Gasification in improved larger-capacity unit with pneumatic coal-feeding and dry-residue recovery system

The pneumatic coal-feeding system especially developed by the Morgantown Station of the Bureau of Mines[17] permitted charging powdered coal into the generator at a much more constant feed rate and also allowed an increased coal throughput up to about 50 pounds per hour. Charging the coal at a

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[16] Each burner developed 155,000 B.t.u. (gross) per hour, consuming 135 cu. ft. of natural gas per hour.

[17] Albright, C. W., Holden, J. H., Simons, H. P., and Schmidt, L. D., Pneumatic Feeder for Finely Divided Solids: Chem. Eng., vol 56, June 1949, p. 108.

uniform rate and its very thorough mixture with oxygen prior to injection into the generator at a high velocity, together with a considerably increased capacity, resulted in substantial improvements in the quality of the synthesis gas made, in the percent of coal gasified per pass, and in the thermal efficiency of the process.

The generator head was redesigned in order to suit the pneumatic method of charging the coal. Details of the latest arrangement, together with the "fuel-oxygen mixing chamber", representing the third stage of development, are shown in figure 5, and a flow diagram of the entire feeding system is shown in figure 6.

The finely powdered coal, 70 to 90 percent of which passes through a 200-mesh screen, is charged from a hopper into one of the two intermittently operated "batch-feeders", 6 feet high and 10-inch I. D. cylindric steel vessels, in which the coal is kept in a fluidized state by air introduced at the bottom of the vessel at a rate of about 5 standard cubic feet per minute. The excess air leaves the vessel at the top, as shown in figure 6. While one of the batch-feeder vessels is in operation, the other one is loaded with fresh coal. A small "inverted funnel" is used as outlet from the batch feeder vessels.

Coal in a fluidized state is removed continually from one of the batch feeders through a 3/16-inch copper delivery tube (3 mm. I. D.) into the so called "continuous feeder," a cylindric steel vessel of 4 inches I. D., in which a fluidized bed is maintained at a constant level. Fluidizing air is introduced at the bottom of this feeder at a rate of about 2 standard cubic feet per minute, so that the superficial velocity of the air passing upward is about 0.3 foot per second. The excess air is released through an outlet at the top and is passed into an auxiliary small dust-recovery train, which removes the small amount of powdered coal carried along by the excess air before it is vented. The coal dust recovered is returned to the system. At the same time, coal from the continuous feeder is delivered in fluidized state through another 3/16-inch tube, serving as feed line, into the "fuel-oxygen" mixing chamber situated above the generator.

The movement of the coal, carried by a surprisingly small quantity of air, through the 3-mm. I. D. feed lines is caused by pressure differences between the vessels. The static pressures maintained in the batch feeder, continuous feeder and fuel-oxygen mixing chamber are 8.5 to 9.5, 5.0 to 6.0 and 2.0 pounds per square inch, respectively. As the pressure in the generator is kept essentially constant at a slight positive value, and as the oxygen is injected into the mixing chamber at a fixed pressure and flow rate, the existing static pressure in the latter is constant. Therefore, as the constancy of the feed rate of the coal in pounds per hour is a direct function of the pressure differential ($\triangle$ P) between the continuous feeder and the mixing chamber, it is essential to maintain the static pressure in the continuous feeder constant or vary it automatically when slight fluctuations occur in the pressure of the generator. The objective of the differential pressure controller shown in figure 6 is to maintain the value of $\triangle$ P constant at 3.0 to 4.0 pounds per square inch, depending on the coal feed rate desired.

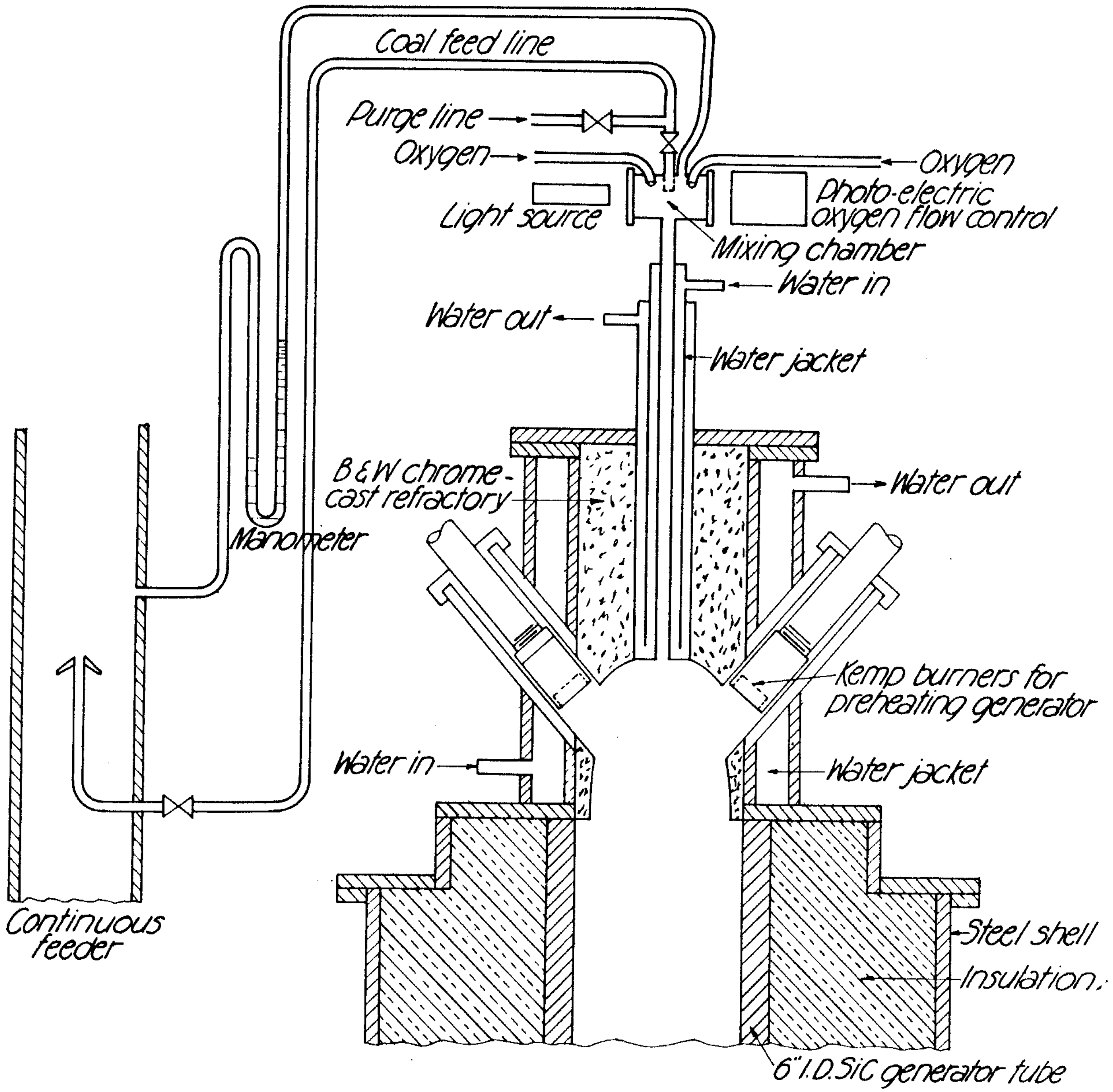

Figure 5. - Generator head and mixing chamber in third stage of development.

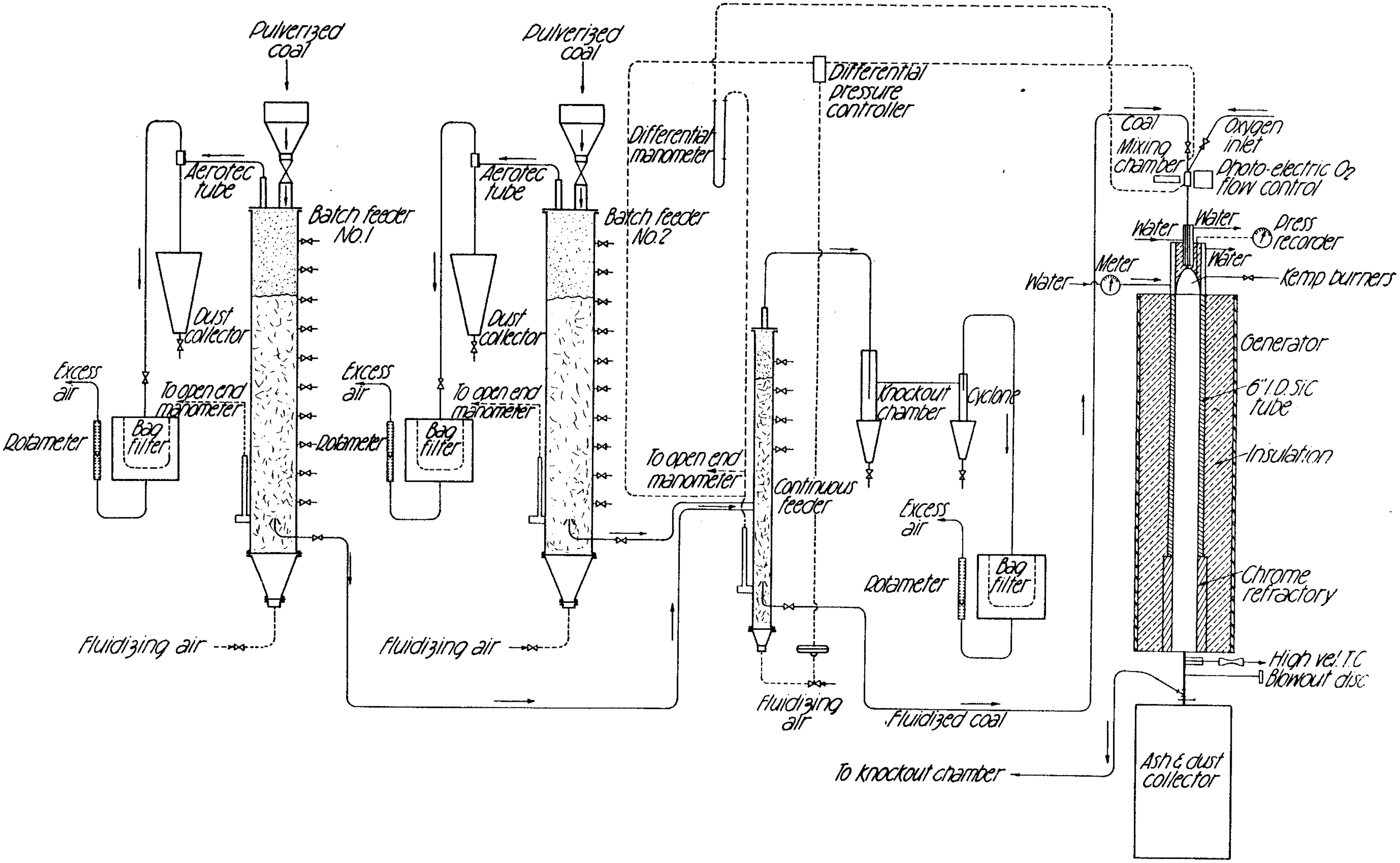

Figure 6. - Flow diagram of pneumatic feeding system and generator in third stage of development.

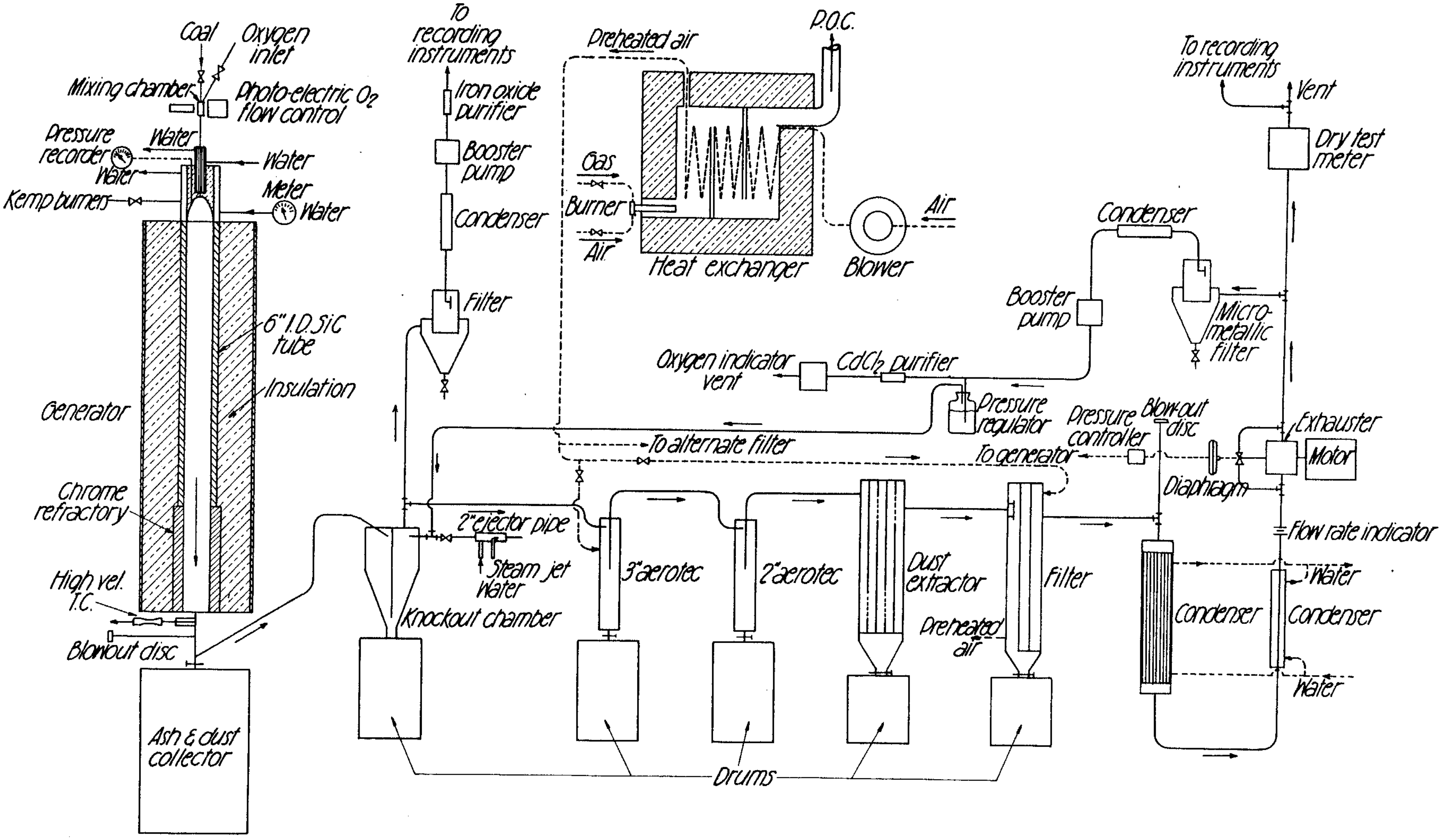

Figure 7. - Flow diagram of generator and residue-recovery system in third stage of development.

The oxygen mixing-chamber, the purpose of which is instantaneous entrainment of the coal in oxygen, is provided with two parallel sight glasses, which are swept clean by the oxygen entering at four points into the chamber. At the same time, the oxygen intimately mixes with the powdered coal and carries it as a continuous stream through a water-jacketed 1/4-inch, standard, alloy-steel pipe of 0.339-inch I. D. and 3 feet in length into the generator. Efficient cooling of the oxygen-coal stream is highly essential down to the point of inlet into the refractory-lined generator-head in order to prevent the coal particles from clogging the entrance, owing to their plasticity, caused by the intense radiation of heat. Just as important is the high velocity of the stream, 110 to 130 feet per second, which is about four times the calculated rate of flame propagation, so that any possibility of "flashback" is excluded. A sudden change of velocity of the oxygen-coal stream below the point of injection causes a high degree of turbulence and rapid heating of the coal particles to the temperature of gasification (2,000° to 2,200° F.), passing through the plastic stage so rapidly that their agglomeration is prevented.

The quantity of air conveying the coal into the oxygen-mixing chamber, 0.06 to 0.09 cubic foot per pound of coal charged (corresponding to 150 to 200 pounds of coal carried per pound of air), is negligible. The resultant increase in the percentage of nitrogen in the synthesis gas is slight, usually less than 0.5 percent. The linear velocity of the air-coal stream in the 3/16-inch feed lines is 10 to 11 feet per second, which appears to be essential, as the coal tends to settle out and clogs the line if the velocity is allowed to drop below a critical limit, probably 8 feet per second. Thus, in order to maintain a sufficiently rapid flow, a small-diameter tube must be used, whose disadvantage in small-scale work is occasional clogging of the line by oversize particles unless the coal is carefully sifted prior to gasification.

Essential improvements also were made in the dry residue recovery system shown by the flow diagram in figure 7. One of the 2-inch Aerotec tubes and the circular fiberglass filters were replaced by a "dust extractor" and two "plate and frame" type glass cloth filters. The dust extractor consists of four alloy-steel plates provided with staggered perforations, which cause removal of dust from entrainment by impact, decrease of gas velocity, and changes in the direction of the flow. In the plate and frame type filters the gas is passed through two densely woven glass cloths stretched over tightly fitting frames.

Other units in the train include labor-saving automatic controls and a heat exchanger for the purpose of preheating the dust-recovery train with warm air above the dew-point of the synthesis gas prior to each run made. Thus, condensation of moisture in the Aerotec tubes and in the filter units, in which the slightest amount of moist residue causes detrimental back pressures and clogging, has been avoided.

The automatic controls (see figs. 6 and 7) include:

(a) A differential pressure controller, maintaining a constant pressure differential (Δ P) between the continuous feeder vessel and the oxygen mixing-chamber. Pressure-impulse lines from the control instrument are connected to the continuous feeder and oxygen mixing chamber. Thus, any slight pressure change in the generator causes an identical change of pressure in the continuous feeder by closing or opening a diaphragm-operated valve in the fluidizing air line.

(b) The pressure in the generator is controlled by a diaphragm-operated valve in a bypass line around the exhauster. This valve closes when the back pressure develops in the generator due to an overloaded filter or other causes. As a result, the suction at the inlet side of the pump increases, which tends to restore the original pressure.

(c) For safety in operation, a photoelectric control on the fuel-oxygen mixing chamber causes a valve on the oxygen line to shut off the flow the very instant an interruption in the coal feed permits rays from a source of light to strike a photo-sensitive cell.

(d) As an additional safeguard, a pressure-impulse line connects the fuel-oxygen mixing chamber to a limiting pressure controller. This causes a solenoid-operated valve on the oxygen line to shut off the flow when clogging of the coal-oxygen delivery tube below the mixing chamber increases the pressure in the chamber beyond a set limit.

(e) As a labor-saving device, a temperature-control instrument connected to a thermocouple in the generator causes interruptions in the flow of premixed natural gas and oxygen to the two Kemp burners as the temperature preset for the generator is exceeded. This permits preheating of the generator during the night prior to a run. Flame arrestors in front of each burner prevent flashbacks and consequent combustion in the pipe line.

A picture of the top half of the generator and pneumatic feeding system is shown in figure 8. The lower half of the generator with the dry residue recovery units is seen in figure 9, and the generator head is illustrated in figure 10.

Life of silicon carbide as generator lining, repairs and replacements

The silicon carbide lining of the generator, originally of 6-inch internal diameter with a wall thickness of 1 inch, was found to have a limited life under the severe conditions, such as repeated heating and cooling, effects of slagging coal ash and oxidizing atmospheres to which it had been exposed frequently in 2 years of use.

The upper 2-foot section of the silicon carbide lining, which was exposed to the severest conditions and was directly heated by the flames of two burners during the long preheating periods, was found to be worn thin with cracks developed at the end of the first year and had to be replaced by a new section at that time. At the end of the second year, both the upper 2-foot section and the middle 3-foot section of silicon carbide were found to be worn and cracked and needing immediate replacement. The lower 2-foot section of

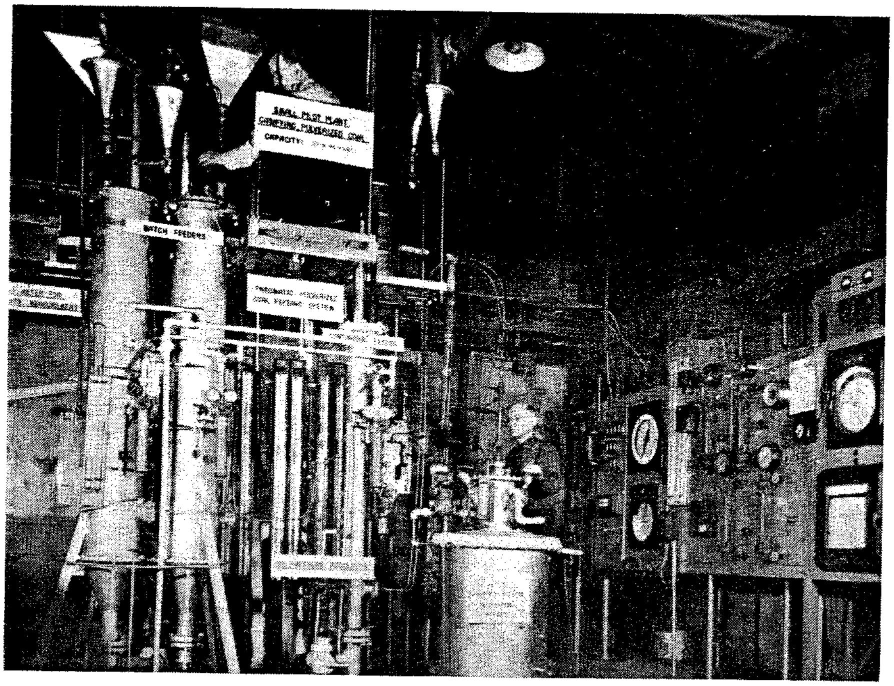

Figure 8. - Laboratory unit (upper floor) in third stage of development.

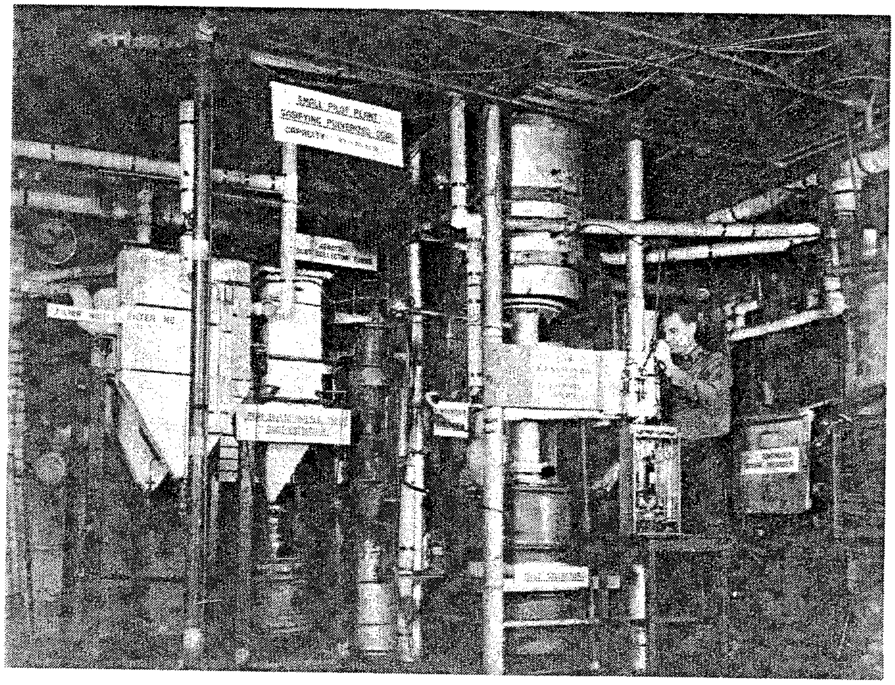

Figure 9. - Laboratory unit (lower floor) in third stage of development.

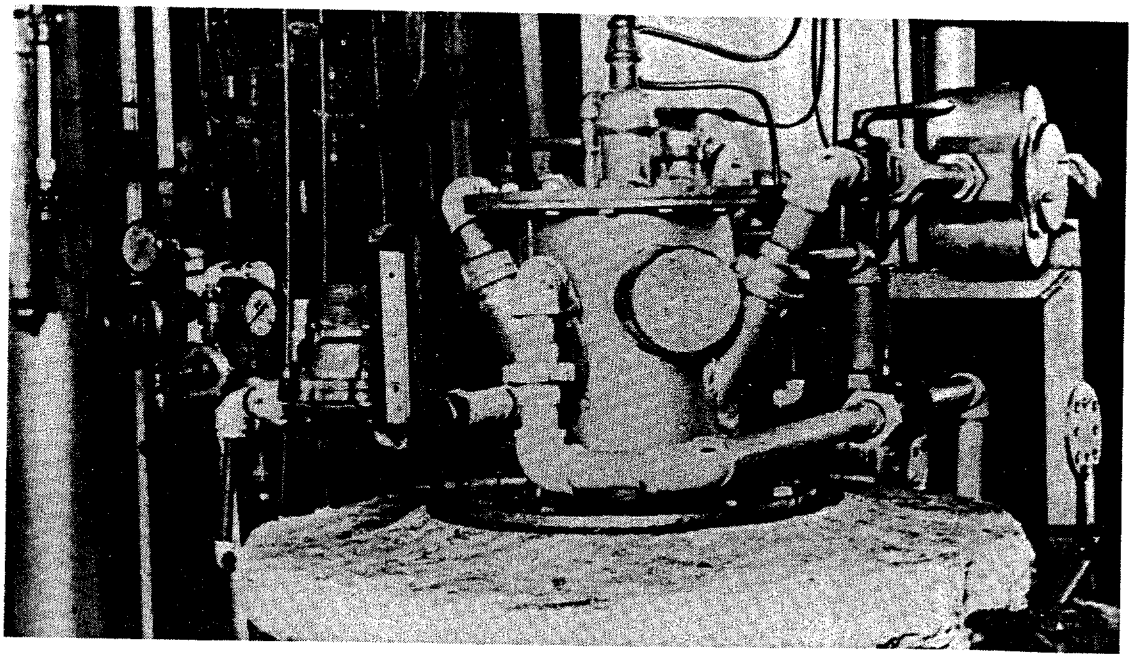

Figure 10. - Generator head in third stage of development.

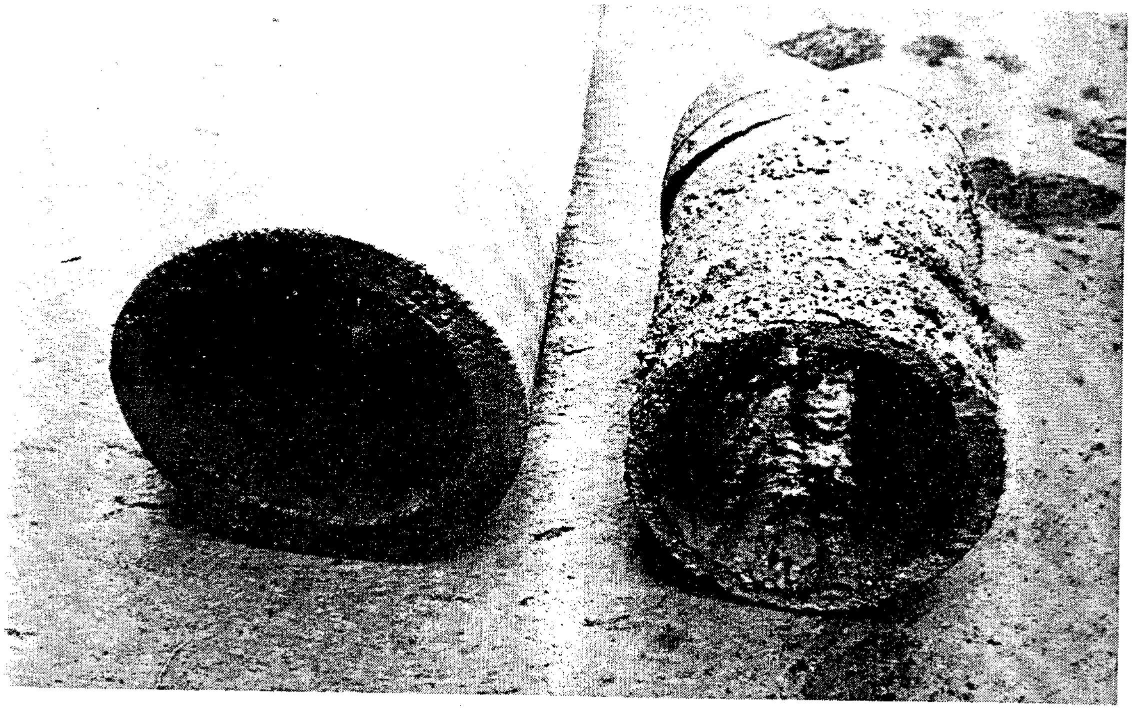

Figure 11. - Silicon carbide generator lining before and after use in pulverized-fuel gasification.

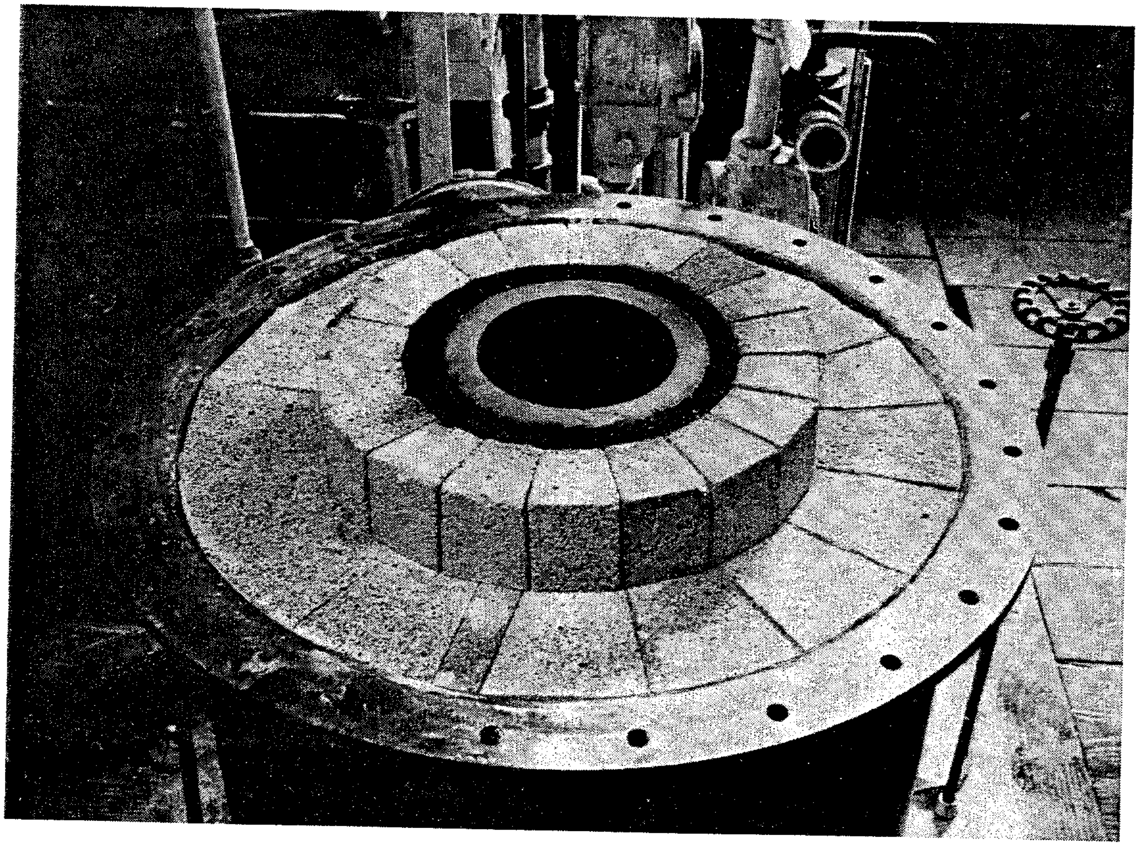

Figure 12. - Internal construction of generator lining for pulverized-fuel gasification.

the generator, lined with a chrome-base refractory, which had been exposed to the mildest conditions, and whose temperature had seldom exceeded 1,700° to 1,800° F., was still in fair shape.

Figure 11 is a picture of a new silicon carbide tube compared with the recently removed "middle section," which has withstood the effects of 2,520 hours of preheating prior to the runs made and 210 hours of gasification, or a total exposure of 2,730 hours (114 days) to temperatures up to 2,300° F. During this service, irregular cracks developed, and the original thickness of the tube wall decreased from 1 inch to an average of 0.5 inch. In addition, the internal surface of the tube became covered by irregular, spongy deposits of hardened slag. At the end of each run, much of the slag adhering to the lining was knocked off by a sharpened, heavy, iron bar, but, as complete clearing was impossible, some extremely hard slag always remained attached to the wall.

Although developed slight cracks have always been repaired successfully in the past by "Carbofrax" cement, after 52 runs the condition of the silicon carbide tube deteriorated so badly that replacement of the entire lining appeared advisable.

The new silicon carbide tube recently placed in the unit is 7 feet long (6 inches I. D. and 1 inch wall thickness), so that it extends throughout the entire gasification chamber. The silicon carbide lining is surrounded by a 1-inch thick annular ring of crushed chrome bricks and a 6.5-inch thick layer of insulating fire-clay bricks. The space between the flat ends of the insulating key bricks and the circular steel shell is filled with diatomaceous earth. The internal construction of the completed generator lining is shown in figure 12.