It is anticipated that the large-scale gasifier now being built by a chemical company, which embodies many features of the design described here, will be in operation in 1955.

High-Pressure Gasification Pilot Plant

Operation of the high-pressure gasification pilot plant described in the 1953 report continued during early 1954. Twenty-three tests were made involving about 100 periods of varying operating conditions. These experiments, with Sewickley-bed bituminous coal, were designed to determine more accurately the effect of residence time and heat loss on the material requirements per 1,000 cu. ft. of product gas.

Previous work with the refractory-lined reaction chamber had not produced satisfactory results, for erosion of the refractory caused a progressive increase in reaction volume. With a water-cooled reaction space, the reaction volume was kept virtually constant. However, it was not possible to build up a thick layer of slag on the water coil. Heat losses were high, averaging about 900 B.t.u. per pound of coal. This did not vitiate the experimental work, and the significant effect of residence time on results was demonstrated. Modifications are being made so that the effect of heat loss may be determined. Flowsheets of the pneumatic coal feeder and pilot plant used in these tests were shown in the 1953 report.

A few tests were made with a high (35-percent) ash content anthracite culm. The results were unsatisfactory due to slag buildup in the gasifier and showed that the reaction-chamber coil design should be modified for each particular coal being gasified.

The tests of Sewickley-bed coal were arranged as a factorial experiment, using 3 oxygen-coal ratios, 3 coal rates, and 4 pressures. The steam-coal ratio was held constant at 0.3 lb. per lb. By use of the cocorrelation technique it was found that the oxygen requirement, expressed as std. cu. ft. per thousand std. cu. ft. $CO + H_2$, was a linear function of the heat loss, expressed as B.t.u. per thousand std. cu. ft. $CO + H_2$. The slope of this relation was found to be 3.0 std. cu. ft. oxygen per 1,000 B.t.u. heat loss. When results of the experiment were corrected by this relation to a constant heat loss, it was found that the residence time had a significant effect on both coal and oxygen requirements. Residence time was the gas-residence time, the volume of the reactor divided by the gas throughput rate at reactor exit conditions. Considering the turbulence in the reactor, gas residence time is the best approximation of particle residence time.

From results of the factorial experiment corrected to constant heat loss, empirical equations were derived for both coal and the oxygen requirements and the results plotted as figures 16 and 17. Figure 18 was obtained from the two previous figures and a material balance. Both coal and oxygen requirements were approximately linear functions of the reciprocal of residence time.

The optimum gasifier is that requiring the minimum oxygen and coal per unit of $CO + H_2$ produced. As the size of the gasifier is increased for a given throughput, residence time becomes longer; however, at the same time, heat loss also is increased by the increase in external area of the gasifier. These two changes have opposite effects on the oxygen and coal requirements. Therefore, to determine optimum gasifier design, a balance must be made between the increase in requirements produced by an increase in heat loss and the decrease produced by an increase in residence time.

Satisfactory methods were developed for obtaining gas samples from the gasifier, enabling a more accurate determination of the actual reaction volume. Information also was obtained that will make possible better designs of slag-removal equipment.

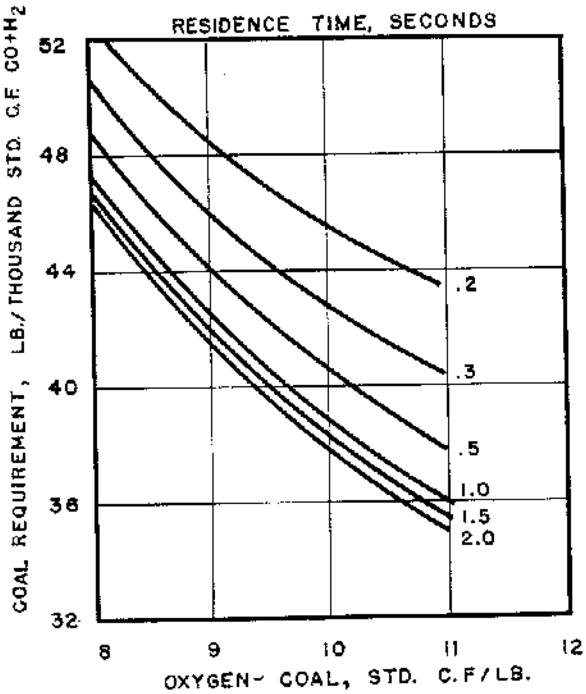

Figure 16. - Effects of oxygen-coal ratio and of residence time on coal requirement at constant heat loss of 36 B.t.u. per std. c. f. CO + H_2 (300 p.s.i.a.).

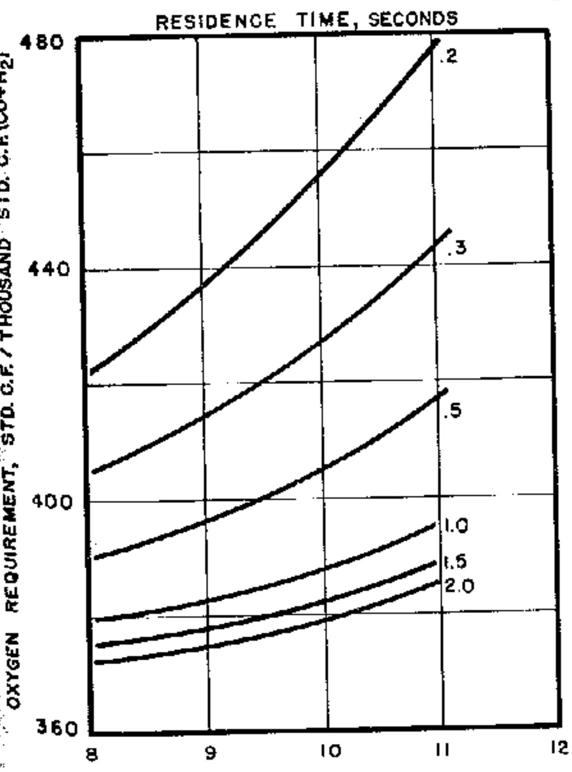

Figure 17. - Effects of oxygen-coal ratio and of residence time on oxygen requirement at constant heat loss of 36 B.t.u. per std. c. f. CO + H_2 (300 p.s.i.g.).

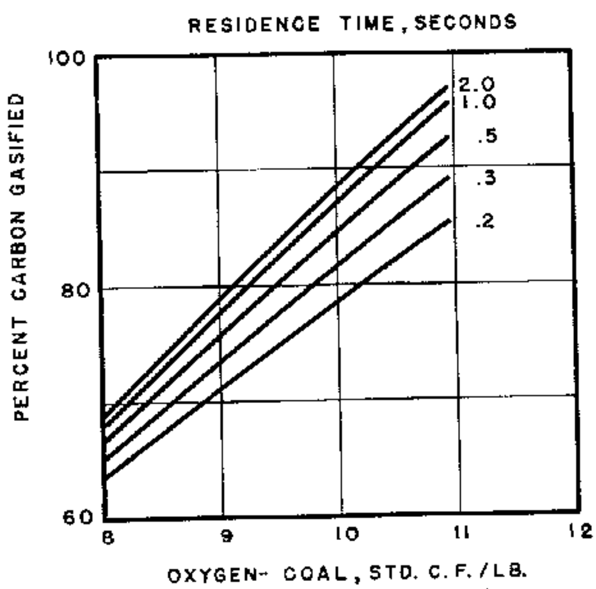

Figure 18. - Effects of oxygen-coal ratio and of residence time on carbon gasification at constant heat loss of 36 B.t.u. per std. c. f. CO + H_2 (300 p.s.i.g.).

in the pilot plant. The control equipment functioned very well, and it appears that a plant of this type can be operated by remote control, thus greatly increasing safety.

Experience with the water-cooled reaction space showed that, to obtain a satisfactory thickness of slag buildup on the water-cooled coil, it is necessary to establish an interrelationship between the following factors:

1. Rate of heat input to the reaction space (this depends on coal feed rate, oxygen-coal and steam-coal ratios).

2. Rate of heat loss to the coil (this depends on coil design, coolant rate, and temperature).

3. Ash-fusion characteristics.

The implication is that, to obtain a satisfactory slag deposit and thus keep heat losses at a minimum, the reactant-chamber coil design should be modified for each particular coal being gasified.

Projected Experimental Program

At present (November 1954) the high-pressure pilot plant and auxiliary equipment are being rebuilt and installed at the Morgantown Experiment Station. Further studies will be made of the effect of residence time and heat loss on the gasifier capacity, and of various methods for coal feeding as described later in this report.

A cross section of the redesigned gasifier is shown in figure 19 and details of the new refractory-lined reaction chamber are given in figure 20. The new lining provides for higher heat transfer at the point of reactant entry than at the exit. It is believed that, with this design, the reactant-chamber volume of about 2.4 cubic feet can be held reasonably constant. The relationship between heat loss and the oxygen requirement, per 1,000 cu. ft. of $CO + H_2$ produced, has been found for an average heat loss of about 35 B.t.u. per std. cu. ft. $(CO + H_2)$. If other points can be found at a heat loss of about 10 to 20 B.t.u. per std. cu. ft. $(CO + H_2)$, extrapolation to still lower values of heat loss in the range to be expected in large-scale equipment will be possible.

The bottom of the gasifier has been modified to permit better slag removal (see fig. 21), and provisions have been made for trying automatic slag-removal equipment if that appears desirable.

In figure 22 the high-pressure gasification pilot plant is shown under erection.

The program of experimental work now outlined will require several years to complete. It follows:

1. By repeating previous tests with the new refractory-lined reaction chamber, obtain more data on the effect of pressure, contact time, and heat loss on the percent carbon gasification and material requirements.

2. Obtain more information on the effect of diameter-length relationships of the reactant space. This is a coordinated study with that of reactant injection burner design.

3. Obtain additional data on the effect of coal rank on the completeness of carbon utilization under given conditions. Those data can be correlated with those obtained previously using the low-pressure gasifier.

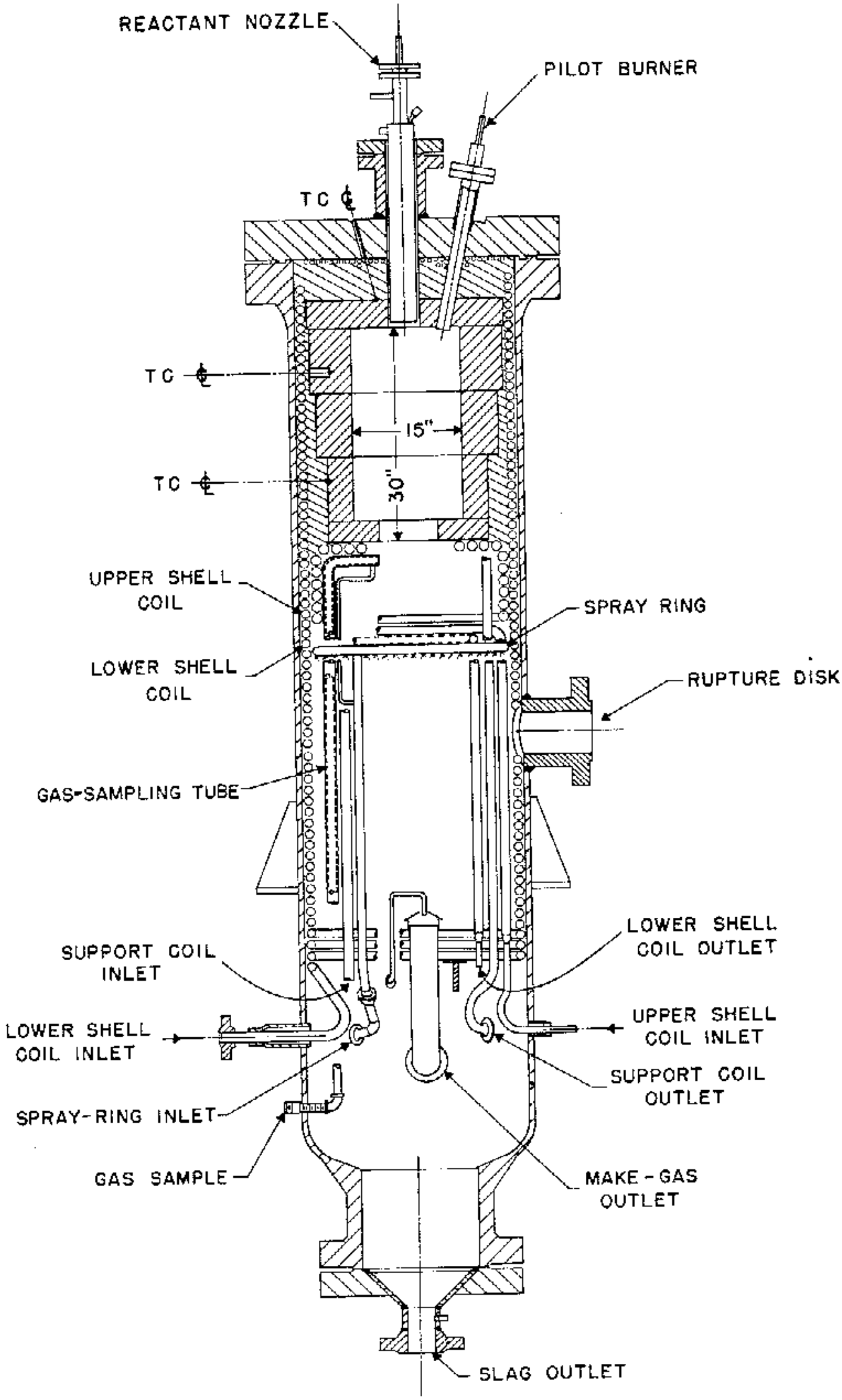

Figure 19. - Pressure gasifier No. 3.

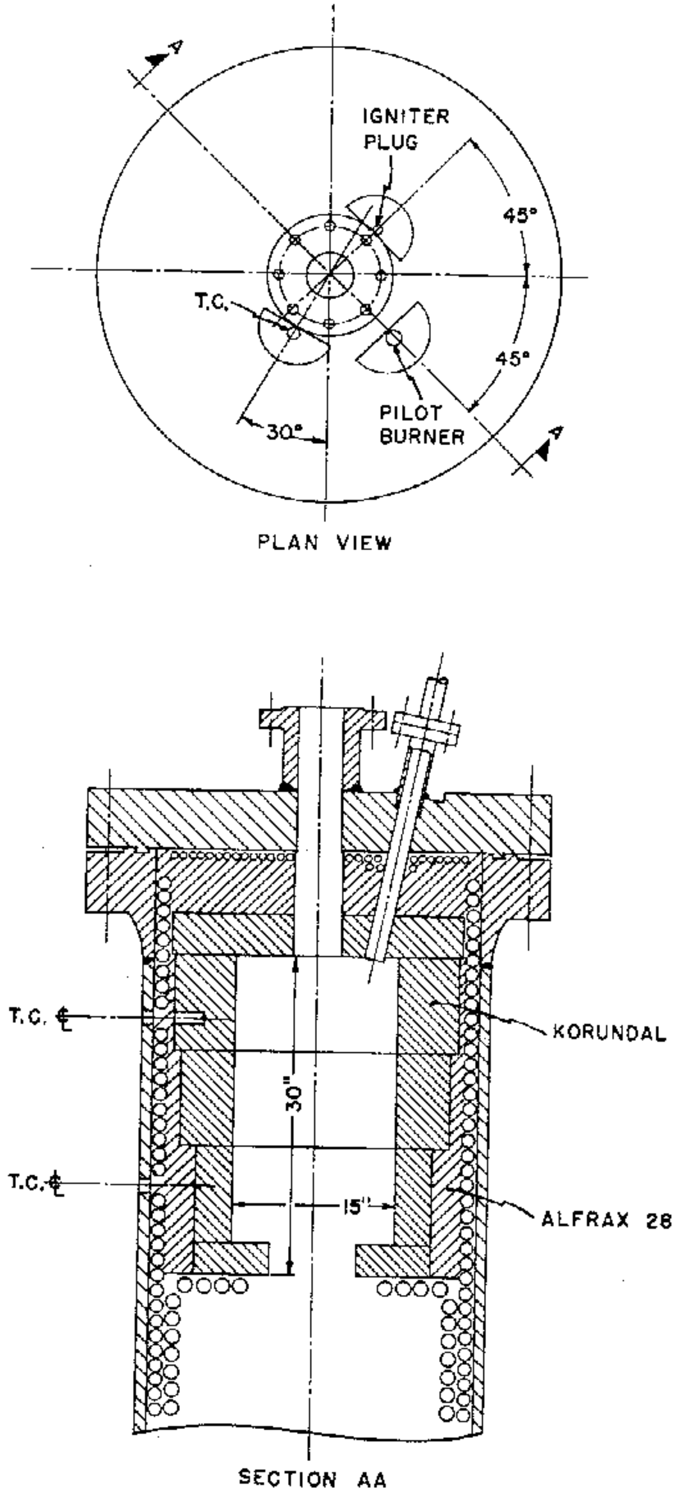

Figure 20. - Refractory lining of high-pressure gasifier.

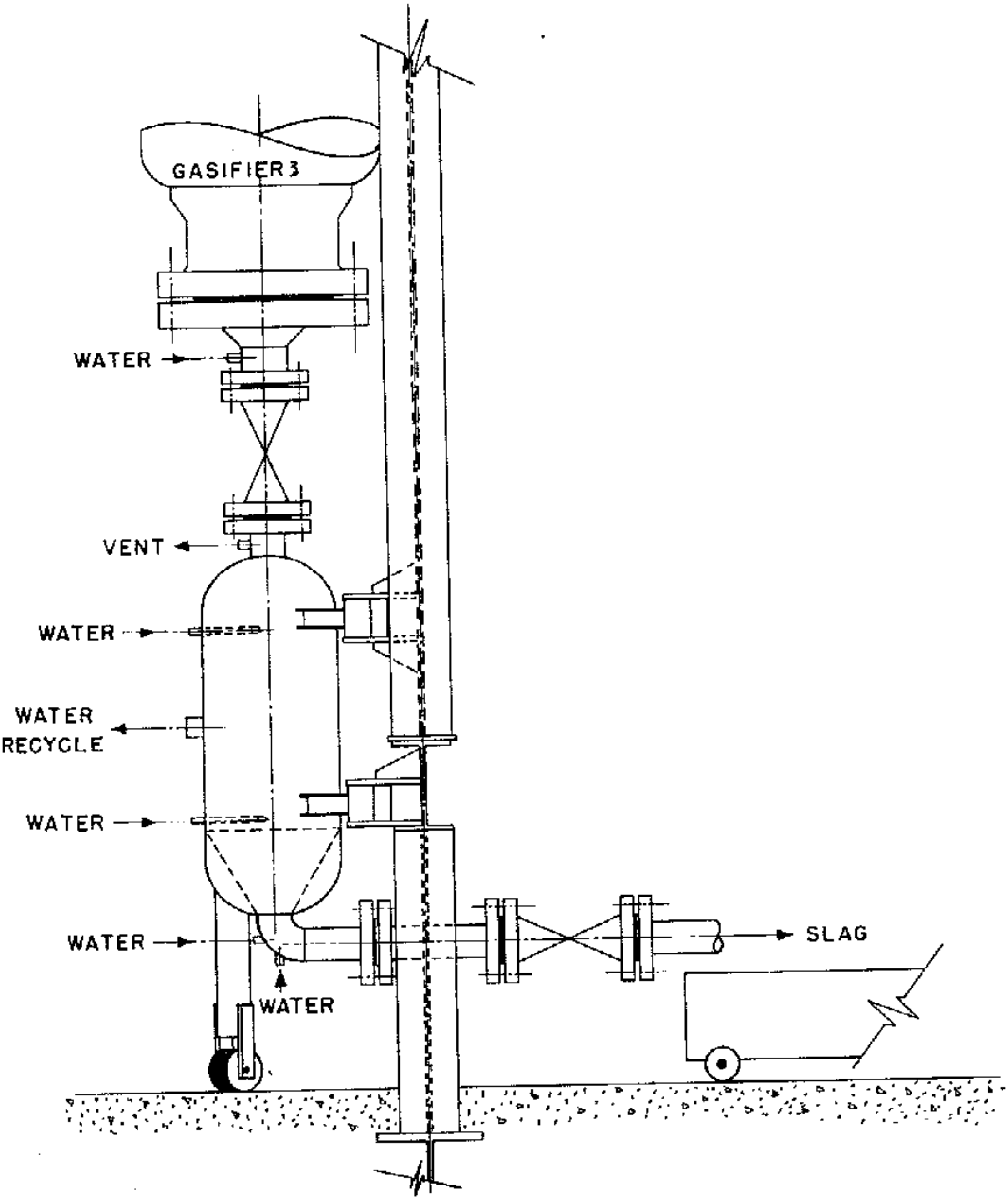

Figure 21. - Slag removal equipment of high-pressure gasifier.

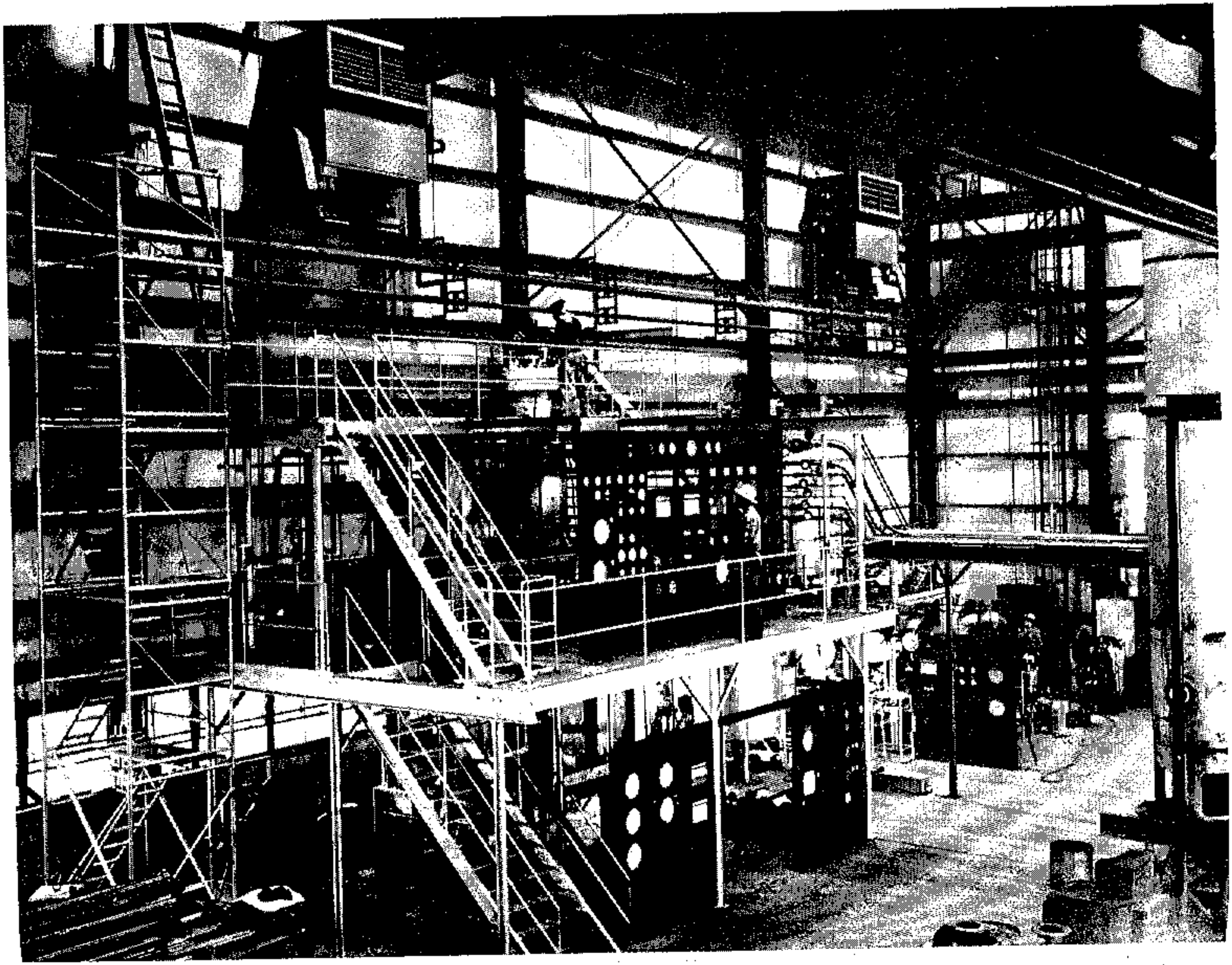

Figure 22. - High-pressure gasification pilot plant in Building 4, Morgantown Experiment Station. Operator on upper level stands near top of gasifier where reactants are injected. Scrubber is at left of gasifier and coal slurry feeding apparatus at right. Cylindrical container at extreme right is pneumatic coal feeder.

4. Obtain more data on high-pressure water scrubbing for dust removal.

5. Try out various coal-feeding methods.

Investigations of Coal-Feeding Methods

In the 1953 report experimental programs were outlined on coal slurry feeding (see fig. 23) and on a pickup system for adding pulverized coal to a flow of steam (see fig. 24). Because of the demands made by other research programs and the move to the new station, only preliminary data were obtained in 1954.

A small-scale system was set up to test the feasibility of pumping cold slurries containing 50 percent or more of coal in water. It consisted of a mixing tank, centrifugal recycle pump, two piston pumps in parallel, and orifices for creating a back pressure against the piston pumps. Sewickley-seam coal and anthracite were used.

The work has advanced to a pilot plant system for feeding a coal-steam mixture into a pressurized vessel. This unit (see fig. 23) is designed to mix, pump, vaporize, and superheat 1,600 pounds per hour of slurries containing as high as 50 percent coal in water. Subsequently the final mixture of steam and coal is fed into a pressure gasifier operating at 450 p.s.i.g. The system consists of:

1. A slurry mix tank, complete with turbomixer for obtaining intimate contact between the coal and water. The capacity of this mixing tank is 1 ton of slurry.

2. A slurry pump of the standard commercial duplex reciprocating type. The output may be varied from 1 to 5 gallons of slurry per minute at 600 p.s.i.g. The pistons and ball-type valves are made of 1808 stainless steel.

3. A slurry heater resembling a monotube boiler, which uses a continuous coil wound in two concentric helices made of 530 linear feet of 1-inch schedule 80 carbon-steel pipe. This coil is installed in a refractory-lined shell and heated with natural gas. The design assumed an overall heat transfer of 10,000 B.t.u. per hour per square foot of inside tube surface. Rating is 1,600 pounds per hour of 1:1 slurry at a pressure of 450 p.s.i.g. and a temperature of 800° F. Figure 25 shows the slurry-feeding system.

This equipment has been placed next to the high-pressure-gasification pilot plant to facilitate its use with that equipment. The following information is to be obtained:

1. Heat-transfer data, using water only, at heater-discharge pressures of 50, 100, 200, and 300 p.s.i.g., water-flow rates up to 2,000 pounds per hour, and discharge temperature up to 800° F.

2. Similar data using various coal-water mixtures. Coals used in preparing the slurries will be of varying degrees of fineness to determine the coarsest size that can be fed.

3. Data on the size distribution of the coal in the cold and heated slurry.

When satisfactory information at 800° F. has been obtained, higher heater-discharge temperatures, to the practical limit of the unit, will be tried. As preliminary experimental work indicates that it is impossible to lower the water content of the slurry enough for the steam-carbon reaction, an intensive program is envisioned to design a satisfactory separator for reducing the steam concentration in the steam-coal mixture. Also, a study will be made to find the best alloys for the slurry

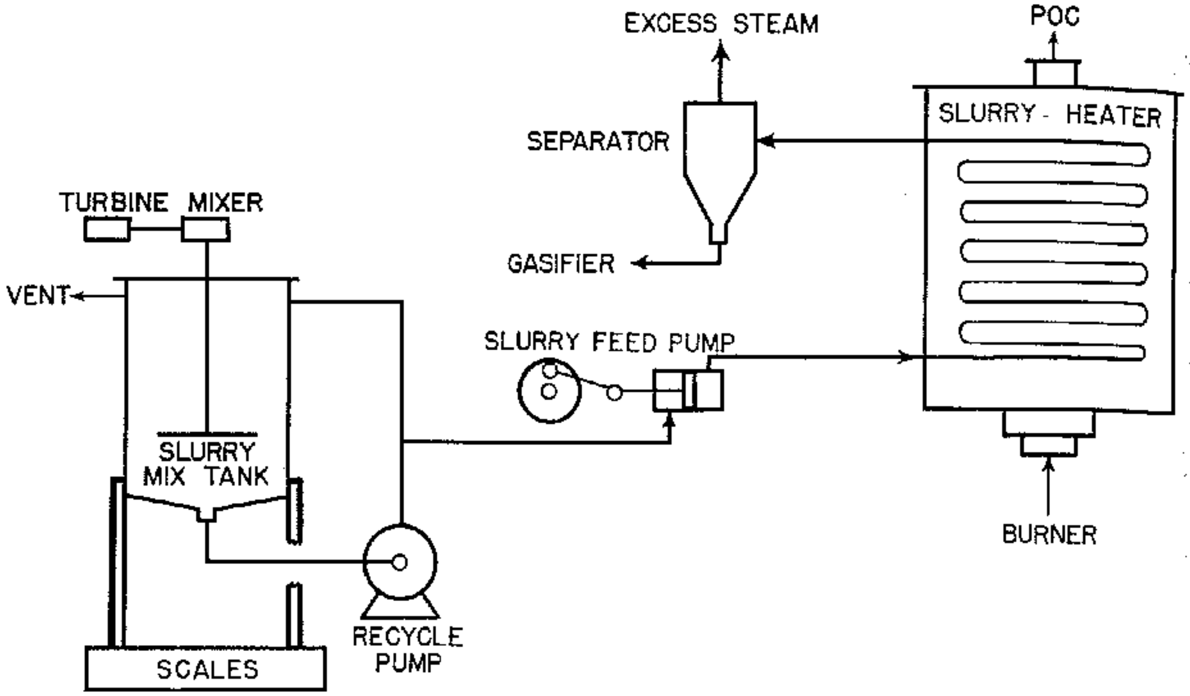

Figure 23. - Simplified flowsheet for slurry system.

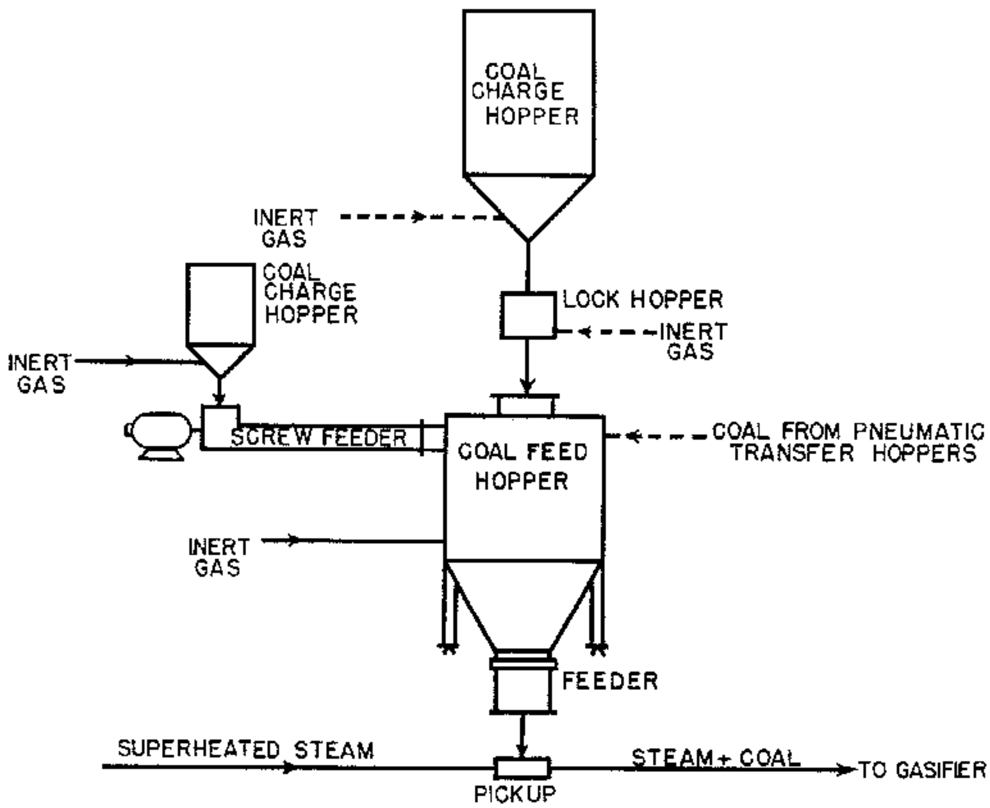

Figure 24. - Simplified flowsheet for steam pick-up system.

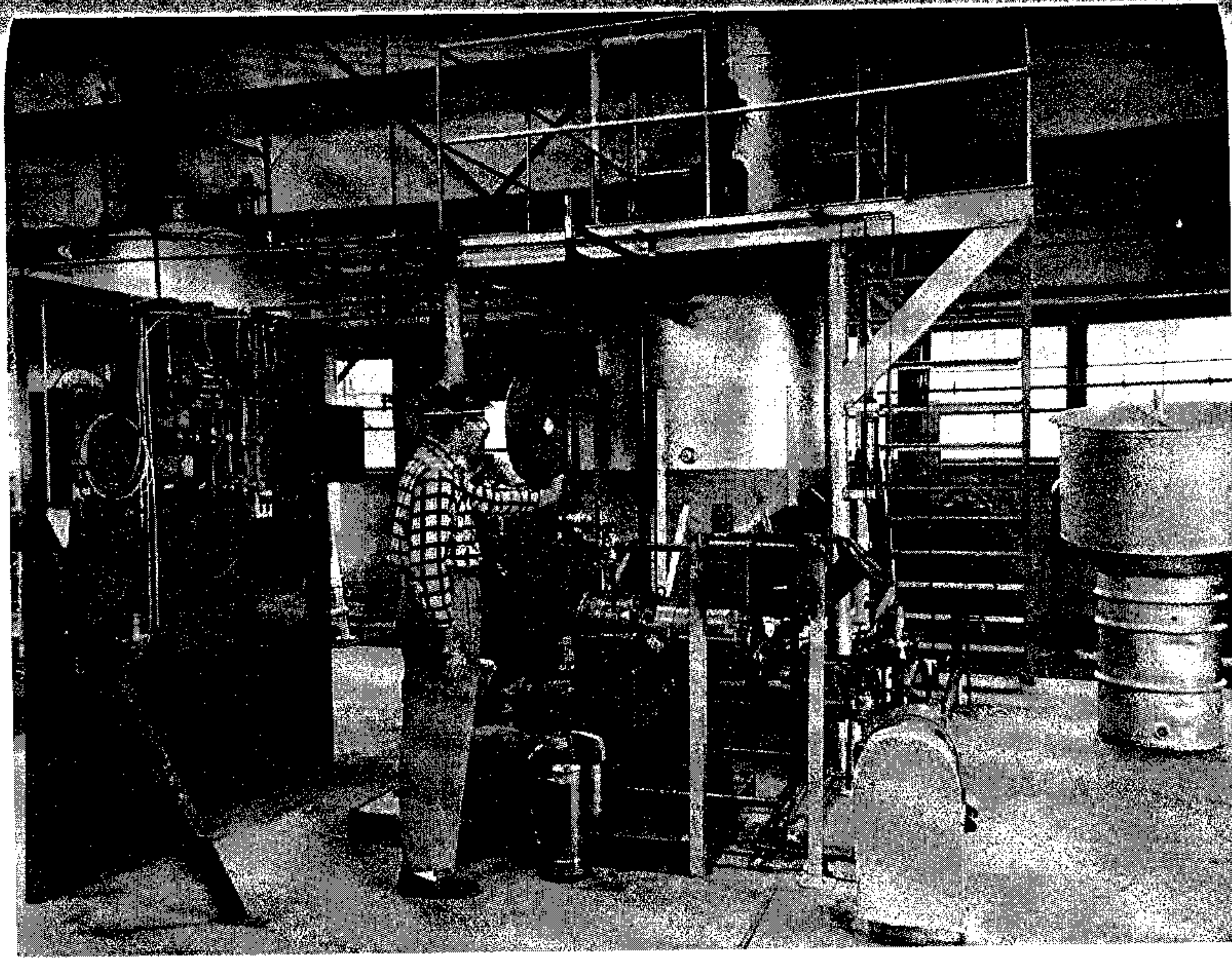

Figure 25. - Slurry-feeding system showing scale slurry pumps, mix tank, and rear of control panel in Building 4.