THE WINTERSHALL - SCHM LFELDT PROCESS
FOR THE MANUFACTURE OF SYNTHESIS GAS AT LÜTZKENDORF

SUMMARY

A description is given of the process, with sketches and flowsheets. The process consists essentially of gasification of dry brown coal dust in the entrained state; the heat of reaction is added by burning producer gas, storing heat in a regenerator and then abstracting it by recirculating saturated synthesis gas, with also the addition of oxygen at various points; sensible heat in the final gases is used to dry and disintegrate the raw brown coal. The producer gas is made by gasifying dry brown coal dust in the entrained state, using air with a little steam. The processes are now technically established, but dust losses are high and synthesis gas contains substances deleterious to Fischer-Tropsch catalyst, although not to hydrogenation of oil and tar; the plant is very large for the output and capital costs are high. In its present state of development the process appears to be less economic than the alternative Winkler process, operating under similar circumstances. The producers are particularly inefficient. Because of its dependence on the availability of a very cheap and active fuel, the process appears to have little application to British conditions.

INTRODUCTION

Members of the Oil Mission attached to the C.I.O.S. Section of SHAEF G.2 Section, under the auspices of the Ministry of Fuel and Power, visited the Wintershall A.G. plant (Target No.30/4.12) at Lützkendorf, Krumpa, near Mücheln on May 9th and 11th, 1945. A short description of this process and of other parts of the factory has already been given in Ref.1, but the present report brings together all the information on the synthesis gas process, obtained from the visit and from subsequent study of captured documents. Where statements in this report are at variance with those in Ref.1, the present report should be assumed to be more correct.

PERSONNEL

The following visited the plant on May 9th, 1945:

Dr H. Hollings and Mr G.U. Hopton (Gas Light & Coke Company)
Mr T.F. Hurley (Fuel Research Station)
Mr L.L. Newman (U.S. Bureau of Mines)
Dr R.J. Morley (I.C.I. Billingham Division)

The following visited the plant on May 11th, 1945:

Dr A.J.V. Underwood (U.K.)
Mr J.F. Ellis and Dr R.J. Morley (I.C.I., Billingham Division)

The following members of the staff were interrogated:

Dr Schneeberger : Director
Dr Schneider : Director and power plant specialist
Dipl.Ing. Dassow*: Manager of gas plant (* or Dassau)
Dipl.Ing. Schültz: Manager of Fischer Tropsch plant

All staff interviewed were very co-operative, but the Mission received the impression that the technical standards of the staff were not as high as those of other plants visited. The plant was shut-down at the time of the visit, and had been out of commission since the last air-raids.

GENERAL INFORMATION ON THE FACTORY

The plant was built in 1938 and was intended originally to operate for Fischer-Tropsch synthesis only. Later a hydrogenation plant was added, hydrogenating natural oil and bituminous coal tar. The plant was unique in that synthesis gas and hydrogen were produced by the Wintershall-Schmalfeldt process, which was essentially a gasification of brown coal in the entrained state.

The factory as a whole had a bad reputation in Germany, presumably due to the extreme difficulties encountered during the first 18 months of running. The state of the factory became so bad that in October 1939 I.G. experts from Leuna (7 miles away) were brought in to help put matters right; the periodic I.G. reports (Ref.2) on this work gives a very illuminating account of the factory at this time and certain points are worth noting, in order to appreciate that the difficulties were by no means all the result of the use of a novel gasification process. Apparently the whole factory was very badly designed and engineered, was poorly staffed and weakly managed. There was poor design and poor workmanship by several contractors, notably by Koppers in the regenerators, Bamag in the alkacid plants and others in the La Mont boilers. Originally the civil engineering, notably drainage and surfacing, was very poor and there was no provision at all for protecting any plant against frost. The various stages of the factory were often quite out of step, so that spares were either too numerous or else non-existent; inadequate provision was made to keep a supply of steam to the factory, when synthesis gas and producers were shut down and not producing any dry dust or any waste heat steam. Moreover since the novel gasification processes required more than the usual amount of modifications in the first few months of running, they caused a heavy drain on what skilled labour there was, and so the factory could not be got out of the rut. There was a severe shortage of skilled engineers and foremen and the labour was mainly inexperienced, and as can be imagined discipline and morale were poor. In fact the whole reads as a classic example of how not to design, build and run a factory!

At one time I.G. had 7 staff men, 25 foremen, 140 tradesmen and 15 process operators at Lützkendorf, trying to bring order into the chaos. Gradually the position improved and the worst was over by the spring of 1940, although even in 1945 C.I.O.S. investigators still got the impression that technically the standards of the factory were not as high as those of other plants visited.

With the above as a background it will be realised that the Schmalfeldt process has not had a happy infancy, and it is quite likely that in better circumstances and with better technical attention the process would have been better developed today.

AIR-RAID DAMAGE

Whilst the factory as a whole was very badly damaged and seemed unlikely to run again, the gas plant itself was not so badly damaged and could readily be inspected.

STANDARDS OF MEASUREMENT

All gas quantities are measured at 0°C and 760 mms Hg, the standard figures used at Lützkendorf, unless otherwise stated. Weights expressed as t signify metric tons or tonnes. Heat units are generally expressed as T cals (=1,000kg.cals).

GENERAL INFORMATION ON THE PROCESS

The designer, Dr H. Schmalfeldt, was once a director of Wintershall and lived at Lützkendorf from the start-up in 1938 until 1940; he is now believed to be living in the Kassel area. Previous to this plant there had been an experimental unit at Ruhland-Schwarzheide (Ref.6), which is probably the same plant referred to in Ref.1 as "Rühlen", probably a mistaken spelling of the place mentioned during interrogation. As far as is known there is no other large-scale installation.

The principles of the gasification process were as follows.

The heat of reaction was originally supplied solely by burning producer gas in one of two regenerators, used alternately, the heat being stored in chequer brick until given up to a mixture of recycled synthesis gas and steam; however since the increased gas requirements, following the start-up of the hydrogenation plant, heat had also been supplied by burning oxygen in the recycled gases. Dried brown coal dust was fed into the recycled gas and steam, heated to over 1,000°C, and mainly gasified whilst entrained in the gas stream, as it passed up and down two large generators in series. The sensible heat in the final gases was used to dry and disintegrate raw brown coal, fed into the gas stream as lumps; the sudden heating caused decrepitation and the particles became entrained. The dust was separated from the gas stream and partly used for making producer gas, the rest being fed to the generators. Part of the synthesis gas was led off, cooled and scrubbed and represented the make, whilst the remainder was recirculated, primarily to act as a carrier of heat from the regenerator to the generators.

Producer gas was also made in a separate installation by gasification of entrained brown coal dust but there was no recycling of gas or use of oxygen; air, steam and dry coal dust were fed into a tower and the sensible heat in the exit gases abstracted by waste heat boilers. The bulk of the producer gas was used for heating the regenerators of the synthesis gas units.

There were four synthesis gas units and five producers, with usually one of each out of action. The plant was very spacious, considering its capacity, although it was made up of relatively simple pieces of equipment. The four synthesis gas units, with regenerators, stacks and washers occupied an area of about 100 m x 30 m, with the vessels about 20-24 m. high. The gas boosting house was outside this area, whilst the producers occupied a separate site.

The original designed output per synthesis gas unit was 20,000 M^3/hour, but the maximum obtainable without using oxygen was normally only 15,000 M^3/hour. When using oxygen the maximum output was 30,000 M^3/hour, although more usually 20 to 25,000 M^3/hour were produced.

The maximum output of a producer was about 30,000-35,000 M^3/hour.

MAIN FEATURES OF THE PERFORMANCE

The two main features which caused operating difficulties were the relatively high content of organic sulphur ring-compounds and gum-forming compounds and the difficulty of removing dust from its suspension in synthesis gas and producer gas. Troubles in the Fischer Tropsch plant due to sulphur ring-compounds and gum-forming compounds arose presumably from the fact that about 40% of the gases evolved during drying and carbonisation was in effect not recirculated, since about 40% of the synthesis gas mixture was led off from the system before the regenerators, where presumably a good deal of cracking of such compounds occurred. Sulphur ring-compounds are difficult to remove by catalytic action, but it should be noted that for the last few weeks of operation active carbon had been used in the purification train to remove these undesirable impurities, and this it was claimed had produced a marked improvement in the Fischer Tropsch plant. Again it should be noted that these impurities were not harmful when the gas was to be used for hydrogenation.

The difficulty of removing dust from its suspension in synthesis gas and producer gas caused very poor carbon efficiencies; indeed at least one-third of the carbon in the raw brown coal left the system as a sludge, formed in the gas washers. This inefficiency however was not quite so serious as it sounds, owing to the cheapness of brown coal, which at Lützkendorf cost only 1.80 to 2.20 RM/t; thus the carbon loss in itself increased the cost of synthesis gas directly by only above 2 RM/1,000 M^3. However dust also caused more or less serious difficulties due to fouling of washers, blowers, disintegrators and waste heat boilers.

The three main advantages claimed for this process over other gasification processes based on brown coal, viz. the direct use of raw wet brown coal, the suitability of dusty fuels without briquetting and the gasification of tar formed, were closely connected with the troubles due to impurities in the synthesis gas. Gasification with entrainment did not appear to have any great advantages in itself; reaction spaces were very large e.g. in comparison with Winkler generators, and difficulties with dust would be very serious with a dearer source of fuel.

Nevertheless it cannot be denied that the Schmalfeldt process as developed at Lützkendorf was a workable process for the manufacture of synthesis gas and hydrogen from cheap brown coal and at any rate may be regarded as especially useful in extending knowledge of what can and what cannot be done in gasification processes.

DESCRIPTION OF THE PLANT

Figures 1A and 1B show a rough layout and arrangement of a synthesis gas unit, whilst Figure 2 is a diagrammatic representation of the flow, etc. Figure 3 is a photograph of one end of the synthesis gas plant, taken during the visit. Figure 5 is a rough layout of a producer gas unit and Figure 6 is a diagrammatic representation of the flow, etc. The individual items of plant will now be considered in turn.

Coal Preparation

Brown coal was obtained from a neighbouring open mine. It was elevated and crushed in hammer mills to all below 20 mms. Everything passing the mill dropped into a raw coal bunker, from whence it was fed by Redler screw conveyors (one working, one spare) through star feeders, dropping into the side of the bottom of the gas drier. The contents of the bunker were kept under nitrogen pressure.

Typical analyses of the raw coal were:

	as received		dry basis
H_2O	50-54%	C	60%
Ash	5-6%	H	4%
Tar	4-5%	O	18-20%
Total S	2-2.5%	S	3%
Vol. S	1-1.5%	N	1%
Cal.val. k.cals/kg(net)	2300-2400	Ash	12%

The tar content was rather low for brown coal, and so the coal was not well suited to the normal treatment, i.e. carbonisation to recover tar for hydrogenation, with use of the coke in Winkler generators and boilers.

Gas Drier

This was merely a vertical brick-lined chimney, 1.2 m. I.D. and 22 m. total height; the height from coal inlet to gas exit was 15 m. The crushed raw coal dropped straight into the drier without any conveying gas; two inlets at an angle of 30° to the vertical were available, one working and one spare; each was steam heated to prevent sticking of the coal, but were brick-lined near the drier itself. The coal met the upward rising synthesis gas and steam, then at about 1,000°C; the sudden heating caused the formation of a steam pressure inside each particle, resulting in decrepitation, and the fine coal became entrained with the gas.

No special mixing of coal and gas was attempted; coal was merely fed through the sides of the drier and the high turbulence of the gas, which had just passed round a bend, together with the explosion of each particle, were sufficient to give good mixing.

The final temperature at the top of the drier was 200° to 300°C. At full output the dry gas rate entering the drier was about 90,000 M^3/hour, so that taking account of the steam present, calculated in Appendix 2 as 91,500 M^3/hour, the average actual velocity of gas through the drier was about 100 m/sec.(agreeing with a statement of Dassow) and the time of drying 0.15 secs. Normally however the velocity was nearer 70 m/sec. and the time of drying 0.20 sec.

Dust Separation

The synthesis gas and dust mixture leaving the top of the drier at 200° to 300°C passed through a rough classifier, where any large pieces of coal were separated: these were sent to a separate hammer mill, and returned to the drier; (presumably they were not returned to the raw coal hammer mills, because the mixing of hot dry coal and raw brown coal would have caused trouble).

The mixture then passed through a simple cyclone to effect the main separation of dust. According to Appendix 3 the dust content of the wet gas leaving the drier was 150 to 200 g/M^3, and that of the wet gas leaving the cyclone was about 30 to 40 g/M^3, so that the separator and cyclone had a combined efficiency of about 85 to 90%. Even so this inefficiency represented a serious carbon loss from the system, since all such dust had to be removed subsequently in washers and could not be recovered from the resultant slurry. In this way some 10 to 13% of the carbon in the raw coal was lost (See Appendices 2 and 3).

In 1942 it had been planned to install multicyclones to reduce the dust content of the gas to 6 g/M^3 but this project had never been undertaken. Dust recovered from the multicyclones, of course, could have been returned for gasification.

The dry coal dust contained some 18 to 20% ash and 60% carbon. The ash content was higher than that of raw brown coal without its water, because the dry coal dust contained nearly all the ash remaining from the gasification of dry coal dust fed to the generators; the carbon content however was the same as that of raw brown coal without its water, presumably because some oxygen and hydrogen were given up in the drier. There was of course a large ash purge from the generator system in the dry coal dust fed to the producers.

No figures were available for the grading of the dust.

Dust Handling

Dry coal dust fell from the cyclone into a bunker, at the bottom of which were star-feeders, passing dust into pneumatic lines, working on the ejector principle. Nitrogen was used for conveying dust, at a concentration of about 3 kg/M^3, to the producer gas bunkers, but synthesis gas was used for conveying dust, at a concentration of about 3.8 kg/M^3, to the synthesis gas units, since the conveying gas actually entered the generators along with the dust: this synthesis gas, amounting to about 10% of the make, in effect recirculated through the generator system, but not through the regenerators.

Rather more dust was sent to the producers than returned to the generators, the exact proportion depending on output.

Regenerators

These were brick-lined towers, 7.1 m. O.D, 5.5 m. I.D. and 24 m high. Two were provided for each synthesis gas unit, one being heated up by producer gas whilst the other was giving up its heat to the recycled gases; they were changed over automatically every eleven minutes, with a purge to atmosphere of 1 minute after heating up.

The design of these regenerators was obviously based on that of air preheaters used for blast furnaces. They were filled with chequer, made of high quality brick, such as sillimanite or silica, to a depth of 17-18 m. Two designs of chequer had been tried; one a Brassert type and the other, which had given better results, a type made by Messrs Didier, of Berlin. The Didier type, known as "Schieffer-Strack", consisted of hexagonal blocks, about 12¾" across and 7" deep, each having about twenty 1¼" diameter vertical holes, spaced at 2½" centres. A plan view is shown in Figure 4A. The surface area of the channels from these dimensions amounts to about 11,500 M^2/regenerator, a figure somewhat in excess of 8,540 M^2, as quoted in Ref.2 (Item 83) for 1940. These bricks were carefully stacked and lined up, so that the holes came in line. The lining bricks were well-finished, so as to permit the minimum amount of cement to be used. It was stated that there was no trouble due to dust deposition in the chequers and that the bricks stood up very well to the conditions. No figures were available for the dust content of clean producer gas or recirculated synthesis gas.

Preheated air and producer gas were fed into the top of the regenerators through ring mains. Flue gases left the bottom of the regenerators and entered an underground line, common to the two regenerators, leading to a stack; no waste heat boiler was installed, but one was projected. Recycled synthesis gas, saturated with water vapour at 82°C, entered the bottom of the regenerator and left it through the cupola at the top, on its way to the first generator.

The maximum brickwork temperature was 1450°C at the top. The average exit flue gas temperature was 450°C. The recycled gas entered at 82°C and left at about 1,300°C.

Double isolation valves were used on each flue gas and recycled gas line, with the portion between valves automatically vented to atmosphere, when the valves were shut. This was a safety measure, but usually it was found that the valves were a good enough seal. The isolation valves on the air and producer gas were not seen, but these may also have been double.

In line diagrams in Refs. 2 & 3 valves are shown on the line from each regenerator to the first generator, but by an oversight details were not obtained during interrogation. Working at 1,300°C the duty would appear to be arduous but nowhere is there any mention of difficulties encountered.

Originally there had been some trouble with erosion at the top of the cupola but this had been cured by constructional changes, aimed at making the linear velocities of the gas in the cupola and off-take pipe more nearly equal.

First Generator

This was a brick-lined vessel, 5.5 m I.D. and 24 m high. The special design of the cupola, with its false roof, is shown in Figure 4B. Dry coal dust, conveyed by synthesis gas at a pressure of 2.5 ats, was fed down through a passage in the centre of the cupola; in this way it was kept out of contact with the walls of the vessel, where it would slag up. The hot recycled gas and steam mixture from the regenerators was fed through ports in the false roof of the cupola.

Oxygen, saturated at 82°C, was introduced from ring mains through ports at points near the top and middle of the generator; near the bottom, steam as well as oxygen was admitted, to avoid slagging. The temperature fell from 1,300°C at the top to 1,000°C at the bottom.

Second Generator

This was also a brick-lined vessel, 24 m high and having an I.D. of about 5.5 m. On three units it was divided internally by a vertical wall, but on the fourth unit it had no such division wall. The division wall was shaped as shown in Figure 1, being curved towards the inlet and possibly hotter channel, a device presumably connected with considerations of strength and expansion; the two portions were of approximately equal area. In the unit with no division wall the gas was brought down to the bottom of the drier by an external pipe.

One-third of the total oxygen was added near the bottom inlet of the generator, whilst steam was added as required at various points in order to control temperatures and avoid slagging. The aim was to maintain temperatures throughout at about 1,000°C.

In the opinion of Dassow the central division wall was not necessary; the unit without it worked just as well. This is understandable, since the division wall gave only higher turbulence and increased linear velocities but no greater contact time. He also said the second generator was not really required if the output was not too high, but was necessary for the higher outputs using oxygen. This indicated that gasification was substantially complete after the second generator.

Gasification Times

From the data given it can be deduced that the approximate gasification time (time of contact of coal in generators) was 4.5 secs at 30,000 M^3/hour make and 6.0 secs at 20,000 M^3/hour.

Washers

The recycled gas had to be cooled and dedusted in order to avoid trouble with the blowers and to avoid slagging troubles in the regenerator. Each unit had two washers, one working on recirculated gas (about 50-60,000 M^3/hour) and one on synthesis gas (about 25,000 M^3/hr). The washers were the same size and took the same water rate, despite the difference in gas rate. A typical arrangement is shown in Figure 4C. Each was 5.5 to 6.0 m I.D. by 22 m total height. Each was divided into two sections with its own water circulating system, each section being packed with six trays of stacked 80 mm. spiral Raschig rings. About 750 M^3/hour of water were circulated round the bottom section, removing the bulk of the dust; a purge was maintained on this system to keep the solids concentration at about 80-100 g/l. Similarly 750 M^3/hour of water were circulated through the top section but also through a water cooling tower.

The object of dividing into two the cooling and dedusting in each tower was presumably to remove the bulk of the dust in the lower portion, sending the purge to waste, whilst removing the bulk of the heat in the top portion, where the relatively clean conditions enabled the water to be passed through a water cooling tower and re-used.

So long as the water quantities were maintained no trouble was experienced with chokage of the packing with dust. However at each six monthly shut-down the rings were removed and washed. This job for eight washers on the synthesis gas units and five on the producers kept fourteen day men continuously employed.

Synthesis gas to be recirculated left the washer saturated at a temperature approaching 82°C. After boosting to 0.15 ats.g. an amount of live steam roughly equal to the vapour in the saturated gas was added, and the mixture passed to the regenerators.

Blower and Control House

This building at the end of each unit housed the automatic control gear for the valve change over and also blowers for boosting synthesis gas, recirculated gas, oxygen, nitrogen, etc.

Pressures

The gas pressure at the bottom of the regenerator was 0.150 ats.g. Since the pressure at the point of entry of coal into the drier had to be kept very close to atmospheric, to prevent gas leaking back up the coal feed line, the drier and washers had to be run at a pressure below atmospheric; the pressure at the top of the washers was about -0.020 ats.g. but this varied with the cleanliness of the washers. The pressure in the drier was controlled by a damper, located between the second generator and the drier.

Control of H_2/CO Ratio

This was controlled at 2.0 by adjustment of the steam to gas ratio. Calculations in Appendix 2 indicate that the steam/gas ratio was about 1.0 at the exit of the drier.

Synthesis Gas Analysis

This was as follows:

	With Oxygen	Without Oxygen
CO	25%	27.5%
H_2	49.5%	55%
CO_2	18 %	10%
CH_4	3 %	3%
N_2	3 %	3%
H_2S	1.5%	1.5%

Dust Losses and Carbon Balances

As in the Winkler process the high dust content of the make gases introduced large inefficiencies and some technical and mechanical difficulties. Dust losses were a very undesirable feature of the process, and no doubt an obstacle in the way of new installations.

Carbon balances have been calculated in Appendices 1 and 3 for three periods - early 1942, whole of 1943 and whole of April 1944. Taking the synthesis gas units and producers as a whole the figures for early 1942, which were used in a Wintershall report (Ref.4) and which Dassow thought were rather optimistic, show that 26% of the carbon was lost as dust; the figures for the whole of 1943 show that 39% of the carbon did not appear in synthesis gas or producer gas, whilst the figures for the whole of April 1944 show that as much as 43.5% of the carbon did not appear in synthesis or producer gas. The figures for the whole of 1943 are probably the most reliable and taking into account other possible losses of carbon we can say that at least one-third of the carbon was lost as dust in synthesis gas and producer gas.

It was stated that the washers reduced the dust content to 30-40 mg/m^3 and that Theisen disintegrators reduced it further to 23-25 mg/m^3. If these figures are true they represent a poor performance for a Theisen disintegrator. There was a further water wash before the H_2S removal plant (Alkacid), which apparently experienced little difficulty due to dust.

Outage

Dassow stated that originally there were some difficulties, mentioned in various places above, but that now these had been largely overcome. Ash and slag gradually accumulated in the first generator and when oxygen was used the generator had to be cleaned out every six months, but if no oxygen were used the plant could be run longer. During these shut-downs other maintenance work was carried out, such as cleaning rings in the washers, repairs to brickwork. As a rule a shut-down would last 42 days - 14 days to cool down, 14 days to carry out repairs and 14 days to heat up. The ash and slag mixture was white and very hard and had to be chiselled out.

Producer Gas Plant (See Figures 5 and 6)

There were five producer units, each making a maximum of 30,000 to 35,000 M^3/hour producer gas, although normally making less. Again gasification of the dust was carried out with entrainment. Each unit consisted of the producer proper, followed by waste heat boilers, multicyclones, wash tower and Theisen disintegrator.

The producer was a brick-lined tower, 5 m I.D. and 24 m high, with an internal division wall, very similar to that of the second generators. Dry coal dust was blown into the bottom of the tower, along with steam and air, the mixture passing up one side and down the other. The maximum temperature reached was 1,000°C. The gasification time (time of contact) was about 11 secs when making 30,000 M^3/hour.

The dry coal dust (18% ash, 60% C) was conveyed from the synthesis gas units to a bunker by means of nitrogen, but it was conveyed from the bunker to the producers by means of air. About 15 t/hour dust was conveyed by 1,000 M^3/hour air through three lines, each 125 mms I.D; assuming atmospheric pressure this corresponded with a velocity of 7.5 m/sec. and a dust content of 15 kg/M^3.

Gases from the producer passed through a horizontal and a vertical waste heat boiler in series, reducing the temperature to 250°C, and raising about 0.5 t steam/1,000 M^3 producer gas to a pressure of 10 ats.g. Some erosion at the inlet of the first boiler was experienced and this limited the running time of a unit to six months between overhauls; some slagging up also occurred at this point and at one time consideration was given to injecting water just in front.

Multicyclones followed the boilers; the recovered dust was blown back by compressed air into the bottom of the producer, although at times some was sent to the main boilers.

The washer tower was 5 to 5.5 m. I.D. and 22 m. high, filled with ordinary 2" Raschig rings; in design it was very similar to washers on the synthesis gas units, but the water rate was only 500 M/hour. Dassow said the tower was too small and passed too much dust. A Theisen disintegrator removed most of the remaining dust, and after passing through a spray arrestor, the gas was boosted into the factory fuel gas system. Here it was mixed with tail gases from the Fischer-Tropsch and hydrogenation plants. The chief consumers of fuel gas were the regenerators of the synthesis gas units: in 1943 these consumed 73% of the T.cals in fuel gas, an amount only slightly greater than the total amount of producer gas made. So as a first approximation it can be considered that in effect the producers were run solely for the benefit of the synthesis gas units and hence all the coal fed to driers of the synthesis gas units and all the dust from the coal drying plant, etc., fed to the producers was in effect eventually consumed in making synthesis gas, even though over half the dry coal dust was consumed through the medium of the producers.

The pressure was 0.150 ats. g. at the bottom of the producer and 0.080 ats.g. before the Theisen disintegrator.

The analysis of producer gas was -

CO_2	12%
O_2	0.3%
CO	16%
H_2	16%
CH_4	2%
N_2	53.7%

The above analysis yields a calorific value of 1.070 T.cals/M^3 (net), but the average value for 1943 was in the official records as 1.046 T.cals/M^3 (net).

From figures given in Appendix 2 it appears that 35 to 45% of the carbon entering a producer was lost as dust to the washers. Apart from showing the poor efficiency of the multicyclones this figure shows that gasification within the producer was by no means complete. The dust content of gas entering the multicyclones was as high as 200 to 250 g/M^3 wet gas, and 150 to 200 g/M^3 leaving them. Presumably the multicyclones did not remove more dust, because the dust at this stage was very fine, much finer than the dry coal dust leaving the drier of the synthesis gas units. (On the Winkler generators at Zeitz the multicyclones reduced the dust concentration from 300 to 60 g/M³).

In Ref.5 Koppers refer to the Schmalfeldt producers as being little more than distillation and cracking units, with practically no gasification of solid carbon; calculations in Appendix 2 confirm that this is no exaggeration. The cause of this is uncertain, but may lie in the fact that all free oxygen has disappeared by the time the coal particles have been stripped of their volatile matter, and the subsequent reactions between H_2O, CO_2 and the coke particles are comparatively slow.

Coal Drying Plant

Three of the boilers installed in the power plant could use only dry coal, and a coal drying plant, fired by coal and producer gas, was installed to provide this dry coal. The plant was also used to a certain extent to supply dry coal to the producers, when for any reason the driers of the synthesis gas units were unable to dry enough coal.

Purchased Coal Dust

A small quantity of dried brown coal dust, containing 12% H_2O and 53% C, was also purchased and used partly on the boilers and partly on the producers.

Labour

Dassow gave the following figures for labour.

Process:	Synthesis gas	180
	Producer gas	80
	Coal transport and preparation	70
	Total	330
Maintenance:	Fitters and labourers	80
	Bricklayers	10
	Electricians	5
	Instruments	5
	Total	100

Split of 180 Process Workers for Synthesis Gas Production

(a) Shift Men	Men/shift/unit	Men/3 shifts/3 units
Chargehand (Vorarbeiter)	1	9
Leading-hand (Schichtsführer)	1	9
Automatic Control (Steuerhaus) and air heating	2	18
Cupola operator	1	9
Recycled gas blowers	1	9
Plant fitter	1	9

(a) Shift Men (Cont'd)	Men/shift/unit	Men/3 shifts/3 units
Control room (Kommandohaus)	1	9
Automatic valves	1	9
Dust conveyors	2	18
Hammer mills	2	18
Raw coal bunkers	2	18
Gas, air, oxygen, nitrogen compressors	2	6
Gas blowers	2	6
Oil purification	1	3
Leading-hand for belt conveyors	1	3
Total shift men		153

(b) Day Men	3 units
Column for cleaning washer rings (incl. rings from producer washers)	14
Cleaning drains, gas lines, plant	10
Management office	3
Total day men	27

The shift men worked 56 hours/week and the day men 60 hours/week. Most of the men were German workers.