RESULTS OF FOUR YEARS OPERATION OF THE TEXACO COAL-GASIFICATION-PLANT AT OBERHAUSEN-HOLTEN AS DEVELOPED BY RUHRKOHLE AG AND RUHRCHEMIE AG

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Summary

The demonstration plant of Ruhrkohle/Ruhrchemie in Holten has been on stream over a period of four years. The project targets - process optimizing and development and testing of components - were achieved. Ruhrkohle/Ruhrchemie are planning now a commercial scale gasification plant using the obtained scale-up data.

It is intended to continue operating the demonstration plant to test the application of the Texaco technology to the gasification of residues of coal liquefaction processes.

1. Introduction

If one considers the present worldwide reserves and consumption figures for fossil fuels, which are represented in Figure 1, it will be seen that there is a market imbalance between oil and natural gas as compared with coal.

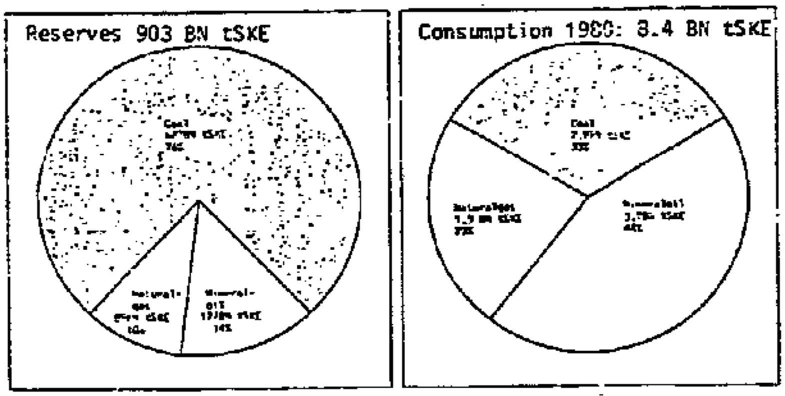


Fig.1 : Worldreserves and -consumption of Fossil Fuels

In order to reach a balanced ratio, coal consumption, on the basis of present-day figures, would have to be more than doubled at the expense to mineral oil and natural gas.

The longer the current consumption structure continues to prevail, the sooner the signs of shortages will have to be anticipated.

In view of this situation, there is a tendency on the part of the exporting countries to preserve the reserves by throttling production and to raise the prices in consequence of this artificial shortage. This is only possible if the market can be influenced by the formation of cartels.

It was out of this situation that the oil crises of 1973 and 1978 developed; in both these cases it was possible to maintain this shortage for a certain period of time.

The consumption structure of the Federal Republic of Germany, which has to import up to 95 % of its mineral oil and up to 68 % of its natural gas, though having large coal reserves of its own, is very similar to that of the world as a whole.

Fig. 2 demonstrates the influence of the oil crises on the consumption and the payments in foreign currencies for the imports into the Federal Republic of Germany.

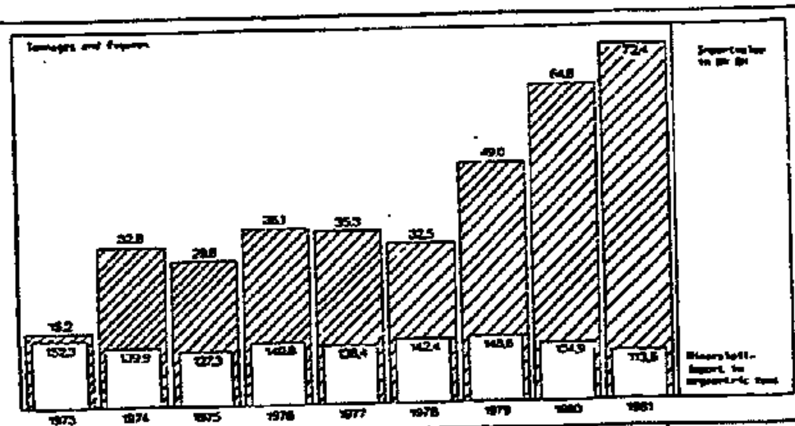


Fig.2 : Import of Crude Oil and Mineral-oil Finished Products into German Federal Republic

From the above diagram it will be seen that while savings are an absolute necessity, they cannot prevent, that the flow of foreign funds increases, however.

Short-term oversupplies on offer, which lead to a temporary price stop, should not delude us into thinking that controlled limitations on production and the formation of still further-reaching cartels are to be ruled out in the future, but are even to be expected.

The consumption structure in the industrialized countries, which are mainly oriented to oil and gas, cannot be sufficiently reconverted to coal, either in the short or medium term. It is therefore necessary to supply the coal in a processed form to the consumers.

In the Federal Republic of Germany such processes of coal gasification and -liquefaction had been developed already at an early stage, and employed on a large industrial scale away back in the 1930's. These processes are no longer comparable, however, with industrial standards of today. For this reason, great efforts have been made in the past all over the world to develop new coal processing technologies. Some of these are being tested today on a demonstration plant scale.

At the present time coal gasification is playing the more important role, since it approaches closer to the profitability break-even point, and the commercial plants require considerably lower investments than is the case with coal liquefaction.

Consequently, in 1975 Ruhrkohle AG - as company producing and preparing bituminous coals on a major scale - and Ruhrchemie AG - as large-scale producer and consumer of synthesis gas - decided to operate jointly a coal gasification process on a demonstration plant scale and to develop it up to the stage of industrial operational maturity.

2. Choice of the Gasification Process

Of the gasification processes of the first generation several have reached the stage of productional maturity. Two of these processes have maintained till today their importance for bituminous coal. Both these processes have technological disadvantages, however, as compared with heavy oil gasification, which impair their competitiveness. The disadvantages of the processes are to be found either in the atmospheric operation, which has adverse effects on the gasification investment costs and the downstream gas treatment stages and necessitates compression of the product gas, which is much more expensive than the compression of the gasification oxygen. Secondly, the utilizable fuel band is limited by restrictions concerning the caking tendency and the size consist of the feed coals. Furthermore, by-products are produced that contaminate the product gas and the effluents, and can only be separated at high cost.

For these reasons, the processes of the socalled second generation have been developed, which are intended to satisfy the following requirements:

- it should be possible to attain gasification pressures of up to 100 bar
- as far as possible, all coals should be usable as feedstock
- no production of by-products that pollute the environment
- as far as possible the gasification process should proceed without fluctuations, and provide a possibility of a high degree of automation.

- the gasification process should have a high degree of availability, so that it can be linked to chemical processes that have an annual service period of 8.000 hrs.

- the residues produced in the process, should not contain any organic of other ecology-polluting components that can be leached out by water.

In 1975 the Ruhrkohle/Ruhrchemie-Consortium was confronted by the problem of finding a gasification process which would possibly meet to a large extent the above-mentioned requirements. The first fact to be ascertained was that such a process had still not been employed industrially anywhere, but that several processes were in various stages of development, however.

The demands made for a wide fuel band and the highest degree of environmental compatibility led to the development of the entrained bed gasification process.

Among the gasification processes based on this technical principle the Texaco Development Corporation had developed a process in its principal features and were operating a pilot plant at Montebello with a throughput of 0.6 tonnes per hr.

By simply feeding the coal into the reactor in the form of a coal-water suspension this process had a distince edge over other developments. Since it was found that with this uncompliciated technology - compared with the other competitive processes - advantages were also to be expected in the future as regards availability, process automation and investment requirements, it was the Texaco-process that was selected.

3. Project Targets

The final objective envisaged by the Ruhrkohle and Ruhrchemie companies was to produce a synthesis gas for the chemical industry with the aid of the Texaco gasification system. This enables coal to be substituted for oil.

In order to proceed from the then state of the art right through to operational maturity on a commercial scale, it was necessary to build a demonstration plant as an intermediate step. It was the task of the present project to carry out the development of components, testing of the components and process optimization in this demonstration plant. It was scheduled to obtain conclusive data required for the scale-up to a large-scale commercial plant.

4. Project Execution

The engineering work took about 2 years, whereas it was possible to complete the erection work in approx. 8 months. The plant was officially commissioned on April 3rd, 1978.

Up to this time the investment costs had amounted to approx. 11 million DM. The testwork was carried out over a period of over 4 years. This research and development project was concluded on April 30th, 1982. The total project costs on completion of the project amounted to approx. 55 million DM.

We have to thank the Federal Minister of Research and Technology for sponsoring the project.

5. Process Description

Coal and water is fed into a wet grinding system, where a pumpable slurry is preparated. In a store tank it is homogenated by stirring.

By means of a special pump the suspension is passed to the top of the fireproof-lined, uncooled reactor, where it is going to be sprayed together with oxygen through a burner into the reactor. The formed rawgas and the liquid slag leave the reactor at the bottom. The gas is pre-cooled in a radiation cooler and most of the ash (about 90 %) is separated off.

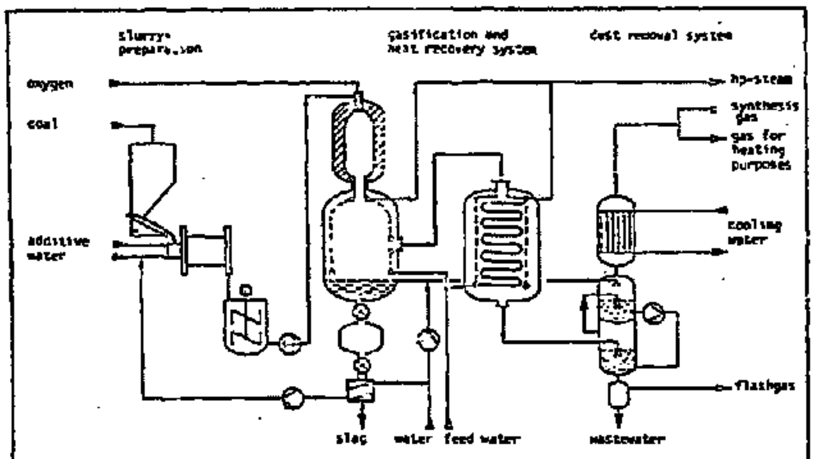
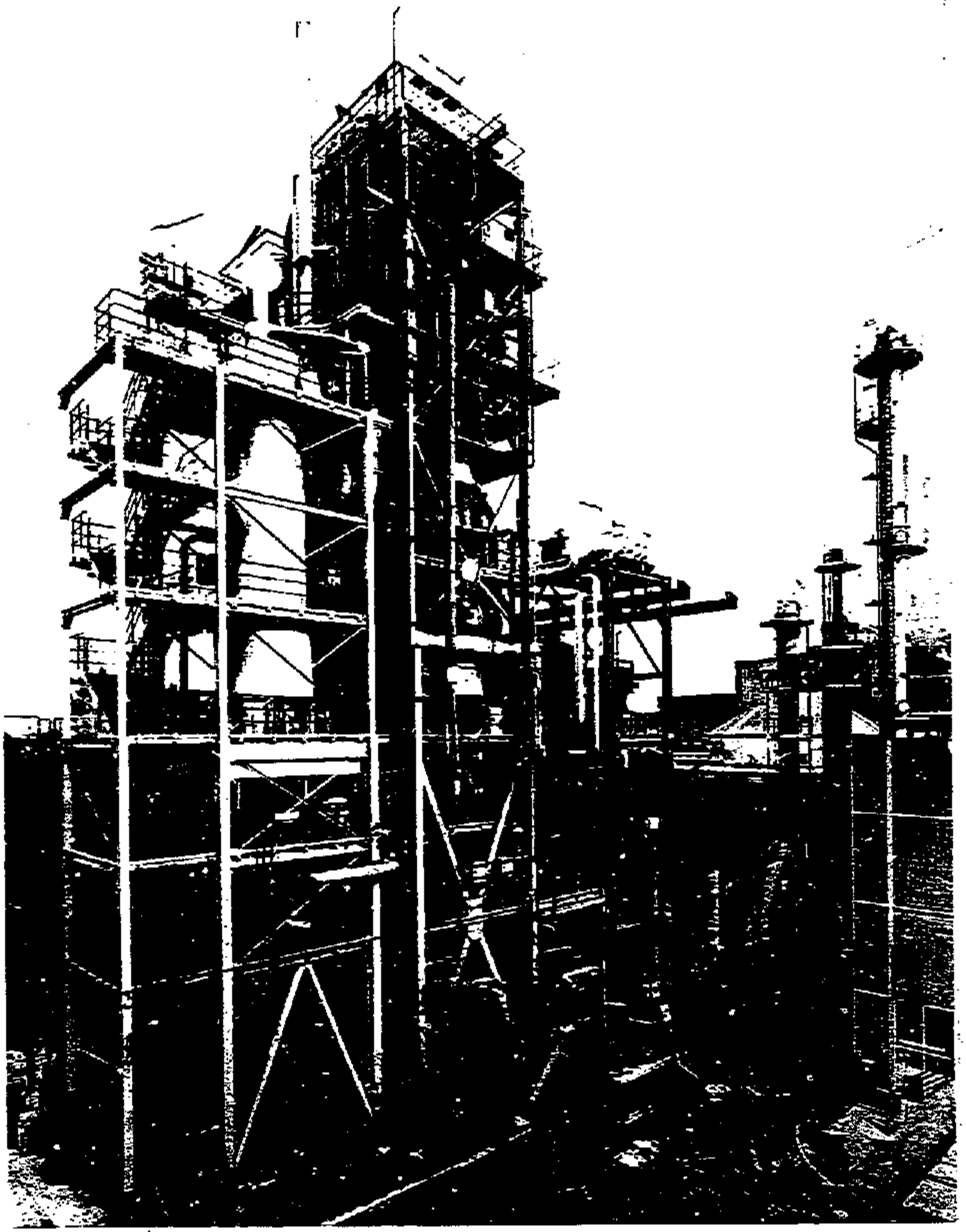


Fig.3 . Simplified Flowsheet of the TEXACO-gasification in Holten

Further cooling of the gas, which is now low in ash-content, occurs in a convection cooler. Both cooling stages produce high pressure process steam. For removal of the residue ash, the gas is then passed through a waterscrubber. Depending on specifications, this is followed by further heat exchangers to save available heat or exchangers to cool the gas completely.



Ash suspended in water is removed both from the base of the radiation cooler, as well as from the washing stage.

After mechanical cleaning, the wash water is directly led into the waste water cycle, in order to remove soluble inorganic compounds for the plant.

Fig. 4 gives a visual impression of the plant. The height of the steel structure is approximately 31 m; the required ground area is about 460 m^2.

6. Test Results Obtained at the Holten Demonstration Plant

In the course of the approx. 4-year testing period which came to a close on April 30th, 1982, roughly 60,000 tonnes of coal were converted to 110 Mio m_N^3 of synthesis gas during a total operating period of approx. 11,000 hrs. The longest uninterrupted test run lasted 800 hours. During the remaining test period the plant was available for inspection, reconstruction and repairs purposes.

12 different coals, 6 of which were foreign, were employed. The ash content of the coals lay between 6 and 28 %, the sulphur content between 0.6 und 3.6 %, and the Volatile Matter content between 16 and 42 %.

All the coals charged could be converted; the yields were good and no technological difficulties were enountered. The dynamic behaviour of the plant was characterized by a decidedly quiet and steady-state operation.

The data used as basis for the layout could be achieved in all cases in most cases they could be clearly exceeded. Compared in Table 1 are the test data achieved with the design data. Special points to be observed in this are the high gasification efficiency and the low oxygen consumption rate, the high solids content of the suspension, achieved with German coals (with American coals the values achieved were somewhat lower), and the high carbon conversion rate.

Table 1 Current Status of the Test Results (optimum results of different test runs)

	Reached	Acc. to design
Temperature, °C	1200 - 1600	1500
Pressure, bar	40	40
Coal thru, tons/hr.	up to 8.2	6.0
Amount of pure gas		
$(CO + H_2)$, m_N^3/hr	up to 15200	10000
Suspension concentration, %	up to 71	55 - 60
C-conversion at single pass, %	up to 99	95
Gasification efficiency (Ho), %	up to 77	70
spec. O_2-demand		
$m_N^3/1000\ m_N^3\ (H_2 + CO)$	≥ 340	
Gas composition, Vol.-%		
CO	55	45 - 55
H_2	33	30 - 40
CO_2	11	15 - 20
CH_4	0.01	1
H_2S/COS	0.3	—
N_2	0.6	—

Shown in Fig. 5 is the operation time of the plant during the entire testing period. It can be seen that a constant improvement in the availability was experienced in the first years. In 1981 a high availybility was achieded in spite of the installation of a new convection cooler and of detailed measuring programmes in conjunction with commission gasification tests.

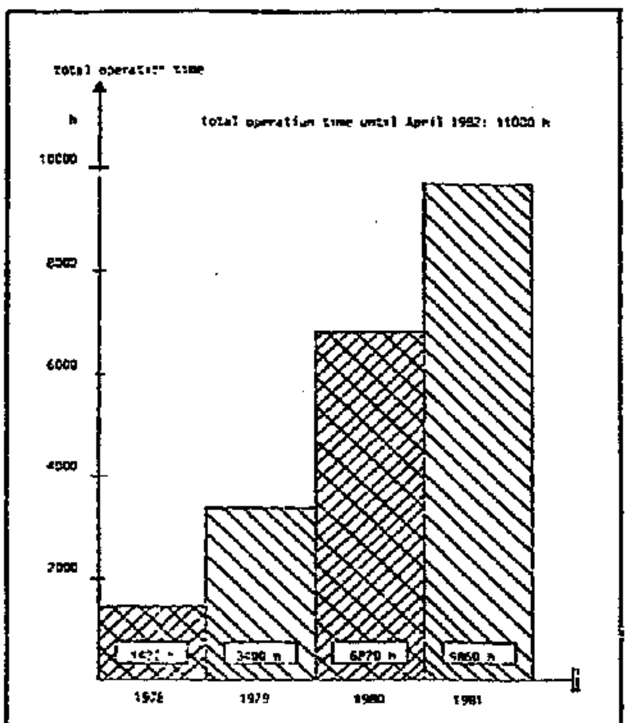


Fig.5 : Total Operation Time of the TEXACO-gasification in Holten

At the end of the test operations, the plant was converted to direct quenching during the first months of 1982. It was the aim of these tests to saturate the gas as high as possible with steam. The aim of this procedure is to achieve a higher H_2 : CO-ratio with the aid of a downstairs conversion unit.

The desired steam saturation of the gas was attained; no problems arose.

At the start of the test operations the gas after being dedusted was fed to the Ruhrchemie power-station and fired there. Later on, it was admixed to the synthesis gas which had been produced in an oil gasification process, jointly desulphurized, and then fed to the oxo-synthesis plant of Ruhrchemie. It was found that the coal gas as compared with gas bases on heavy oil had no disadvantageous properties. It was equally well-suited for the chemical synthesis. This became clear especially in periods of time when the oxo-synthesis units were fed entirely with coal gas.

Summarizing, it can be stated that the project targets were fully achieved, and that the process has reached a stage where it would be possible to plan a commercial plant.

7. Development of components

The development of the components was the main target of the project. During the 4-year testing period all components could be improved related to performance and availability. It reached the status of productional maturity.

7.1. Slurry Preparation

As a result of fundamental considerations carried out in advance, wet grinding was given preference over dry grindings, since in this case drying of the coal and coal dispersing are not necessary, and special safety precautions when handling dry coal dust become superfluous.

First of all a toothed-wheel mill was installed, but which was found to be very breakdown-prone in the case of contaminations, and supplied a far too coarse a size spectrum. With the tube mill that was installed afterwards, which did not have these disadvantages, it was possible to achieve not only a higher grinding fineness but also a larger solids content in the suspension.

By means of suitable additives it became possible to obtain a marked rise in the solid concentration of the slurry.

7.2. Reactor

7.2.1. Burner

In the Texaco-process the burner acquires a central significance. It has three tasks:

- introduction of the gasification media into the pressurized chamber
- spraying the suspension and mixing it with oxygen
- distribution of the reaction mixture by making good use of the geometry of the reactor

With these measures the reaction processes are influenced to a major extent. During the testing period it was possible to improve distinctly the gasification result by developing the burner. All together, 5 different types of burner were employed, 3 of them were basically different, Fig. 6 demonstrates the effects of developments carried out in the areas of suspension production and burners.

An important improvement in the burner sector, whose spraying characteristics are normally load-dependent, is the development of an adjusting facility, which eliminates the load dependence. A great importance attaches to this development especially for the combined-cycle power-station, since in the case of power generation the partial load is a frequent operating condition.

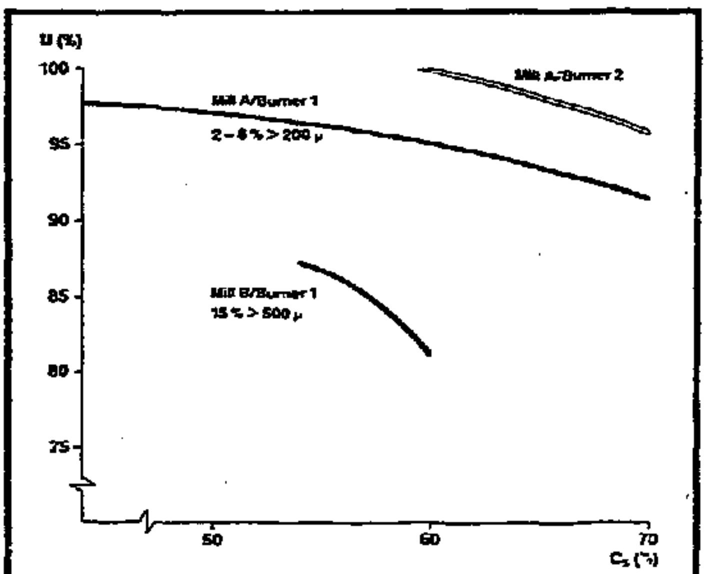


Fig. 6: C-Conversion (U) Versus Slurry Concentration (C_S)

7.2.2. Reactor Lining

In the choice of the refractory lining for the reactor,namely between a cooled and a non-cooled variant, the decision fell in favour of the non-cooled type. Thermal efficiency, simplicity of design and burner ignition, which is always assured by the high wall temperature, were the essentail criteria governing this choice.
The reactor lining must be able to withstand at temperatures of up to about 1.600 °C the corrosive attacks of the gas atmosphere and the liquid slag, the erosive attack of the solids as well as the attacks due to changes in temperature.

In the course ot the development approx. 50 materials were pre-tested, roughly 20 of these being used in the reactor. Depicted in Fig. 7 is the "success curve" of the developments in reactor lining.

The best results were obtained from the Picrochromite bricks made of chrome oxide and highly purified magnesia. These bricks were found to have erosion rates of approx. 0,01 mm. Hence, service life values of far more than 8.000 hrs. are attainable.

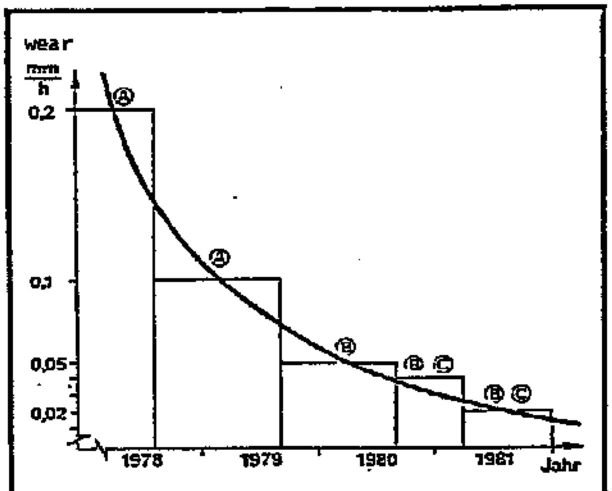


Fig.7 : Improvement of Refractory Materials

7.3. Waste Heat System

Since the gas temperatures at the reactor outlet amount to between 1.200 and 1.600 °C, depending on the mode of operation employed, a recovery of sensible heat for the generation of steam is desirable in the waste heat system.

However, in case, hydrogen shall be produced, the direct-quench is favoured before the waste heat system, because the internal mode of steam production is cheaper than the external one.

The waste heat system operates without any difficulties. Initial problems due to plugging in the convection cooler could be eliminated soon by optimizing the entire system. In the course of the project two different types of convection coolers have been tested, the later installed proved itself during approx. 2.000 hours of operation.

7.4. Process Water System

In the course of the project the process water system was modified in such a way that the process water flows most highly charged with solids and salts are discharged direct. All pumps and fittings are located in the water stream low in solids. The operational reliability was increased to such a high degree by this measure that it is now sufficient for commerical plants.

8. Environmental Protection

The introduction of new technologies is being increasingly impacted today by aspects that are of significance for the environment. Therefore, in the course of the test period elaborate measuring programmes were carried out, one of their aims also being to provide planning data for the licencing procedure for high-capacity plants. When assessing a process it is necessary to distinguish between active and passive environmental protection.

Active environmental protection avoids emission, whereas passive environmental protection restricts them only locally. Passive environmental protection makes the plants more complicated and more prone to breakdown, and always leaves behind a residual pollution of the ecology.

Regarded from these points for view, the texaco-process offers a number of advantages:

- thanks to the high gasification temperature the formation of higher hydrocarbons is avoided, and due to the reducing atmosphere the development of NOx and SO_2 is suppressed

- the gasification temperature lies above the ash fusion point. As a result of this, the majority of impurities in the coal are smelted in the vitreous residue and can no longer be leached out by water

- the solids are fed in and discharged as suspension. This prevents the formation of dust and emissions of lock gas. Also during the pre-treatment of the coal no dust arises, since no drying of the coal is carried on

TABLE 2—Water blowdown quality (Illinois No. 6 coal)

pH		8.7
TDS	ppm	1480
COD	"	600
TOC	"	375
Ammonia	"	1660
Anions		
Bromide	"	< 10
Chloride	"	680
Fluoride	"	62
Cyanide	"	3.4
Formate	"	97
Nitrate	"	59
Sulfide	"	195
Sulfate	"	16
Trace Organics		
Benzene	ppb	< 1
Toluene	"	< 1
Anthracene	"	< 0.05
Fluoranthene	"	< 0.05
Naphthalene	"	5.0
Pyrene	"	< 0.2
Phenanthrene	"	< 0.8
Phenols	"	4.5

TABLE 3—Waste water trace elements (Illinois No. 6 coal)

Antimony	ppm	< 0.001
Arsenic	"	0.008
Barium	"	0.16
Beryllium	"	0.010
Cadmium	"	< 0.010
Chromium	"	0.07
Cobalt	"	< 0.05
Copper	"	< 0.05
Lead	"	0.014
Manganese	"	0.17
Mercury	"	< 0.001
Molybdenum	"	0.002
Nickel	"	< 0.05
Selenium	"	0.070
Silver	"	< 0.03
Thallium	"	< 0.002
Vanadium	"	< 0.2
Zinc	"	0.19

Tables 2 and 3 characterize the quality of the waste water, while Table 4 shows a typical result of a slag leaching test.

TABLE 4 —Properties of dionized water leachate (Illinois No. 6 coal) EPA extraction procedure

pH		4.9
TOC	ppm	250
Ammonia	"	1.1
Anions		
Bromide	"	< 0.1
Chloride	"	0.30
Fluoride	"	3.3
Cyanide	"	0.02
Sulfate	"	14
Metals		
Antimony	"	< 0.5
Arsenic	"	< 0.05
Barium	"	< 0.5
Beryllium	"	< 0.02
Cadmium	"	0.02
Chromium	"	< 0.40
Cobalt	"	< 0.05
Copper	"	< 0.5
Lead	"	< 0.5
Manganese	"	0.72
Mercury	"	< 0.002
Molybdenum	"	< 0.5
Nickel	"	0.27
Selenium	"	< 0.001
Silver	"	< 0.03
Thallium	"	< 0.5
Vanadium	"	< 0.2
Zinc	"	2.1

9. High-Capacity Plants

In the USA a plant using Texaco-gasifying-technology with a coal consumption of 900 tpd for production of synthesis gas is in the construction phase. The contractor is Tennessee Eastman. The plant has two gasifiers, each with a capacity of 100 %, one of them is a stand-bye component.

Another plant, the so called Cool-Water-Project, is being planned for power generation of about 100 MW.

In the Netherlands, a plant is being planned shortly for a power generation of about 50 MW. Presumably the consortium RAG/RCH will collaborate in the planning.

These power generation plants are still in the demonstration plant stage, though the gasifiers already have commercial size.

Ruhrkohle AG and Ruhrchemie AG are planning the "Synthesegasanlage Ruhr" on the premises of Ruhrchemie AG. This plant will have a throughput of approx. 30 tph for a synthesis gas production ($CO + H_2$) of 40.000 m_N^3/hr and a hydrogen production of 10.000 m_N^3/hr. This synthesis gas is scheduled to supply the oxo-synthesis plants with gas, whereas the hydrogen is destined for the production of fertilizers.

The commissioning of the "Synthesegasanlage Ruhr", which represents together with the Tennessee Eastman-plant a first replacement of oil by coal on an industrial scale with a gasifier of the second generation, is scheduled for 1986.

10. Comparison of Dry Feed and Slurry Systems

The slurry feed system of the Texaco gasification process is often represented as a disadvantage from the viewpoint of energy.

In our opinion, however this disadvantage is more than compensated outweighed by the higher availability and the lower investment costs.

For the chemical industry, which requires a specific H_2 : CO-ratio this energy disadvantage is not present.

In the case of dry feed input the plant runs at a considerably higher gasification-temperature. The waste heat production is approximately equal in both cases. Accordingly, also the oxygen consumption rate is nearly the same.
Table 5 shows a comparison of the gasification characteristics of the various input systems. The same coal was selected as base, and the temperatures of gasification assumed to be process-typical.

Tab.5 : Comparison between Dry- and Slurry-Feeding System

		Feeding system	
	Dimension	dry	slurry
Pressure	bar	40	40
Gasification temperature	°C	1.950	1.350
Specific waterdemand per kg coal mf	kg	0,025	0,449
Carbon conversion	%	98,5	98,5
Specific O_2-demand			
- per 1.000 m_N^3($CO+H_2$)	m_N^3	347	348
- per t coal mf	m_N^3	673	673

11. Outlook

It is intended to continue operating the Holten plant and to test the application of the gasification process to the utilization of residues from the coal hydrogenation process. Negotiations are currently being conducted on the execution of further commission tests. This supplementary program will also provide an opportunity for optimizing further individual process components.

It should be noted that there already exists today a worldwide interest in the gasification process further developed by Ruhrkohle AG/Ruhrchemie AG.

Applying this technologie, there are various possibilities to replace oil by coal.

As Fig. 8 shows, by selecting suitable conversion stages it is possible to produce hydrocarbons, oxo-alcohols, hydrogen or heating gas.
At this present point in time, however, of the above products only synthesis gas for oxo-products can be produced on a cost-covering basis.

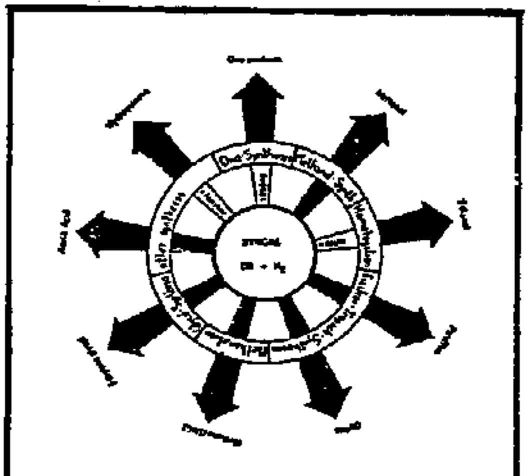


Fig.8 : Syngas as Building Block in Organic Chemestry