LURGI-GASIFIER TESTS OF PENNSYLVANIA ANTHRACITE[1/]

by

R. E. Morgan,[2/] J. W. Eckerd,[3/] J. Ratway,[4/] and A. F. Baker[5,6/]

SUMMARY

Two sizes of Pennsylvania anthracite were gasified in the new-type Lurgi pressure generator at the Dorsten, Germany, works of the Steinkohlengas, A. G. These tests demonstrated that Chestnut-size anthracite and a Rice-Buckwheat mixture containing 27 and 19 percent ash, respectively, could be gasified satisfactorily at an elevated pressure in a fixed bed with oxygen and steam. These coals were especially prepared to approximate a rough-cleaned coal and a washed and screened product.

The operating data obtained from the two tests and materials requirements are summarized. A wide range of reactant ratios could not be tested, nor could optimum operating conditions be determined, as the generator was being used throughout the testing program, employing normal operating practices, to produce gas for the gas grid; and the most economical coal, steam, and oxygen ratios may not have been used. Comparative costs are presented of the raw materials required for producing a high-B.t.u. gas, based on the operational data obtained from these tests and, to some extent, on data extrapolated from laboratory experimentation. A flowsheet of a proposed process for producing a high-B.t.u. gas by Lurgi gasification, followed by methanation, is also included.

To provide a comparison of this process with others, operating data are presented for different gasification processes, both experimental and commercial. These comparisons should be useful in planning any future anthracite-gasification program.

INTRODUCTION

The Bureau of Mines Division of Anthracite is engaged in a program directed toward the utilization of anthracite for manufacturing a high-B.t.u. pipeline gas, liquid fuels and chemicals, and hydrogen for ammonia synthesis and iron-ore reduction. The immediate objective is to study the behavior of anthracite in gasification equipment and to determine optimum conditions and equipment.

1/ Work on manuscript completed June 1958.

2/ Assistant chief, Division of Anthracite, Bureau of Mines, Washington, D. C.

3/ Chief, Branch of Utilization and Preparation, Anthracite Experiment Station, Bureau of Mines, Schuylkill Haven, Pa.

4/ Chemical engineer, Division of Anthracite, Bureau of Mines, Washington, D. C.

5/ Fuel technologist, Anthracite Experiment Station, Bureau of Mines, Schuylkill Haven, Pa.

6/ In preparing this report, the authors were assisted by H. A. Dierks, chief, Branch of Mine Drainage, and W. R. Scheffley, fuel technologist, Anthracite Experiment Station, Bureau of Mines, Schuylkill Haven, Pa.

Performance data and cost estimates for processes of this type have been examined; the information available indicates that the Lurgi process is the most suitable for producing synthesis gas from a fuel having the characteristics of anthracite. For optimum mechanical performance the Lurgi gasifier requires a noncaking or only mildly caking fuel having a high ash-softening temperature. Pennsylvania anthracite has these desired properties.

The rising demand for natural gas has prompted a more vigorous search for processes that will provide supplementary or alternate supplies of this important fuel. High-B.t.u. gas derived from solid fuel is an excellent substitute for natural gas; and Pennsylvania anthracite, because it is near the heavy industrial areas and growing markets of the East, appears to be a reasonable choice for use in any gasification process.

Additional demands on the Nation's natural-gas supply are expected if and when the various processes now being developed for the direct reduction of iron with hydrogen, methane, and mixtures of hydrogen and carbon monoxide become commercially feasible.

The amounts of hydrogen, carbon monoxide, and methane obtained by the gasification of anthracite in Lurgi equipment favor the production of high-B.t.u. gas. Changing the reactant ratios should, however, affect the carbon-steam reaction so as to form a product gas that would be more suitable for the production of hydrogen or for the Fisher-Tropsch synthesis.

ACKNOWLEDGMENTS

The authors express their appreciation for the cooperation extended by Steinkohlengas, A. G., through Drs. Weittenhiller, Bieger, and Hess, and Messrs. Ellinghaus, Lebkucher, and Steding; Lurgi Gesellschaft through Dr. Hubmann and Mr. Rudolph; and The Glen Alden Corp. through William Everett.

GENERAL

Gasification of anthracite has been investigated in laboratory and pilot-plant scale Lurgi-type equipment, in both the United States and Europe. In 1946-48 the Bureau of Mines conducted several tests in three generators (4, 6, and 13.5 inches inside diameter) at the Central Experiment Station in Pittsburgh, Pa.; however, only a few runs were made with anthracite.7/ Data from the tests with the 4-inch generator indicated only that anthracite gasified satisfactorily. The size of the generator, with its relatively large heat losses plus the absence of a superheater for the steam and oxygen, resulted in the production of a gas with an unfavorable H_2:CO ratio for the synthesis of methane. Because it was not feasible to operate such a small generator continuously, a second generator with a 6-inch inside diameter was designed and assembled. Three tests were made, each lasting about 2 hours and using anthracite as the fuel. Anthracite Buckwheat Nos. 3 and 4 sizes gasified, as well as char of comparable size, but difficulties were experienced in gasifying Buckwheat No. 5. Satisfactory steam:oxygen ratios of 0.325 and 0.287 pound per cubic foot were reported for Buckwheat Nos. 3 and 4 sizes, respectively. The CO_2 in the product gas ranged from a low of 23.7 percent with Buckwheat No. 3 to 31.8 percent with Buckwheat No. 4; however, with Buckwheat No. 5 size, the CO_2 was even higher because the gases channeled through the charge. It was also noted that, when the pressure was increased from 300

7/ Cooperman, J., Davis, J. D., Seymour, W., and Ruckes, W. L., Lurgi Process: Use for Complete Gasification of Coals With Steam and Oxygen Under Pressure: Bureau of Mines Bull. 498, 1951, 38 pp.

to 400 pounds per square inch (p. s. i.) to slow down the rate of gas flow through the charge to prevent channeling, methane formation increased irregularly from 4 to 8 percent. As Barley (Buckwheat No. 3) anthracite was used in the 13.5-inch continuous generator to determine operating conditions alone, only incomplete yield and operating data were taken. Since the main object of this program was to test char and to determine the capacity of the generator, no further studies were made with anthracite.

Gasification tests were conducted by others on several British coals in a Lurgi pilot plant at Holten, Germany; however, none of the coals used was anthracite (on the basis of the ASTM classification), and, because the data obtained were controlled by the limited amount of oxygen available, they are not considered representative of operations with anthracite.8/ The objective of these tests was to determine how efficiently a Lurgi generator can handle coals that soften when heated under pressure.

Further pilot-scale work was carried on at the Nechells Gas Works, Birmingham, England, with three selected coals (including a Welsh anthracite) to study the influence of volatile matter upon the product gas and the reactivity of coal toward steam under different operating conditions obtained by varying the steam:oxygen ratios, pressures, and rates of gasification.9/ These tests indicated that anthracite could be used successfully but with lower gasification rates and higher oxygen requirements than for bituminous coal. These tests showed also that the oxygen and steam consumption per therm were lower for bituminous coal than for anthracite because the former contained more volatile matter and less fixed carbon. The volume of $CO + H_2$ was higher and the CH_4 lower in the gas produced from anthracite, with the result that the heating value was approximately 8.6 percent lower than for the gas produced from bituminous coal.

A series of tests conducted by others on Korean anthracite in the experimental Lurgi generator at Holten, Germany, gave further evidence of the suitability of anthracite for the Lurgi process. In these tests the gas-production (CO_2-free) rate was about 1,995 cu. ft./sq. ft./hr. for a run-of-mine coal containing 23.2 percent ash, and 2,330 cu. ft./hr. for a washed and screened coal containing 14.5 percent ash. Satisfactory operations were maintained with a steam:oxygen ratio of 0.362 (lb./cu. ft.) with the washed and screened coal; in the test with run-of-mine coal a steam:oxygen ratio of 0.423 (lb./cu. ft.) was necessary, and the speed of the grate had to be reduced to maintain operations. Consumption of oxygen was 291 cu. ft./M cu. ft. of purified gas for the washed coal and 338 cu. ft./M cu. ft. of purified gas for the run-of-mine coal; however, the low-volatile matter (2 to 3 percent) and high ash content of the coal were expected to affect the consumption of oxygen in this manner. The high ash content also caused a reduction of the gasification temperatures and resulted in higher steam requirements as well.

Realizing that the data obtained from the tests of Korean anthracite should be supplemented by experiments in commercial-size equipment, the Bureau of Mines made arrangements with Steinkohlengas, A. G., a division of Ruhrgas, A. G., to conduct tests in a commercial producer at its plant in Dorsten, Germany. This plant is suitable for test work because the individual producers can be isolated and controlled separately, except for the oxygen supply. The quantity of oxygen available during the tests was limited by the valves and instruments to the amount of oxygen required by the fuel regularly gasified.

8/ Griffith, R. H., and Dent, F. J., Research Programme of the Birmingham Research Station: British Gas Council Res. Communication GC-8, 1953, 38 pp.
9/ Hebden, D., Edge, R. F., and Foley, K. W., Investigations With a Small Pressure Gasifier: British Gas Council Res. Communication GC-14, 1954, 32 pp.

DESCRIPTION OF THE PLANT

Steinkohlengas, A. G. is in Dorsten, Germany, in the northwest section of the Ruhr district, approximately 20 miles from Essen. The plant property adjoins that of the Fuerst Leopold mine, which supplies coal to the plant by belt conveyors. Figure 1 shows the plant site. The installation consists of buildings housing the gas producers, an oxygen plant, a tar plant, a laboratory, administrative offices, and auxiliary equipment for refining the tar and tar-distillation products produced in the operation. High-pressure steam for the entire operation is furnished by a powerplant on the adjoining mining property. The high-pressure steam fed to the gas producers is actually steam-turbine discharge; hence, its quality is limited to some extent.

As this study was concerned only with gas production, the auxiliary facilities were not investigated; however, Steinkohlengas is a supplier for the Ruhrgas grid, which is interconnected with grids supplying gas to France and Holland, as well as to Western Germany. Although no attempt was made to examine the economics of this operation, it is known that the revenue obtained from the tar byproduct is an important factor.

As previously mentioned, the producer plant is near the mining property, and coal is conveyed to it by belt. Figure 2 shows the conveyor system, and figure 3 a portion of the anthracite and an open section of the conveyor, which carried the American coal to the producer hoppers during the tests. The generator house contained six Lurgi producers with the necessary feed and ash-discharge mechanisms. Each producer was equipped with separate instruments for recording temperature, pressure, and volume of oxygen; temperature, pressure, and weight of steam; percentage of CO_2; temperature, pressure, and volume of make gas; ashpit temperature; and gas temperatures at the producer, cooler, and waste-heat boiler outlets. The instrument room of the plant is shown in figure 4.

A normal complement of 78 men operates the plant on a 3-shift, 7-day-week basis. Fifty-nine of these men are assigned to plant operation and 19 to maintenance.

PRODUCER DESCRIPTION AND OPERATION

Figure 5 includes a diagrammatic sketch of one producer. Each producer unit is approximately 46.3 feet overall from the top of the charging hopper to the bottom of the ash-discharge mechanism. The gasifying chamber is 27 feet 4 inches from top to bottom. The distance from the bottom of the charging mechanism to the top of the grate is 9 feet. The producers are equipped with an agitator, because the coal used regularly is mildly caking and must be stirred to prevent channeling. The inside diameter of the producers is 8 feet 10 inches and the diameter of the grate, 8 feet 2 inches. The fuel is charged through a pressurized lock hopper, which can be depressurized as required. The gas recovered while the lock hopper is being depressurized is added to the make gas at a rate of approximately 9,300 cubic feet per hour. The ash is removed through a pressurized ash chamber into an ash hopper, from which it is flushed with water onto a conveyor belt. Charging is accomplished by a manually controlled valve system, based on the amounts of ash removed and gas produced. The ash-removal rate may be varied by changing the speed of the rotating grate to accord with variations in the temperature of the ashes and make gas. In actual operation increases in the temperature of the make gas indicated an upward movement of the oxidation zone, and the ash-removal rate was increased to compensate for the rate of movement. Increases in the temperature of the ash indicated that the oxidation zone was too close to the grate; hence, the rate of rotation was decreased. The ashes were examined visually at regular intervals to guard against hard clinker formation, as the Lurgi grate mechanism will not handle this type of material satisfactorily. Hardness of the clinker was controlled by the steam:oxygen ratio.

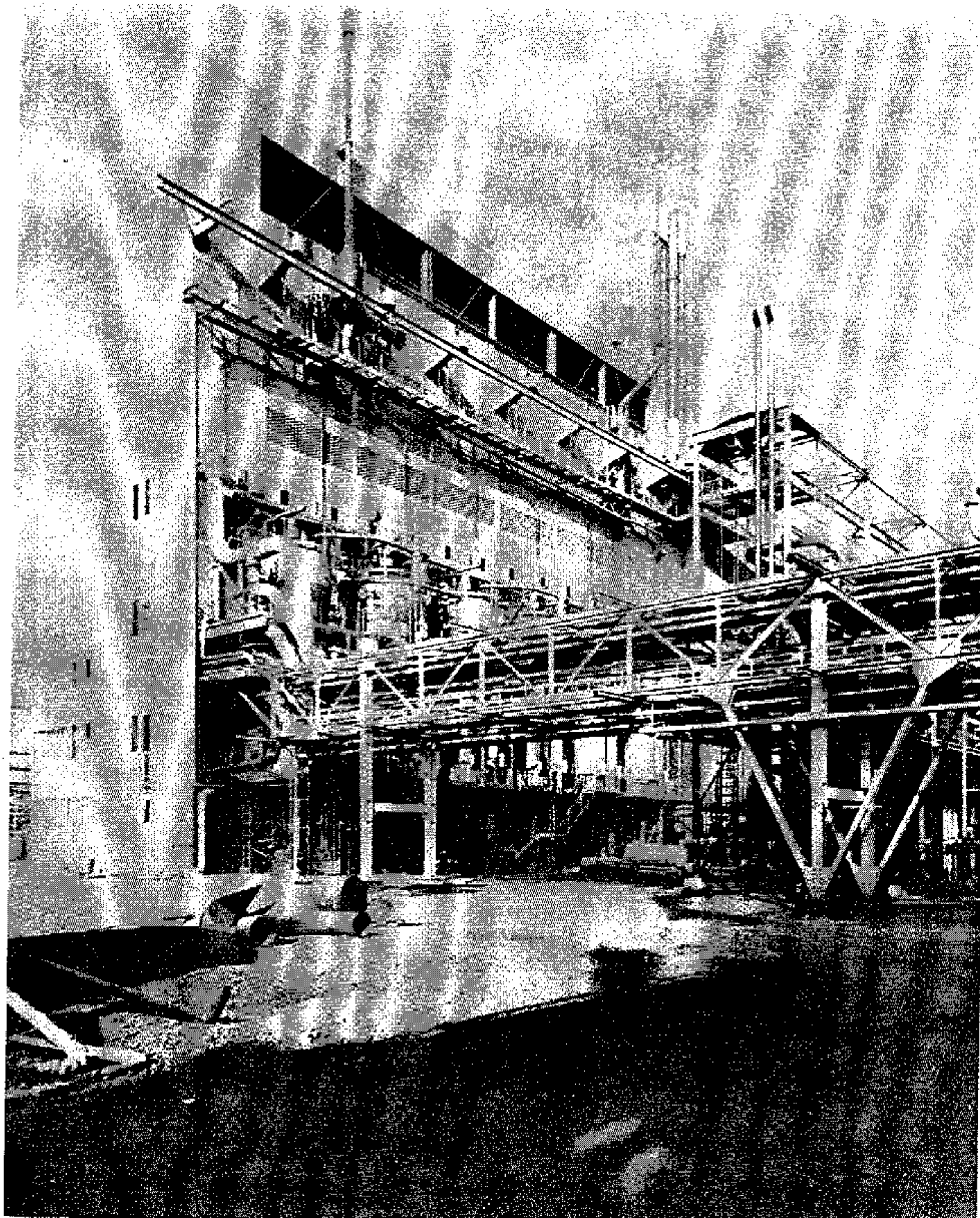

FIGURE 1. - Plant Site, Steinkohlengas, A. G., Dorsten, Germany.

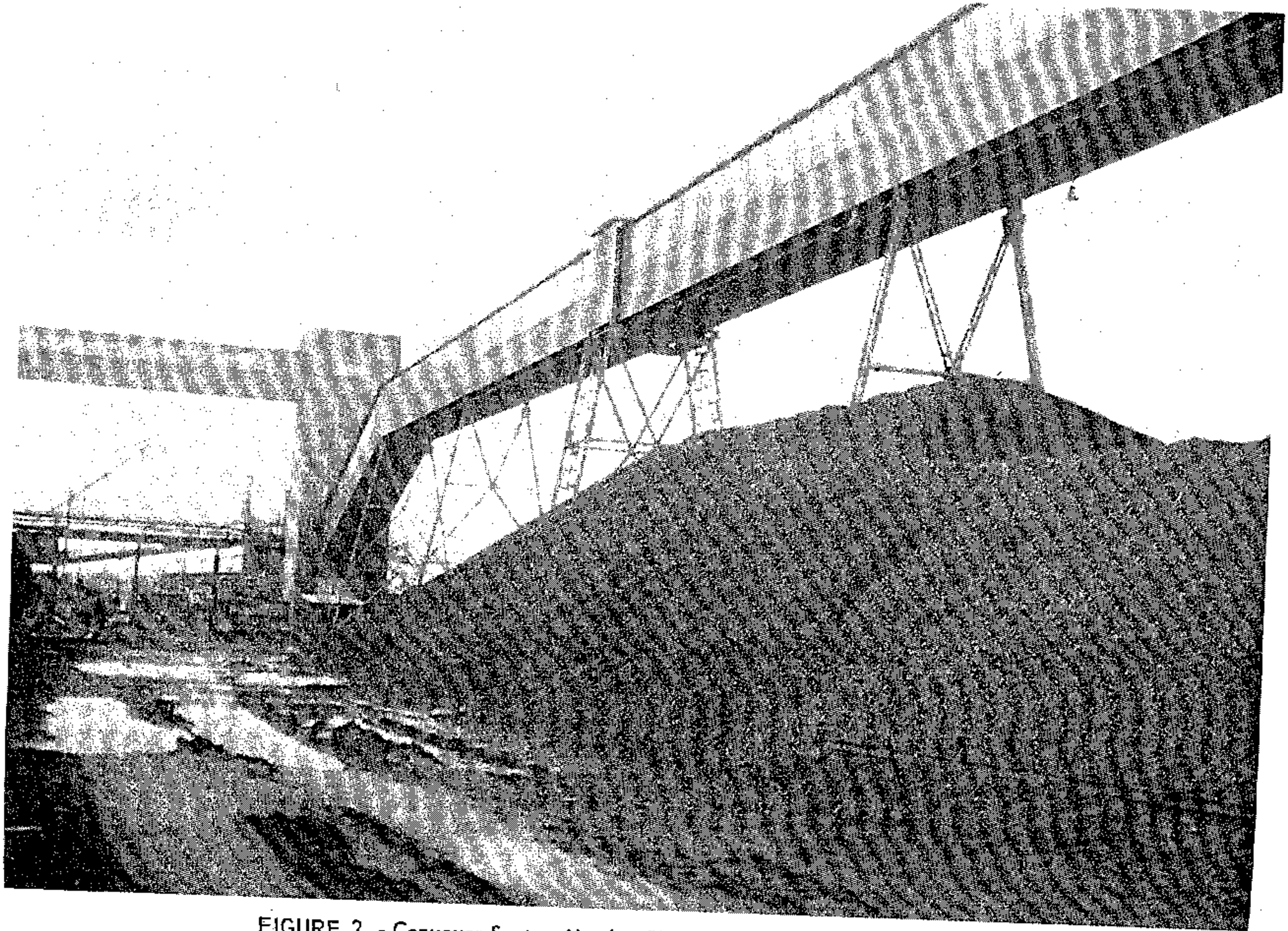

FIGURE 2. - Conveyor System Used to Transport Coal to Storage Bunkers.

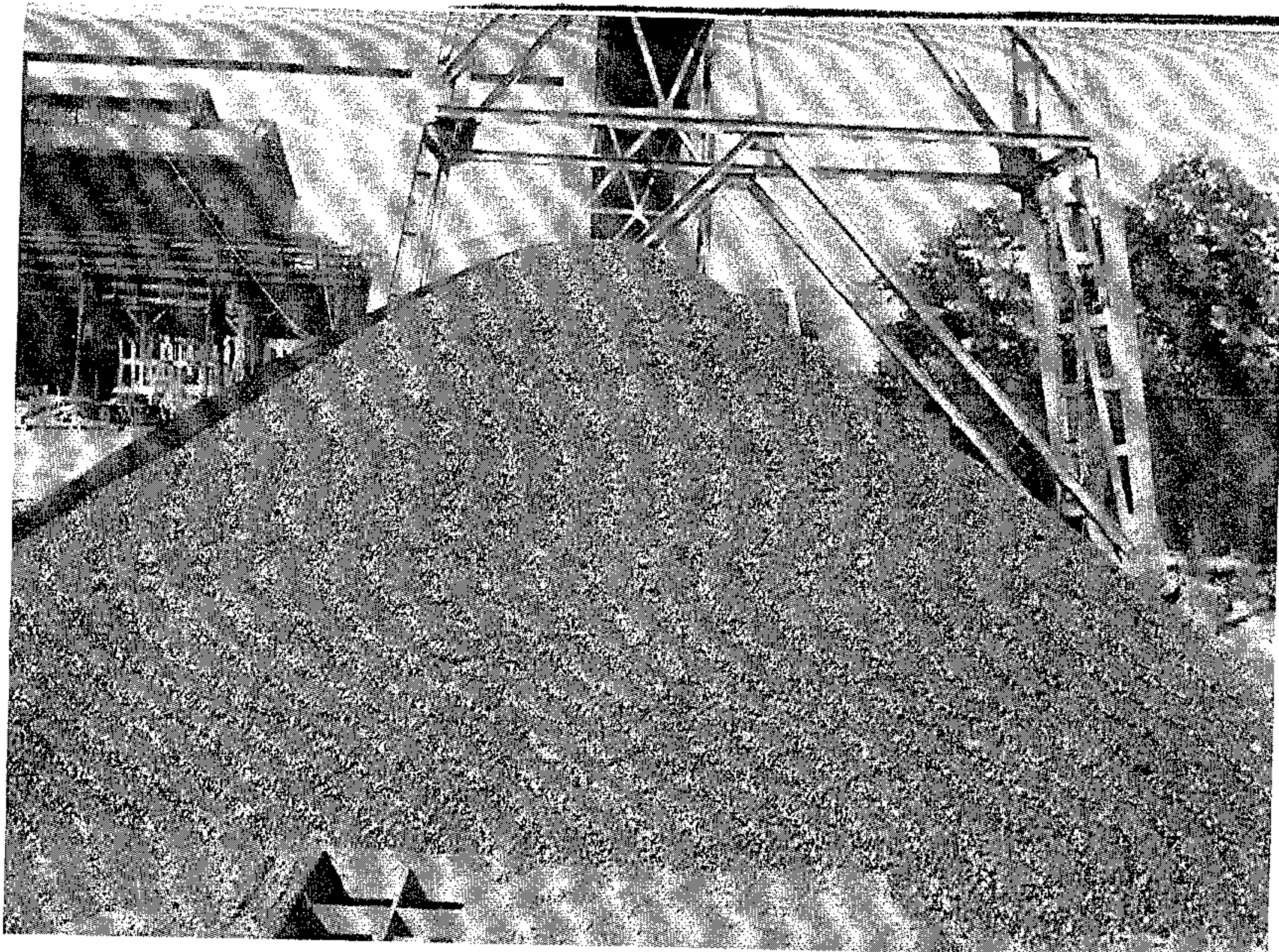

FIGURE 3. - Anthracite and Open Section of Conveyor Used to Transport Fuel for Tests.

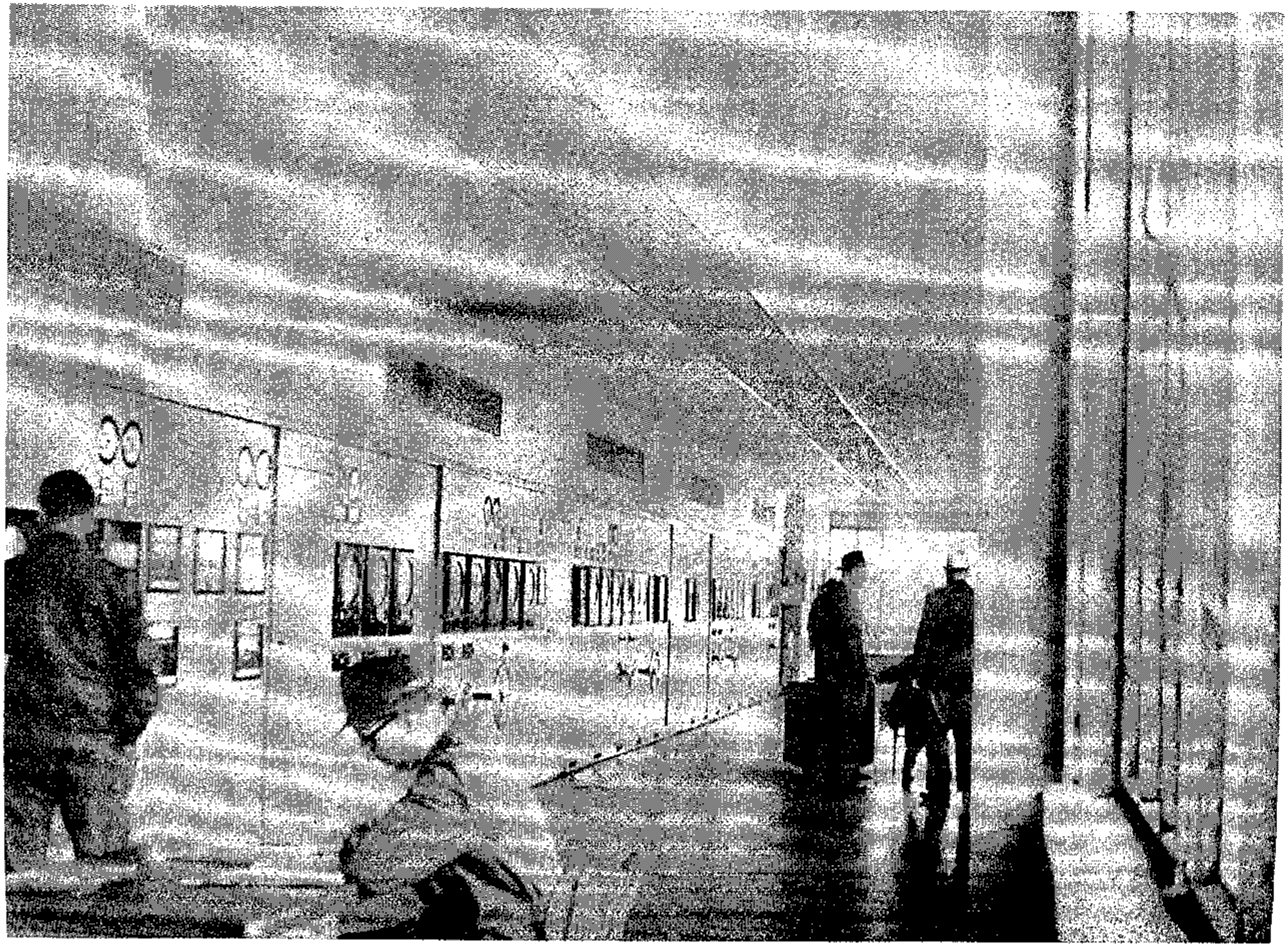

FIGURE 4. - Instrument Panel in Gashouse.

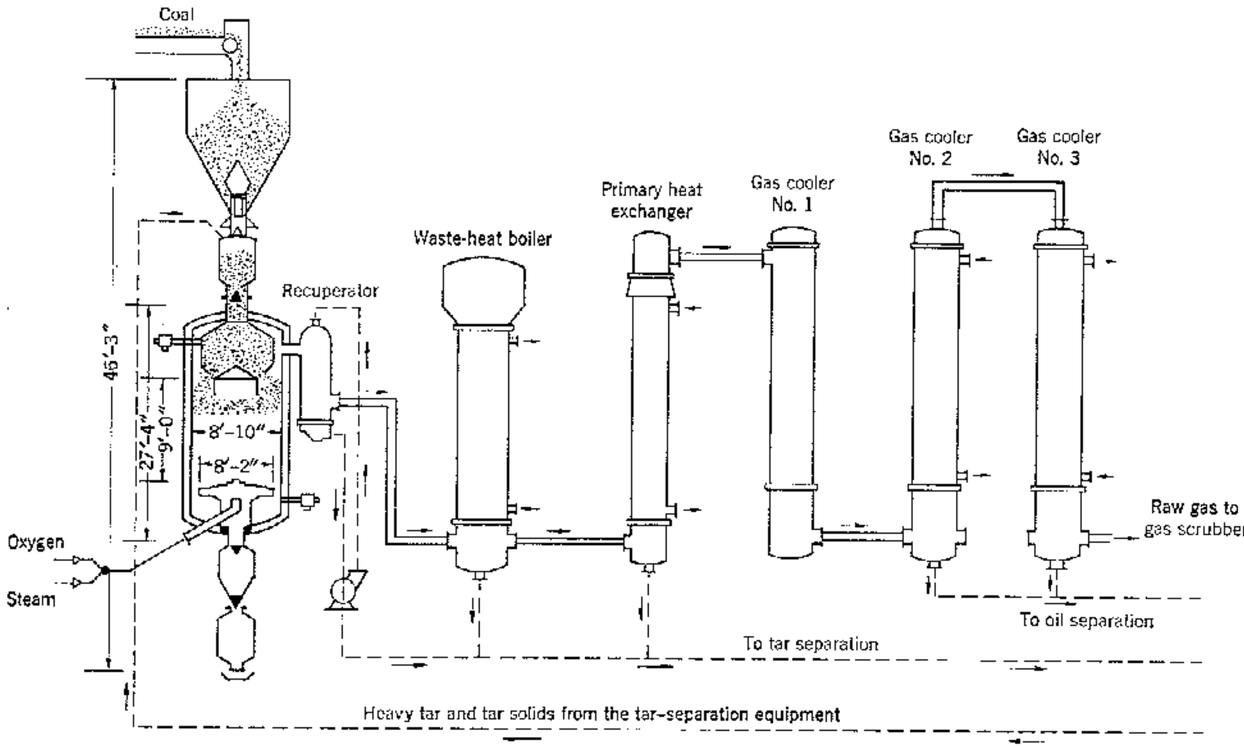

FIGURE 5. - Sketch of Producer and Auxiliary Equipment.

The generator was constructed entirely of welded steel. The upper part of the gasification zone was lined with firebricks, and the walls are water-cooled. Oxygen and steam are fed through and distributed by the grate.

DESCRIPTION OF ANTHRACITES USED

The proximate and ultimate analyses of the anthracites used in these tests are shown in table 1, and the screen analyses in table 2. The anthracites, obtained from the Northern field, were specially prepared to contain approximately 25 percent ash in the Chestnut size and 15 percent in the mixture of Buckwheat and Rice. Every effort was made to keep to a minimum the amount of rock or low-carbon slate appearing in the mix, so as to obtain a material of fairly uniform ash content rather than a mixture of high- and low-ash fuel.

The coal was transported by rail to Port Richmond pier, Philadelphia, Pa., transferred to an ocean-going vessel, and discharged into barges in Rotterdam Harbor; from Rotterdam it was transported by barge and discharged onto a loading ramp of the Fuerst Leopold Mining Co. The coal was then transferred to railroad cars for shipment to the test site.

The anthracite, which was stored in piles before shipment from the United States, was handled seven times before being gasified. The coal was moved three times by clamshell and once by front-end loaders. Degradation was not considered excessive. Unfortunately, however, the fine, broken material was concentrated, to some extent, by final stacking with the belt conveyors and was believed to have caused some variations in operating with the Chestnut-size anthracite.