VIII. DISCUSSION OF EXPERIMENTAL RESULTS

In addition to the above comments on the performance of successive types of experimental reactors Totzek expressed his personal opinions on many other aspects of coal dust gasification in answer to the FIAT questionnaire. These views are summarized below.

A. Coal Characteristics

Koppers experiments indicated a substantially greater reactivity for lignite or lignite coke than for bituminous coal. This difference would be especially important in the preparation of fuel gas by reaction with steam and air without oxygen enrichment. Totzek stated that lignite had been gasified at 900°C. while the usual temperature for bituminous coal was 1200°C.

The coal should be ground to the same fineness as used for powdered coal combustion, that is, so that 80% would pass a 4900 mesh sieve. Uniformity of particle size would also be desirable since particles less than 0.05 mm in diameter tend to escape gasification because of insufficient motion relative to the gasifying medium, and particles coarser than 0.1 mm in diameter tend to fall out of the gas stream before they react. The Koppers process was stated to be operable on any coal or coke therefrom, provided it could be ground to the required fineness.

Totzek recommended the use of screw feeders for handling the powdered coal as for powdered coal combustion but admitted that these had given trouble on the experimental units. He thought that more uniform flow might be obtained by a rotating valve feeder, but Gumz and Nistler, who had used such a feeder on the Ruhrgas unit, held exactly the opposite opinion. Apparently this problem is not completely solved. For high pressure operation Totzek suggested a feeder such as used for coal dust engines, not further specified.

Koppers had no data on the relationship between sulfur content of the coal, operating conditions, and sulfur content of the gas. However Totzek pointed out that the sulfur in their gas had always been easily removable by standard procedures.

The water content of the coal was stated to be important chiefly because of its effect on ease of grinding. On this basis water contents should not exceed the following limits

Bituminous coal	2%
Lignite	15%
Peat	35%, dependent on nature of the peat

In the generator, water in the coal has the same effect as steam from an extraneous source.

Weathering of the coal was stated to have no effect on gasification properties but this does not seem to be in agreement with the observed difference in reactivity of different kinds of coal. It was suggested that ageing might affect the content of available hydrogen. No data along these lines were available.

B. Operating Procedure

The following information on operating procedure was given mainly in Totzek's answer to the FIAT questionnaire -

"To start up a Koppers unit it is first warmed up with air preheated in the recuperators. When one Cowper regenerator reaches ignition temperature its burner is lighted and the hot gas is passed through the gasifier. When operating temperature is reached the regenerators are switched

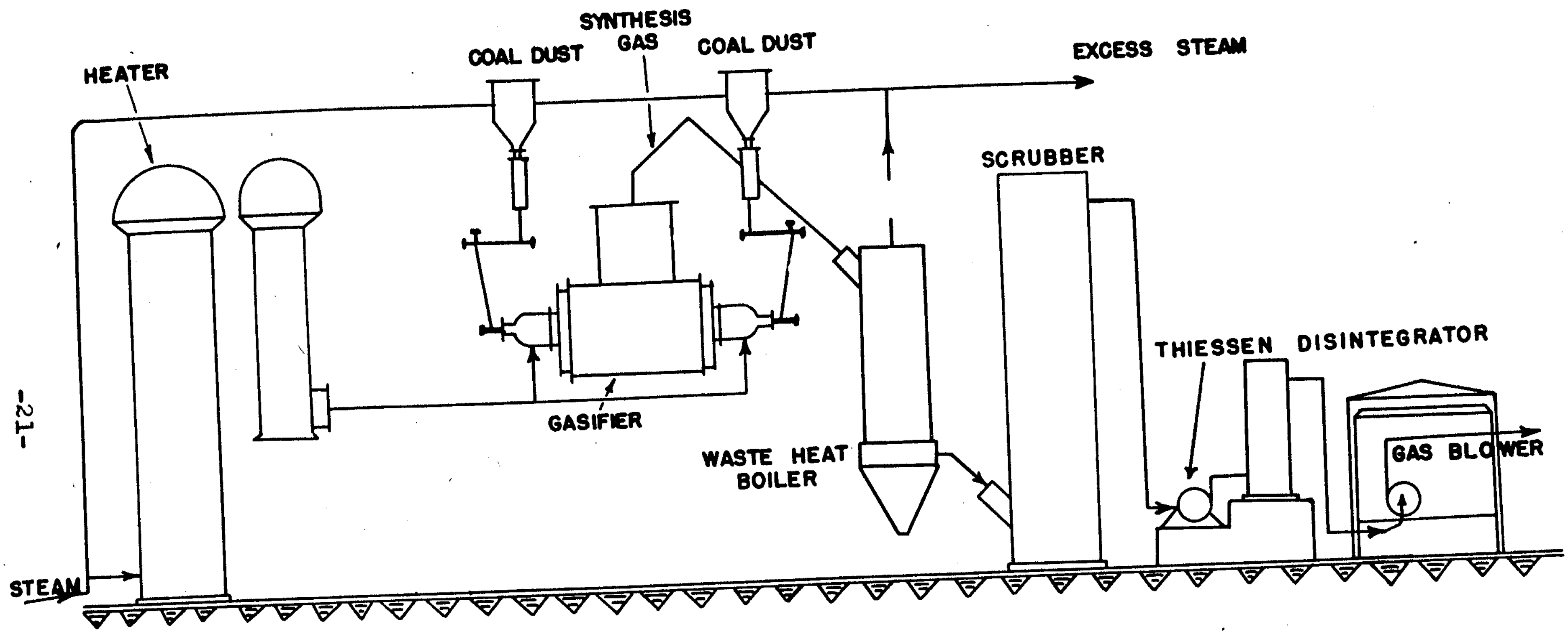

FIGURE 9

RHEINPREUSSEN
FINAL UNIT FLOW DIAGRAM

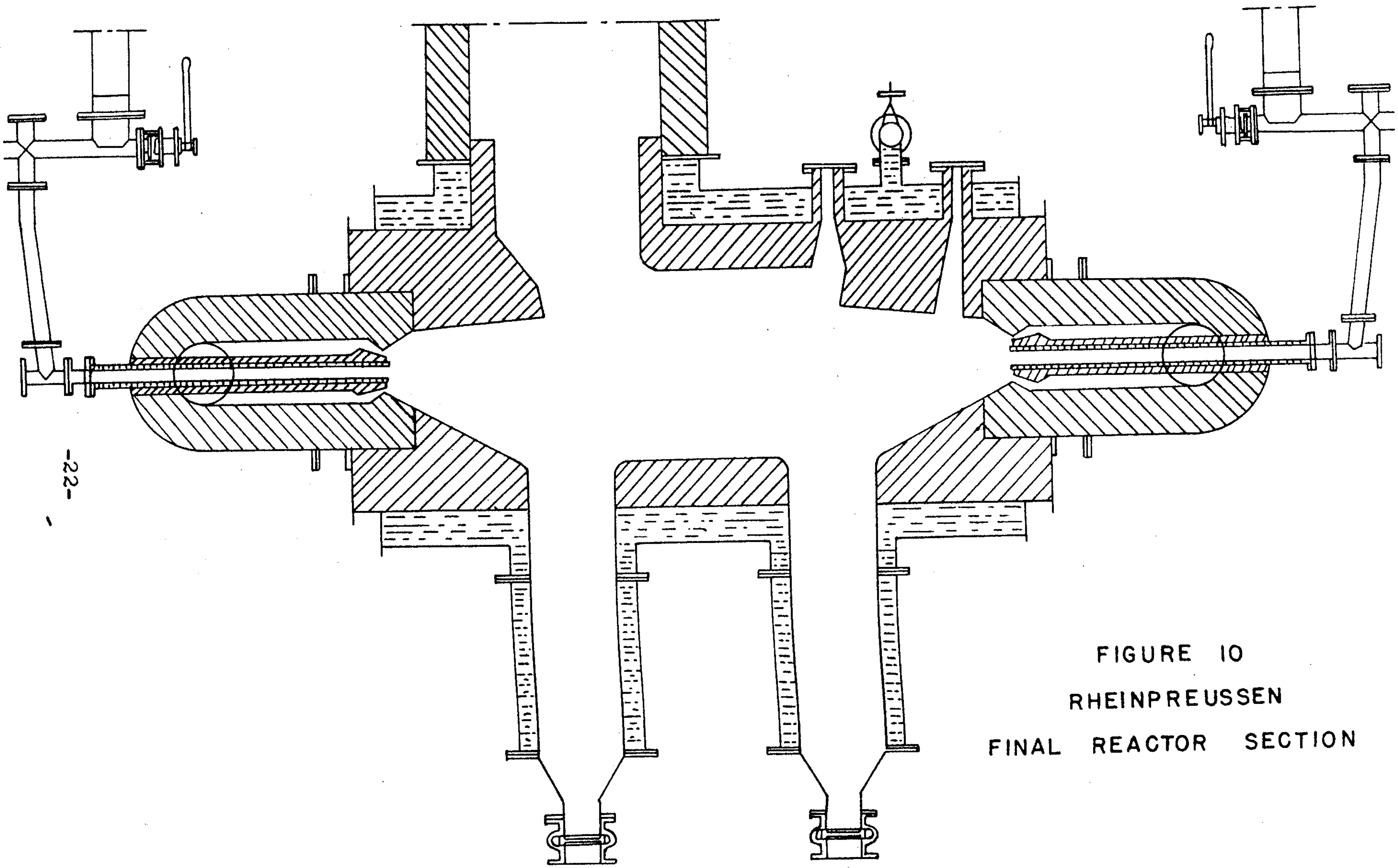

FIGURE 10
RHEINPREUSSEN
FINAL REACTOR SECTION

to automatic cycling and an air-steam mixture is supplied to the Cowper. Simultaneously the powdered coal feed is started and the air to the Cowper is replaced by oxygen to the desired extent. In this way the individual burners of the gasifier are brought into operation. After the equipment beyond the gasifier has been purged with combustion products, the blowers are started. Every half hour the Cowpers are switched so that the air-steam supply to the reactor is not interrupted."

"In shutting down the unit, the oxygen supply is first replaced by air. Thereafter the powdered coal streams are shut off in succession so that only flue gas is passing through the unit. After the apparatus is purged with flue gas the Cowpers are shut down."

The greatest danger in operation, according to Totzek, is the interruption of coal supply which would permit relatively pure oxygen to pass through into the gas holder. To minimize this danger it is recommended that several burners be attached to a single gasifying chamber with the expectation that the supply to all burners would not be interrupted simultaneously. Totzek admits that additional safety precuations would be needed on a commercial unit but they would have to be developed by experience.

Corrosion or erosion of equipment ahead of and beyond the reaction chamber was not observed in the Koppers experimental operations and was not expected to be serious in commercial units. However Totzek admits that long time deterioration of the reactor itself could not be predicted on the basis of the relatively short operating experience to date. The longest runs on the Rheinpreussen unit were only four or five hours duration so this may be a very serious uncertainty.

Totzek intimated that a powdered coal gasifier would not have much flexibility in charge rate since coal and gasifying medium must be definitely proportioned and high flow rates would give incomplete reaction while low flow rates would permit coarse particles to settle out. However no data were offered on this point. Totzek had calculated that the normal time of contact of coal particles in the Rheinpreussen reactor was 1/2 to 3/4 seconds, but even in this short time, with suitable preheating, practically complete gasification was obtained.

The ratio of H_2:CO in the product gas is dependent on coal composition to the extent that a "high volatile" coal will contain a higher ratio of hydrogen to carbon. Gas composition, is also influenced by coal reactivity since this determines the temperature level required to get complete conversion in a reasonable time. With the temperature and coal composition fixed, the gas composition will normally be governed by the excess steam in accordance with the water gas equilibrium. This will obviously influence the

CO_2 concentration as well as the $CO:H_2$ ratio. There is a definite limit to the permissable excess steam and hence the hydrogen concentration, determined by the tendency of excess steam to lower the reactor temperature. The $H_2:CO$ ratio can be increased if desired by a subsequent convertor (water gas shift) stage.

In spite of persistent questioning, Totzek made no specific statement regarding the distribution of ash in the Koppers process. He maintained that it was essentially a "dry" operation in contrast to the claims of Gumz that temperatures must be so high that all ash will be fused. However Totzek's written summary of the Rheinpreussen experiments admitted that some molten drops of ash formed in the generator and the final generator was given a sloping bottom to drain this molten ash. In fact in the early stages of this work special effort was made to insure that the ash would be molten and quite fluid. In such short runs as made at Rheinpreussen the normal ash distribution might not be attained. No ash balance data were available, but Totzek said the ash recovered from the product gas contained about 40% carbon. No free carbon was observed in the gas.

Totzek felt that operation under superatmospheric pressure would be undesirable unless a high methane content was desired in the gas, as was characteristic of the Lurgi middle pressure operation.

For conversion of highly reactive coals, high purity (98%) oxygen might not be necessary but for bituminous coals and coke therefrom the highest possible purity of oxygen would be desirable to attain the necessary reaction temperatures. No data on this point were available.

Water gas produced in the Koppers coal dust generator was tested for resin forming constituents by passing 4000 m^3 of the gas from a gas holder through activated charcoal. No condensible hydrocarbons were recoverable from the charcoal which was construed to indicate no resin forming constituents. Water gas from a conventional generator was stated to give a positive test by this procedure. Even from bituminous coal the Koppers process gave gas containing no methane. This freedom from hydrocarbons was attributed to the high gasifying temperatures and low pressure. No treatment of the gas to remove resin forming constituents appears necessary. Totzek pointed out that some very fine ash may be carried through the recommended washers and that an electrostatic precipitator may be desirable for final clean up ahead of synthesis units.

No advantage was seen in the recycling of residue gas or the introduction of extraneous gas. If such gases were used to convey the powdered coal their quantity should be limited lest they extract too much heat from the reaction. Multistage conversion was thought to be definitely objectionable because of the difficulty of separating unconverted dust between stages.

C. Plant Design

Koppers regarded the accessories to the reactor itself as standard equipment which had been fully proved in other types of service. The Cowper regenerators, and the recuperators which preheat air and fuel gas for them, had been used extensively and successfully for gas cracking (methane oxidation) at Rheinpreussen, and for recycle gas heating in the Schwarzheide briquette gasification plant. Details of a Cowper unit proposed later for Brabag are shown in Koppers drawing IAK 132,315 dated 17 August 1942, which is not suitable for reproduction here. Waste heat boilers had been used in many industries and static washers were standard equipment with water gas generators. The Theissen disintegrator was commonly used for washing blast furnace gas.

Totzek expressed the opinion that powdered coal gasification units should have a capacity between 50 and 300 tons of coal per day for maximum economy. A plurality of units, but not more than ten, was recommended to insure a substantially continuous supply of gas to a synthesis plant. These were admitted to be offhand opinions and no supporting figures were offered.

In spite of the small size and limited operation of the Rheinpreussen experimental unit, Totzek said that Koppers was, and still is, ready to build and guarantee commercial units of the same type.

D. Comparison with Other Processes

Totzek professed knowledge of only the Schmalfeldt process as used at Lutzkendorf and Ruhland. He pointed out that the latter unit was shut down permanently after a short period of operation, indicating some operating difficulty. Totzek concluded from similar operation of the Rheinpreussen unit (page 14) that the Schmalfeldt principle of reacting powdered lignite with a preheated mixture of recycle gas and steam is unsound because sufficiently high temperatures can not be attained.

Although he had no detailed knowledge of the Gumz-Ruhrgas experimental work, Totzek thought that Gumz had little practical knowledge of powdered coal gasification and that his theories were unsound in that they disregarded the lack of relative motion between very fine particles and the suspending medium.

IX. PROPOSED COMMERCIAL UNITS

Koppers correspondence between November 1941 and September 1942 (TOM Reel 43 frames 259-278) indicates that one, and possibly two, powdered coal gasification units had been proposed for Rheinpreussen. It was stated that these proposals were based on the performance of the experimental unit but no details of proposed design are given. A memorandum dated 16 July 1942, frames 260-266, gives estimated quantities and costs as quoted in Table II, page 31.

Correspondence extending from December 1941 to April 1942 (TOM Reel 43 frames 219 to 244) concerns a unit proposed for the Zeitz plant of Brabag, where the Winkler process was also being considered. Confidential data on operating costs of the Winkler process at Brabag-Boehlen were produced for comparison with the estimated Koppers costs. The problem was to gasify powdered coke from lignite which Koppers contended could not be done completely in a Winkler unit.

The design of the proposed Zeitz unit is not shown in the microfilmed correspondence. However a Koppers drawing IAK 131,928 dated 15 January 1942 showing this unit was given to the present investigators and is reproduced in part as Figure 11, page 27. Although this is not a detailed drawing it does show the reactor as a small horizontal chamber below the coal bunker, which is generally similar to the form being studied on the Rheinpreussen unit at that time. A presumably later drawing of the same type of unit was presented with the Totzek address of 12 July 1942 and is reproduced as Figure 12, page 28. The plant for which this was intended was not specified. Although horizontal reactors are shown in each case it appears that changes in the method of introducing coal and hot gases were being recommended as work on the Rheinpreussen unit progressed.

In presenting this diagram Totzek stressed the fact that the form of the reactor was the distinguishing feature of the unit, and he said that a more detailed discussion of the reactor would come in a later paper. Under interrogation he insisted that no such later discussion had ever taken place.

Letters dated 13 April and 17 May 1943 (TOM Reel 43 frames 210-218) relate to a unit proposed for the Schwarzheide plant of Brabag, also to gasify powdered lignite coke. These documents are the basis of CIOS Report No. XXVIII-36 Item 30 and later publications by Newman[1,2]. The Newman publications include a sketch of a powdered coal gasification unit from a Koppers patent application furnished privately by one of the authors.

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(1) Newman, L.L. Oxygen Gasification Processes in Germany A.I.M.M.E. Technical Publication No. 2116. Class F, Coal Technology, Nov. 1946.

(2) Newman, L.L. Oxygen Production and Utilization in Gas Making Processes. Report of Gas Production Committee. American Gas Association 1946.

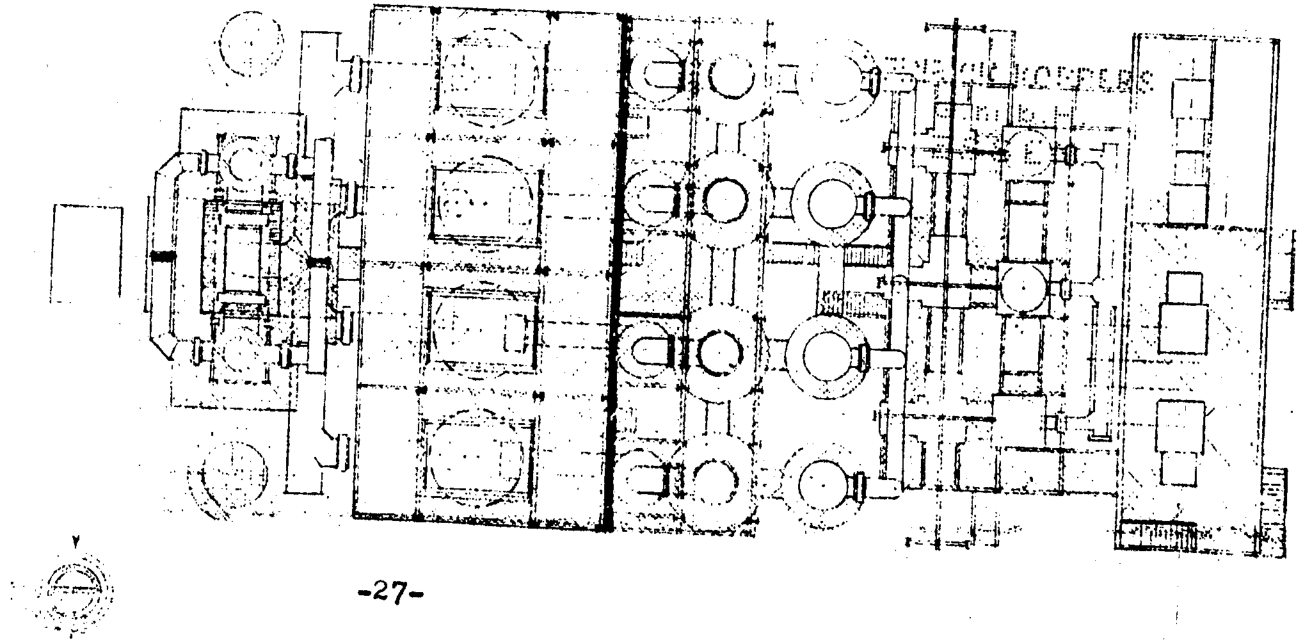
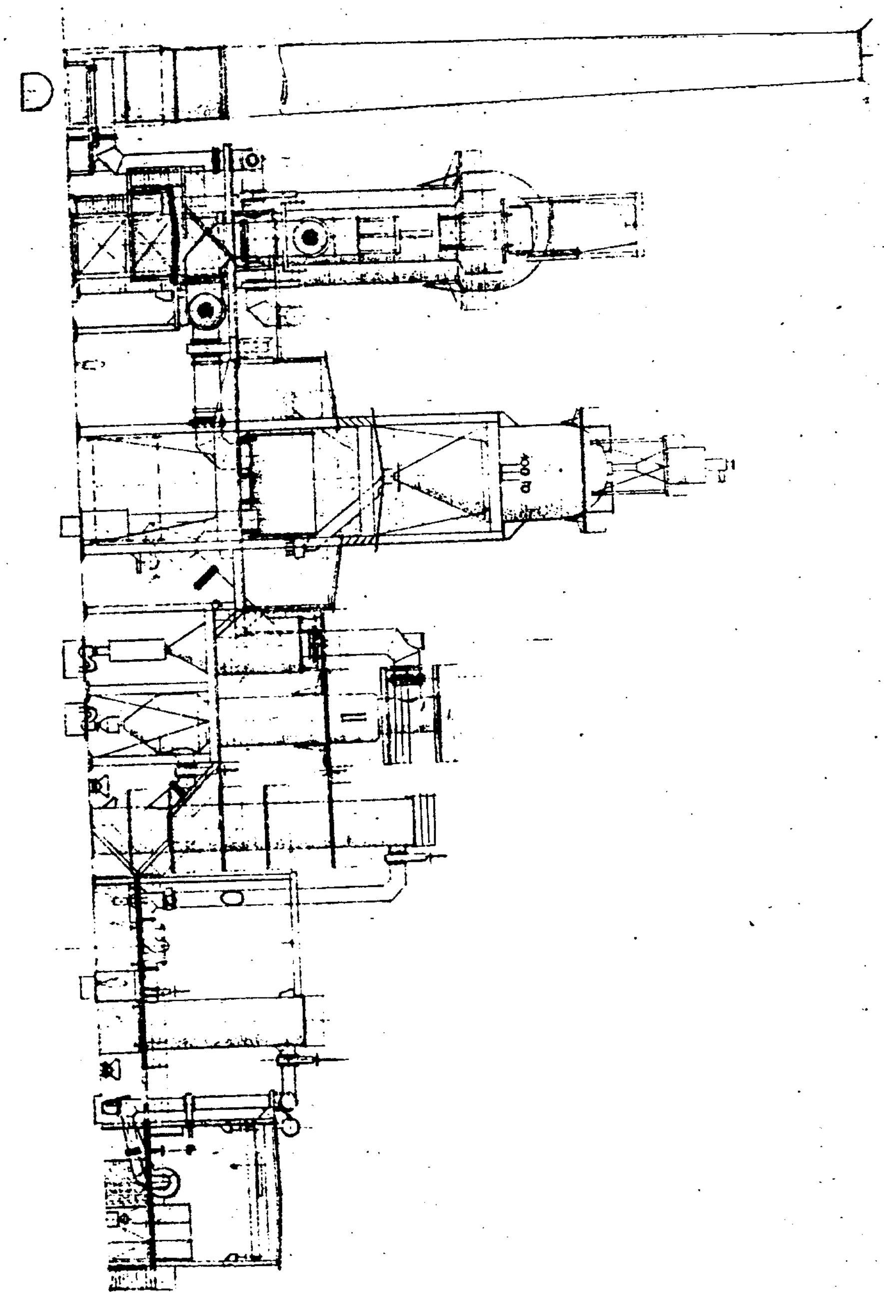


FIGURE 11

BRABAG-ZEITZ
PROPOSED PLANT



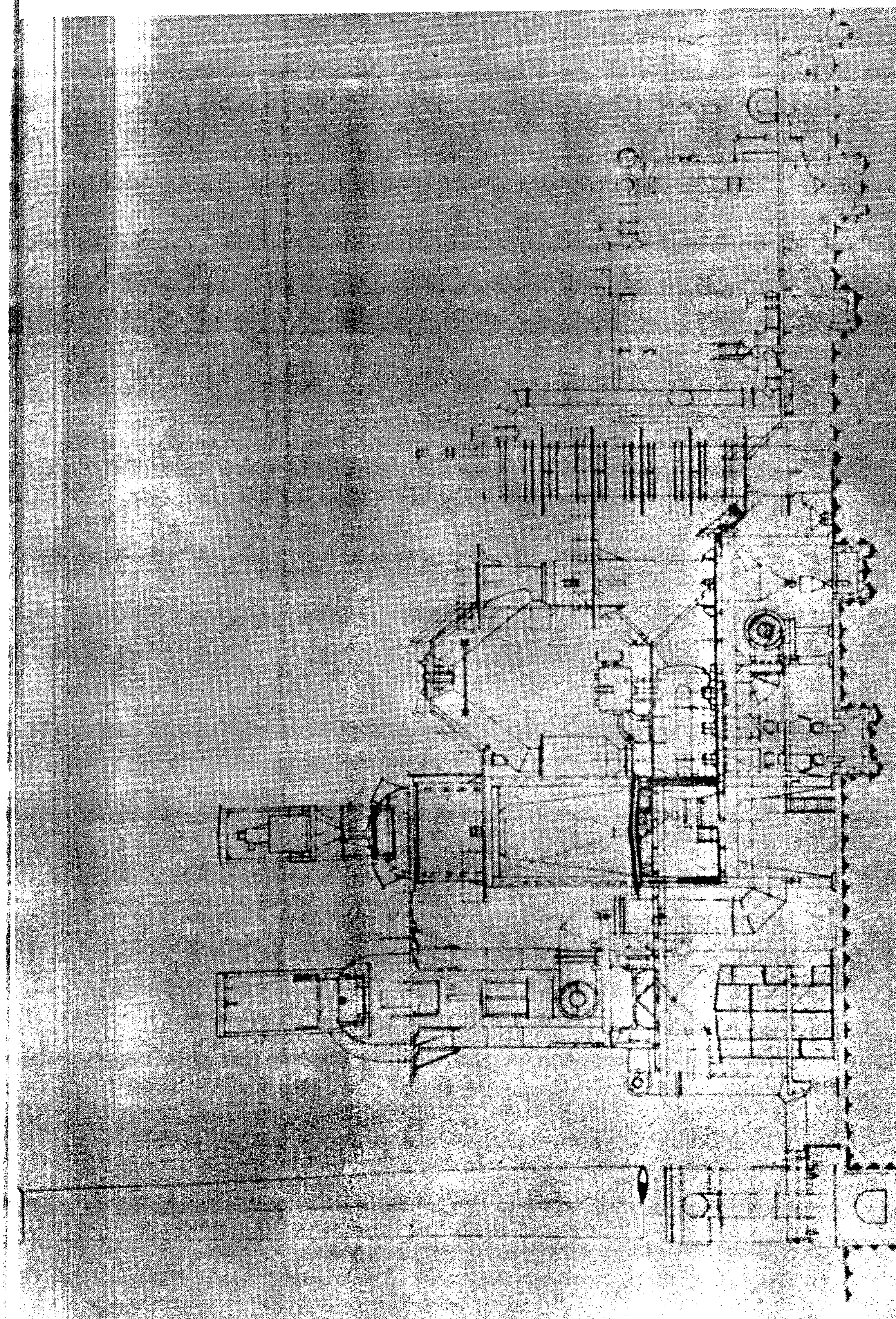


FIGURE 12

PLANT FOR COAL DUST GASIFICATION