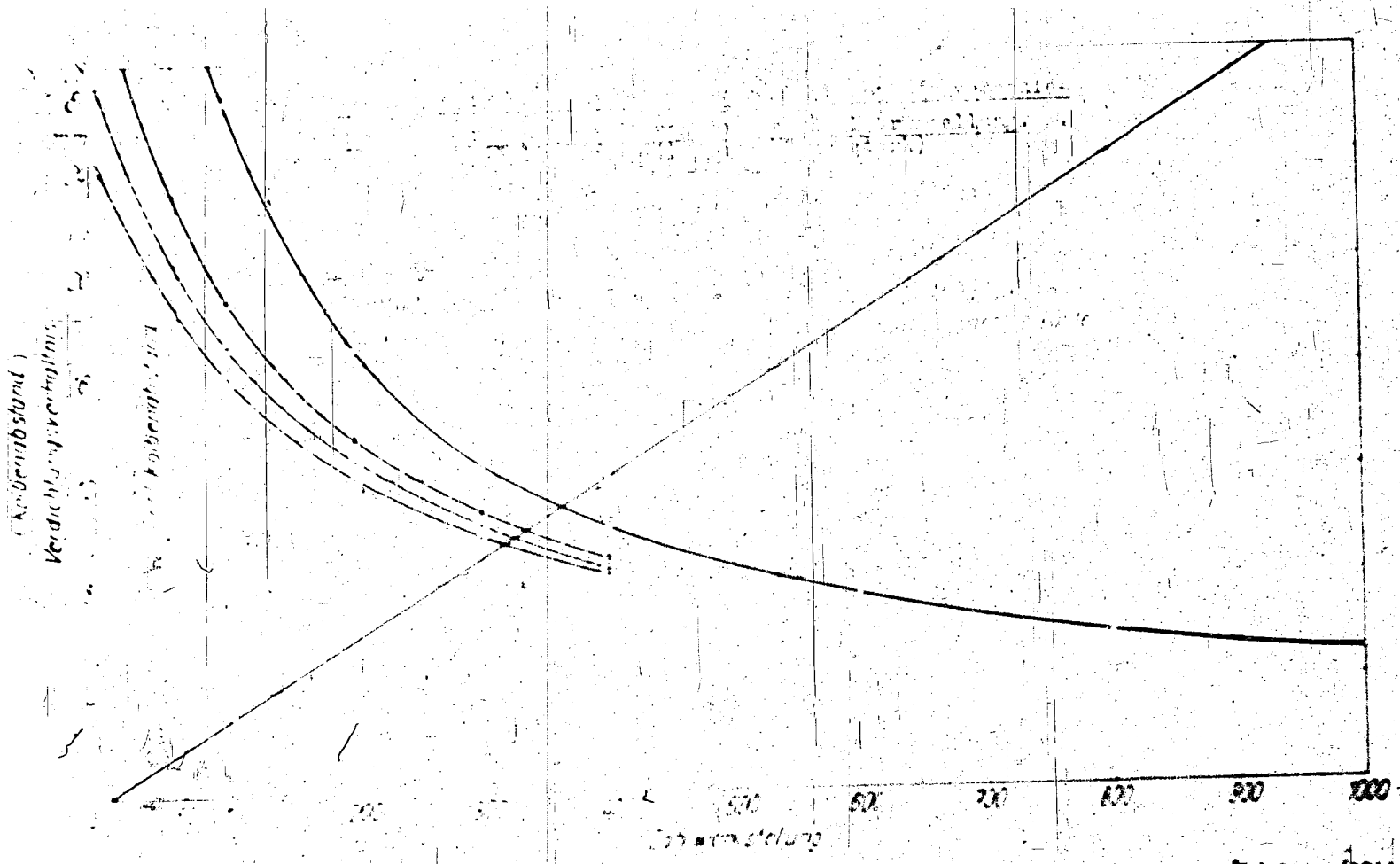
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Technical Report on Diesel Fuels.

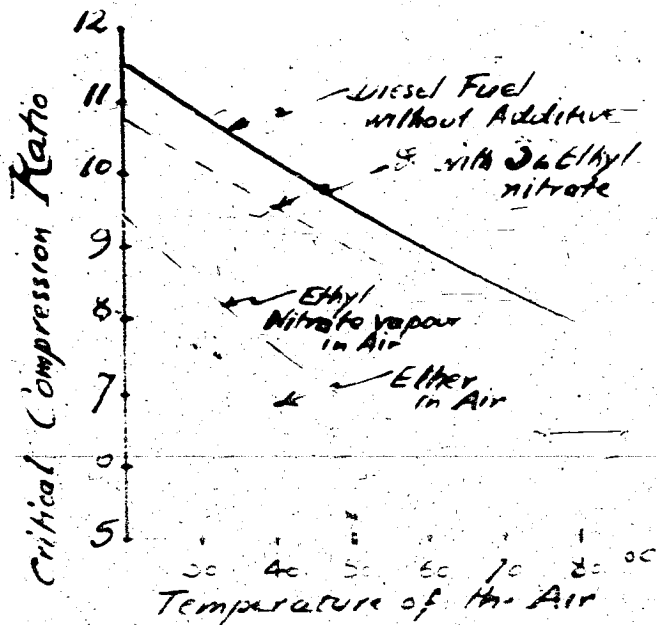


Figure 1

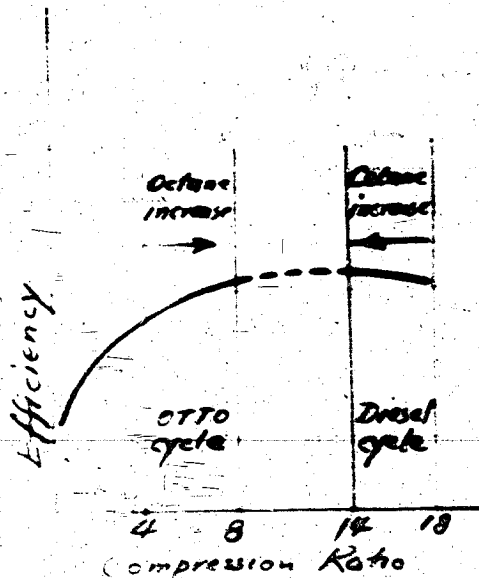
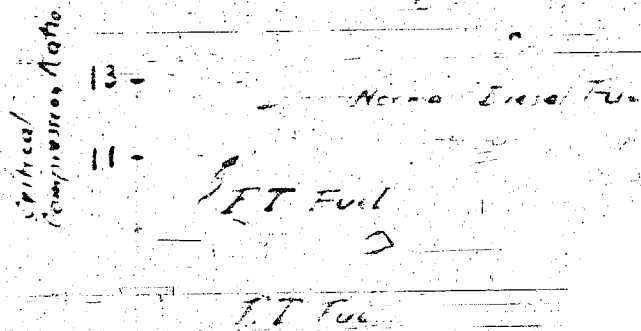


Figure 3.



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APPENDIX II

PRODUCTION IN TONS PER MONTH
For
JANUARY 1944 AND JANUARY 1945
OF
VARIOUS GERMAN DIESEL FUELS

<u>Method of Production and</u> <u>Originization</u>	<u>1944</u>	<u>1945</u>
<u>1. Hydrojenators plants</u>		
Leima	23900	2000
Bohlen	-	1700
Brabag Magdeleurg	3800	5300
Brabag Feitz	14700	8100
Brabag Scholven	-	-
Silzsenberg	-	-
Welheim	1200	-
Politz	-	-
Lutzkendorf	1800	1000
Wesseling	-	-
Ludwigshafen	-	-
Moosleierbaum	-	-
Brusc	12200	-
Elechhammer	600	-
Ileydebreck	-	-
Total	58200	18100
<u>2. Fischer Tropsch</u>		
<u>Synshesis</u>		
Ruhrchemie	1200	-
Victor Rauxel	-	-
Rheinpreussen	1200	-
Krupp Wanne Eickel	-	240
Essener Benzin	1500	600
Schwarzheide	2700	2000
Lutzkendorf	400	-
Schaffgotsch	600	200
Hoesch Benzin	800	-
Total	8400	3040

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APPENDIX II CONT'D

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3. Distillation of Crowncoal tar

Riebeck Weban	900	1200
Riebeck Messel	-	810
Onhaltische Kohlenwerka	-	-
Kopsen	1500	1500
Dea Rositz	2700	2000
Kosag Zolzan	1600	1500
Hefrag Wolfersheim	-	-
Leopold Bosdorf	-	100
Leopold Etteritz	-	-
ASV Espenhain	-	4000
ASV Hirschfelde	-	-
Total	6700	11,100

4. Refining of Natural crude oil.

Rhenania Hamburg	-	650
Rhenania Florisdorf	-	800
Deutsche Vacuum at	-	-
Deutsche Oslebshausen	-	-
Deutsche Wedel	-	-
Deutsche Kagram	-	-
Deutsche Kolin	-	1200
Deutsche Dzieditz	-	-
Deutsche Gasoline at	-	-
" Dollbergen	-	-
" Emmerich	-	-
Dea Korneuburg	-	1700
Dea Wilhelmsburg	-	-
Dea Heide	-	2000
Wintershall LutzRenDorf	-	-
" Salzbergen	-	400
Nova Schewchat	-	5100
Deurag Nery Misburg	-	-
Grassburg	-	400
I.G. Oppan	-	-
Sengewald	-	60
Trzebinia	-	2100
Idaweiche	-	150
Pechelbronn	-	-
Loban	-	6500
Vosendorf	-	1800
Pardulitz	-	1650
Oderfurt	-	1200
Kolin	-	-
Total	-	25,710

APPENCIX II CONT'D

5. Small installations stills started in 1944 in well-protected valleys.

Bogerhof Extertalbahm		880
BrunKensen near Ohlfeld		880
Messinghausen near Ohlfeld		1000
Messinghausen near Brilon		1000
Muhlenheim near Brilon		1000
Muhlental near Halberstadt		1250
Turmitz near St. Polten		1000
Weitenegg near Krems		1500
Olte Post near Pirna		450
Stotzendorf near Vienna		900
HausKirchen near Zistersdorf		2000
Bockatal		750
Total		<u>11,610</u>
Total Known productions	73,300T	69,570T

During the month of January 1944 known productions of other fuels, given as a comparison was:

Aviation Gasoline - From Hydrojenators		141,500T
From Synshens		7,300T.
Total		<u>148,800</u>
Motor Gasoline		
From Hydrojenators		57,100T.
From SynShens		12,550
From Lynite Tar		1,650T.
Total		<u>71,300</u>

Gasoline production from Natural Petroleum Crude constituted however an important item estimated conservatively for January 1944, at: 150,00T