The product gases are being discharged to the atmosphere at temperatures up to 1,100° F. This value can be increased appreciably or decreased at will by varying the length of the cycles. The project is now being operated to store heat underground and thus raise temperature levels there.

The energy derived from coal by underground gasification processes may be utilized either in the form of sensible heat of the product gases or of the heat from combustion of combustible constituents.

A wide choice of operating methods can be applied to this installation. It was originally planned to use a uni-directional air blast; however, as was noted, it was necessary to use a process whereby the blast is reversed periodically. It may be that at a later date this path length will be increased to improve the quality of the product gases or to increase the capacity of the system. Oxygen-enriched air or an oxygen-steam blast have been considered for use in underground gasification and undoubtedly would improve the quality of the product gases obtained; however, fundamental information can be gained from the use of a simple air blast at a much lower cost. Efforts are being made to improve the air blast-coal contact to generally improve the conditions so far obtained on this first section of the project that is being operated.

RESEARCH ON THE PRODUCTION OF SYNTHESIS GAS

Gasification of Pulverized Coal

As a result of substantial improvements made in this simple and easily controlled laboratory-scale synthesis gas process, it is now possible to gasify continuously the most strongly coking coals as well as the cheapest low-grade coal of high ash and sulfur content. The small-scale pilot plant built is particularly well-suited for testing various types of fuels for their synthesis gas-making properties. This is of the utmost importance in designing large-scale equipment, as appreciable differences exist among coals of various ranks and types in completion of gasification, yield of synthesis gas oxygen and steam requirements, etc.

A laboratory-scale pilot unit was designed and a method developed for the gasification of 10 to 50 pounds of pulverized bituminous coal per hour by entrainment in oxygen and steam at generator temperatures ranging from 1,800° to 2,400° F.

A flow sheet (fig. 23)70/ shows the coal-feeding system, the generator chamber, and the following dry residual-dust and fly-ash recovery system. The synthesis gas was then metered, tested, and either stored or vented.

During the first 40 runs, coal up to 30 pounds per hour, pulverized so that 80 to 90 percent passed a 200 mesh-per-inch screen, was fed continuously into the generator from a conical feed hopper in which the coal was kept in a turbulent state by fluidizing nitrogen or natural gas. The charge was moved from the hopper through a vibrated tubular trough and was dropped into the water-cooled generator head at a rate uniform over any given hourly period.

Before each run, the 7-foot long, 6-inch wide, circular generator chamber, whose upper 5-foot length was lined with silicon carbide, was preheated by two natural-gas

70/ See footnote 6.

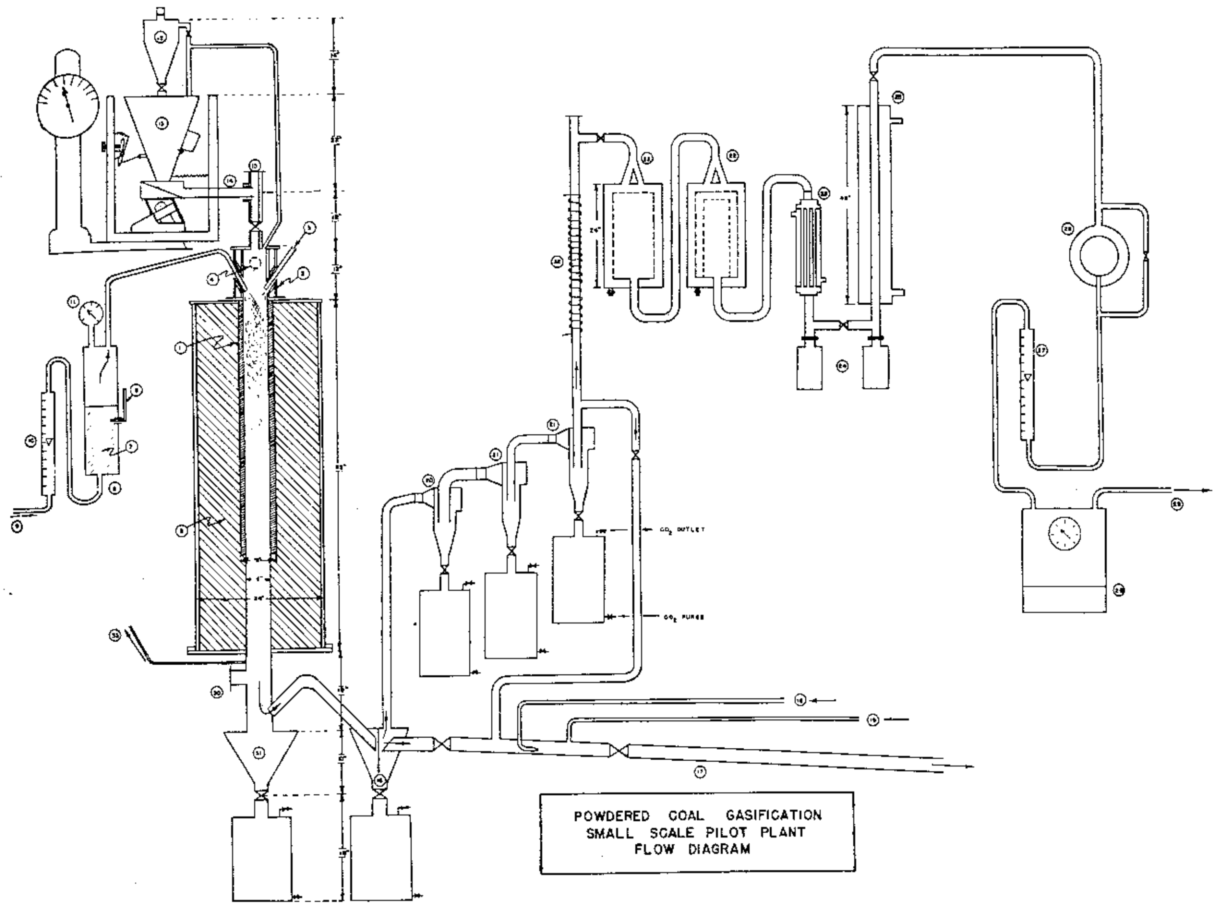


Figure 23. - Flow diagram of small pilot plant for powdered-coal gasification.

1. Silicon carbide generator tube.
2. Water-cooled jackets.
3. Oxygen jets.
4. Burner ports.
5. High-temperature insulating brick.
6. Steam:oxygen ratio controller.
7. Water.
8. Thermometer.
9. Oxygen.
10. Flow indicator.
11. Pressure gage.
12. Charge hopper.
13. Syntron hopper and vibratory feeder.
14. Feed tube.
15. Rupture disk.
16. Knock-out chamber.
17. 2-inch ejector pipe.
18. Steam to jet.
19. Water.
20. 3-inch Aerotec tube.
21. 2-inch Aerotec tube.
22. Fiber-glass filters.
23. Tubular condenser.
24. Condenser water.
25. Secondary condenser.
26. Exhauster.
27. Rotameter.
28. Dry meter.
29. To gas holder.
30. Rupture disk.
31. Slag and residue collector.
32. Heating coil.
33. Gas sample to instruments.

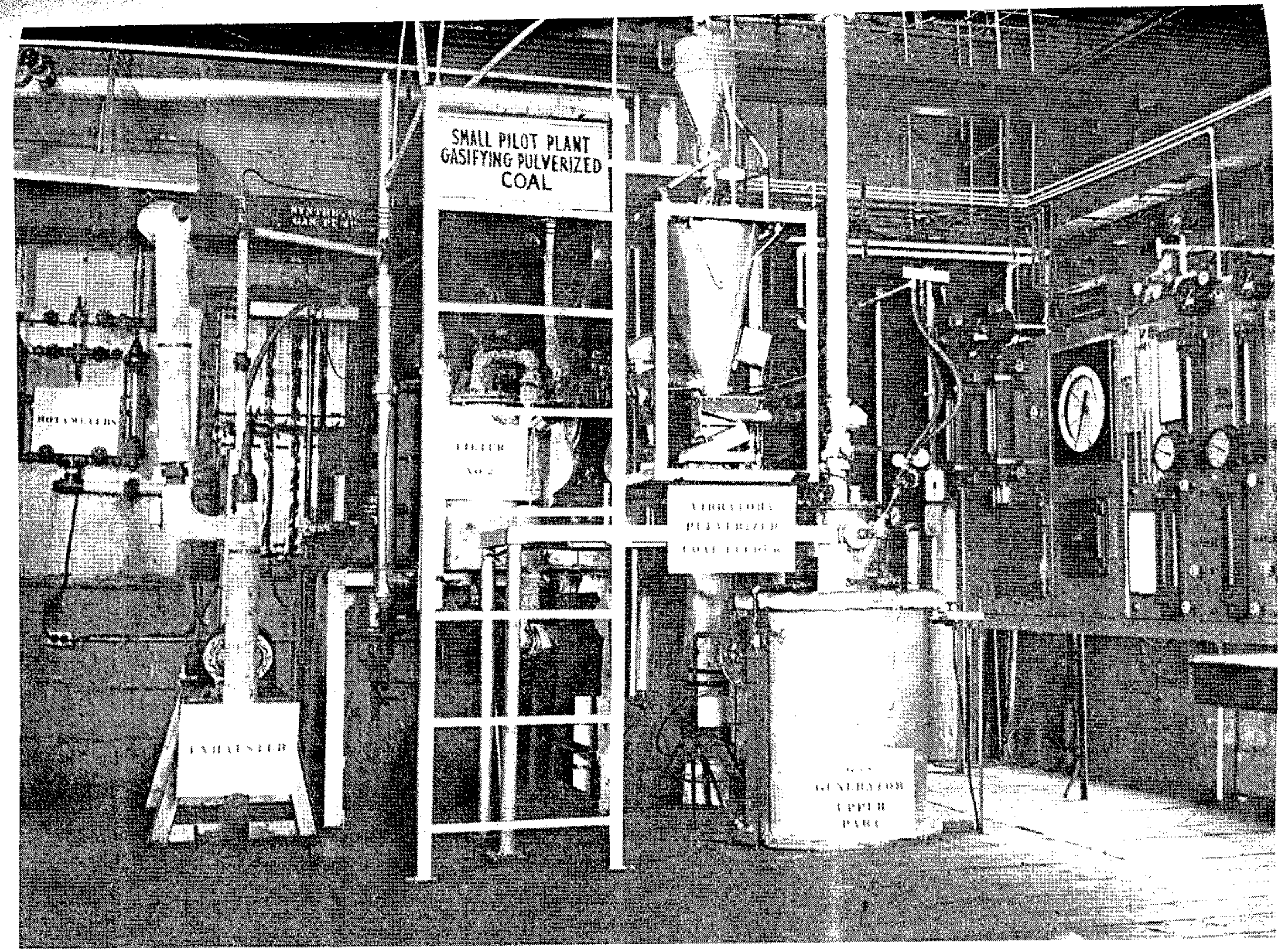


Figure 24. - Upper section of small pilot plant for gasification of pulverized coal at synthesis-gas production laboratories, Morgantown, W. Va.

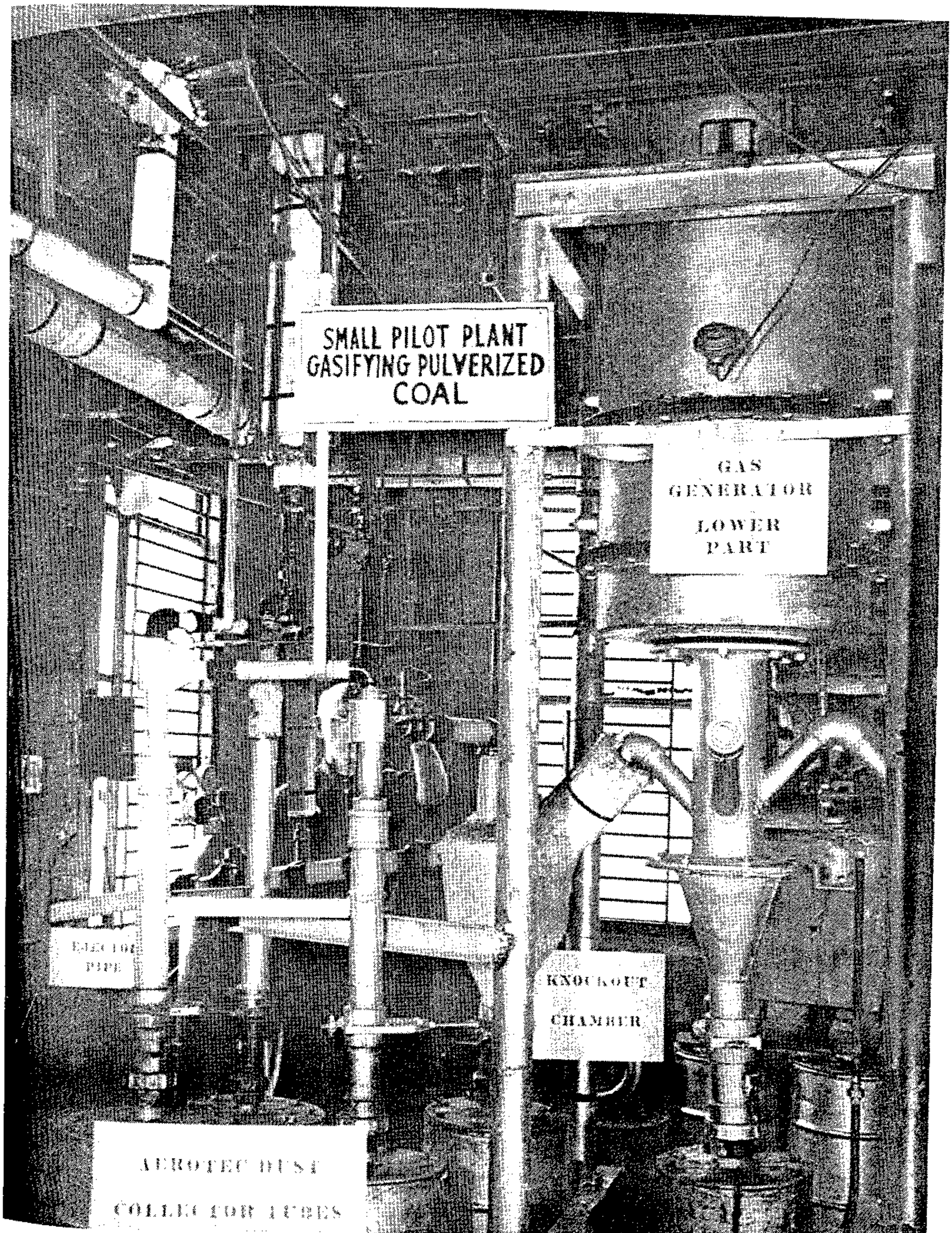


Figure 25. - Lower section of small pilot plant for gasification of pulverized coal.

flames until the upper half of the lining reached a temperature of about 2,300° F. The run was then begun by shutting the burners off and starting charging of the coal and introduction of oxygen. Steam could be added by passing the oxygen used for gasification through saturating water at constant temperatures, which permitted a close control of the ratio of steam to oxygen.

In the gasification chamber, the fine-coal particles quickly became entrained in turbulent currents resulting from impingement of the two oxygen-steam jets. The carbon in the coal reacted with oxygen to form carbon monoxide and with steam to form carbon monoxide and hydrogen, in addition to minor amounts of other gaseous constituents. Owing to the intentional use of excess carbon and deficiency of oxygen, a certain amount of carbonaceous residue was carried along, together with fly-ash, by the downward-flowing stream of synthesis gas. Coarser particles of slag and residue dropped into the "dust collector" beneath the generator, and the remaining extremely fluffy and light residual dust was recovered in the subsequent units shown in the flow diagram.

The products of gasification could also be discharged through a 2-inch ejector pipe to the outside atmosphere until conditions at the beginning of each run became stable. A constant pressure (up to 3 inches of mercury gage) was maintained in the generator by means of an exhauster, at the end of the train, controlled by a pressure regulator.

Pictures of the upper and lower sections of the small-scale pilot plant are shown in figures 24 and 25.

For the development of the process, a noncoking, high-volatile, bituminous coal from Rock Springs, Wyo., No. 9 seam was used. The coal as charged contained 4.5 percent moisture, 4.9 percent ash, and 37 percent volatile matter, and its ultimate analysis showed 11.9 percent oxygen and 0.8 percent sulfur.

The synthesis gas made in the first 40 runs generally contained 25 to 30 percent of hydrogen, 45 to 50 percent of carbon monoxide, 1 to 2 percent of methane, 0.5 to 1.0 percent of oxygen, 0.2 to 0.9 percent of unsaturated hydrocarbons, 10 to 18 percent of carbon dioxide, and 1 to 2 percent nitrogen. The heating value and specific gravity of the synthesis gas ranged from 240 to 310 and from 0.72 to 0.81, respectively.

A gradual improvement in the quality of the synthesis gas made, i.e., decreasing carbon dioxide content, was observed as the steam-to-coal and oxygen-to-coal weight-ratios were lowered from 0.7 to 0.2 and from 1.4 to 0.7, respectively. In spite of this, owing to unavoidably high heat losses caused by operating the generator below its maximum capacity, the oxygen consumption, 300 to 400 cubic feet per 1,000 cubic feet of "make gas", remained high, as expected. In large-scale production, provided that the generator is run close to its maximum capacity, the consumption of oxygen should be considerably less, probably only half as much.

Approximately 61 to 67 percent of the coal charged was actually gasified, corresponding to a coal consumption of 27 to 33 pounds per 1,000 cubic feet of gas made. The low percentage of conversion of coal into gas was due partly to the use of excess carbon, which permits the production of a synthesis gas low in carbon dioxide and allows a considerable saving in the cost of oxygen. The carbonaceous residue, containing 25 to 30 percent ash, could be recycled and further gasified. However, owing to the extremely fine particle size (50 percent less than 7.5 microns) and highly fluffy consistency (bulk density: 2.0 to 2.5 pounds per cubic foot) of the residue, its industrial utilization is not excluded. As shown in figure 26, the particles of the residue approach the characteristic shape, structure, and size of certain commercially used carbon blacks.

The over-all thermal efficiency of the process, i.e., ratio of B.t.u. in coal, was 74 to 82 percent, notwithstanding the high heat losses due to the reasons mentioned. The temperature of the generator was 2,200° F. to 2,450° F. on the top and 1,250° to 1,750° F. at the outlet on the bottom, depending on the combination of several experimental variables. The proportion of steam decomposed was generally 50 percent. The larger pilot plant for pulverized-coal gasification was described 71/ and is shown in figure 27. This plant was completed to the point where gasifying runs were started in the Fall of 1948. To date, approximately 13,000 pounds of coal has been gasified with excellent results at rates ranging from 200 to 350 pounds per hour. Gasification efficiencies of over 85 percent were obtained in these runs, and the thermal efficiency of steam superheating in the range 3,000° to 3,600° F. has been satisfactory.

Sufficient data on refractories have been obtained so that construction of steam superheaters or pebble stoves for continued operation at temperatures up to 4,000° F. can be started soon.

The pneumatic feeder (fig. 28) for pulverized coal has given excellent results in supplying a constant feed of coal to the generator.

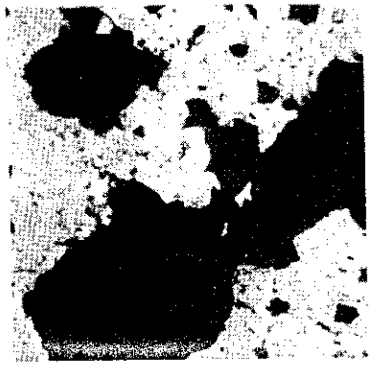
A pneumatic feeder 72/ has been developed for feeding pulverized solids to a zone of utilization. This feeder gives promise of solving one of the most difficult problems in conducting heterogeneous reactions, as it provides a method of feeding solids at a uniform rate to a reaction zone. The feeder operates by forming a fluidized bed of solid and gas, from which the solid flows with its carrier gas in dense-phase flow. Most of the fluidizing gas is vented from the top of the apparatus and can be recirculated. A shield around the entrance to the delivery tube evens out the bulk density of the bed, so that the ratio of solid to gas entering the tube is essentially constant. Figure 29 shows a feeder designed to deliver 10 tons per hour of coal to a gasifier operating at 150 p.s.i.g. The carrier gas used in this feeder is synthesis gas.

Studies have been made of the operating characteristics of the feeder, using pulverized coal as the solid and air as the fluidizing gas. It has been found that the coal-air mixture flows through the delivery tube in streamline motion. The viscosity of the mixture is about 30 times that of air alone. The volume-percent of coal in the delivery tube is about 20 percent, and it is controlled by the velocity of the air flowing up through the fluidized bed. Figure 30 shows the calibration curve of the feeder at present installed at the Morgantown pilot plant. This feeder has been found to be quite reliable and accurate.

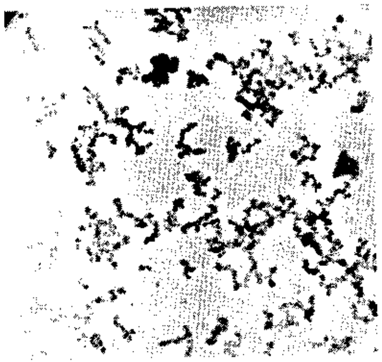
71/ See footnote 6.

72/ Albright, C. W., Holden, J. H., Simons, H. P., and Schmidt, L. D., Pneumatic Feeder for Finely Divided Solids: Chem. Eng., vol. 56, 1949, pp. 108-111.

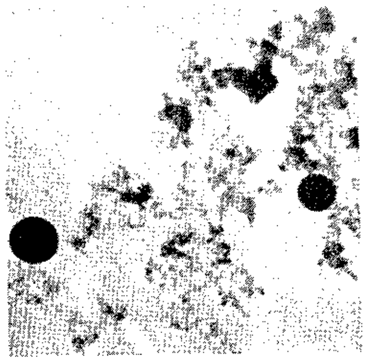
1000 X
Original coal
91% through 200 mesh



1000 X
Carbonaceous residue
from "Dust Collector"



10,500 X
Carbon black
Explosion of acetylene
and natural gas



11,100 X
Carbonaceous residue
from "Dust Collector"

Figure 26. - Electron micrographs of carbonaceous residue obtained in pulverized coal gasification.

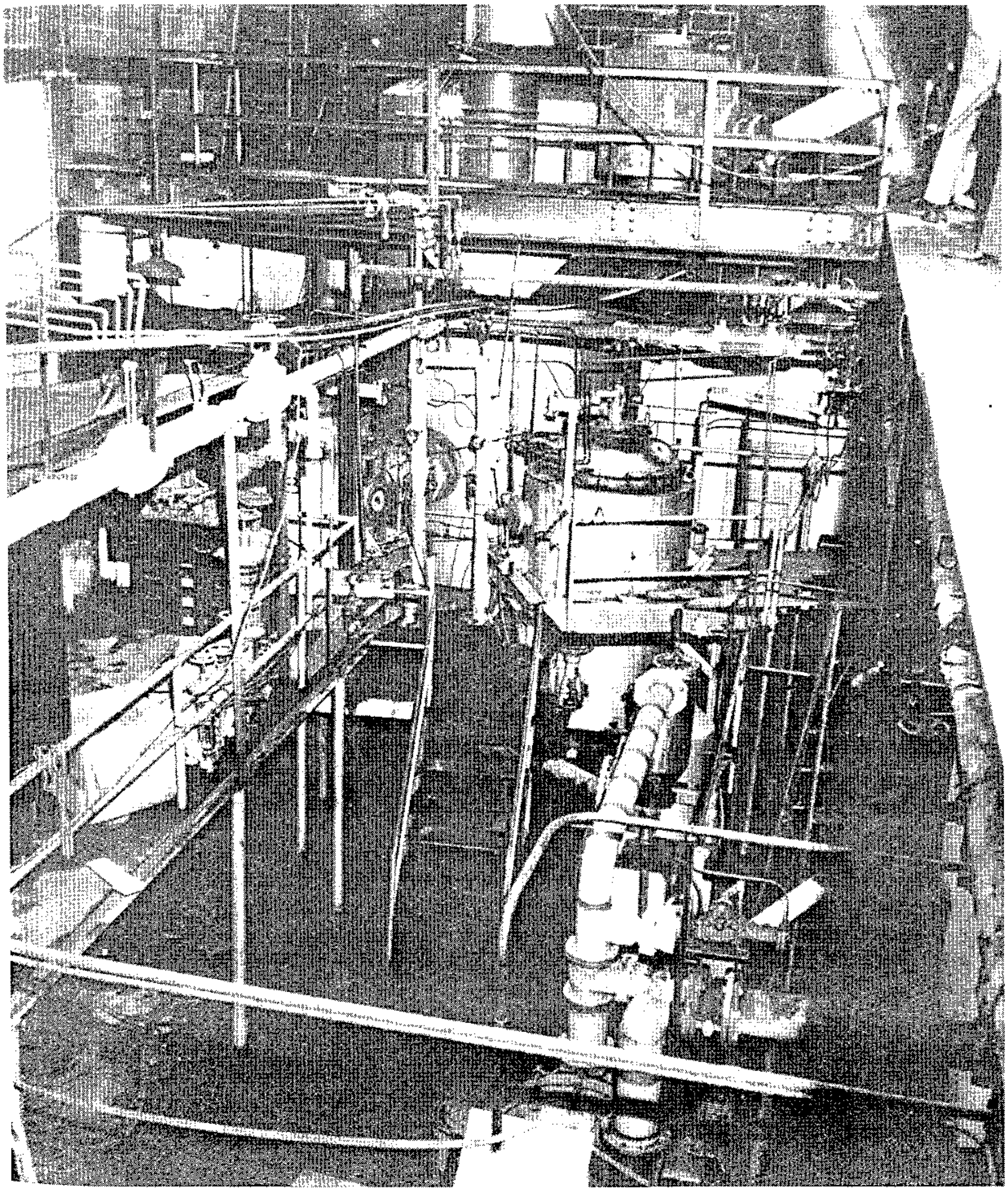


Figure 27. - Inside of pilot plant showing construction work during installation of automatic control equipment, Morgantown, W. Va.

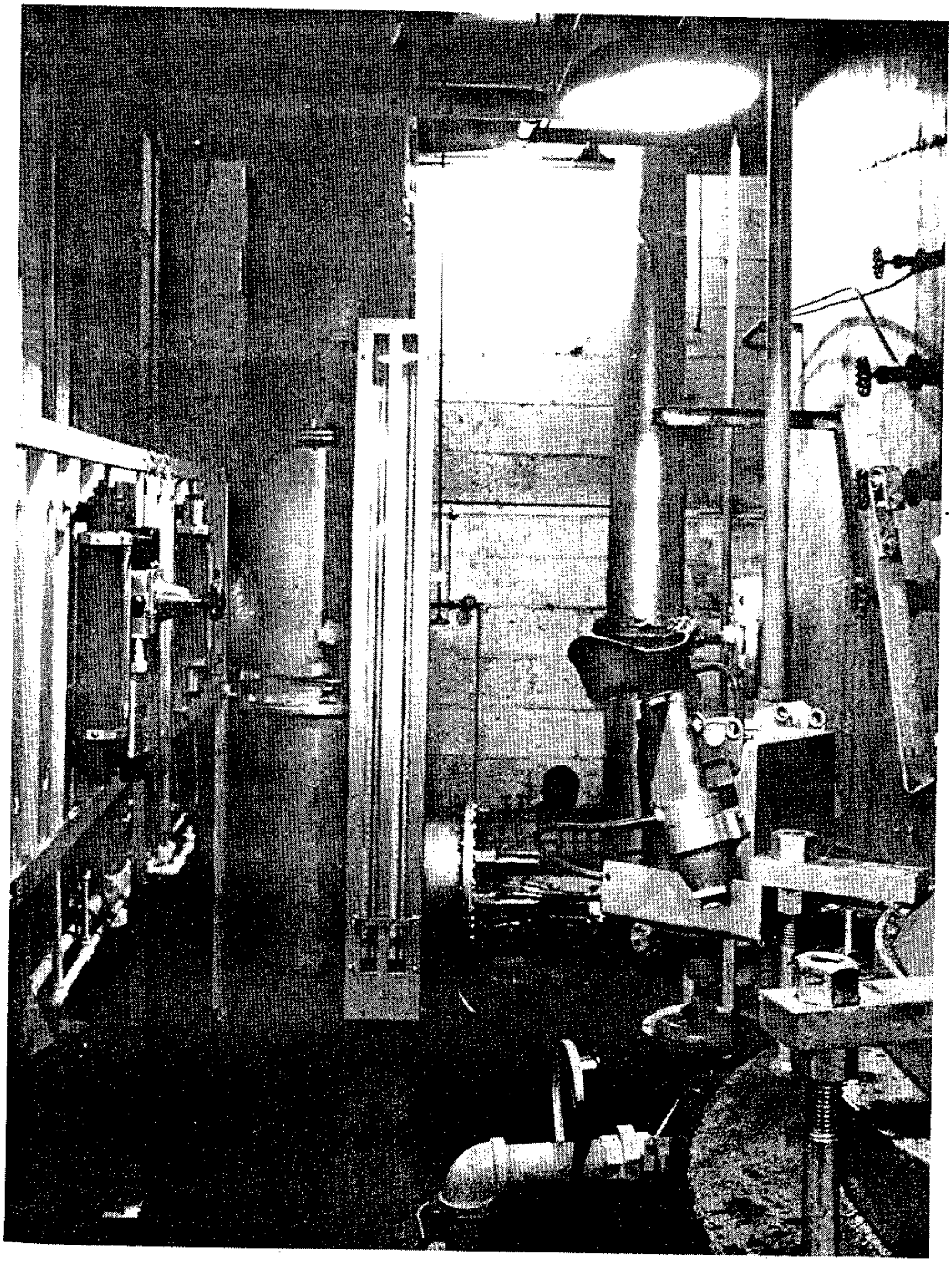


Figure 28. - Pneumatic feeder for charging pulverized coal to gas generator.

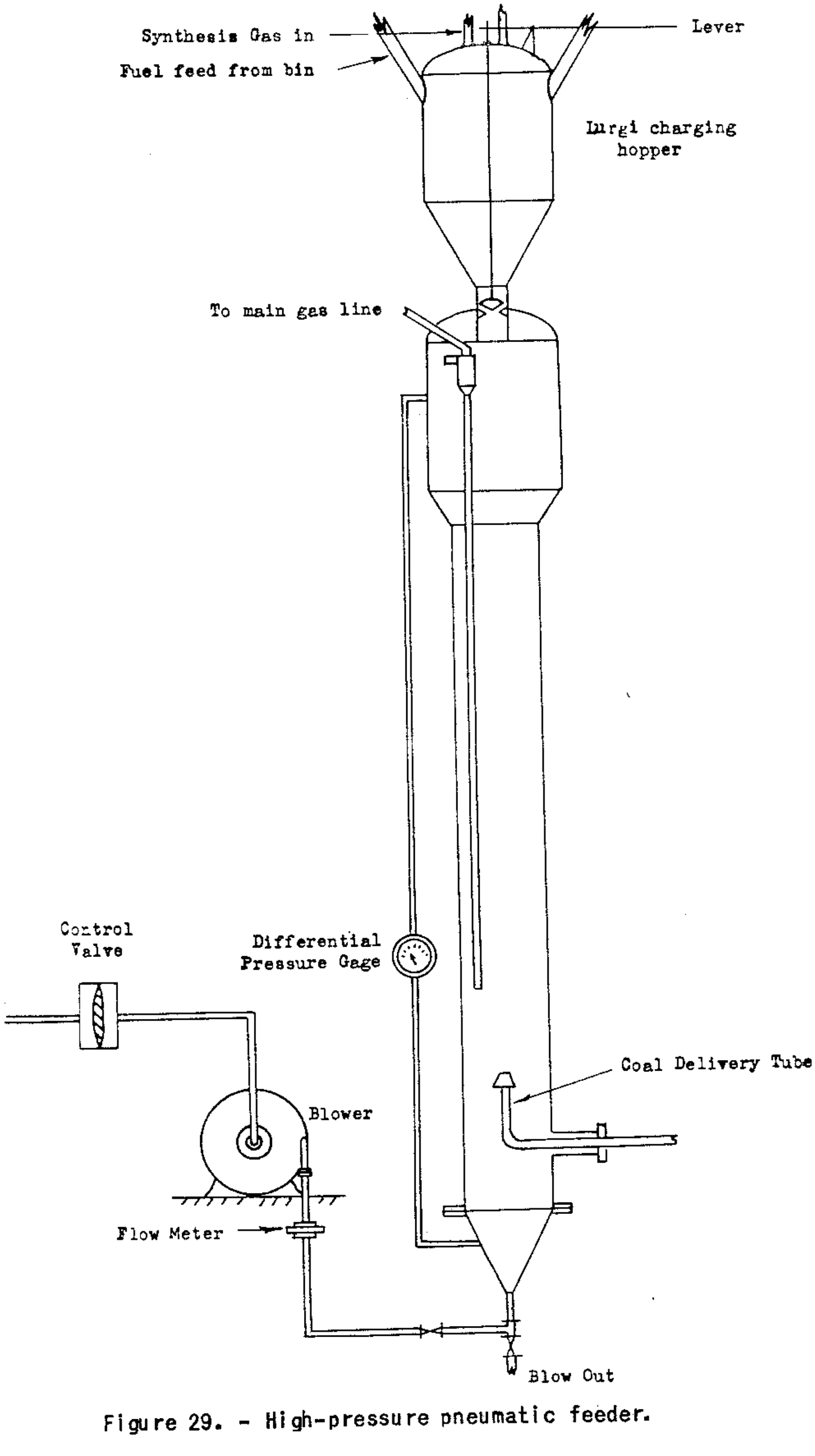


Figure 29. - High-pressure pneumatic feeder.

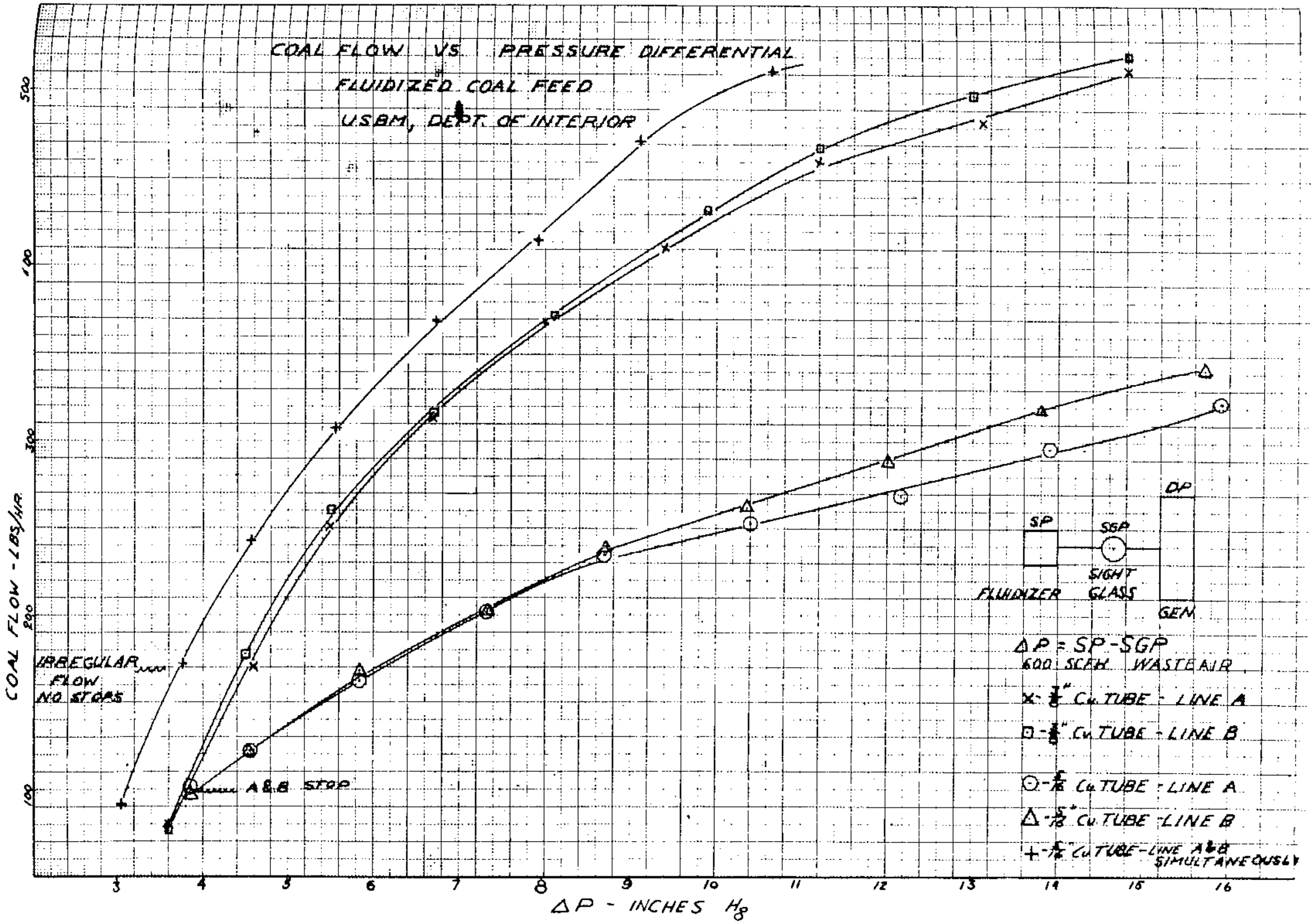


Figure 30. - Calibration of pneumatic feeder.