### Section 9

# THE GASIFICATION OF COAL AND LIQUID RESIDUES IN RUHRCHEMIE/RUHRKOHLE'S TEXACO COAL GASIFICATION PLANT

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# INTRODUCTION AND BACKGROUND

### This first slide

Fig. 1: Ruhrchemie/Ruhrkohle's Texaco Coal Gasification Demonstration Plant

gives you a pictorial introduction to the topic of my lecture. What you can see is the Texaco Coal Gasification Plant built and operated jointly by the two german companies Ruhrchemie AG and Ruhrkohle AG on the premises of Ruhrchemie at Oberhausen, FRG, between 1978 and 1985.

The cooperation between the two partners in the project started in 1973. Both companies were interested in the possibility of producing synthesis gas from coal, whereby Ruhrkohle was looking above all for a way to increase its coal sales and Ruhrchemie was seeking alternatives to heavy oil as a feedstock for its synthesis gas production. At the time Ruhrchemie's research department was also being influenced by the idea that the components of synthesis gas, CO and H<sub>2</sub>, had potential as chemical building blocks. These considerations gained considerably in importance when the first oil supply crisis supplied the impetus to reestablish the traditional connection between coal and chemistry.

For this special case – the "chemical" utilisation of the carbon in coal – synthesis gas produced from coal is ideally suited as a linking medium. It is chemically identical with synthesis gas produced from heavy oil and can therefore be substituted for it in existing infrastructures, either partly or completely depending on the plant layout.

The pressure generated by the first oil supply crisis led to raw material research programs in Germany which were sponsored by the federal government. In the course of one of these programs the Ruhrchemie/Ruhrkohle team planned and erected a demonstration plant based on the TCGP between 1975 and 1977. The next slide gives details of the time schedule for the activities.

Fig. 2: Time Schedule of Ruhrchemie/Ruhrkohle's Gasification Program

The stated aim at the time was to transfer pilot plant know-how up to a commercially feasible scale and to provide technical solutions for a whole range of new problems, such as wet-grinding the coal, the process burner, the metallic and ceramic materials and above all for the energetically important heat recovery. The demonstration plant, the construction and operation of which was supported from 1975 to 1982 by the Federal Ministry for Research and Technology

and from 1982 onwards by the Northrhine-Westphalian Ministry of Economics, went on stream in 1978. From 1978 until 1982 coal was gasified primarily; since 1982 residues from coal hydrogenation plants have also been fed in. In this contribution I will discuss some of the details of the development work and also go into the state of the planning and construction work of our large-scale gasification plant.

A twist of fate and the cunning of the organisers have combined to place my contribution after the other lectures on the applications of the TCGP. For this reason I would like to say quite openly and with no false modesty that all our work was done <u>prior</u> to the mentioned commercial applications. We also intended to gather and make use of licensable know-how; all of the plants which you have heard about today have benefited considerably from the Holten know-how. This was only possible because of the close cooperation between all the parties concerned and also between the project partners and Texaco Dev. Corp., which enabled a rapid evaluation, transfer and utilisation of the results as they were achieved.

After this necessary comment let us now look at the process flowsheet as it has been realised in the Holten demonstration plant.

# Fig. 3: Process Flowsheet of the gasification of aqueous coal/residue suspensions using the TCGP

Following the course of the process, coal is first wet ground in a mill after the addition of water. Grinding, dispersion and homogenisation thus take place in a single step. The suspension contains additives to improve flowability and stability.

The suspension is passed through a storage tank, then pumped up to gasification pressure, transported to the head of the gasifier and fed through a burner into the reactor together with oxygen.

**Depending on the reactivity and ash flow behaviour of the coal the reaction takes place at temperatures between 1 200 and 1 500 <sup>O</sup>C.** The liquid slag falls in drops into a water bath **below the reactor and is removed through a lock vessel.** 

Depending on the subsequent application the gas is cooled using one of two methods. A technical concept has been worked out for both cases by Ruhrchemie/Ruhrkohle.

If the downstream conversion of the synthesis gas does not require hydrogen alone, that is, for example, if the gas is for electricity generation, for heating purposes and — above all — for all syngas processes where carbon monoxide is required in addition to hydrogen, the gas

is cooled down by indirect heat exchange thereby producing high pressure steam. The waste heat system then consists of a radiant cooler with a downstream convection cooler.

# Fig. 4: Direct Quench Mode of Coal/Residue Gasification using the Texaco Process

If, however, only hydrogen is required in the downstream process — for instance in the production of ammonia of for hydrogenation purposes — the gas is cooled by direct contact with water injected into the radiant cooler vessel, which thereby acts as a quench chamber. Thus the gas is saturated simultaneously with steam which is required for subsequent shift conversion of carbon monoxide to hydrogen.

After cooling the gas is washed free of solids, before it is passed on for further processing.

This diagram and the previously shown flowsheet for the heat recovery apply to the gasification of both coal and hydrogenation residues in the form of aqueous suspensions.

The hydrogenation residue is a mixture of unreacted carbon, high-boiling hydrocarbons, the ash of the feed coal and – if utilized in the hydrogenation process – the hydrogenation catalyst, preferably iron oxide. It is a solid material at ambient conditions, but can be melted at elevated temperatures. Therefore, it can be fed to the gasifier either in a solid form – as shown here – or in a liquid form.

Fig. 5: Flowsheet of the Gasification of molten Residue using the Texaco Process

If the residue is fed in as a liquid, a special feed system is required. In principle it resembles that of a heavy residual oil gasifier adapted to the higher melting temperature of the feedstock and the handling of large amounts of ash. The two main sections are the discharge of the hot liquid residue to a storage tank and the feed conveyance to the gasifier.

The current status of the results achieved in the demonstration plant are summarised in the next slide:

Fig. 6: Current status of the test results (optimum results of different test runs)

Since 1980 the gas produced in the synthesis gas plant has been admitted regularly into Ruhrchemie AG's syngas network and has contributed to the manufacture of oxo products.

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# FOCAL POINTS OF DEVELOPMENT

The focal points of the seven-year development work are shown in the next slide.

Fig. 7: Focal points of development

I would like to back up the results shown with some more detailed information:

Since 1978 some 100,000 tons of carbonaceous materials have been gasified, including 70,000 t of coal and 24,000 t of hydrogenation residues. A compilation is given in slide 8.

Fig. 8: Coals and Residues tested

These feedstocks are listed here in the order of their volatiles content and classified according to the German terminology. The second row denotes the name or location of the mine or seam. The feed coals included mainly German coals from the Ruhr area. Three coals originated from the United States, one – a Lorraine coal – from France and two coals from South Africa.

The liquefaction residues used came from the coal oil plant at Bottrop as well as from the Exxon Donor Solvent plant at Baytown, Texas.

All feedstocks, some of which were tested under contract for foreign customers, proved to be well suited for Texaco gasification, furnished excellent performance data and caused no operational problems worth mentioning.

Fig. 9: Properties of Feedstocks tested

An overview of the compositions of the feedstocks employed and their characteristic data relating to coal quality, reactivity, environmental impact, corrosion potential, grinding energy and gasifier temperature to be applied is given in this table.

In some cases the data cover relatively broad ranges. Just to mention a few, an ash content between 6 and 40 %, a sulfur content from 0.6 to 4.3 % and chlorine between 0.01 and 0.5 %. The Hardgrove index as a measure of the grindability ranged from 47 to 100, the ash fluid temperature from 1 220 to 1 450 °C.

As well as the runs with coal and hydrogenation residues, tests on the scale of 1 000 t of coal feed have been carried out on a German high volatile bituminous coal to which fluxing agents had been added.

The <u>wet grinding</u> procedure was a focal point of the Holten development. Thus grinding, dispersion and homogenisation were combined into a single process step. A tube mill has proved to be the most suitable grinding device. The grinding bodies are shaped according to the grain properties required. The plating of the mill is made of suitable material, whose properties are also regarded as know-how.

During the first year in which the demonstration plant was running toothed disk mills were used to grind the coal. This type of mill is advantageous as far as investment costs and grinding energy are concerned. The fineness of grinding, however, the wear and the relatively high sensitivity towards foreign bodies made it necessary to change over to a ball mill. This type of mill is characterised by high reliability, insensitivity towards impurities, low wear and a sufficiently high fineness of grinding for suspensions of high concentration. The fineness of grinding can be controlled simply by varying the filling of the grinder and the speed. No scale-up problems are encountered with the tube mill and they are available in all sizes up to the largest units. Typical grain-size distributions are shown in slide 10.

## Fig. 10: Particle Size Distributions

If no additives are involved, pumpable suspension of up to 64 % coal can be prepared. In practice the pumpability limit is defined as a viscosity of 3 000 mPa.s for a shear rate of 11.5 cm<sup>-1</sup>. Far higher concentrations can be achieved if flow improvers are used. Their effectiveness is highly dependent on their steric arrangement and the intramolecular charges. We tested, therefore, more than fifty different additives in the laboratory. These were, above all, long-chain anionic and non-ionic tensides from the classes of substance shown in slide 11, among others.

## Fig. 11: Additives for Slurry Stabilisation

In laboratory tests pumpable solids contents of up to 73 % could be achieved with optimal grain distribution. In the demonstration plant a value of 71 % was realised for continuous operation.

The maximum suspension concentration depends strongly on the type of coal, above all, its geological age. Residue suspensions do not differ principally from coal dispensions as far as the solids content is concerned. However, for residue slurries an increased tendency to foaming and sedimentation was observed, which led to certain transport and measurement problems and occasionally to clogging. These problems could be solved by changing the grain size and the dosing of the additive, by constructional alterations within the storage vessel and by adding stabilisers.

Progress in the development of the <u>process burners</u> has led to improved burners of the type shown in slide 12.

### Fig. 12: Process burner

The principal characteristic of this burner is the separate introduction of the material streams in concentric passages within the burner. The mixing of slurry and oxygen takes place in two stages. The flow is designed to keep erosion to a minimum. The burner can be constructed in a adjustable form in order to improve the partial loading characteristics. The following advantages are combined in this principle:

By finely dispersing the suspension it is possible to achieve high conversion, high selectivity to CO and  $H_2$  and low oxygen consumption. The suspension leaves the slurry pipe with a low linear velocity so that no erosion occurs within the slurry opening. The suspension stream is enveloped by the outer oxygen stream, thus preventing erosion at the exit nozzle of the burner.

Cold tests on a testing stand have shown that the dispersed slurry stream leaving the burner is bell-shaped. This results in a favourable residence-time distribution in the gasifier, protects the reactor wall cladding against erosion and prevents caking of the slag on the base plate of the burner.

The oxygen impulse can be kept constant during loading changes by remote-controlled alteration of the cross-section of the oxygen exit nozzle while gasification is taking place. In this way conversion and selectivity remain independent of the reactor loading and no scale-up problems are encountered with the burner.

The burner is suitable for the gasification not only of coal and residue suspensions but also for heavy oil and liquid hydrogenation residues. In the latter case the steam which is required is added as one of the material streams within the burner.

The development of <u>refractory materials</u> was carried out together with external institutes and manufacturers. The test sequence followed is shown in the next slide:

Fig. 13: Test procedure for ceramic lining materials

A candidate which appears suitable is first examined in a mineralogical/physical study in the laboratory. If the results are promising tests in a rotary furnace follow: the test material is subjected to conditions resembling those in practice in a gas-fired rotary furnace in which the

slag is continuously renewed. It is subsequently investigated in the laboratory with regard to abrasion, slag penetration and changes in constitution.

So far some 70 different materials have been subjected to this procedure in the rotary furnace and about 40 have been tested in the test reactor. They are largely mixed oxides with high contents of  $Cr_2O_3$  and sometimes  $ZrO_2$  and  $SiO_2$  belonging to the systems  $Cr_2O_3$ -MgO and  $Cr_2O_3$ -Al<sub>2</sub>O<sub>3</sub>. They have been used in the form of stones, concrete, stamping mass or mortar.

The refractory development has now reached an initial conclusion. Recent results show that we now have materials available with a rate of wear of 0.004 mm/h. This value was determined over an operating period of 3 400 hours with about 20 interruptions and in which liquid residues were the principle feedstock. It can be ascribed to a large extent to the low reactor temperatures made possible by the burner development, to the stationary mode of operation which has now been obtained and to the careful attention paid to ensure smooth temperature control.

Linear extrapolation suggests that after 5 years of operation with 8 000 hours per year 160 mm of brickwork would have been removed. This should be compared with the usual thickness of a wearing layer which is of the order of 200 to 300 mm. The progress achieved during the development of the brickwork is revealed in Slide 14.

#### Fig. 14: Wear rates of refractories

In the Holten development particular attention was given to the gas cooling and the heat recovery. This aspect had not been studied in the previous laboratory development at Texaco. For energetic reasons, however, it is an indispensable part of any successful process. In order to cool the raw gas leaving the reactor process routes were adapted which to a certain extent involved completely differing principles.

If a high thermal efficiency is required of the gasification process and if the raw gas generated is not to be processed further to hydrogen, the gas is cooled in a waste-heat system in which high-pressure saturated steam is generated. In the concept developed by Ruhrchemie/Ruhrkohle the waste-heat system has two steps. It consists of a radiation cooler which is followed by a downstream convection cooler. The radiation cooler must perform the two tasks shown in the next slide:

Fig. 15: Functions of the radiation cooler

The convection cooler has the task of cooling the gas down further. The gas temperature attained must lie above the dew point in order to avoid corrosion and plugging. The convection cooler operates either on the water-pipe or the internal flue principle. Slide 16 shows these concepts.

# Fig. 16: Alternative concepts for cooling

Both process principles have been tested over long periods in the Holten plant. Their respective advantages and disadvantages have to be aligned to the purpose for which the gas is intended. The further cooling down of the gas is accompanied by further removal of useful heat in the form of preheating of boiler feed water and generation of low-pressure steam. The gas and water streams have to be switched in such a way that the water washing is operated as isothermally as possible, i. e. essentially in the sense of a material exchange rather than a heat exchange.

If no importance is attached to the recovery of process steam, e. g. for a "green fields" plant or if the gas produced is to be processed to hydrogen by means of shift conversion, it is more sensible to cool the gas by quenching with water. In this way, due to the vaporisation of the water, the gas is simultaneously charged with the steam required for the down stream conversion reaction.

Whereas Texaco has employed dip tube technology, we at Ruhrchemie prefer spray quenching. It suffers from no fouling of any sort and by adjusting the amount of quench water it is possible to control the cooling and the water vapour saturation effects.

From an <u>environmental point of view</u> entrained-bed gasification is regarded as particularly sound compared with other gasification principles, above all fixed-bed gasification. On account of the wet-feed system the Texaco process occupies an exceptional position. Since the coal processing – grinding, transport and feed into the reactor – is carried out totally with the suspension, dust formation can be ruled out from the start. The product streams – raw gas, waste water and slag – possess only a minimum danger for the environment.

In order to document these advantages as well as to provide data for the plant conception and for the approval procedure by the authorities an extensive measuring program was undertaken for a whole range of feedstocks. The analytical examinations were carried out by Ruhrchemie and Ruhrkohle themselves, in the laboratories of the test-run customers and by appointed neutral institutions. The range of the analytical data measured may be seen in slide 17:

#### Fig. 17: Composition of raw gas

The variations can be traced primarily to the differing compositions of the starting materials. Process technological influences due to, for example, the temperature, pressure or the concentration of the suspension, are of relatively minor importance. Hydrogenation residues exhibit an almost identical behaviour to coal.

As well as the main components the raw gas contains several undesirable by-products. Of these, only  $H_2S$  and COS are present in quantitatively significant amounts. Both, however, are removed in a downstream desulfurisation scrubber unit. The other components together amount to less than 100 mg/m<sup>3</sup>. Organics, mainly benzene, toluene and naphthalene, are present to an extent of less than 10 vppm. Heavy metals can only be detected in the range of  $\mu$ g/m<sup>3</sup>.

The waste water - slide 18 - proves to be less problematical than in other comparable processes, not to mention other coal gasification processes which generate large amounts of hydrocarbons, phenols and tars.

#### Fig. 18: Typical data of waste water

It its necessary to process the water, in particular to remove solids as well as ammonia, hydrogen sulfide, hydrogen cyanide and fluorides. The heavy-metal content is in the region of  $\mu g/l$  and can be regarded as unobjectionable.

In order to judge the disposability of the slag particularly stringent leaching tests were carried out under laboratory conditions. The data from the slag eluants are summarised in slide 19. Only alkali and alkaline-earth metals are present in concentrations of mg/l. Heavy metals can be detected only in the #g/l region. The values are within the standards for drinking water in nearly all cases.

#### Fig. 19: Data from slag leaching tests

A few words on the <u>flexibility</u> of the process as far as the variability of the feedstock is concerned. As I already mentioned, as well as some 70,000 t of coal, 25,000 t of solid and liquid hydrogenation residues from the Bottrop coal hydrogenation plant and the EDS plant in Baytown have been used astarting material. The characteristic data and compositions of these residues are shown in slide 20, the compositions and melting behaviours of the ashes in slide 21.

Fig. 20: Properties of Residues tested

Fig. 21: Composition and Melting Behaviour of the Ash

Solid residues were fed in at the rate of 4 to 8 t/h with suspension concentrations of up to 71 %. Liquid residues were transferred from Bottrop, which is about 15 km away, in a heated road tanker. On account of the low rate of production of residues in the coal-oil plant and our restricted storage capacity, throughputs of only 3 t/h could be achieved.

No serious problems were encountered with either the solid or the liquid residues. In some cases the chlorine content of the residue was extremely high which led to increased rates of corrosion in the waste-heat system and the mechanical gas scrubber. These could be counteracted by means of process and material alterations.

All of the residues proved to be highly active and exhibited favourable ash-melting behaviours. As a result practically complete conversions and high efficiencies were achieved at remarkably low reactor temperatures. This can be verified in slide 22.

Fig. 22: Range of Operation Conditions for Residue Gasification

The diagram of temperature against time shown in slide 23 is an example of coal gasification in which fluxing agents are employed.

Fig. 23: Temperature/time diagram of gasification run

By using additives trouble-free gasification was possible even at temperatures below the melting range of the untreated coal. The next slide shows in an exemplary manner the carbon conversion for gasifications with and without the addition of 2 % limestone.

Fig. 24: Carbon Conversion versus gasification temperature

Holmo Eclass Ewish to say a few words on Ruhrchemie/Ruhrkohle's plans for establishing their process. The propert partners Ruhrchemie/Ruhrkohle are currently constructing their own commercial coal gasification plant. It is being erected at Ruhrchemie's works in Oberhausen,

West Germany, and will enable Ruhrchemie to change the basis of syngas generation completely from heavy oil to coal. The syngas will be used for the production of organic chemicals and ammonia.

# Fig. 25: Block Flow Diagram of the commercial Ruhrchemie/ Ruhrkohle Syngas Plant

The existing Texaco heavy-oil gasifier will be integrated in the new gasification complex. The hot raw gas leaving the coal gasifier will be partially cooled in a radiant boiler. It will then be split into two streams, the main gas stream to be further cooled in a convection cooler and used for Oxo production after mechanical washing and desulfurization, the minor stream to be quenched, shift converted and used as hydrogen after purification. The time schedule is given in the next slide. According to this the start-up phase will begin in 1986.

Fig. 26: Time-Schedule of Ruhrchemie/Ruhrkohle's commercial Syngas Project

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			1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
	Eng	jineering	C		ב										
Scale	Cor	nstruction													
nstration S	Coal Gasification									]					
Demo	Sol Ga	id Residue sification													
	Lic Ga	uid Residue sification													
ale	En	gineering									C				
Commercial Sci	Co	nstruction												5	
	Or	peration												C	L
	Time Schedule of Ruhrchemie/Ruhrkohle's Gasification Program														

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FIGURE 2

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FIGURE 3



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FIGURE 4



FIGURE 5

Total operation per	iod	(h)	approx. 18	000			
Total amount of fee	edstock	(t <u>)</u>	approx. 94	000			
<ul> <li>as coal</li> <li>as solid resid</li> <li>as liquid resi</li> </ul>	ue due	(t) (t) (t)	approx. 70 000 approx. 15 000 approx. 9 000				
Total gas amount		(m <mark>3</mark> )	approx. 180	MM			
Coal throughput		(t/h)	up to 8.2				
Number of tested c and residues	oals		15				
<ul> <li>ash content</li> <li>content on v</li> <li>water content</li> <li>Hardgrove in</li> <li>ash melting</li> </ul>	volatiles nt 1dex point, reduc.	(% m.f.) (% m.a.f.) (%) ( <sup>0</sup> H) ( <sup>0</sup> C)	6 16 1 .47 1 220	- 40 - 49 - 55 - 100 - 1 450			
Solids content in sl	urry	(%)	up to 71				
Temperature	- 1	( <sup>0</sup> C)	1 200	- 1 500			
Pressure		(bar)	up to 40				
Gas Composition		(vol-%)	coal	residue (molten)			
CO H2 CO2 CH4 H2S/COS N2			54 34 11 < 0.1 0.3 0.6	59 35 5 0.3 0.3 0.6			
C-Conversion		(%)	> 99				
Efficiencies (cold gas/ther	mal)	(%)	77/94	83/94			
RUHRCHEMIE AG	RUHRCHEMIE AG Current status of the test results						
RUHRKOHLE AG (optimum results of different test runs)							

FIGURE 6





Country	Location	Туре
West Germany	Friedrich—Heinrich	Forge Coal
	Friedrich—Heinrich	Fat Coal
	Osterfeld	Gas Coal
	Lohberg	Gas Coal
	Mix	Gas Coal
	Westerholt	Gas Flame Coal
	Prosper	Coal Sludge
USA	Illinois Nr. 6	Gas Flame Coal
	Utah	Gas Flame Coal
	Pittsburgh Nr. 8	Gas Flame Coal
France	Merlebach	Gas Coal
South Africa		Gas Coal
		Gas Coal
West Germany	Bottrop	Residue
USA	Baytown	Residue

FIGURE 8

		Coal	Residue						
Ash	% mf	6 - 28	18 - 40						
Volatiles	% maf	17 - 44	47 - 49						
Carbon	% mf	60 - 85	59 — 73						
Hydrogen	% mf	3.5 - 5.0	3.5 - 4.7						
Oxygen	% mf	2.6 -12.4	1 - 4						
Nitrogen	% mf	1.1 - 1.6	1.1 - 1.5						
Sulfur	% mf	0.6 - 4.3	1.0 - 2.6						
Chlorine	% mf	0.01-0.25	0.01-0.5						
Hardgrove I	ndex <sup>o</sup> H	47 — 100	77 - 98						
Ash Fluid T	emp. <sup>0</sup> C	1220-1450	1240-1310						
	Properties of Feedstocks tested								

FIGURE 9



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FIGURE 10



FIGURE 11



FIGURE 12



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FIGURE 13





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FIGURE 15



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FIGURE 16



FIGURE 17

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Solids pH elect. conductivit Total hardness NH 3 + NH 4 <sup>+</sup> Sulfide (H2S) Sulfate (SO4) Nitrite (NO2) Nitrate (NO3) Phosphate (P2O5 Chloride (Cl) Fluoride (F) Cyanide (CN) Thiocyanate (SCI Phenols (C6H5O TOC (C) COD (O) BOD5 (O) As Ba Be Pb Cd Cr Mn Hg Se Zn Na K Ca Mg	y $\frac{g/l}{\int_{0}^{L} \frac{g}{\partial d}} 3$ mg/l h) $\int_{H} \frac{g}{\int_{0}^{L} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\int_{0}^{L} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\int_{0}^{L} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\partial d} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\partial d} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\partial d}} \frac{g}{\partial d} \frac{g}{\partial d} \frac{g}{\partial d}} \frac{g}{\partial d} \frac{g}{\partial d} \frac{g}{\partial d} \frac{g}{\partial d}} \frac{g}{\partial d} \frac{g}{\partial d}} \frac{g}{\partial d} \frac{g}$	$\begin{array}{c} 4 - 14 \\ 7 - 9 \\ 000 - 12 \ 000 \\ 1 - 5 \\ 600 - 2 \ 000 \\ 20 - 70 \\ 20 - 90 \\ 0.03 - 11 \\ 1 - 2 \\ 0.1 - 3 \\ 40 - 1 \ 700 \\ 30 - 160 \\ 13 - 16 \\ 4 - 50 \\ 0.02 - 0.7 \\ 200 - 500 \\ 90 - 200 \\ 40 - 300 \\ 3 - 100 \\ 30 - 100 \\ 0.2 - 10 \\ 0.6 - 500 \\ 0.3 - 10 \\ 0.4 - 30 \\ 20 - 700 \\ 0.1 - 1 \\ 40 - 400 \\ 9 - 40 \\ 400 \\ 20 \\ 6 \\ 3 \end{array}$
RUHRCHEMIE AG	Typical data of waste water	

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FIGURE 18

pH Sulfate Chloride Cyanide NH <sub>3</sub> + NH <sub>4</sub> <sup>+</sup> Na K Ca Mg As Cd Cr Cu Hg Mn Pb	mg/l μ g/l	
Se Zn	Ļ	< 0.4 - 4 < 0.1 - 2 100
electr. conductivity Total hardness Phenols	۳ S/cm o <sub>d</sub> س <sup>g/I</sup>	100 - 400 3 - 6 < 5
RUHRCHEMIE AG	Data of slag leaching t	ests
RUHRKOHLE AG		

FIGURE 19

Ash	wt-%	mf	18 - 40				
Volatile Matter	wt%	maf	47 - 49				
Carbon	wt-%	mf	59 — 73				
Hydrogen	wt-%	mf	3.5 - 4.7				
Nitrogen	wt-%	mf	1.1 - 1.5				
Sulfur	wt%	mf	1.0 — 2.6				
Chlorine	wt-%	mf	0.01 - 0.5				
Fluorine	wt-%	mf	0.004 - 0.02				
High Heating Value	MJ/kg	mf	24 – 31				
Low Heating Value	MJ/kg	mf	23 – 30				
Hardorove–Index	°н	mf	77 — 98				
(							
Softening—Temp. *)	0C		110 — 190				
 * \							
<sup>7)</sup> Kraemer—Sarnow							
Properties of Residues tested							

FIGURE 20

Composition			
SiO <sub>2</sub>	wt-%	25 —	48
AI <sub>2</sub> O <sub>3</sub>	wt-%	14 —	28
TiO2	wt-%	1 –	8
Fe <sub>2</sub> O <sub>3</sub>	wt-%	7 —	27
CaO	wt-%	3 —	15
MgO	wt-%	1 –	5
Na <sub>2</sub> O	wt-%	1 -	6
к <sub>2</sub> 0	wt-%	1 -	2
so <sub>3</sub>	wt—%	1 –	7
P205	wt-%	0.2 -	0.4
Melting Behaviour			
oxidizing Atmosphere			
Softening Temp.	°C	1180 —	1220
Hemisph. Temp.	°C	1210 —	1380
Fluid Temp.	оС	1230 —	1420
reducing Atmosphere			
Softening Temp.	°C	1090 —	1140
Hemisph. Temp.	°C	1190 —	1260
Fluid Temp.	°C	1240 —	1310
Composition and Melti	Ash		

FIGURE 21

		solid	molten				
Gasifier Pressure	bar	36	- 40				
Gasifier Temperat	ure <sup>o</sup> C	1 200 - 1 600					
Throughput	t/h	3.5 — 7.6	2.5 — 3.5				
Slurry Concentr.	%	42 — 71					
Steam/Residue R	atio —		0.2 - 0.7				
RUHRCHEMIE AG							
RUHRKOHLE AG	inge of Opera	ating Conditions for F	Residue Gasification				

FIGURE 22

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Temperature/time diagram of gasification run

FIGURE 23



Carbon conversion versus gasification temperature

FIGURE 24

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Project Phases	81	82	83	84	85	86	87	88
Decision								
RCH/RAG			5					
Government								
Approbation								
Engineering								
Design								
Procurement			Ľ					
Delivery								
Construction								
Foundations					<b>-</b>			
Structure								
Equipment								
Operation								
Shake-down runs								
Commissioning						Ċ		
Production								
Time Schedule of t	the Rul	ırchemi	ie/Ruhr	kohle S	Syngas F	Program		

