Questions 1 & 2

The Fischer Process - Hydrogenation

Table 1

Total Coal Consumption, Capital Charges and Total Cost per t. Product

Coal Input (t) for	Fischer Process per t. liquid products	Hydrogenation per t. spirit	
Synthesis-gas or hydrogen	5,2 - 7,0	1,7 - 2,3	Coke is calculated back to bituminous coal (carbon content of the coal very variable)
Hydrogenation		1,2 - 1,6	Calculated as bituminous coal
Power	1,9	3,8	The Fischer figure refers to atmospheric pressure synthesis
Total	7,1 - 8,9	6,7 - 7,7	
Capital Charges			
Cost of the Plant	860 R.M.	970 R.M.	Estimated prices for normal conditions
Amortisation, 8%	70,80 R.M.	77,60 R.M.	
Cost of Production	320-360 R.M.	260-310 R.M.	

Explanation of Table I

(1) The data are estimated from figures in my possession for the actual operation of both types of plant, but I have not here at my disposal the accurate data on which they are based. The individual items are composed of a series of single values (see Introduction). They give an approximate picture for the comparison of large plants (capacity, for hydrogenation, ca. 150,000 t., for Fischer ca. 100,000 t./year).

(2) The comparison is made on the basis of 1 tonne (1000 kg.) liquid products in the case of the Fischer process, but on the basis of 1 tonne motor spirit in the case of hydrogenation. Thus we are concerned with different end-products in comparing the coal consumption and total cost, as these final products have different values. It is therefore essentially, only a comparison of processes. The further evaluation is followed up below.

(3) For the Fischer synthesis a yield of liquid products of 130 g./cu.m. ideal gas is assumed which is based on the results of the Schwarzheide plant with a good catalyst.

(4) Apart from the fixed costs, the total cost is very markedly dependent on the quality and price of the new materials (analysis of the coal, method of generating energy).

(5) The energy requirements can only be estimated roughly and the use of waste heat, waste gases etc. can cause changes from the estimated value.

The Processes

As far as coal consumption is concerned the two processes show no essential differences, but it is to be noted that more of the coal used by the hydrogenation process is used for power production so that cheaper coal can be used (coal dust or waste gases). An essential part of the Fischer synthesis is the preparation of water gas and synthesis gas and this determines the high coke consumption. Although synthesis gas can be prepared from methane either by a purely thermal treatment or by a catalytic process, this, according to our technical results, offers no advantage, if one compares the methane with the calorific value of the coal and uses an equivalent amount. The size and the cost of a Fischer plant are therefore to a large extent determined by the large synthesis gas plant necessary and the cost of preparing the synthesis gas. This forms about 50% of the total price of the plant.

In the case of hydrogenation the final product is motor spirit, which, starting from bituminous coal, has an octane number of about 74-78 without further treatment. The process is flexible in that it can be made to give diesel oil and fuel oil by using a greater throughput; there is a corresponding diminution in the consumption of hydrogen. And either tar or pitch may be used as raw materials. If Fischer products are to be altered by cracking the middle oil and wax then additional costs and losses are involved and the process must be rejected as uneconomic. The octane number of the spirit can be improved from its normal value of 58-60 by isomerisation over new catalysts, but as far as I know, this has not yet been developed into a technical process.

Medium pressure synthesis from carbon monoxide and hydrogen with cobalt, and also with iron or mixed catalysts, has in the first place a much higher cost on account of the compression of all the synthesis gas to about 20 atm. Working so as to obtain saturated hydrocarbons, the total yield of liquid products is not increased. It is possible to conduct the synthesis so as to obtain higher yields of wax, but this always means decreasing the gas velocity. The conditions can also be altered - by altering the gas composition, temperature or catalyst - so as to obtain a greater proportion of unsaturated hydrocarbons in the products, or to obtain a mixture of unsaturated hydrocarbons, aldehydes, ketones and alcohols. The separation of these mixtures is very difficult and has not yet been solved on the full scale.

The project for conducting the Fischer synthesis so as to produce mainly unsaturated hydrocarbons and then to convert these in a separate process - the Oxo-synthesis - by the addition of $CO + H_2$ into aldehydes and then into alcohols or acids has been studied from many angles and a full scale research plant has been built. The economics of this process is very questionable because the price of the olefins is at present too high and no satisfactory technical solution of this problem has been forthcoming (such as simple cracking of waxes).

Medium pressure synthesis, and also synthesis with iron or mixed catalysts thus appears to have a position intermediate between synthesis or pure paraffin hydrocarbons and of pure alcohols - For example, in the position of the double bond in the unsaturated hydrocarbons or in the branching in the long chain paraffins.

Use of the Synthesis Products for Chemical Purposes

The synthesis products are chemically pure and as a result they offer possibilities for the preparation of:

(1) Fatty acids (from wax by direct oxidation or by way of the Oxo-synthesis. Price of wax!)

(2) Lubricating oils (by cracking the wax or lower fractions and polymerisation)

(3) Alcohols (see Oxo-synthesis, - Isoalcohols, Yield)

(4) Detergents (Sulpho-Chlorination of the 260-320°C fraction. Alcoholsulphonates.)

(5) Materials for the Textile Industry (see Oxo-synthesis)

(6) Softeners (Sulpho-chlorination & Phenol; and other ways)

(7) Vaseline

The question then arises as to whether the CO & H_2 synthesis should be used as the basis for these and other similar processes. In judging this, a series of other alternative possibilities must be considered, and the separation of individual fractions from the total synthesis product is also of fundamental importance for the calculation. In my own opinion, the Fischer process is a process for obtaining pure chemical substances as starting materials for further synthesis. It must therefore, in the first place, be compared with other chemical processes which serve the same purpose. In my opinion, it is not very suitable, under normal conditions, for the production of the usual motor fuels, as it has not sufficient flexibility, and, as compared with hydrogenation, is too expensive.

I cannot answer the detailed question under (i) and (ii) nor B(i) and (ii) without documents. Only approximate answers can be given, and it must be also born in mind that here, in particular, alterations in the composition of the raw materials used have a big effect. Differences in the analysis of one brown coal from another, and differences in the analyses of the tars, according to whether they have been produced by direct or by indirect processes, lead to differences in the consumption data even for hydrogenation. For the Fischer process the method of gasification of the brown coal briquettes is important - Koppers, Didier or Schmalfeld processes - as here not only the consumption of raw material but also the capital cost varies.

Thus I can only give a rough comparison between the various possibilities, which however allows the fundamental differences to be appreciated. Documents concerning the details of these comparisons are to be found at Leuna. But at the moment I am still engaged in writing out the rough comparisons.

<u>A(i)</u>

The consumption figures for the Fischer synthesis for the production of synthesis-gas or water-gas from coke, on the one hand, and from brown coal on the other, are very different because several different processes for gas generation are in use- the Koppers, the Didier and the Schmalfeld - and the capital costs of these plants are very different. The Schmalfeld process, used at Schwarzheide and Lutzkendorf (It was not used at Schwarzheide! Translator) lead to no useful technical improvements. Briquettes with a water content of about 15% were used. The absolute coal consumption, calculated back to bituminous coal, should lead to the same figure, but it was, in part, 15-20% higher. I have no accurate data for the specific coal consumptions available, they are in the documents at Leuna. However, so far as the costs of the final products are concerned it can be said that this is about the same as for plants using coke from bituminous coal. This evening-out is due to the smaller price of brown coal as compared with bituminous coal.

A (ii)

I have no data with me for the individual consumptions and analyses of the various raw materials for hydrogenation, - brown coal, tar pitch and petroleum residues. Even the brown coals differ among themselves in carbon, hydrogen and oxygen content so that the specific consumption figures will be different. Thus,

Origin	C	H	O	H2O	
Rhenish Brown Coal	25-32%	2-4%	9-12%	50-60%	Raw Coal *
Middle German Brown Coal	28-29	3	9	50-55	
Sudentenland Brown Coal	69-72	5-6	15	25-30	

The tars have also corresponding different properties, and these further depend on the process used in making the tar. The direct and indirect processes differ very much in this way and the tars from them behave differently. At Leuna the following raw materials, among others, were used:

✓(1) Brown coal generator tar
✓(2) Brown coal low temperature carbonisation tar
(3) Bituminous coal tar middle oil

If petroleum residues or pitch alone are used then a pressure of 700 atms. for the liquid phase process is necessary. The evolution of reaction heat is not sufficient to allow petroleum residues to be hydrogenated at 200 atms.; in the case of pitch the breakdown is not sufficient.

For the hydrogenation of pure brown coal tar, as is done, for example, by Brabag, the price of the tar is so fixed that the price of the final products is the same as for the hydrogenation of brown coal. In the case of brown coal low temperature distillation tar this price is 78-85 R.M./t., and for generator tar 40-50 R.M./t. Low temperature tar from bituminous coal did not come into question as the amount available was so small - only research scale working. Pitch was valued at 40-50 R.M./t. for hydrogenation. As already explained, only very general figures can be given for the consumption of the raw materials, approximate, estimated, figures being:

+ These figures do not add to approximately 100 -

Translator.

	Bituminous coal	Brown coal	Brown coal tar	Petroleum residues
Cu.m.H_2/t. spirit	2500	2600	18-1900	900-1200
Total coal .. .. t.	6,7 - 7,5	14,4 *	7,7*	3,0 ø

* raw material
ø bituminous coal

It is to be noted that the motor spirit from brown coal hydrogenation has an octane number of 69-72 and that obtained by the hydrogenation of brown coal tar has a rather lower value.

I have answered question 3 on lubricating oils and also C and D from my documents as far as they go, and for the rest, from memory.

Question 3

An account of the manufacture, properties and use of the Ester synthetic lubricating oils

Work on synthetic lubricating oils at Leuna had as its object the development of economically possible processes for preparing synthetic oils with properties as good as or better than those of natural lubricating oils of petroleum origin. Two types of oil were prepared:

1. Ethylene Lubricating Oils. These are prepared from waste gases from hydrogenation or from ethylene made from acetylene or alcohol.
Production at Leuna: 10,000 t/year.
Production cost taking 20% amortisation and using ethylene at 43 Rpfg/kg : 85 Rpfg/kg.
Properties: high thermal stability and good freezing properties.

2. Ester-oils. The ester lubricating oils are mixtures of ethylene lubricating oils (also using fore-runnings) with esters of adipic acid, the esters used being those of the higher alcohols from the isobutylol plant. Frequently the higher boiling fraction (over 160°C) C_8-C_{14} iso-alcohols were used.

The mixtures were used for

(1) Aircraft Oil using 60% ethylene lubr. oil, 40% ester

(2) Motor Oil " 60% " " " 40% "

(3) Railway Axle-oil using 80% ethylene lubr. oil, 20% ester

(4) Machine oil using 75% (fore runnings) lubr. oil 25% ester

(5) Aerial torpedo oil using 40% ethylene lubr. oil 57% ester
(+ 3% anti-corrosion component)

(6) Axle-oil using 60% residues } ethylene
20% fore-runnings) lubricating oil, 20% ester

Approximate data for their properties are:

	Viscosity °E	Viscosity Index	Setting Point
Aircraft Oil	1,7 at 100°C	130	- 50°C
Motor Oil	1,7 at 100°C	130	- 50°C
Railway Axle Oil	3-4 at 50°C	130	- 50°C
Machine Oil	3-4 at 50°C	140	- 70°C

These figures are only quoted from memory but Dr. Zorn, the expert on the subject, will have the accurate data.

Question 4

The production data for the war years are given in Table II, III & IV insofar as I have them here at my disposal. They are essentially figures for the delivery of products and so cannot differ any more than a few per cent from the true production figures. The total capacities of the plants are shown in Table V. I have no figures with me for the production of alkylates and octane, and corresponding footnotes are made in Table II (they are not! Translator) The total extensions according to the Krauch and Geilenberg programme can only be estimated here because I have no accurate data for them. It was planned to extend

1. Heydebreck up to 84,000 t. Iso-octane (from isobutyl alcohol)
2. Blechhammer " " 1,000,000 t. liquid Fuel (of which about 30% is fuel oil. Working with direct throughput in the liquid phase was used)
3. Brüx up to 900,000 t. Liquid Fuel (the extension was stopped by air raids)
4. Böhlen up to 12,000 t. Alkylate (stopped by air raids)
5. Pölitz up to 24,000 t. Alkylate

Table V

Capacity of Plants

Plant	Total yearly capacity (tonnes)
Hydrogenation	
Leuna	650,000
Böhlen	260,000
Magdeburg	220,000
Zeitz (planned)	360,000
Scholven	240,000
Gelsenberg	480,000
Welheim	160,000

Pölitz	600,000
Lützkendorf	80,000
Wesseling	240,000
Lu/Oppau	60,000
Moosbierbaum	100,000
Brüx (planned)	600,000
Blechhammer (planned)	1,000,000
Heydebreck	100,000
Hüls (Kybol)	8,000
Schkopau (kybol)	8,000
Total hydrogenation	5,166,000

Synthesis	
Schaffgotsch	40,000
Lützkendorf	60,000
Schwarzheide	160,000
Hoesch	40,000
Essener Benzin	84,000
Krupp	60,000
Rheinpreussen	70,000
Viktor Rauxel	40,000
Ruhrchemie	80,000
Total synthesis	634,000

Total, hydrogenation and synthesis 5,800,000

The idea of the Geilenberg Programme was to effect these extensions, to remove existing plants to safe underground sites and to split up large plants into a number of small units. From memory (I have no notes at my disposal) there were to be

(1) 4 Hydrogenation Plants (underground)

(2) 3 + 2 Topping and Lubricating oil plants (underground at Ebensee, Porta and Deutsch Brech

(3) 2 + 40 Cracking and Topping Plants (small pipe-still Topping Plants, each 3,000 t/month)

(4) -

(5) 1 Catalytic Cracking Plant and D.H.D. plant (Niedersachswerften)

(6) 1 Catalyst Plant.

(Translators Note. Table III gives motor spirit production, whilst Table IV shows total production and aviation spirit production. The periods shown as I, II and III respectively are of 4 months although the figures are given in tonnes per month. The difference between total monthly production and the sum of aviation and motor spirit represents the diesel fuel production)