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9. Description of Pott-Broche Process (cont'd.)

processed as tar or pitch which were further along the path toward middle oil. Since Germany required the maximum production of gasoline from each plant, it was more expedient to process pitch than coal extract. Therefore, the extraction process was not operated to produce stocks for hydrogenation, but rather for special purposes. It was found that the extract could be coked to give a carbon that made good electrodes for use in the aluminum industry, and hence most of the production was diverted to this purpose. The Ruhröl Company felt that the future of the process lay in the production of special purpose materials rather than in the manufacture of motor fuel. They felt that the extract might be used as molding plastics, fillers in structural material, or as insulating coatings for wires and cables. In order to dissolve the extract a solution of cresol, tetralin, benzol, and pyridine was used since ordinary solvents were not suitable. This process may find greater commercial application in the future, although to date its record has not been very impressive.

10. Discussion of the Products of Hydrogenation.

As has been described in the previous sections of this report the Germans made a variety of synthetic fuels by hydrogenation of coals, tars and pitches, but each of the raw materials had its own characteristics which made it a better stock for certain products than for others. This section of the report, therefore, is an endeavor to rationalize the various hydrogenation processes and contrast the variations in the products. Although the German fuel program for the war was a complicated series of balances, yet there were several general principles which governed the production program, and this section will attempt to show how these operated.

All of the five main sources of raw material, namely brown coal, brown coal tar, bituminous coal, bituminous coal tar, and pitches plus cracking residues, could be treated to produce various yields of aviation grade gasoline. There were three main ways of preparing aviation gasoline, namely,

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10. Discussion of the Products of Hydrogenation (cont'd.)

by the three step hydrogenation process for coals and tars, the two step hydrogenation process for pitch as practiced at Welheim, and the two step hydrogenation of coals and tars followed by a DHD treatment. The last mentioned operation was becoming increasingly important in Germany from 1939 until the close of the war, and for further details on this subject the reader is referred to U. S. Naval Technical Mission in Europe Report entitled "The Manufacture of Aviation Gasoline in Germany."(24)

The following table shows the principal characteristics of aviation gasoline produced by the first two methods from brown coal, brown coal tar, bituminous coal, bituminous coal tar, and pitch.

TABLE I

CHARACTERISTICS OF AVIATION GRADE GASOLINE BY HYDROGENATION

Raw Material	Brown Coal	Brown Coal Tar	Bituminous Coal Tar	Bituminous Coal	Pitch
Approximate yield, tons/ton*	0.42	0.72	0.75	0.47	0.23
Specific Gravity, 15°C	0.72	0.71	0.73	0.74	0.78
Distillation:					
Initial °C	45	48		46	
% to 70°C	25	17		15	
% to 100°C	67	64	65	58	38
% to 120°C	89	88		78	

*Includes only the coal processed in the high pressure Sump Phase.

TABLE I (cont'd.)

Raw Material	Brown Coal	Brown Coal Tar	Bituminous Coal Tar	Bituminous Coal	Pitch
% to 150°C	--	--		96	
E.P.°C./1%	139/98	134/98	160	151/98	165
Vapor Pressure, atm.	0.39	0.42		0.50	0.45
Composition:					
% Paraffins	52.5	58.0	37	36.5	35
% Aromatics	8.5	10.5	8	9.0	45
% Naphthenes	38.0	30.5	55	54.0	20
% Unsaturates	1.0	1.0	--	0.5	--
Octane No. (Motor Method)	71	69	76	73	80
Octane No. (+.12% T.E.L.)	90	89	94	91	95

This table shows the relatively high paraffin content of the gasolines produced from brown coal and brown coal tar and the resultant lower octane ratings compared with those produced from bituminous coal and pitch. The yield of gasoline from bituminous coal was also greater on account of the lower oxygen and higher carbon content. Coal tar of course gave the highest conversion to gasoline, while the high asphalt content of the pitches made it more profitable to sell a major portion of the surplus product as fuel oil instead of recycling. The aviation gasoline produced, however, had a very good octane rating on account of its high aromatic and isoparaffin contents.

The German fuel program for the war required consider-

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10. Discussion of the Products of Hydrogenation (cont'd.)

ably more aviation gasoline than motor fuel, and only 25-30 percent of the total gasoline production from the hydrogenation plants was motor fuel grade. Since bituminous coals were superior raw materials for aviation gasoline, those plants processing that material produced only aviation gasoline. Part of the production of the brown coal and brown coal tar plants went to motor fuels, as the high paraffin contents of the oils gave them lower octane ratings. Then, too, it was more difficult to produce a high quality material in the single gas phase treatment of brown coal tar. The following table shows the principal characteristics of motor gasolines.

TABLE 2

CHARACTERISTICS OF MOTOR FUEL BY HYDROGENATION

Raw Material	Brown Coal	Brown Coal Tar
Approximate yield, tons/ton	0.47	0.80
Specific gravity, 15°C	0.77	0.74
Distillation:		
Initial °C	35	43
% to 70°C	21	15
% to 100°C	45	38
% to 120°C	61	57
% to 150°C	81	85
E.P. °C/%	191/98	168/99
Vapor pressure, atm.		0.63 at 40°C
Composition:		
% Paraffins	59.0	56.0

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TABLE 2 (cont'd.)

Raw Material	Brown Coal	Brown Coal Tar
% Aromatics	8.5	17.0
% Naphthenes	30.5	26.5
% Unsaturates	2.0	0.5
Octane No. (Motor Method)	60.5	about 60
Octane No. (+.12% T.E.L.)	about 75	

Some diesel oil was produced by hydrogenation of brown coal and brown coal tars, since the high paraffin contents of the oil gave it a good cetane value. Only the sump phase plus the first gas phase hydrogenation were employed, as the object was to obtain a product high in normal paraffins and naphthenes. The TTH process gave a high conversion of brown coal tar to diesel oil which had the same characteristics as that made by the two stage hydrogenation.

TABLE 3

CHARACTERISTICS OF DIESEL OIL BY HYDROGENATION OF BROWN COAL AND BROWN COAL TAR

Specific Gravity	0.84
Aniline point, °C	45
Distillation:	
Initial °C	194°C
% to 220°C	33
% to 240°C	55
% to 260°C	72
% to 280°C	84

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TABLE 3 (cont'd.)

E.P.°C/%	312/99
Phenol	less 1%
Sulfur	less 0.1%
Cetane NO	45-50

The T.T.H. process using brown coal tar was the only combination of raw material and hydrogenation processes that was used to produce lube oils and waxes, as direct hydrogenation destroyed the paraffin constituents in the other coal substances processed. The Zeitz plant produced two grades of lube oils, a light 4° Engler (180 SSU) spindle oil and a heavy 6-8° Engler (215 SSU) machine oil. The yields were approximately two parts of the former to one of the latter. The waxes were also of two grades, a hard wax and a soft wax. The former, which had a melting point of 40-45°C, constituted one-third of the production, while the other two-thirds had a melting point of 52°C.

Fuel oil was produced in limited amount almost exclusively by the hydrogenation of pitch. As has been previously mentioned, the high asphalt content of the heavy residue oil from the sump phase distillation would have been difficult to hydrogenerate, if it had been recycled. Therefore, this product was sold for fuel oil. The yield of fuel oil was approximately twice that of gasoline. The Welheim plant (Ruhroel AG) was the only large unit to operate on pitch.

11. Operation and control of the Units.

(a) Introduction.

This section of the report deals with mechanical operation of the equipment. It will include a summary of operating sequence for starting up and shutting down the high pressure chambers, safety measures, an outline of control methods, and a brief discussion of instrumentation. Operations which are common to all chemical industry, such as