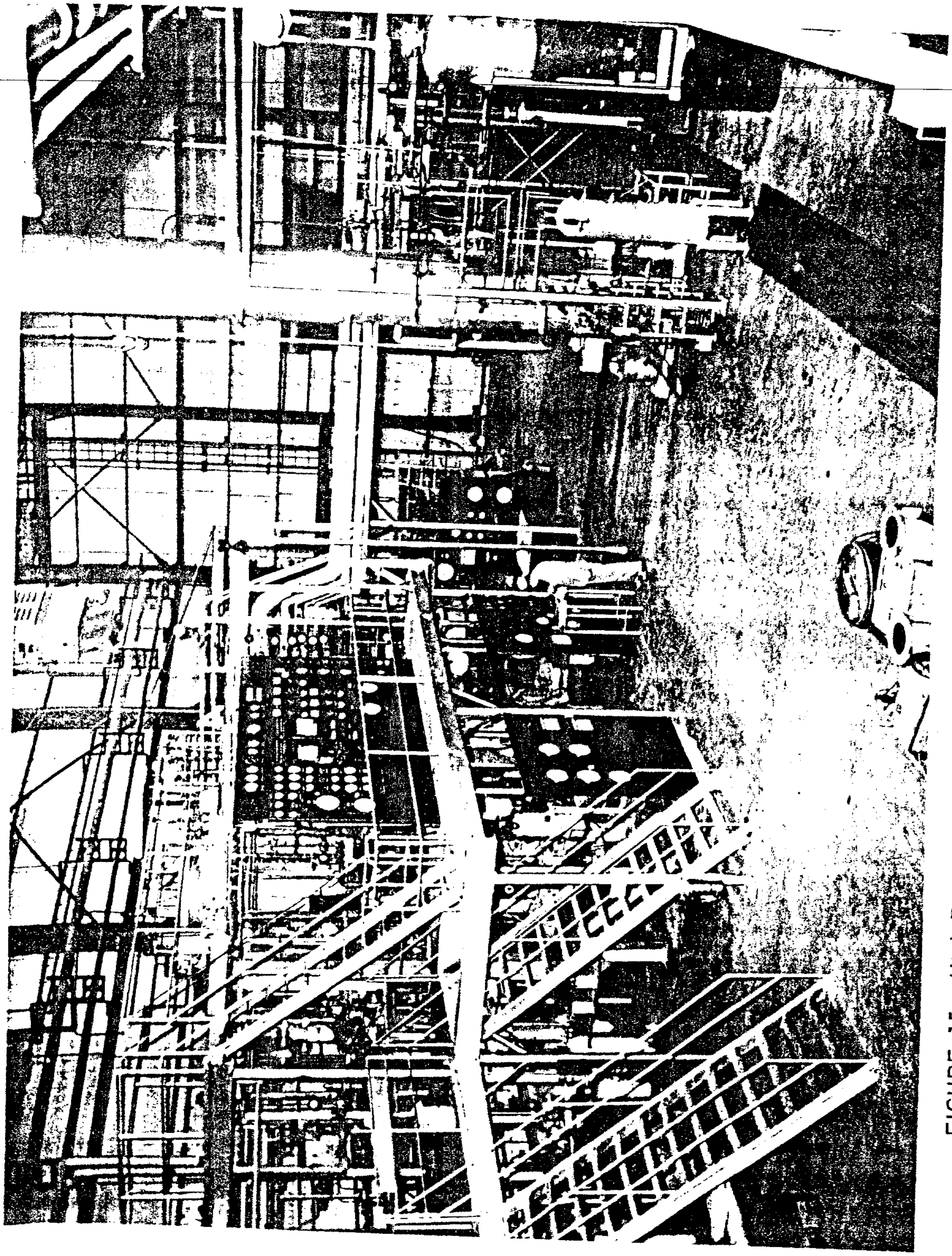

FIGURE 15. - High-Pressure Gasification Pilot Plant With Pneumatic Coal Feeder at Right.

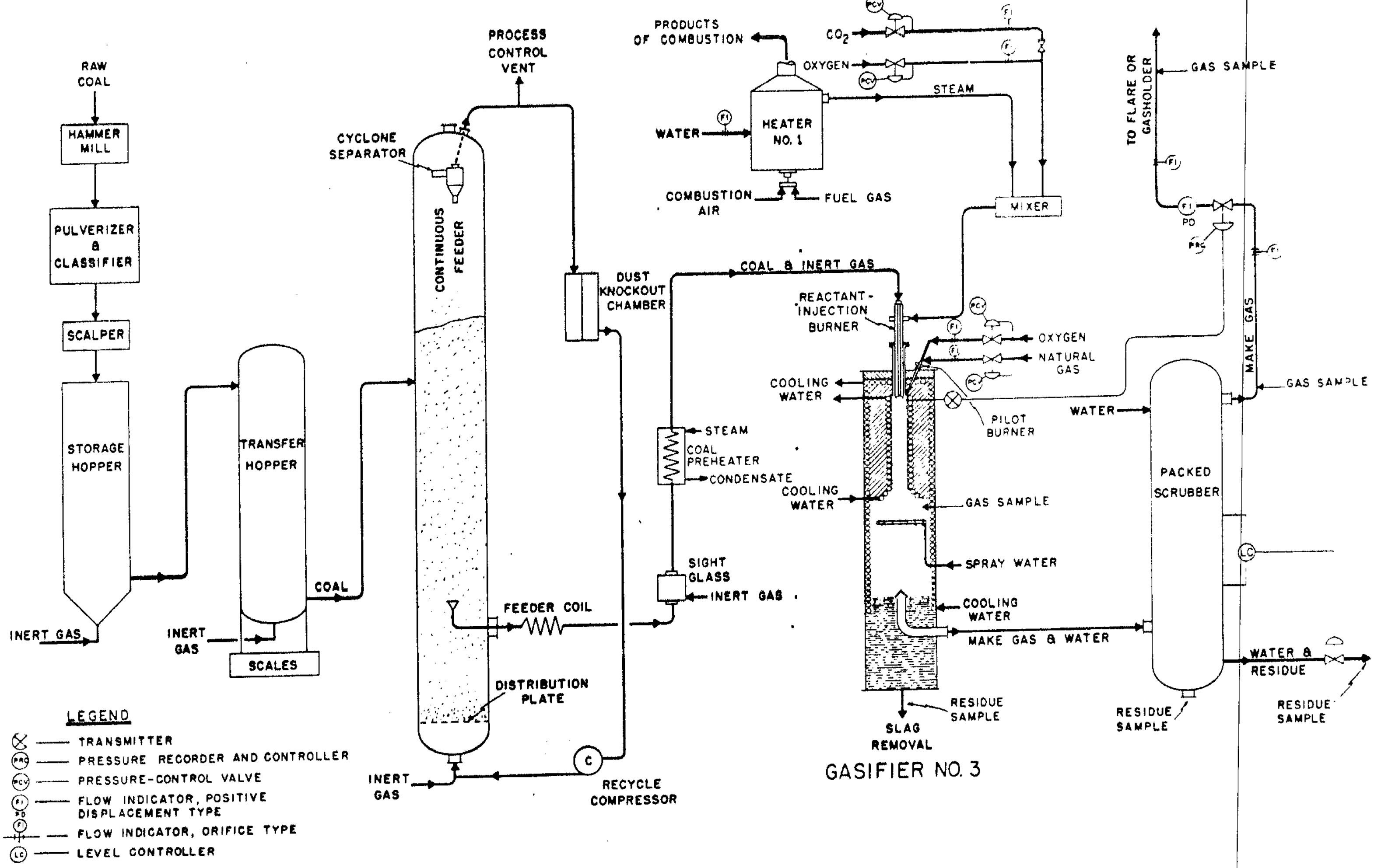

FIGURE 16. - Flowsheet for High-Pressure Gasifier.

5. Preliminary process calculations were made, and tentative flowsheets prepared, for a 150-ton-per-day ammonia plant using the Bureau of Mines powdered-coal-gasification process to produce the synthesis gas required. The primary objective was to obtain guidance in developing the coal-gasification process.

6. A study was made of the effect of refractory durability in commercial-size gas generators on the cost of synthesis gas. For silicon carbide, it was concluded that, if down time rises above 30 percent of total time (down time plus operating time), the cost of synthesis gas may be prohibitive. With 10 percent down time the cost of synthesis gas per 1,000 cu. ft. of $CO + H_2$ would increase 0.3 cent, and for 20, 30, and 40 percent down times the cost increases would be 0.65, 1.10, and 1.75 cents, respectively.

7. An estimate was made also of the cost of compressing synthesis gas (made at atmospheric pressure) for use in a Fischer-Tropsch plant producing 10,000 barrels of liquid fuels per calendar day. This estimate was based on compression of 16,800,000 std. c. f. per hour of raw synthesis gas (after dust removal but before sulfur purification and shift conversion) to 450 p.s.i. pressure. The investment in 12 turbines, 24 centrifugal four-stage compressors with intercoolers, water pumps, buildings, and accessory installations totaled $14,035,000 as of 1950. The operating cost, including various taxes, insurance, and amortization, but no Federal taxes or interest on capital invested, was estimated as 5.2 cents per 1,000 std. c. f. of synthesis gas compressed.

Demonstration Plant

Experimental gasification processes considered in the demonstration plant operated by the Bureau at Louisiana, Mo., were based on the use of pulverized coal (8). However, the Kerpely producer, as an auxiliary source of synthesis gas for periods when experimental gasifiers were not operating, utilized coke in accordance with standard commercial practice. The gasifiers are described separately below.

Kerpely Coke-Gasification Unit

Early in the history of the demonstration plant a standby source of synthesis gas was provided by installation of a commercial Kerpely gas producer. This was a standard continuous unit, but modified to use oxygen instead of air. Coke was introduced intermittently at the top, and oxygen and steam at the bottom, of the brick-lined, vertical combustion chamber. A motor-driven grate facilitated removal of ashes.

This producer operated reliably and satisfactorily as a source of gas when the experimental gasifiers were not being used. Following test runs, seven production runs reached a total gasification time of 245 days (11, 13, 23, 33). Coke was used at 1,700 to 2,300 pounds per hour to produce 80,000 to 95,000 std. c. f. per hour of synthesis gas as required for the Fischer-Tropsch synthesis unit. For 1,000 std. c. f. of carbon monoxide plus hydrogen, the requirements were 27.6 to 30 pounds of coke, 213 to 267 std. c. f. of oxygen (fig. 17), and 31.4 to 47.8 pounds of steam.

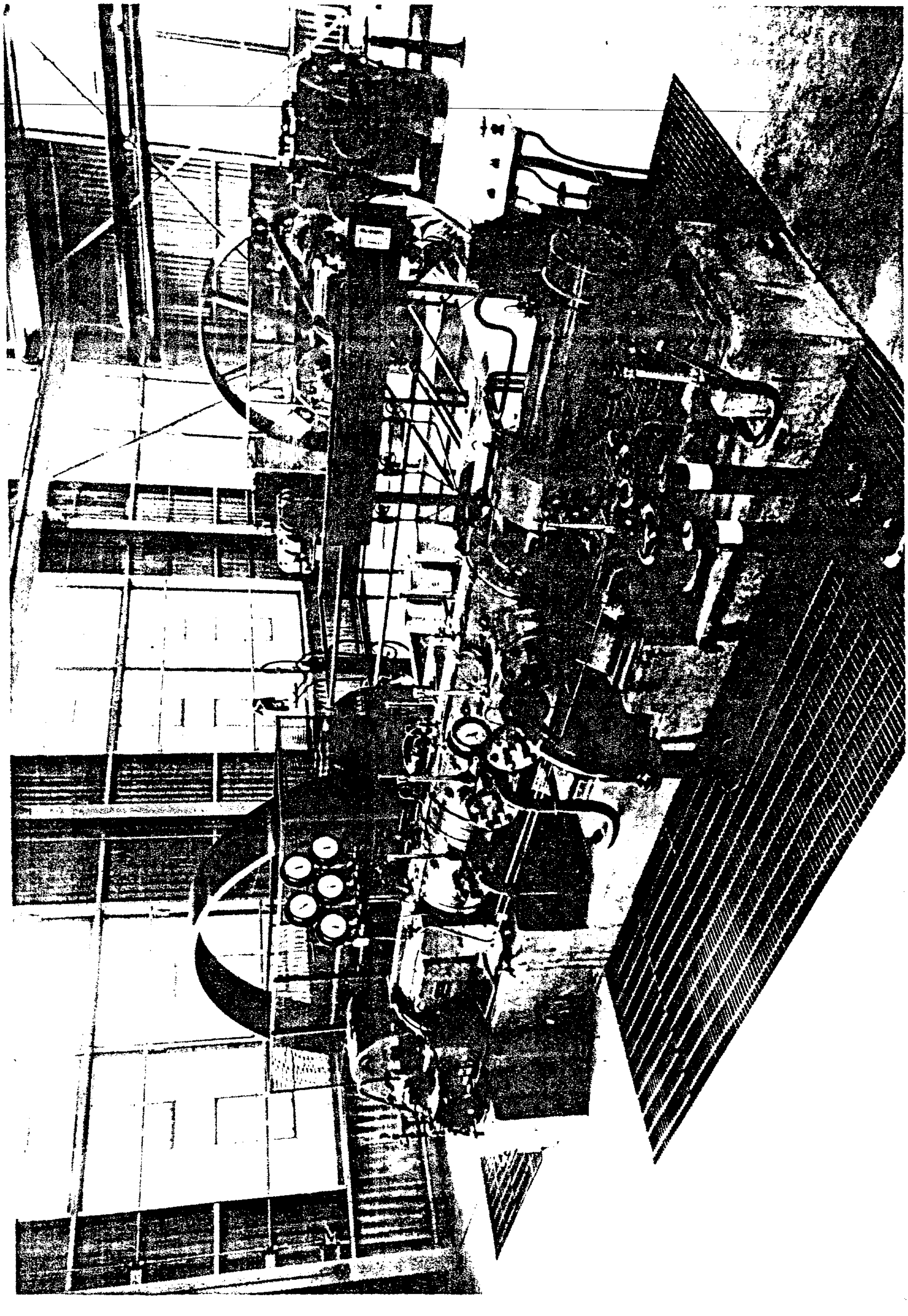

FIGURE 17. - Five-Stage High-Pressure Air Compressor (foreground) and Single-Stage Low-Pressure Compressor (background) in the Oxygen Plant of the Demonstration Plant.

Special runs were made with Pea and Nut sizes of high-temperature coke in cooperation with the American Gas Association, and with a low-temperature char in cooperation with the Koppers Co. (11). All were found feasible for use in the gasifier. With a constant steam rate, adjustment of the oxygen input was found to control the hydrogen:carbon monoxide ratio of the gas produced (33).

Koppers Horizontal Gasifier

The first experimental gasifier set up in the demonstration plant was a horizontal unit, designed and installed by the Koppers Co., Inc. It was essentially a horizontal steel cylinder, lined with refractory brick, and designed to handle 1 ton of coal per hour in nonslagging operation at atmospheric pressure. Pulverized coal and oxygen, and steam superheated first in a gas-fired pebble heater, were fed into both ends of the cylinder (5, 10, 11, 20, 23).

This gasifier was operated in a series of 46 runs, totaling 420 hours, between April 1949 and April 1950. Tests were made of different burner nozzles, and observations were made of the effect of operation on the refractory lining of the gasifier (20). Variables studied during operation included the ratio of oxygen to coal, the coal particle size, the length of burner nozzles, the method of adding steam, and the ratio of steam to coal. An indication of improved gasification efficiency was obtained from very fine bituminous coal (92 percent passing 325-mesh, and essentially all passing through a 200-mesh sieve, as compared to coal ground so that 85 to 90 percent passed a 200-mesh). Burner nozzles projecting 4 or 16 inches into the gasifier did not change gasification efficiency, while 45-inch burners caused a marked drop in efficiency. A significant variable was found to be the ratio of oxygen to coal. Conversion of carbon increased nearly linearly with increase in the oxygen:coal ratio. Synthesis gas was produced most efficiently, with carbon conversion of 80 to 85 percent, in the range of 9 to 10 cubic feet of oxygen per pound of coal.

In one period of operation that extended over 265 hours, some 250 tons of coal, 4,100,000 cu. ft. of oxygen, and 400,000 pounds of steam were used to produce 15,700,000 cu. ft. of synthesis gas, of which 12,700,000 cu. ft. was $CO + H_2$.

Vertical Gasifier

A vertical, atmospheric-pressure gasifier unit was built to test, on a larger scale, results that had been obtained at Morgantown (fig. 18). The unit was an upright cylinder, lined at first with rammed aluminum oxide, designed to handle up to 3,000 pounds of coal per hour (11, 23). Pulverized coal fed by screw feeders was picked up by the oxygen stream and carried in fluidized state into the gasifier, where it emerged through a nozzle installed tangentially slightly above the bottom of the cylinder. Superheated steam was injected nearby. As the coal gasified while passing upward through the cylinder, molten slag accumulated first on the walls, flowed to the base, and was eventually removed through tapping ports (23).

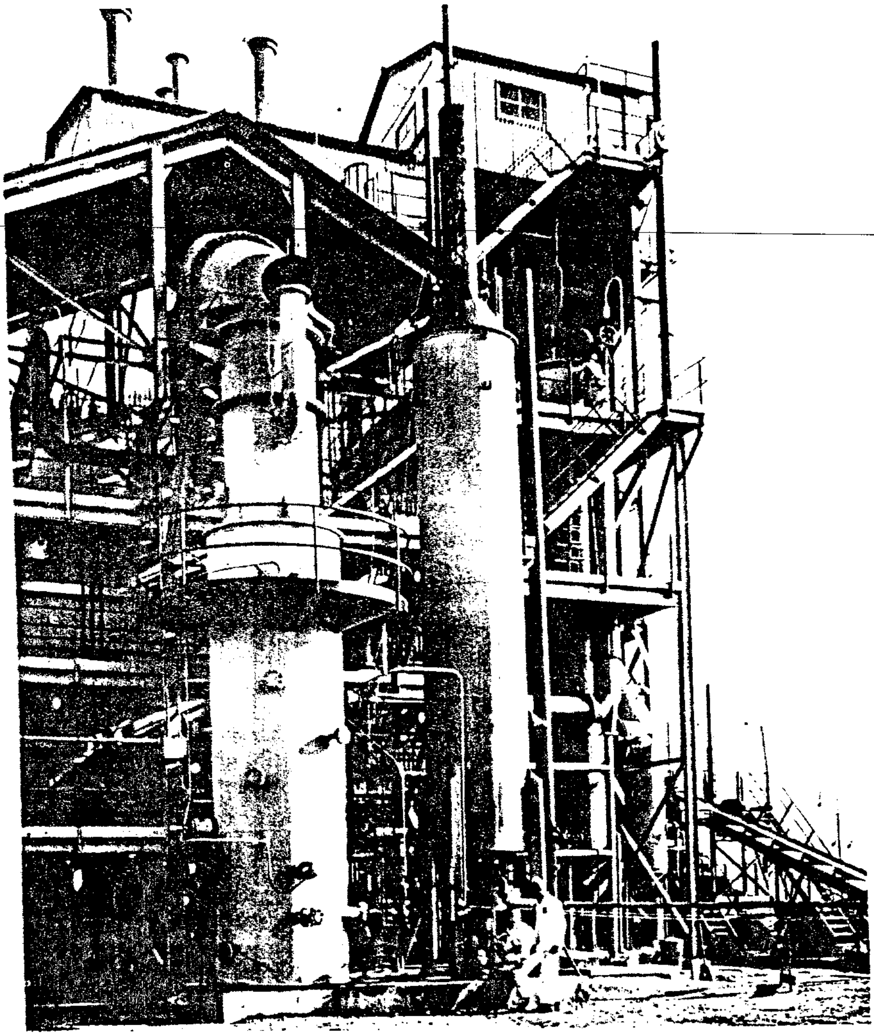

FIGURE 18. - Vertical Coal Gasifier (left) and Preheater (right) in the Demonstration Plant.

Installation of this unit was completed in 1951, and numerous short runs were made until 1953, when the demonstration plant was closed down. In early runs with the oxygen-conveyed coal, high rates of conversion to gas were obtained (97 to 99.5 percent) with use of 11 to 12 cu. ft. of oxygen per pound of coal. Difficulty was experienced from flashbacks in the oxygen-coal stream and from erosion and peeling of the refractory lining, with accumulation of refractory material in the slag and further difficulty in removal of slag (12, 13).

The unit was revised to use superheated steam to pick up the coal; this steam-conveyed coal was then fed through the center pipe of a nozzle, with oxygen entering through an outer, annular pipe. The damaged lower part of the refractory lining was replaced periodically with refractory brick or compounds, and efforts were made to reduce impingement of the flame on the lining by changing the burner angle and eventually by installing a second burner nozzle so that the two flames would meet. Operation with the steam-conveyed coal was satisfactory mechanically, and slag was tapped intermittently without difficulty. There still was minor erosion of the refractory surface.

In a final 209-hour run, carbon conversion was 87.6 to 93.3 percent, with 10 to 10.4 cubic feet of oxygen used per pound of dry coal. Raw coal was fed at 1,900 to 2,000 pounds per hour, to produce 62,000 to 68,000 cubic feet of synthesis gas (4, 14).

The somewhat inconclusive results showed the feasibility of injection of the pulverized coal with steam, and of intermittent slag tapping, allowing substantially continuous operation.

Technology Yet to Be Developed

Gasification With Oxygen and Steam

There are still many problems in pulverized-coal gasification. For evaluating the process of gasification with oxygen and steam, it is necessary to know the effects of heat loss and residence time on the oxygen, steam, and pulverized-coal requirements, per unit of $CO + H_2$ produced. To convert pilot-plant results to large-scale operation, we should know how decreased heat loss will change requirements for materials. The effect of heat loss can be calculated when certain assumptions are made, but the validity of the assumptions is open to question. To size the gasifier, it is necessary to know also the incremental effect of residence time. When the volume of the gasifier increases, by how much are material requirements decreased? Beginnings of work on these problems have been discussed above.

Gasifier construction presents several problems. Determining the effect of reactant ratios on refractory life should make it possible to minimize the total refractory and reactant costs. Further information is needed on types of metals to increase the life of injection nozzles. Removal of slag under pressure also needs further development. Methods for feeding coal to a gasifier at 30 atmospheres pressure are now under study.

For designing waste-heat boilers data are required on heat transfer between water and synthesis gas at 30 atmospheres. Other problems that could be studied with a prototype gasifier are the economics of recycling carbon and the removal of dust at 30 atmospheres and about 1,000° F. Successful solution of these problems should save oxygen, heat, and heat-transfer equipment.

Coal Gasification by Nuclear Energy

A study of coal gasification with nuclear heat substituted for the partial combustion of coal with oxygen has been planned in collaboration with the Reactor Development Division of the Atomic Energy Commission. This gasification with outside heat is attractive because it would obviate the need for oxygen and yield gas with more carbon monoxide and much less carbon dioxide, thereby reducing also the cost of gas purification.

As a first approach to this problem, the indirect cycle was chosen. In this system, an inert gas would be heated to temperatures above 2,500° F. in a nuclear reactor and subsequently give up its heat to a steam-coal mixture in a separate vessel (gasifier). Helium was chosen as the heat-carrying medium, because it is inert chemically and does not become radioactive when irradiated.

In order to study such a system, a bench-scale simulated nuclear test reactor has been designed and is being constructed (see fig. 19). This simulated reactor will consist of a 2-inch silicon carbide tube packed with 3/4-inch spheres of the same material. The tube will be heated externally with a carbon resistance element. Helium will be recycled through the sphere bed and heated to at least 2,500° F.

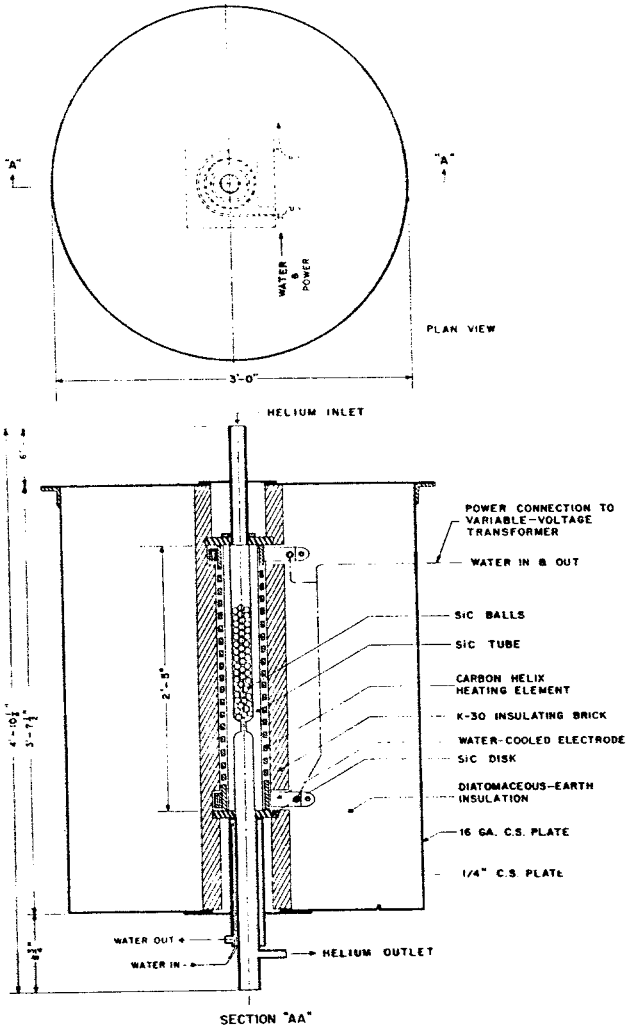

FIGURE 19. - Simulated Nuclear Reactor.

Tests of materials of construction and studies of high-temperature gas technology will be the first steps in adapting nuclear heat to coal gasification. The properties and reactions of such materials as silicon carbide, zirconia, zirconium carbide, etc., will be studied at high temperatures (2,500° to 4,000° F.) in the presence of steam, coal slag, carbon, and various constituents of synthesis gas.

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