WINTERSHALL A.G., LÜTZKENDORF, NEAR MÜCHELN, GERMANY

INTRODUCTION

This report deals with the Schmalfeldt gasification plant for making synthesis gas, the Fischer-Tropsch plant, the hydrogenation plant and the catalyst factory, and includes a report on lubricating oil.

THE SCHMALFELDT GASIFICATION PLANT

The information was obtained on May 9 and 11, 1945, from Dr. Schneeberger (director), Dr. Schneider (director and power plant manager), Herr Dassau (manager of gas plant) and Herr Schultz (manager of Fischer-Tropsch plant). The plant was shut down as the result of very heavy air raid damage to other parts of the works.

The process consists of the gasification of brown coal in the entrained state. The designer, Dr. H. Schmalfeldt, lived at Lützkendorf from the start-up in 1938 until 1940, and is now believed to be living in the Kassel area. Before this plant was built there had been an experimental unit at Rühlen, but so far as is known, there is no other large-scale installation.

The principles of the process are as follows. Brown coal was obtained from an open mine in the neighbourhood. Typical analyses 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%
Volatile S	1-1.5%	N	1%
Calorific Value	2300-2400 k.cals per kg.	Ash	12%

The tar content was rather low for brown coal, and so the coal was not well suited to the normal treatment (carbonization to produce tar for hydrogenation, with use of coke in Winkler generators and in boilers). The raw coal was elevated and crushed in hammer mills to below 20 mm., dropping into a raw coal bunker, from whence it was fed by Redler screw conveyors through star feeders into the side of the bottom of the gas drier. The contents of the bunker were kept under nitrogen pressure. Recycled synthesis gas and steam at a temperature of 1,000°C. flowed upwards in the gas drier (see Fig. 2), and the sudden heating of the raw brown coal caused it to dry and decrepitate, the particles becoming entrained. The gas leaving the drier was passed through a classifier where large lumps of coal were removed, to be crushed and returned to the drier. The gas next passed to a large cyclone separator, and was then divided into two streams, one of which constituted the synthesis gas make while the other was recycled. On each stream there was a small cyclone followed by a washer. The dry coal dust separated in the cyclones was used in the gasifiers (gas generators) and in the producers. The recycled synthesis gas was passed to a hot generator where it was heated to 1,300°C., and then passed through two gasifiers or generators in series, to complete the cycle by entering the drier. Dry coal dust was injected into the top of the first generator and was gasified.

The heat of reaction was originally supplied 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. The gasification plant was intended to supply synthesis gas for the Fischer-Tropsch plant (designed to produce 75,000 tonnes of crude oil per annum), but later a hydrogenation plant was added (designed to produce 50,000 tonnes per annum) and the gas requirement was increased. In order to make more gas, additional heat had been introduced by adding oxygen to the recycled gas. The original designed output per gasifier unit (considering the two generators in series as one gasifier unit) was 20,000 cubic meters per hour (measured at 0°C. and 760 mm.), but in fact the output obtainable without the use of oxygen was only 15,000 cu.m. per hour. When using oxygen, the maximum output was 30,000 cu.m. per hour, although more usually 20-25,000 cu.m. per hour were made.

The producer gas was made by gasification of entrained dry 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 was abstracted by waste heat boilers. The maximum output of a producer was 30-35,000 cu.m. per hour.

The plant consisted of four gasifier units each, as shown in Figure 2, and five producers, and usually one of each was out of action for cleaning. The plant was very spacious considering its capacity, although it was made up of relatively simple pieces of equipment. The four gasifier units (2 generators, 2 regenerators, drier, with stocks and washers) occupied an area of about 100 m. x 30 m., the vessels being 20-24 m. high. The gas boasting house was outside this area, while the producers occupied a separate site. Figures 1A and 1B show a rough layout and arrangement of a synthesis gas unit, while Figure 2 is a diagrammatic representation of the flow. Figure 3 is a photograph of one end of the synthesis gas plant. Figure 5 is a rough layout of a producer gas unit, and Figure 6 is a flowsheet for producer gas. The individual items of plant will now be considered in turn.

The gas drier was a vertical brick-lined chimney, 1.2 m. internal diameter and 22 m. total height. The crushed raw brown coal dropped into the drier without any conveying gas, at a point 15 m. below the top of the drier. Two inlets were available, one working and one spare; each was steam-heated to prevent sticking of the coal, but was brick-lined near the drier itself. The feed pipe was at an angle of about 30° to the vertical. No special mixing of coal and gas was attempted; the high turbulence of the gas, which had just passed through a bend of about 2.5 m. radius of curvature, together with the explosion of each particle, was sufficient to give good mixing. The final temperature at the top of the drier was 200-300°C. At full output, the dry gas rate entering the drier is calculated to be about 90,000 cu.m. per hour, so that taking into account the steam present, calculated as 91,500 cu.m. per hour, the average gas velocity in the drier was about 100 m. per second, the time of drying being 0.15 seconds. Usually the velocity was about 70 m. per second, and the time of drying 0.20 seconds.

The synthesis gas and dry dust mixture leaving the top of the drier passed through a rough classifier, where any large pieces of coal were separated. These were sent to a separator hammer mill and returned to the drier. The gas then passed through a cyclone to effect the main separation of dust. It was stated that the dust concentration of the wet gas leaving the drier was 150 g. per cu.m., but it is calculated that it should be nearer 200 g. per cu.m. It is also calculated that the dust content of the gas entering the washers was about 20-30 g. per cu.m., so that the overall efficiency of the two cyclones in series was about 85 to 90%, indicating a loss of 10-13% of the carbon in the raw coal as slurry from the washers. In 1942 it had been planned to install Multiklons to reduce the dust content of the gas to 6 g. per cu.m., but this project had not been carried out.

The dry coal dust contained 18 to 20% of ash and 60% carbon. The ash content was higher than that of dry raw brown coal because the dust contained nearly all the ash remaining from the gasification of the dust fed to the generators. The carbon content was however the same, 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 sending of dry coal dust to the producers. No figures were available for the grading of the dust. The dust from the cyclones fell 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 to the producer gas bunkers, and synthesis gas for conveyance to the generators. This conveying synthesis gas, amounting to about 10% of the make, in effect recirculated through the generator system. Rather more dust was sent to the producers than to the generators, the exact proportion depending on output.

The regenerators were brick-lined towers, 7.1 m. ext. dia, and 5.5 m. int. dia, by 24 m. high. Two were provided for each gasifier unit, and they were changed over automatically every 11 minutes. The design was obviously based on that of air preheaters for blast furnaces. The towers were filled with chequer of high quality brick, such as sillimanite or silica, to a depth of 17-18 m. Two designs of chequer had been tried; one was a Brassert type and the other, which had given better results, a type made by Didier of Berlin. The Didier type known as Schieffer-Strack consisted of hexagonal blocks, about 12-3/4 " across and 7" deep, each having about 20 1-1/2" dia. vertical holes spaced at 2-3/4" centers. A plan view is shown in Figure 4A. These bricks were carefully stacked so that the holes came into line. The lining bricks were well finished, so that the minimum amount of cement was used. It was stated that there was no trouble due to dust deposition in the chequer and that the bricks withstood the conditions very well. No figures were available for the dust content of clean producer gas or recycled 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 on underground line, common to the two generators, leading to a stack; no waste heat boiler was used but it was intended to install one.

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 at 1,300°C. on its way to the first generator. The maximum brickwork temperature was 1,450°C. at the top; the average exit flue gas temperature was 450°C. Double isolation valves were used on each flue gas and recycled gas line, with the portion between the valves automatically vented to atmosphere when the valves were shut. The isolation valves on the air and producer gas were not seen, but may also have been double. Details were not obtained of the method of isolating the top of a regenerator while heating it on alternate cycles; it is possible that no valves were used, reliance being placed on pressure control to prevent more than a slight flow of synthesis gas into the regenerators. At first there had been 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.

The first generator was a brick-lined vessel, 5.5 m. int. dia. by 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 2-1/2 atm. pressure, was fed down through a passage in the center of the cupola. The hot recycled gas and steam mixture from the regenerator was fed through ports in the false roof. Oxygen, saturated at 82°C., was introduced from ring mains through ports 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.

The oxygen was supplied by three Linde-Fränkl units, two working and one spare, each producing 4,000 cu.m/hr.

The second generator was a brick-lined vessel, 5.5 m. int. dia. by 24 m. high. On three units it was divided internally by a vertical wall, but on the fourth (and latest) unit it had no such division wall. The division wall was shaped as shown in Figure 1A, the two portions having approximately the same area of cross section. 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 used was added near the bottom inlet of the generator, while steam was added as required at various points, the aim being to maintain the temperature at 1,000°C. It was stated that the division wall was not necessary; the unit without it worked just as well. It was further stated that the second generator was not needed at all except for high outputs, such as were obtained by the use of oxygen.

From the data given, it is calculated that the gasification period (time of contact of coal in generators) was 4.5 seconds at 30,000 cu.m. per hour, and 6.0 seconds at 20,000 cu.m. per hour.

Each unit had two washers, one for recycled gas (50-60,000 cu.m. per hour) and one for synthesis gas (25,000 cu.m. per hour). The washers were the same size and were fed with water at the same rate, despite the differences in gas load. A typical arrangement is shown in Figure 4c. Each washer was about 6 m. diam. by 22 m. total height. The washer was divided into two sections with separate water circulation systems, each section being packed with 6 trays of stacked 80 mm. spiral Raschig rings. About 750 cu.m. of water per hour were circulated through the bottom section to remove the bulk of the dust. A purge was taken from this system to keep the concentration of solids at 80-100 g. per liter. 750 cu.m. of water per hour were circulated through the top section and through a water cooling tower. The high water rates were necessary to prevent choking the packing with dust; but at each six monthly shut-down the rings were removed and washed, the work on 8 washers for the generator plant and 5 washers for the producers providing continuous employment for 14 day men.

The gas pressure at the bottom of the regenerator was 0.150 ats. gauge. 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 pipe, the drier and washer had to be run at a pressure below atmospheric. The pressure at the top of the washers was - 0.020 ats. gauge.

There were 5 producer units, each making at most 30,000 to 35,000 cu. m. of producer gas per hour, although normally making less. Each unit consisted of the producer followed by waste heat boilers, Multiklons, washtower and Theisen disintegrator. The producer was a brick-lined tower, 5 m. int. diam. by 24 m. high, with an internal division wall, very similar to the second generator. Dry coal dust was blown into the bottom of the tower 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 was about 11 seconds when making 30,000 cu.m. per hour. The dry coal dust (18% ash, 60% C) was conveyed from the generator units to a bunker by means of nitrogen, but it was conveyed from the bunker to the producers by means of air. About 15 tonnes per hour were conveyed by 1,000 cu.m. of air per hour, through three pipe-lines each of 125 mm. int. diam. Assuming atmospheric pressure, this corresponds to a velocity of 7.5 m. per second and a dust content of 15,000 g. per cu.m. It was also stated that the dry coal dust fed to the producers amounted to 0.5 tonnes per 1,000 cu.m. of producer gas. Gases from the producers passed through a horizontal and a vertical waste heat boiler in series, which reduced the temperature to 250°C. Erosion at the inlet of the first boiler limited the running time of a unit to six months before overhaul. Multiklons followed the boilers, and the dust recovered was blown back by compressed air into the bottom of the producer.

The wash tower was 5-5.5 m. int. diam. by 22 m. high, filled with ordinary 2" Raschig rings. In design it was very similar to the washers on the synthesis gas, but the water rate was only 500 cu.m. per hour. It was said to be too small and to pass too much dust. A Theisen disintegrator removed most of the remaining dust, and after passing through a spray arrestor, the gas was pumped into the factory fuel gas system. The amount of gas used for heating a single gasification unit was 24,000 cu.m. per hour, consisting of 3,000-4,000 cu.m. of rest gas from the Fischer-Tropsch plant (2,400 Kcals/cu.m.) and 21,000-20,000 cu.m. of producer gas (1,075 Kcals/cu.m.)

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

Three of the boilers installed in the power plant could use only dry coal, and a plant fired by coal and producer gas was installed to provide this dry coal. This 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 provide enough coal. 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.

The content of dust in the synthesis gas was stated to be reduced to 30-40 mg. per cu.m. by the water washer, and to 23-25 mg. per cu.m. by the Theisen disintegrator. There was a further water wash before the synthesis gas passed to an Alkazid plant for removal of most of the hydrogen sulfide. There was stated to be no difficulty due to dust in the Alkazid plant.

Ash and slag gradually accumulated in the first generator, and when oxygen was used, the generator had to be cleaned out every six months, whereas if no oxygen was used, the plant could be run for 18 months. During these shut-downs, other maintenance work was carried out. As a rule, a shut-down lasted 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.

The composition of the synthesis gas was stated to be:-

	Without Oxygen	With Oxygen
CO %	28	25
H_2	56	50
CO_2	10	18
CH_4	3	3.5
N_2	3	3.5

Thus no conversion was required before synthesis. The gas composition could be adjusted by varying the conditions of gasification and the amounts of steam and oxygen.

The composition of the producer gas was as follows:-

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

The plant records for 1943 gave the following figures:-

Synthesis gas made		330,774,000 cu.m.
Producer gas made		522,633,000 cu.m.
Raw coal direct to gas production		808,593 tonnes
Raw coal to coal drying plant and thence to producers		119,058 tonnes
Purchased coal dust to producers		7,076 tonnes
Synthesis gas composition	CO + H_2 74.7% H_2/CO	1.98

The results for April 1944 were given as:-

Synthesis gas		45,900,000 cu.m.
Producer gas made		47,950,000 cu.m.
Raw coal direct to gas production		111,823 tonnes
Raw coal to coal drying plant and thence to producers		1,012 tonnes
Purchase coal dust to producers		2,454 tonnes
Synthesis gas composition	$CO + H_2$ 75.2% H_2/CO	2.0
Oxygen used		4,388,600 cu.m.
Nitrogen used for conveying dust		7,193,600 cu.m.
Power for synthesis gas production		1,152,000 kwh.
Power for producer gas production		1,564,000 kwh.
Steam to synthesis gas plant excluding producers		27,375 tonnes
Steam to producers		4,622 tonnes

The labour requirements of the plant were as follows:-

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

GAS PURIFICATION

The synthesis gas contains 17-30 grams of hydrogen sulphide per cu.m., and the bulk of this was removed in an Alkazid plant, the hydrogen sulphide being converted to sulphur of 99.6-99.9% purity in a Claus kiln. The gas also contained 6.8 g. of benzole per cu.m. and was next washed with oil. The remaining hydrogen sulphide was removed in iron oxide boxes in which Lux was used.

The gas then contained 40-100 g. of organic sulphur per 100 cu.m., of which as much as 20% was in the form of thiophen as compared with 10% in coke oven gas. Gum-forming substances were also present. The high content of thiophen and gum-forming substances was ascribed to the characteristic feature of the Schmalfeldt process, where drying and gasification were carried out in the same apparatus. It was considered that the high content of thiophen and gum formers would not be found if the drying were carried out first, for example in a Büttner drier. Furthermore, it might be expected that those substances would be destroyed in passing through the regenerator at 1,300°C., but the system was such that one-third of the gaseous products from the drier was drawn off in the make and did not pass through the regenerators or generators. Similarly one-third of the products from the generators did not pass through the regenerators.

The gas was passed through 70% luxmasse with 30% soda at 160-280°C. for removal of organic sulphur compounds. The gas so purified gave considerable difficulty in the Fischer-Tropsch process, which used a cobalt-kieselguhr catalyst. The gum formers and possibly a little dust still present interfered with the activity of the catalyst, but the main difficulty was thought to be poisoning of the catalyst by sulphur. There was no difficulty in using the gas for hydrogenation, where sulphur is not a poison. In an attempt to increase the efficiency of purification, an active carbon plant had been installed before the hot luxmasse, in the belief that it would remove the gum formers which (apart from their action on the Fischer catalyst) were thought to reduce the activity of the hot luxmasse as a sulphur purification material. The installation of the active carbon plant reduced the organic sulphur content of the gas leaving the hot luxmasse from 1.5-2.5 g. per 100 cu.m. to 0.3 g. per 100 cu.m., which was a satisfactory figure. The plant was run with this improvement for only two months before bombing stopped work, but during this period, the results were promising. It was stated that it had been intended as a further improvement to use a special sulphur removal type of active carbon instead of the benzole recovery type.

FISCHER-TROPSCH PLANT

The following information was obtained mainly from Herr Schültz on 11 May 1945.

There were 2 catalyst chamber buildings with 144 chambers altogether. These were generally worked in two stages, but sometimes in three stages. Conversion in the first stage was about 50%. The division between the two stages was variable and dependent upon gas purity. During the period when the gas was bad, the first stage was largely the means for purifying the gas and was operated with a throughput of 1,500 m^3 per chamber per hour instead of the normal 800-900 m^3 per hour.

The most recent yields after difficulties with the gas had been overcome were 115-118 gm. per Nm^3 Idealgas. In 1940 and 1941, a yield of 130 gm. per Nm^3 was attained by changing the catalyst every 1-1/2-2 months. The catalyst chambers were started up with 5-1/2 atm. on the steam side and ultimately went up to 15 atm. (200°C.). The catalyst was extracted with solvent in situ every four weeks. It was only hydrogenated in special cases. The catalyst chambers were heated with steam at 19-20 atm. for starting.

For the last 1-1/2 years they had used catalyst obtained from the adjacent catalyst factory, which was owned 50% by Ruhrchemie and 50% by Wintershall. The catalyst was obtained from the catalyst factory in the unreduced stage and was reduced with hydrogen from the hydrogenation plant. Reduction was carried out at 400°C. The hydrogen was dried by ammonia cooling and silica gel to less than 0.1 gm. per m^3 moisture. The hydrogen used contained 94% H_2, the remainder being N_2 and CH_4. The circulating hydrogen contained about 1/2% CO_2 but no CO.

The production of the plant was at the rate of about 30,000 tons per year without Gasol, during the short period when good gas was available before the bombing. They were in the process of increasing production when the bombing took place.

The plant included a Carl still cracking plant which had never been worked owing to a change in the policy of dealing with the products.