TABLE 6. - Representative runs, Koppers powdered-coal gasifier

Run No. / Duration	32 / 3 hr.	35 / 5 hr.	36 / 6 hr.	43 / 11 days	Remarks
Coal feed, lb./hr.	2,052	2,297	2,151	2,695	Burner nozzles projecting 16 inches into the gasifier were used in run No. 32. It was the special objective of this run to observe operation at a high oxygen-to-coal ratio.
Percent coal through 325-mesh	72	72	93	79	
Std.c.f. oxygen/lb. coal	10.6	9.0	9.3	8.0	
Lb. steam/lb. coal	0.78	0.80	0.81	0.75	Run No. 35 was a standard run made to observe operation with "flush" burner nozzles.
Temp. steam, °F.	1,680	1,700	1,705	1,640	
Gasification temp., °F., by thermal balance	2,600	2,480	2,535	2,260	Run No. 36 was made with 4-inch projecting burner nozzles and with "extra fine" grind coal. Better over-all results obtained in production of gas than in any other comparable run.
Carbon conversion, percent	89.9	83.4	89.0	73.8	
Lbs. steam decomposed/lb. coal	0.08	0.13	0.15	0.12	
Materials required/M c.f. of $CO + H_2$, lbs. coal	37.5	38.6	36.7	41.0	Run No. 43 was an extended run made with 4-inch projecting burner nozzles. Data here given were taken during 7-1/2-hour period on 10th day.
Std.c.f. O_2	399	349	342	328	
Lb. steam	29.3	30.4	29.6	30.8	

The powdered-coal gasifier work involved attempts to improve the degree of reaction achieved between carbon and steam. The means tried thus far are as follows:

1. Increased fineness of coal feed. Coal used in the first experiments was relatively coarse (about 65 percent through 200-mesh screen). The operation of the pulverizer was altered to permit the production of coal of almost 90 percent through 200-mesh screen with very little noticeable improvement in operation. However, a further alteration that resulted in the production of coal that was substantially all through 200-mesh and about 75 percent through 325-mesh screen did result in a definite improvement in the operation. Comparison of this run with others under similar conditions showed that approximately 7 percent more coal was gasified, and the raw-material requirements for a given gas production were reduced correspondingly. However, the very fine coal caused difficulties in the coal-feeding system that prevented sustained operation without complete revision of the system. This revision was deferred until other methods for improving operation had been explored.

2. A study of the effect of varying coal-burner nozzle lengths was broadened to include one burner nozzle that extended through the cone to the main barrel of the gasifier. Little if any improvement in operation was observed, and several mechanical difficulties were encountered.

The first runs were made with coal nozzles flush with the outboard end of the gasifier cone, some of which seemed to give better results than were achieved later. For this reason the flush burners were reinstalled. Some slight improvement in results was obtained, but the earlier difficulty with slag deposition recurred to the extent that this operation was deemed inadvisable.

3. In the previous work the oxygen:coal ratio had been varied from 7.0 to 9.9 std.c.f. of oxygen per pound of coal. One run was made at a ratio of 10.6 cu. ft. per pound, in which the temperature in the gasifier reached 2,700° F. Carbon conversion was increased, but the higher yield of gas obtained per pound of coal was more than offset by the decrease in gas production per unit of oxygen. Further, temperatures were too high for continuous operation.

4. In various runs, saturated steam had been added through the burner nozzle or through lances in the body of the gasifier with little improvement. It was believed that the chilling effect of the low-temperature steam may have offset any advantage that its addition might have created. A small steam superheater was constructed, and steam at about 1,400° F. was added through a pipe in the center of the burner nozzle. The result of this run agreed quite closely with those of preceding runs in which no auxiliary steam was added.

To determine whether the addition of auxiliary steam would be more effective if it were premixed with the coal, a small amount of moderately superheated steam was added to each of the oxygen-coal pipes just before the burner nozzle. This resulted in a somewhat erratic operation, and in no case was any significant improvement noted in the results.

5. The effect of increased time of residence in the gasifier was explored in a run in which the oxygen, coal, and steam flow rates were decreased by about one-third with other operating conditions substantially normal. This resulted in an increase in the calculated time of residence from about the usual 2-1/2 seconds up to 4 seconds for this run. No improvement was noted.

To determine the mechanical performance of the unit on sustained operation, one run of 11 days was made. There were various interruptions, usually of short duration.

Of the total elapsed time of about 264 hours, there were 104 hours of operation with six burners, 97 hours of operation with five burners, almost 24 hours of operation with less than five, and about 40 hours down time. This gives a figure of approximately 75 percent of the total elapsed time for operation with five or six burners, but a few relatively simple improvements should considerably improve the on-stream time. Approximately 270 tons of coal, 4,100,000 cubic feet of oxygen, and 402,000 pounds of steam were used to produce about 15,700,000 std.c.f. of make gas, of which 81 percent, or 12,700,000 cubic feet, was carbon monoxide plus hydrogen. On this basis, the production of 1,000 std.c.f. of carbon monoxide plus hydrogen requires 322 cubic feet of oxygen and 42.5 pounds of coal. These figures do not necessarily represent the optimum condition, for the reason that the run was purposely made with a coal-rich mixture in order to control temperatures better.

Major operating difficulties during the run included the following:

1. Rapid accumulation of a coal refuse, which perhaps was less readily wettable and harder to handle than that obtained in most of the previous operations. In any case, the amount produced was more than could be handled by the present sluice and overflow water system on a continuous basis.

2. Accumulation of a viscous or semisolid slag tending to seal off the top of the ash legs. In some instances this was impossible to remove by rodding from above, and it was necessary to cut an opening into the ash leg to permit its removal.

3. Aggravation of the slag accumulation and refractory erosion previously noted in both the cones. The north cone is more seriously affected, and the south cone is affected to some extent.

4. Mechanical troubles with the coal screw drive mechanisms and the relatively short life of the radiation pyrometer tubes.

Results achieved during the various portions of this run agree very closely with the results of the short experimental runs made previously under comparable operating conditions. The powdered-coal gasifier was shut down on April 27, 1950, and the brickwork was allowed to cool under controlled conditions for 3 weeks. The interior was inspected thoroughly, and measurements and photographs were taken of the erosion of the refractory, deposits of slag, and other pertinent items. Briefly, this inspection showed the main barrel of the gasifier to be in quite satisfactory conditions except for deposits of slag on and around the ash-leg openings. The brickwork in the cones showed appreciable attack, some of which is known to be due to direct impingement of the oxygen-coal flame during one period of operation. The rest may be considered normal for operations such as were undertaken during this first year of experimental service.

This Koppers coal-dust gasifier is the first unit of its size ever built for suspended coal gasification, although small-scale experimental units have been operated in this country and in Germany. The anticipated operating efficiency has not yet been reached, but it is considered to be an accomplishment that carbon-gasification efficiencies exceeding 80 percent were attained without excessive consumption of oxygen. Further experimental work is necessary to improve the efficiency of gasification by increasing the reaction between carbon and steam to form carbon monoxide and hydrogen. An alternate method of removing slag in a liquid form would bear consideration.

As a part of the gasifier operations, and as an aid to analysis and interpretations of the results, various features in the system were studied. The amount and manner of the loss of heat from the gasifier proper were determined, as this is a matter of considerable importance in determining the efficiency and in correlating the results with the theoretical studies.

The "pebble heater" or steam superheater is a piece of equipment not in ordinary use in industry in this country and is of interest to those concerned with the production of superheated steam at 1,600° to 2,500° F. The performance of this unit was followed quite closely, and determinations were made of the thermal efficiencies, operating limitations, and rate of loss of the pebbles by attrition. After a fairly extensive period of operation, the pebble charge was found to be in a condition unsatisfactory for continued operation. Through a cooperative agreement with the Aluminum Co. of America, a new supply of pebbles of high-purity alumina was obtained, and the technical assistance of the company's engineers was provided. Operating characteristics and wear rates of the two types of pebbles were compared carefully. The results of this study form the basis for a Report of Investigations.

The thermodynamic studies of coal gasification, which originally were undertaken to provide a guide for the first operations of the Koppers unit, have been continued and extended to provide means for the study of coal gasification in suspension under a wide variety of operating conditions. Parts of this study have been presented before the American Chemical Society and published in Industrial and Engineering Chemistry. This method of calculation has been useful in comparing the results actually achieved with those theoretically attainable, in making economic studies of proposed alternate methods of operation, and in making process calculations for design purposes.

Kerpely Producer

After the gasifier cooled, work was started immediately on preparations for the operation of the Kerpely producer. This is a standard, 7-foot diameter, fixed-bed producer that had been used in the St. Louis plant of the Laclede Gas Light Co. for several years. The grate was modified slightly, and a variable speed drive was installed on the ash pan. No other modifications were made.

Cooperative agreements had been concluded between the Bureau of Mines and the American Gas Association for study of the behavior of two sizes of high-temperature coke in this unit, and with the Koppers Co., Inc., for a study of the "Disco" low-temperature char.

Tests were made with air and with 50, 76, and 90 percent oxygen mixtures. During these tests the producer was operated almost continuously for more than 4 weeks. A total of about 500 tons of the various types of coke was consumed, about 4 million cubic feet of oxygen was used, and approximately 30 million cubic feet of gas was produced. Measurements were taken on the feed and product streams and the operating variables, and the results were studied carefully to evaluate the operation as a potential source of synthesis gas for this plant, to compare it with similar operations previously reported, and to develop information useful to those interested in the commercial application of this process.

The most interesting of the relationships developed were those that were a function of the change in oxygen concentration. Figure 14 shows the change in pounds of coke required to produce 1,000 std.c.f. of carbon monoxide plus hydrogen as the

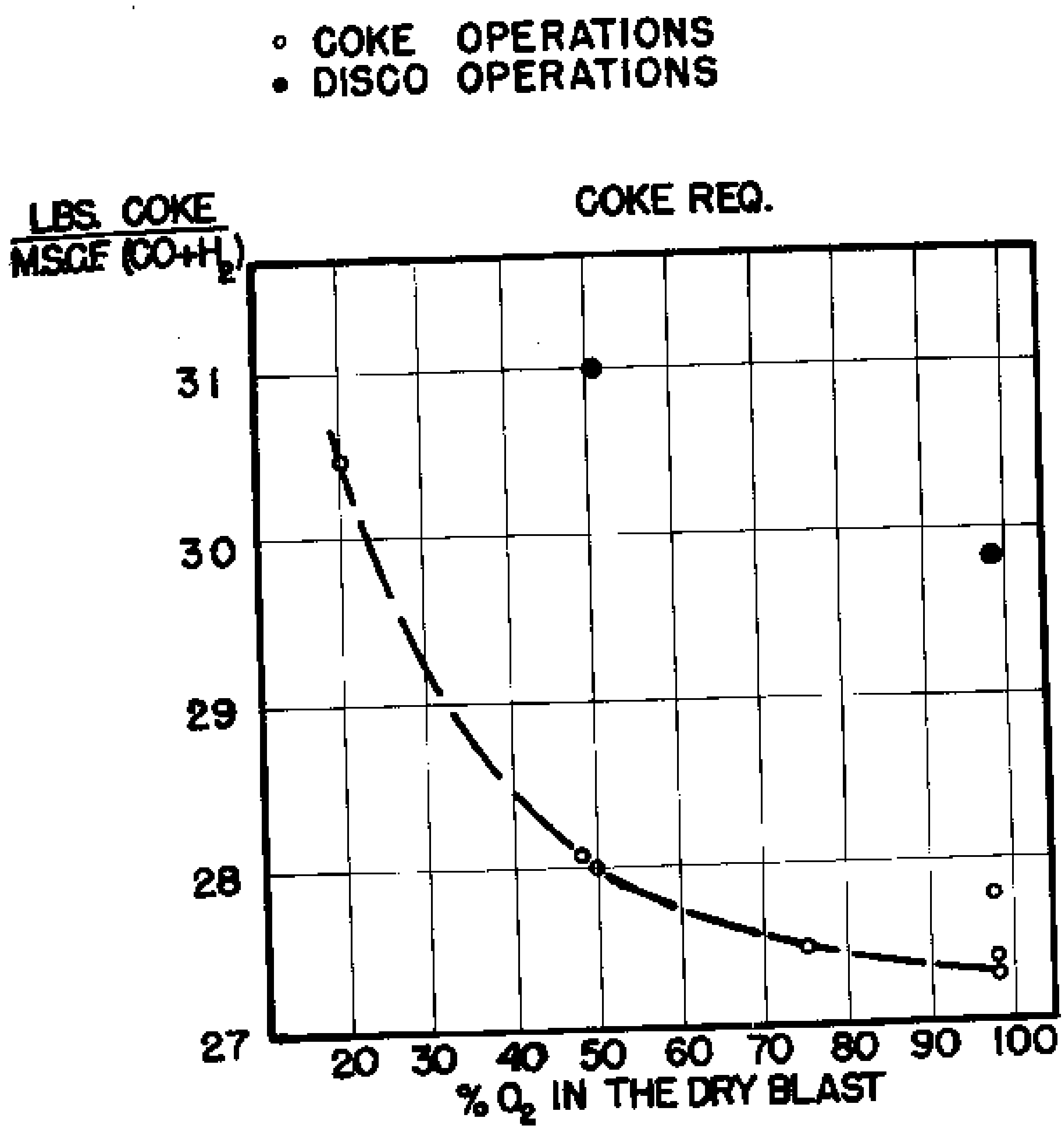


Figure 14. – Relation between coke requirement and oxygen content of dry blast.

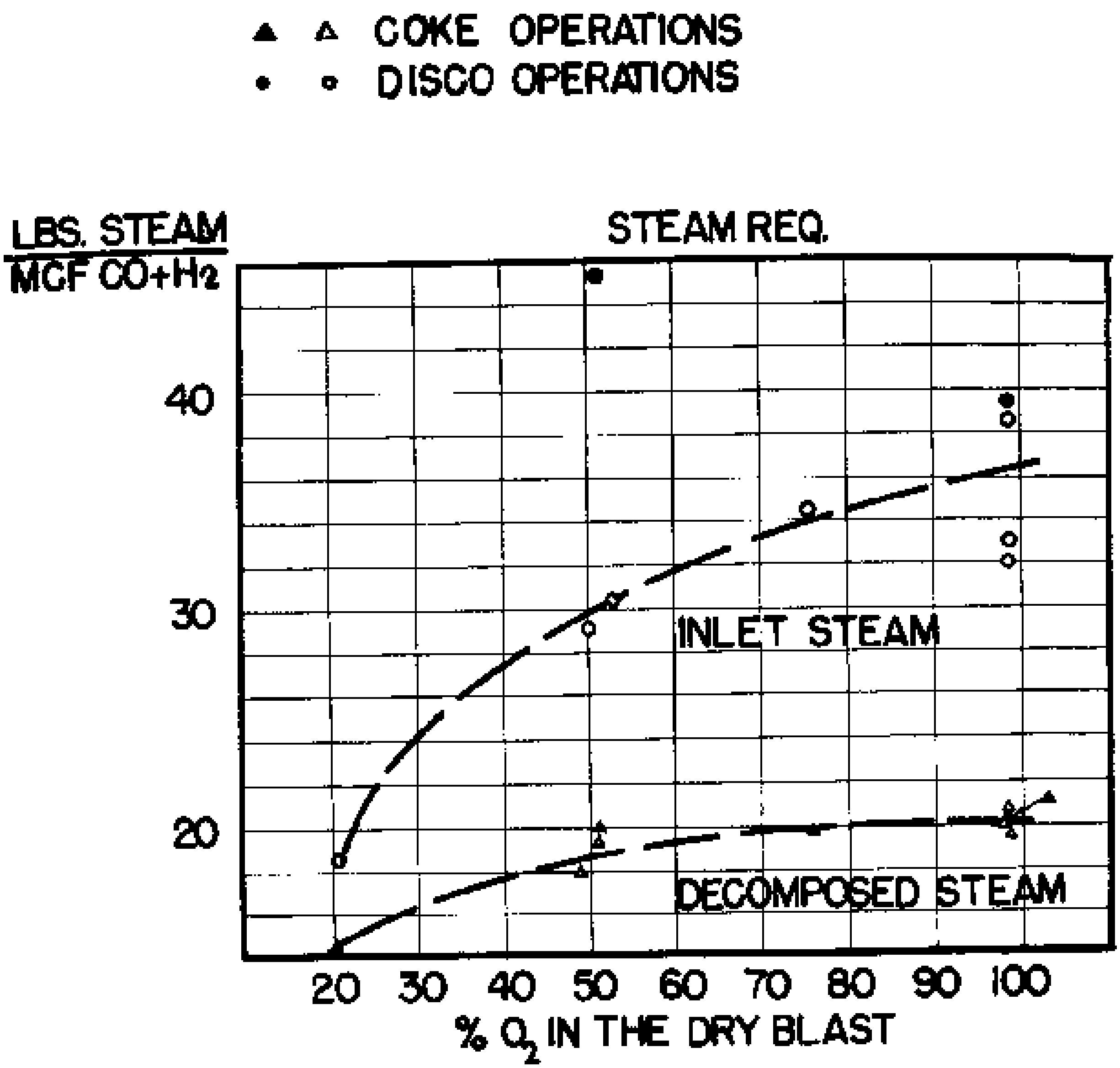


Figure 15. - Relation between steam requirement and oxygen content of dry blast.

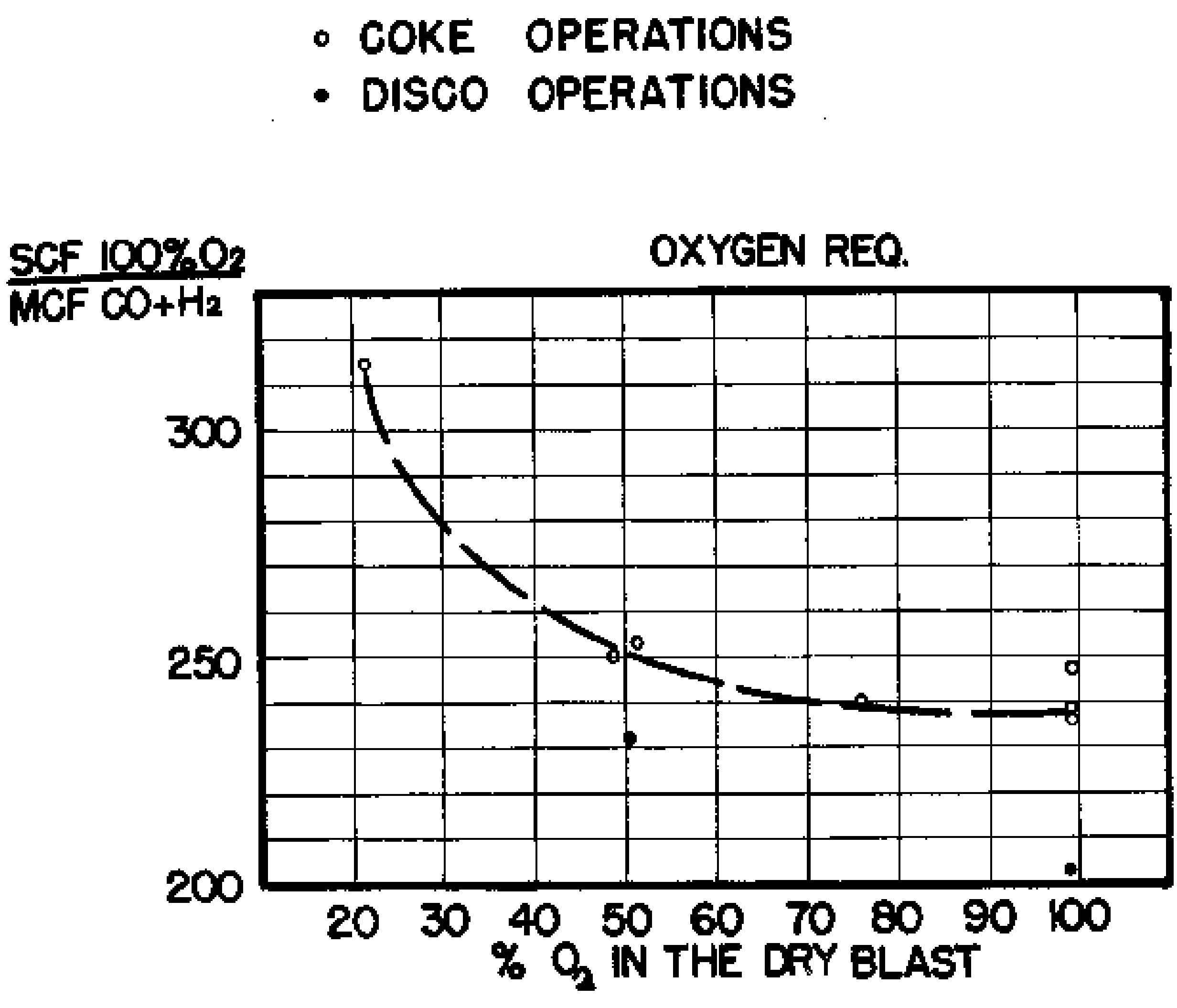


Figure 16. - Relation between oxygen requirement and oxygen content of dry blast.

oxygen content of the "blast" mixture is increased from 21 percent (atmospheric air) to 98 percent. It will be seen that on air operation about 30-1/2 pounds of coke is required. This drops to about 28 pounds when the oxygen content is increased to 50 percent, and then decreases only slightly, to about 27-1/2 pounds, on 98 percent oxygen. The solid points shown above the curve represent the tests on the Disco low-temperature char. Here the requirements are relatively higher because of the lower carbon content of the fuel.

Figure 15 shows the variation in steam requirements with change in oxygen content. To prevent fusion of the ash in the coal, with consequent formation of troublesome clinkers, it is necessary to use higher steam rates with the purer oxygen blast. The excess steam helps to remove the increased heat of combustion and to maintain the desired temperature in the fire zone. The steam, which is decomposed to form synthesis gas, increases from a low of about 14 pounds per M c.f. of carbon monoxide and hydrogen on air operation to about 20 pounds with the higher purity oxygen.

In figure 16 is shown the change in oxygen requirement per M c.f. of carbon monoxide and hydrogen with change in oxygen content of the blast. On air operation, approximately 315 cubic feet of pure oxygen is required for each 1,000 cubic feet of synthesis gas produced. This drops to 250 cubic feet when 50 percent oxygen is used and to about 240 cubic feet when 98 percent oxygen is used.

The composition and heating value of the gas made, of course, change markedly as the oxygen concentration in the blast is increased. From air operation, a gas containing more than 50 percent nitrogen with a heating value of 130 B.t.u. per cubic foot is obtained. The nitrogen content decreases and the heating value increases regularly with increasing oxygen content in the blast. From operations on straight process oxygen, a gas containing only 1 percent nitrogen with a heating value of 250 B.t.u. per cubic foot is obtained.

Work had been reported in a few instances on oxygen-blown producers. However, no results had been published on previous operations on the small sizes of high-temperature coke or the low-temperature char that were used in some of these tests. No work had been reported in this country on the use of oxygen-enriched air.

It was found that operations on small coke sizes at rates up to the limit of the producer auxiliaries or of the oxygen plant were entirely feasible and not greatly different from operations with the larger coke sizes. It is probable that a somewhat higher ratio of steam to coke is required for the small coke.

Disco operations presented more difficulties. This particular fuel had been stored in the open for about a year prior to its use and had disintegrated somewhat in weathering. It is probable that the large amount of fines present contributed appreciably to the operating difficulties. Fresh char, properly handled to avoid breakage, could be used without undue operating difficulties. It had been anticipated that deposits of tar from this fuel in the equipment and piping might be serious enough to interfere with proper operation. This did not occur, for no appreciable deposits were found anywhere in this system. Analytical determinations of the dust and tar in the make gas showed that concentrations probably were too low to cause difficulties in sustained operations.

As the Kerpely producer was installed to provide an alternate source of synthesis gas in event of any difficulty with the operation of the coal gasifier, it was necessary to train plant personnel in its operation, so that it could be put "on stream" on relatively short notice. The test program carried out last summer provided this training.

Because of the limited capacity of the oxygen plant and limitations of certain of the producer facilities, it was not possible to determine the maximum capacity of the producer itself. Runs were made on both air and process oxygen in which more than 100,000 cubic feet of gas per hour was produced.

Operation of the gasification pilot plant at the Morgantown station had indicated that perhaps there were fundamental differences between the results achieved on a vertical, tangentially fired gasifier and those achieved on the Koppers unit, which is horizontal and fired longitudinally from each end. To explore this point and extrapolate the Morgantown results to demonstration plant scale, there has been built at Louisiana a unit (see fig. 17) similar to the Morgantown pilot plant and designed to operate with a maximum input of approximately 3,000 pounds of coal per hour.

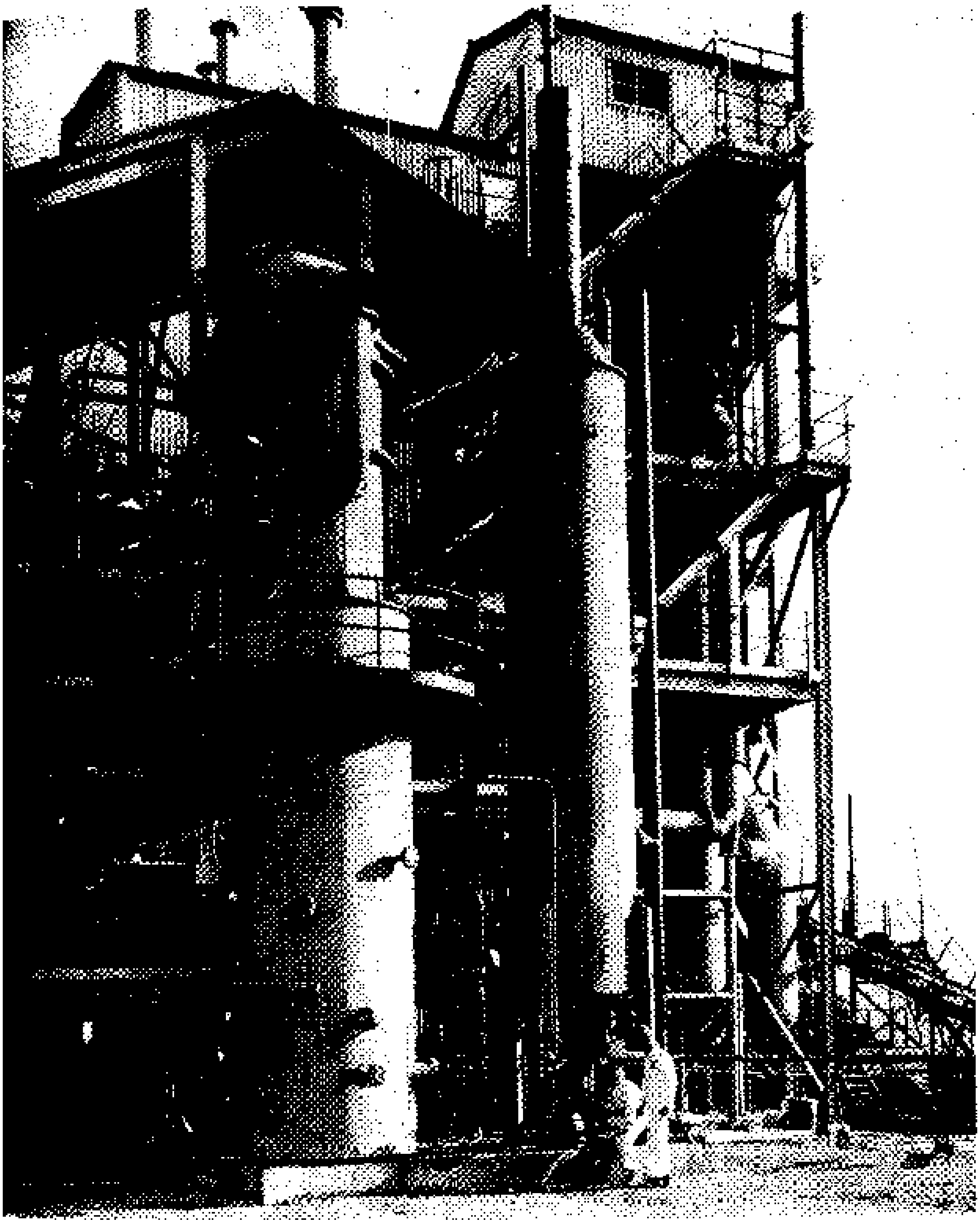
A careful study was made of refractories suitable for the proposed service, and a high-purity aluminum oxide refractory material, installed as a monolithic lining, was selected as the most desirable. A cooperative agreement was concluded between the Bureau of Mines and the Aluminum Co. of America, which provided for supplying a certain part of the necessary material, technical supervision, and consultation on the preparation, installation, and firing of the lining. The cooperator's engineers evidenced a very high degree of interest in the project and contributed substantially to the completion of the work. The lining is installed and fired, the various auxiliaries to the new gasifier have been installed, and the preliminaries to actual operation with coal and oxygen are now in progress. It is anticipated that operation of this unit, besides providing a supply of gas for the synthesis unit, will yield much information not only as to factors affecting the results of the gasification step but also as to the behavior and characteristics of the refractories.

Gas-Purification Unit

All preparations have been completed for initial operation of the gas-purification unit (see fig. 18). On the basis of studies made at Louisiana and at the Synthesis Gas Production Branch at Morgantown, W. Va., final choices were made of all purifying materials, i.e., iron oxide, alkalized iron oxide, and active carbon. Preliminary testing of lines and equipment and the calibration and trial of the instruments also are virtually completed, and a period of dummy operation is planned, using inert gas instead of synthesis gas, in order to make a final test of the whole unit under operating conditions and provide opportunity for final training of the operating personnel. In this connection, the compressors have been serviced and are being tested for operation under load.

In studying the behavior of various active carbons for removal of organic sulfur, it was established that the presence of carbon dioxide in the gas had a marked influence on the capacity of the active carbon. As removal of the carbon dioxide is of benefit to the synthesis, an investigation is in progress to determine whether the benefits to be derived in both the purification and synthesis units will justify alteration of the system to permit substantially complete removal of carbon dioxide in scrubbing for hydrogen sulfide removal.

Analyses made during the early operation of the gasifier on a low-sulfur Rock Springs coal have indicated organic sulfur contents of about 20 grains per 100 cubic feet. This can be expected to increase as higher-sulfur coals are used in the gasification step. However, studies carried out at the Synthesis Gas Production Branch at Morgantown, W. Va. have indicated that the inlet concentration of organic sulfur does not affect the performance of the active carbon appreciably.



ure 17. - View showing Morgantown-type vertical coal gasifier on left and steam-coal preheater on right, Gas-Synthesis Demonstration Plant.

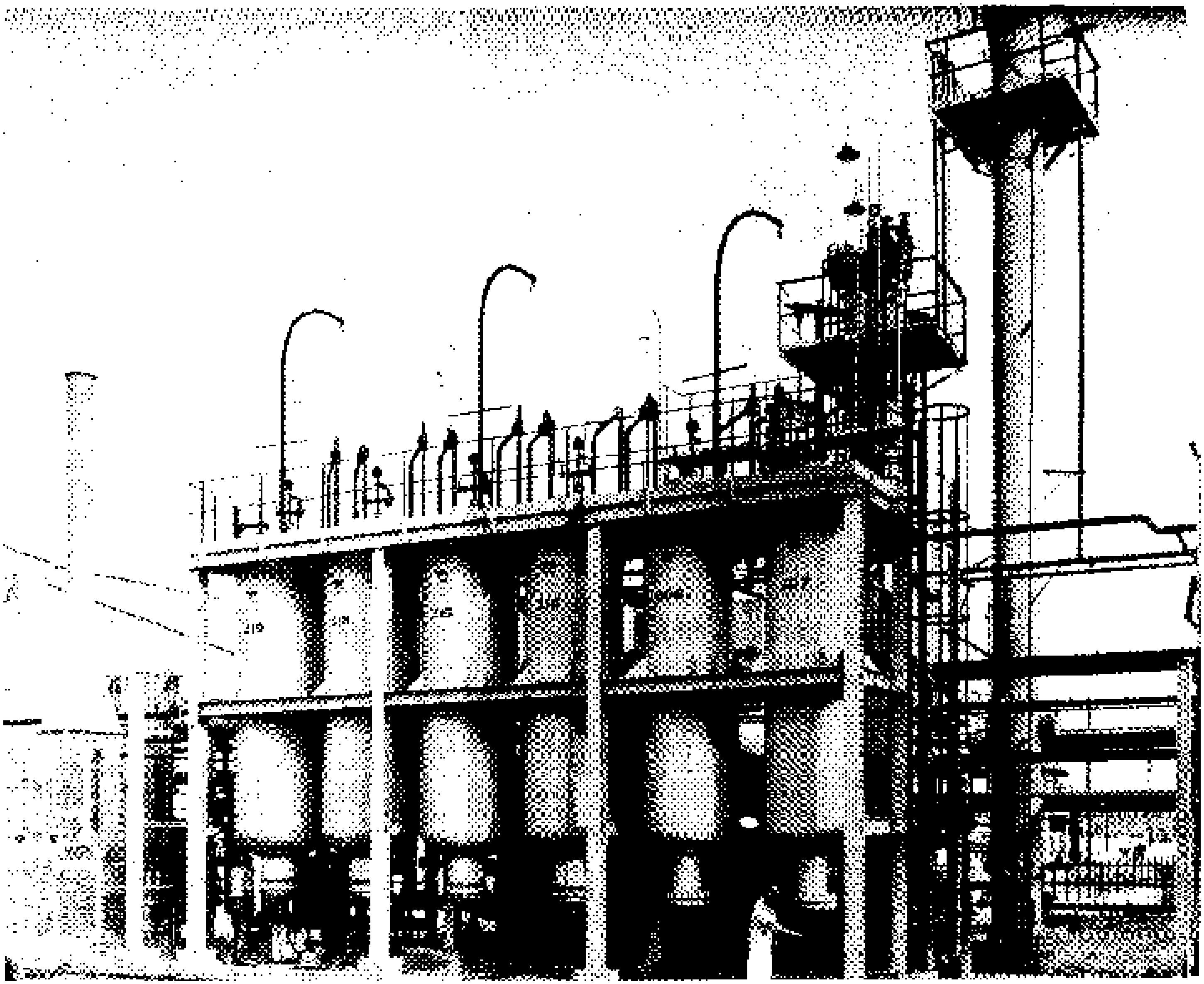


Figure 18. - Equipment for sulfur removal from synthesis gas, Gas-Synthesis Demonstration Plant.

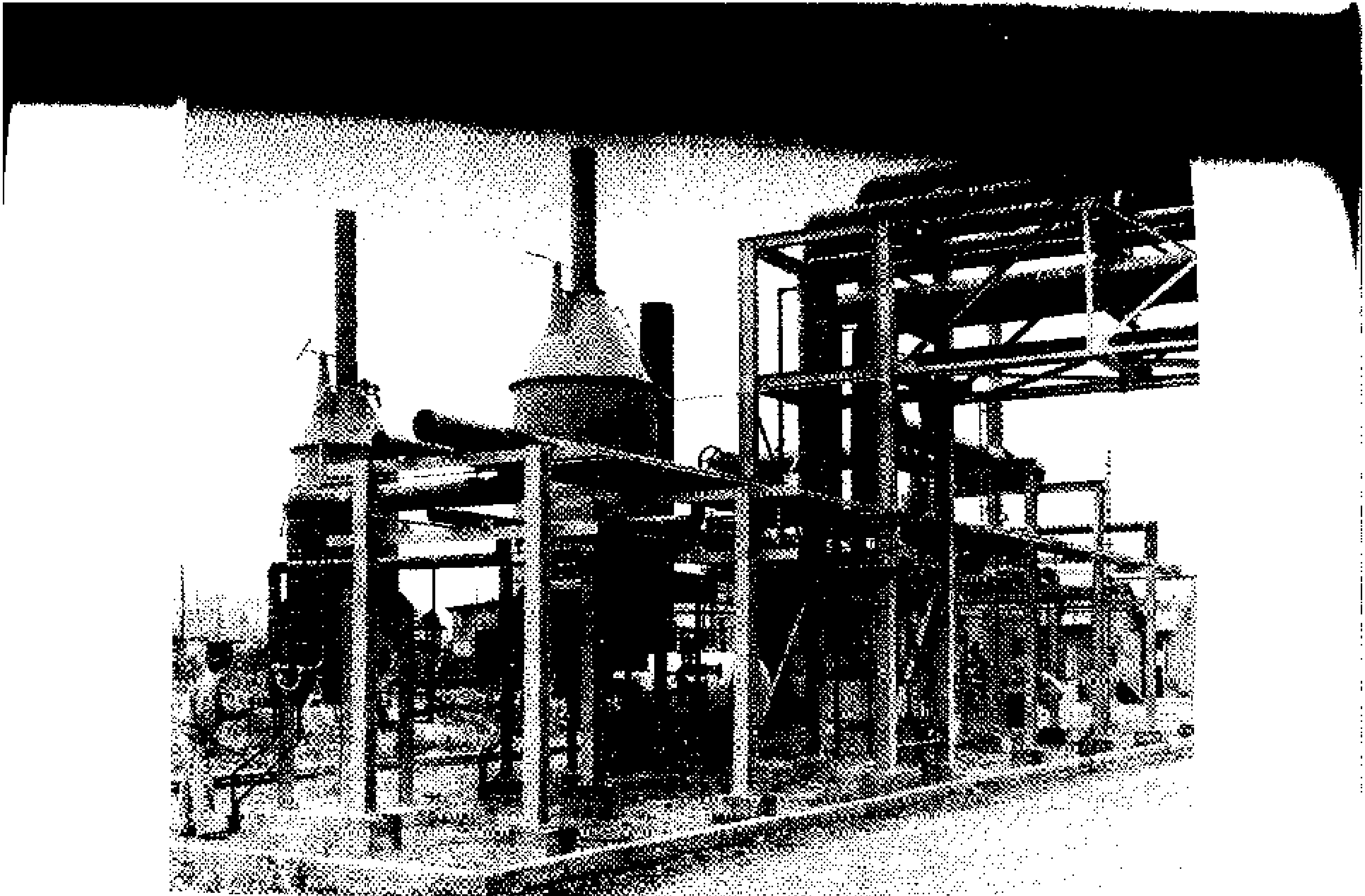


Figure 19. - Gas-fired heaters for preheating feed streams to synthesis and distillation units, Gas-Synthesis Demonstration Plant.

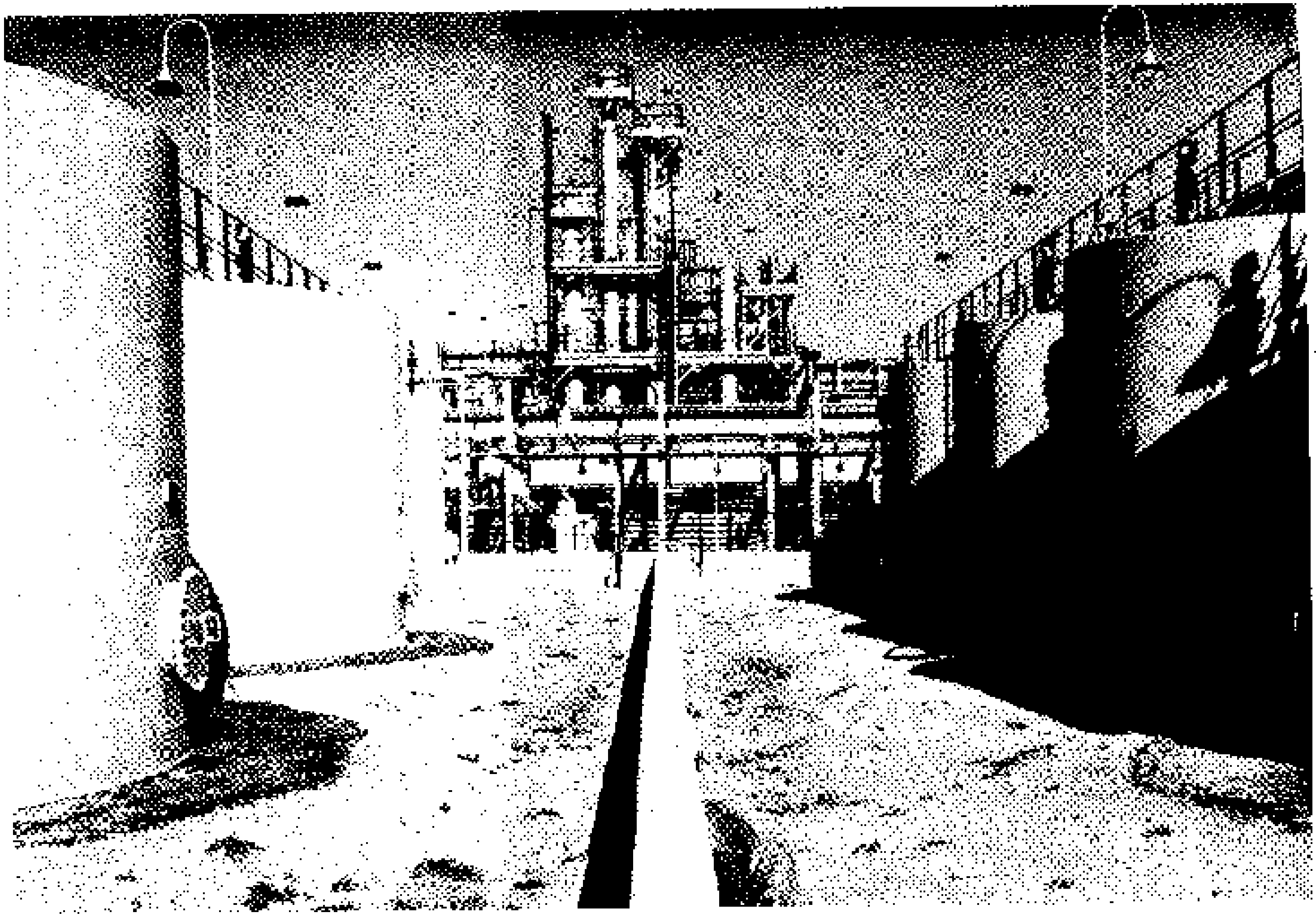


Figure 20. - View (looking north) of distillation unit, with tankage in foreground, Gas-Synthesis Demonstration Plant.

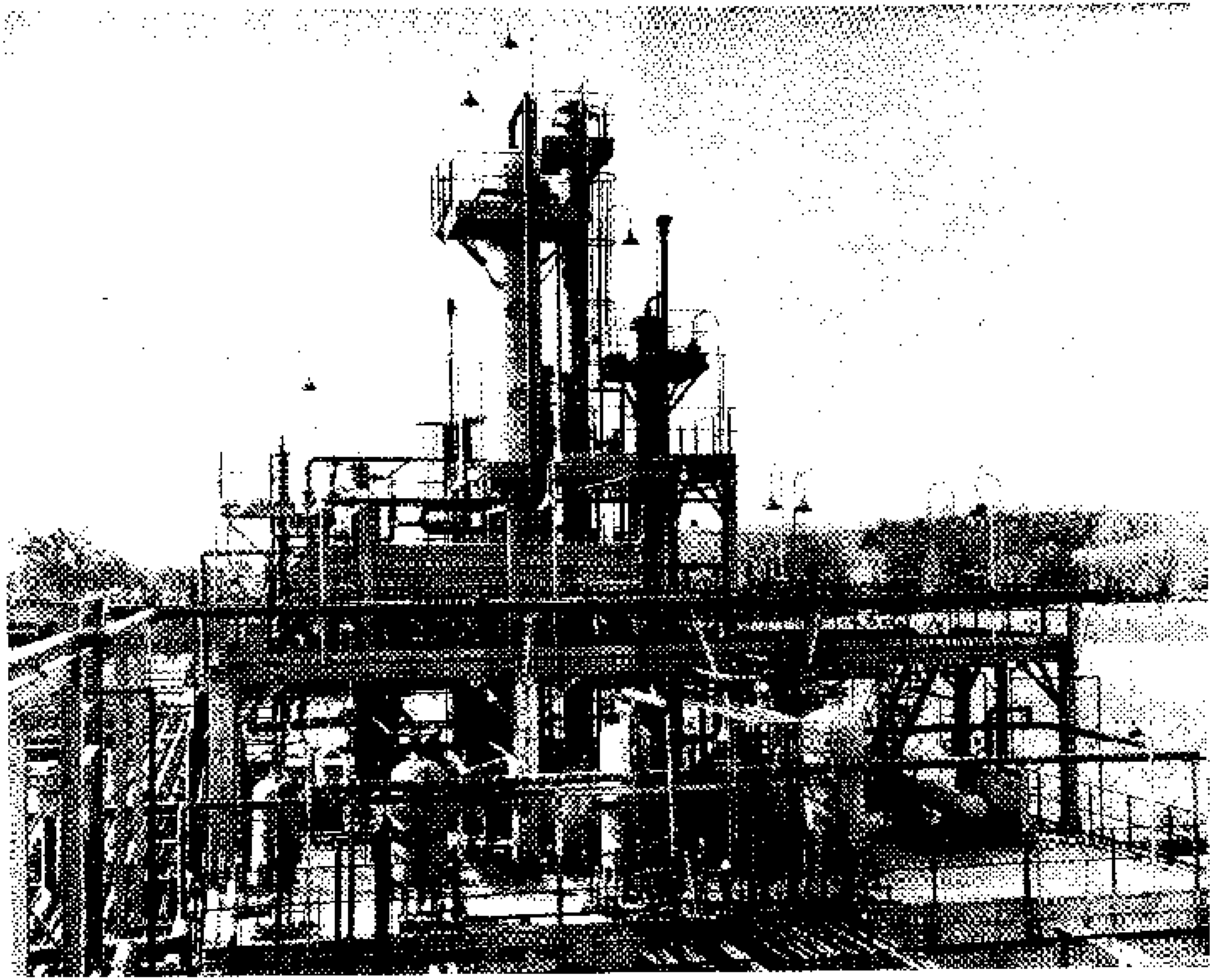


Figure 21. - View (looking south) of distillation columns for refining synthesis crude into finished products, Gas-Synthesis Demonstration Plant.

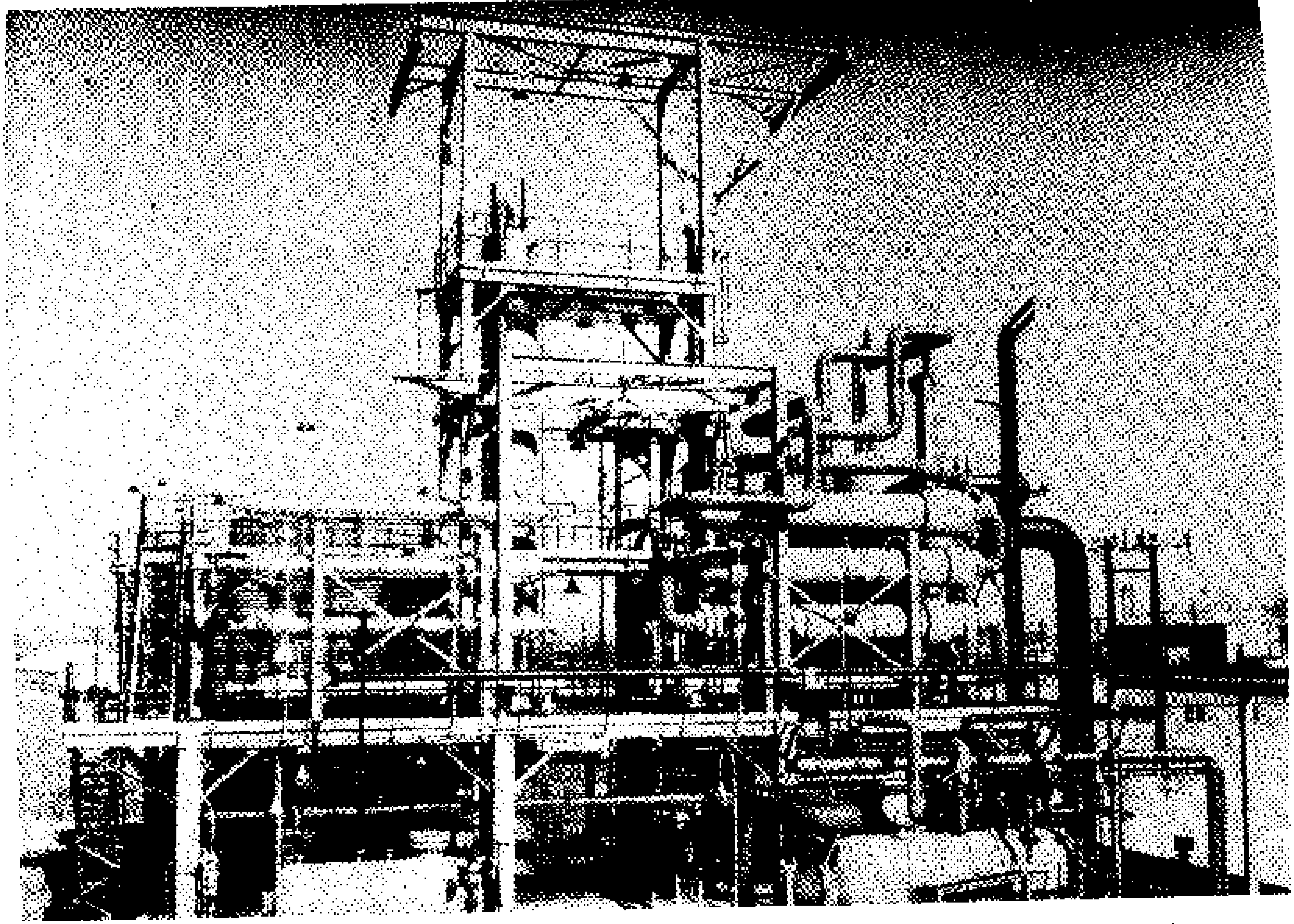


Figure 22. - View (looking north) of auxiliary equipment and piping of synthesis reactor, Gas-Synthesis Demonstration Plant.

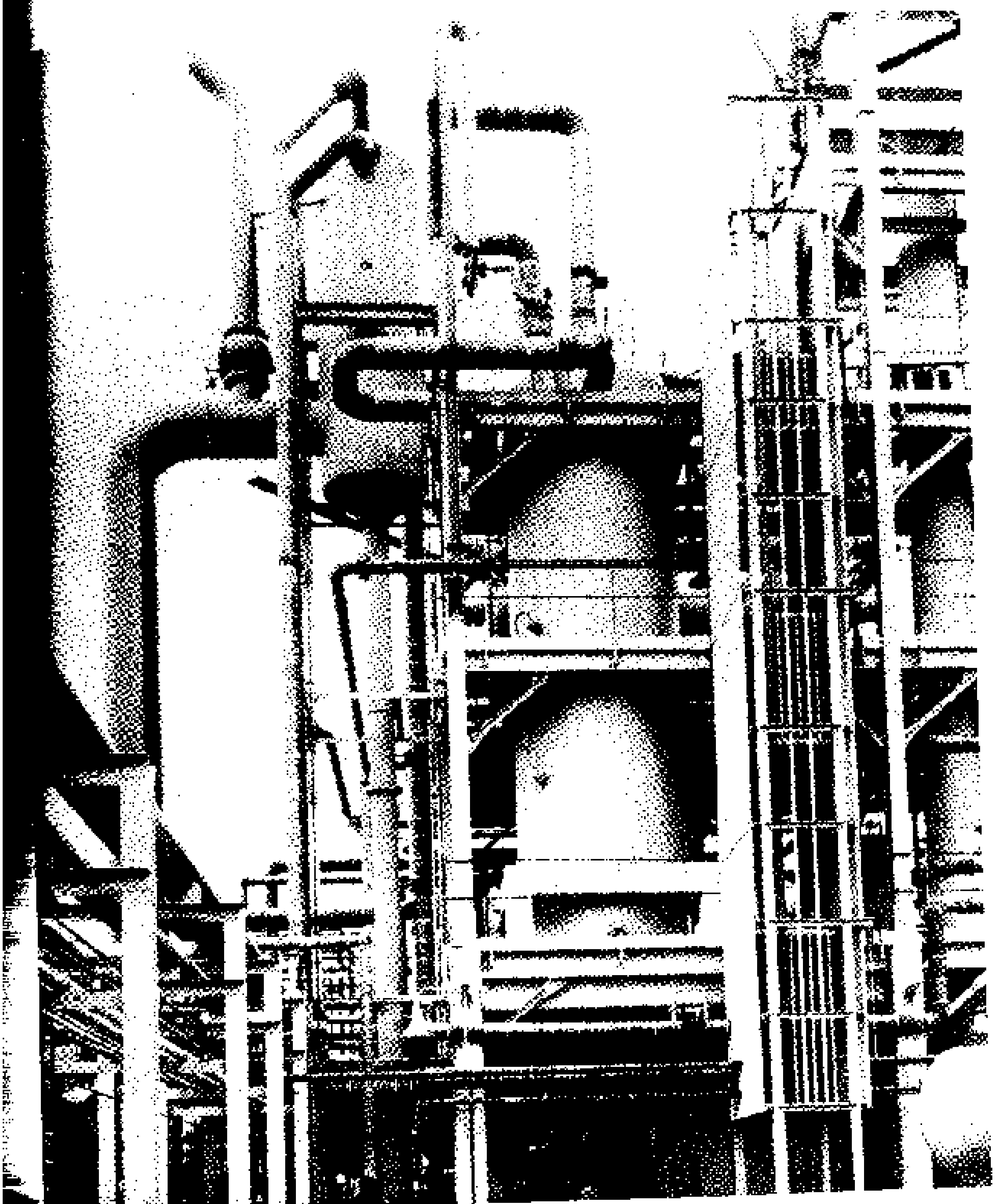


Figure 23. - Gas-synthesis reactor, Gas-Synthesis Demonstration Plant.

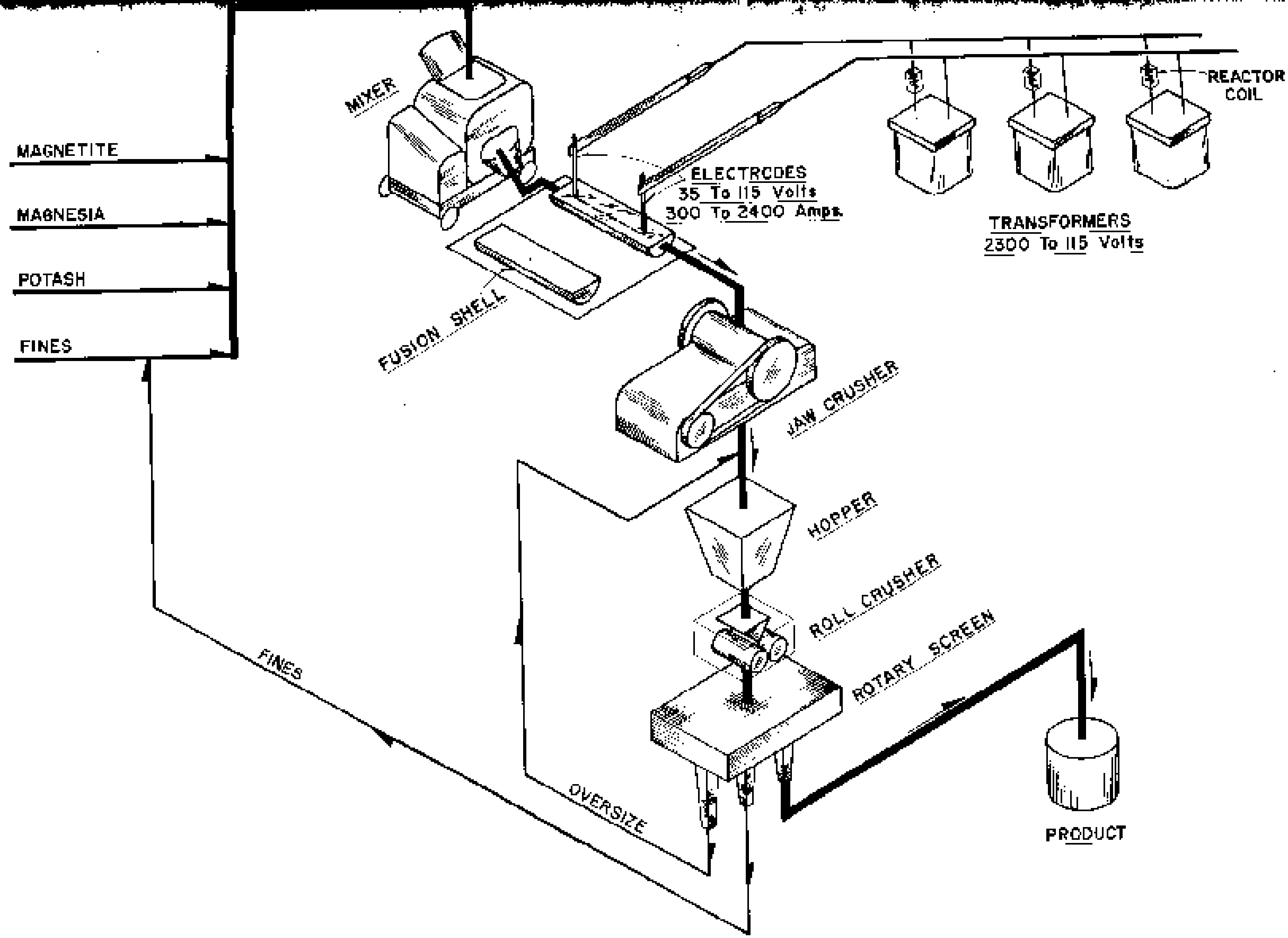


Figure 24. - Flow diagram of catalyst fusion unit.