allowed sufficient time of contact for reaction. The velocities in the apparatus used were too low and not sufficiently controlled to gasify the entire particle. The greatest part of the coal dust settled out along the way to the gas exit and thus escaped gasification."

Although this unit was not successful its operation indicated other lines along which greater progress might be expected. At the same time it was concluded that future experiments should be conducted on powdered bituminous coal since any process which would gasify this material should be well suited to the gasification of the much more reactive lignite. In order to be near a suitable supply of bituminous coal the experimental work at Schwarzheide was discontinued and a new program was instituted at Rheinpreussen Shaft IV between Moers-Meerbeck and Homberg.

VII. RHEINPREUSSEN COAL DUST GASIFICATION

The best source of information regarding the Rheinpreussen gasification unit seemed to be Mr. Totzek who was the Koppers engineer in charge of this work. During the present interrogation Totzek insisted that none of the men engaged in the Rheinpreussen experiments would have any more knowledge of the data than he has and that no experimental records escaped destruction. However Mr. Totzek was able to locate a number of drawings of various experimental units and produced correspondence files regarding proposals for commercial units which were under discussion with Rheinpreussen and Brabag. Mr. Totzek was interrogated personally on several occasions and he also furnished detailed answers to a written questionnaire. In this way the following summary of experimental work, including that at Rheinpreussen Shaft IV, was assembled.

For the experimental plant at Homberg, Rheinpreussen furnished a site and provided coal and utilities. On special occasions analyses of gas from the experimental unit were run in the Rheinpreussen laboratories but otherwise, according to all accounts, the Rheinpreussen representatives had no contact with the experimental work. They were not permitted to visit the plant and were not given any experimental data or reports. In fact Koppers has kept this work quite secret and no one outside of the Koppers organization has been found who knew anything of consequence about the Rheinpreussen experiments.

The first form of reactor tried at Rheinpreussen is shown by Figure 3, page 9, reproduced from Koppers drawing IOS 146,506. The assembly of this reactor with accessories is shown by Figure 4, page 10, reproduced from Koppers drawing IOS 146,511. In succeeding Rheinpreussen units different reactors were tried with no substantial changes in the accessories. This design was based on experience at Schwarzheide which

indicated the importance of intense agitation of the reaction medium with the coal dust particles.

"To simplify the experiments, gas instead of coal dust was used for the primary combustion. This was brought through a duct system into a cylindrical gasifying chamber and was admitted to the gasifier through nozzles directed tangentially into the bottom. The coal dust was allowed to fall freely into the front end and was carried through the gasifier. By this arrangement the coal dust was forced to travel through the gasifier in small spirals which was expected to insure a sufficiently long path of travel. The velocities at the entrance to the gasifier were so high that the carbon was forced to remain in suspension."

"Experiments with the cold apparatus showed that the underlying considerations were sound. The coal dust would travel through the gasifier in a spiral path in suspension in the cold medium. These experiments were carried out in a wooden model of the same design. After the apparatus had been brought to temperature and coal was to be gasified, a considerable collection of dust was observed on the walls. This dust remained fast. The carbon was completely gasified and the ash remained behind and slagged the generator. Sillimanite had been used as a lining material and was not resistant to attack by slag. After a few days operation, the generator was completely destroyed and could no longer be used."

"The generator was reconstructed several times in the same form and was equipped with nozzles varying in number and arrangement. Instead of being located in the bottom, the nozzles were located in the upper walls. However, these changes did not improve the results. The coal dust was driven against the bottom of the gasifier and accumulated there. Although measurable results were obtained from operation with brown coal coke (heating value 900 kcal. per cubic meter with about 50-60% gasification), the gasification of caking bituminous coal was not possible because the dust would settle out and coke, thereby obstructing the passage."

"It was concluded from the results of this work that velocities were still too low to hold the larger particles of coal in suspension while the fine particles were swept out without complete gasification because of insufficient relative motion in the gasifying atmosphere. In order to prevent slag accumulation the temperature of the combustion gas was reduced to about 900°C. With respect to slagging, some improvement resulted. However, the degree of gasification was still poorer so that a continuation of the experiments along this line appeared futile."

"In general it was concluded from the experiments conducted up to this time that the strictly mechanical difficulties such as settling out of dust, slagging etc., were so great that exact measurements of the degree of

gasification, gas quality, economy et cetera could not be made".

"Observations during these experiments led to the next form of apparatus shown by Figure 5, page 13, (taken from Koppers drawing IOS 146520). This design was based on the premise that since slagging cannot be prevented it is necessary to operate at a considerably higher temperature so that the slag can flow as a liquid and that every effort must be made under all conditions to keep the dust away from the bottom of the gasifier or to keep it continuously swirling without letting it come to rest. How these objectives were attained is shown by Figure 5. The coal dust was introduced from above through five separate inlets. As lining material, a slag resistant magnesite was chosen."

"Even with these expedients, the difficulties encountered in the preceding reactor were again present, that is, the coal dust was not maintained entirely in suspension. The particles of coal which settled out were completely gasified but formed a viscous slag. The gasifier could not be kept clean. The degree of gasification and the gas quality were unsatisfactory and could not justify continuation of the experiments along this line."

"One of the most important conclusions reached, was that means must be found to keep the slag more fluid. The necessary temperatures however, cannot be obtained with flue gas. For this reason the flue gas was supplied with an appreciable excess of air. The production of a fluid slag however was obtained only when a highly preheated mixture of air and steam was introduced in place of flue gas. To this end it should be noted that the apparatus was equipped with a regenerator as is still used on the experimental unit."

"With this method of operation however, the exit gas temperature is very high, in the vicinity of 1600°C., as is experienced in the coal dust firing of smelting furnaces. With this method of operation the larger particles of coal are completely burned or gasified while the smaller particles especially from the last inlets, escape reaction because of insufficient relative motion between them and the gas medium. In spite of the higher preheat of the gasifying medium, (air and steam to about 1200°C.) the high exit gas temperature changed the gas concentration so that heating values of only 800 to 900 kcal/m^3 were obtained. In comparison with the previous experiments it is seen that the gas quality was not improved although the degree of gasification of the coal was better, but still not satisfactory."

"In continuing the experiments special efforts were made to find some way of accomplishing complete gasification of the carbon. To this end the coal particles must be maintained entirely in suspension. A procedure used in powdered coal combustion was chosen, the apparatus for

for which is shown by Figure 6, page 16, (taken from Koppers drawing IOS 146531, dated 25 October, 1941. Details of the air and gas connections to this unit are shown by Koppers drawing IOS 146523, not reproduced in this report. Details of the entire unit are shown by Koppers drawing IAK 146551 which is not suitable for reproduction here) In this procedure the coal dust was introduced at the head end of the gasifier by means of a side stream of cold air and the hot air-steam mixture was introduced through a mixing nozzle in the head of the reactor and through separate nozzles extending along one half of the length of the reactor."

"When using lignite and lignite coke a practically complete gasification of the carbon was attained. The slag was quite fluid. The gasifier chamber was given a conical form in order to provide a natural outlet for the slag."

"Experiments with bituminous coal showed that the degree of gasification would be considerably poorer and the gas concentration would be maintained only because of the high content of volatile constituents in the coal. For complete gasification of this coal the preheat temperatures of the steam-air mixture must be still higher with a simultaneous increase in the exit gas temperature. However, even with these expedients of extensive increase in the preheat temperature of the gasifying medium and high exit gas temperatures, economical gasification of bituminous coal dust by means of air is not attained."

"At this stage of experimental work the results justified the following conclusions: 1) with higher preheat (up to 1200°C.) of the gasification medium (air, steam) the more reactive coals such as lignite and lignite coke can be economically converted to heating gases, 2) the gasification of bituminous coal dust for reasons set forth above does not appear to be economical."

"After the experiments for the preparation of air gas had reached a practical conclusion at this point, experiments for preparation of water gas were begun. These experiments were carried out in the apparatus last described in such a manner that a mixture of steam and recycle gas was preheated to 1200°C. in the regenerators (Schmalfeldt principle). The coal dust was carried into the gasifying chamber with a partial stream of this mixture."

"The principal consisted in using the sensible heat between 1200° and about 900°C. for the gasifying process that is, the quantity of heating gas was maintained so high that the heat of reaction will be contained within these temperature limits."

"The experimental results indicated that the mechanical conditions in the generator were normal but the degree of gasification was still poor. Even with lignite it was possible to convert only a small percentage, approximately 20%, of the solid constituents in addition to driving off the volatile components. In the gasifying of bituminous coal dust the behavior was even poorer and therefore because of the poor economy the experiments were not carried further along these lines."

"In summary it can be said that it is not possible to gasify coal dust in a recycle gas stream at a temperature level of about 1200°C. This must be due to the fact that the gasification is an entirely endothermic process and the rate of gasification falls off rapidly with decreasing temperature. The residence time in the gasifying chamber must be almost infinitely great in order to attain satisfactory results. The data available previously for a similar method of operation showed this clearly, since a calculation of the material balance showed that even in such an operation the content of volatile constituents is driven out and all of the solid carbon is recovered as such. It cannot be considered complete gasification."

"These results point to a considerable elevation of temperature in the gasification process and this is possible only with the help of oxygen if a satisfactory gas composition and degree of gasification is to be obtained."

"Next the recycle gas-steam mixture was replaced by an oxygen-steam mixture. This mixture was brought to a temperature of about 1000-1200°C. in the regenerator. To loosen up the coal and somewhat improve its distribution, the coal dust was blown in by a superheated gas-steam mixture."

"This step was completely successful and the results are set forth in the address of 12 June, 1942. It was observed that as a result of the hot oxygen-steam mixture a very rapid ignition of the coal dust took place and by calculation a temperature of more than 2000°C. was obtained. This temperature accelerated the gasification process so greatly that the coal dust was gasified to the extent of about 95%. The exit temperature was about 900-1000°C. with lignite and lignite coke, and about 1200°C. with bituminous coal. Since the heat in this method of operation is used up completely for gasification there are no superheated zones in the gasifier and the ash occurs only to a very small extent as a liquid which forms small drops on the walls and falls into the ash outlet."

At this stage of the experiments, the final results of which were set forth in Totzek's address of 12 June 1942, the Rheinpreussen unit was destroyed by bombing. It was subsequently rebuilt as shown by Figures 7 and 8, pages 17 and 18, taken from Koppers drawings IOS 146,544 dated 15 September 1942 and IOS 178,452 dated 22 December 1942 respectively. A

simplified flow diagram of the unit is shown by Figure 9, page 21, from Koppers drawing IOS 178,479 and the reactor is shown in some detail by Figure 10, page 22, from Koppers drawing IOS 178,480. The general assembly of the unit is shown by Koppers drawing IAK 146,551 which is not suitable for reproduction in this report. The Koppers drawings reproduced as Figures 9 and 10 are undated but from the dates on other drawings in the same numerical series it appears that they were made after 17 June 1943, thus being about six to nine months later than the drawings used for Figures 7 and 8, pages 17 and 18. During this period the unit was not in operation so any changes in design must have been adopted for reasons other than experimental results. The most important change incorporated in this final design is the use of a water jacketed reactor having powdered coal inlets at both ends. It is understood that the reactor actually had conical ends as shown by Figure 10, page 22, rather than square ends indicated by Fig. 8.

Operation of this unit was begun in 1944 and continued until September when exigencies of war caused a permanent shutdown. Runs were made only with air because of the scarcity of bottled oxygen on which the plant was dependent. According to Totzek satisfactory gasification was not attained and this was attributed to excessive cooling of the reaction zone by the water jacket.

The unit was inspected by the writer on April 3, 1947 and appeared superficially to be in good condition. However Totzek said it had been robbed of many essential parts and had deteriorated so that in his opinion it would cost 30,000 marks to restore it to operating condition. Then he estimated it would have a capacity of 10 to 25 tons of coal per day and would require about 500 cubic meters of oxygen per ton of coal.