Thermocouple stations 1, 2, 3, and 4 were the main points used in establishing the temperature of the system. For run 4, two additional points below points 1 and 2, respectively, as shown in figure 21, were attached to controllers that sounded an alarm when temperatures exceeded established maximum values. The temperature of the inner retort was determined by several thermocouples attached to the metal and located about as shown in figures 9 and 21. The location of these interior thermocouples was changed slightly as different inner retorts were tested. They were considered as research information, and only a few of the data obtained from these points are presented in this report.

The heating value of gases made was measured by a Thomas recording calorimeter, which received gas from the line after leaving the scrubbing system. This instrument gives a continuous record of the heating value of the gas. The CO_2 content and the specific gravity of the cleaned gas also were determined by Republic and Ranarex recording instruments. These instruments were useful in indicating operating conditions, but the physical and chemical properties of the gases also were determined by direct analysis. The Fischer precision gas-analysis apparatus and the Burrell Orsat analyzer were used in determining the composition of the gas. Organic and inorganic sulfur were determined by standard methods.11/

A special device was built to indicate the amount of undecomposed steam in the make gas. Mixed make gas emerging from the retort and gases from the upper and lower annuli were cooled, and the condensed moisture was measured. The amount of moisture carried by the gas was calculated from measurements of the temperature and the volume of gas.

The temperature of the outer wall of the metal retort tube was observed by an optical pyrometer from several ports opening through the furnace wall. These ports are on two sides of the furnace and at several elevations, as shown in figure 9.

The Steam Drying Unit

A steam-drying pilot-plant unit was built in conjunction with the gasification plant to furnish dried fuel for gasification. A commercial plant some distance from lignite mines probably would use steam-dried lignite because of the considerable saving in freight by removing the moisture at the mine. Furthermore, it has been demonstrated in the small pilot plant that steam-dried lignite performs better than the natural fuel and is a more efficient fuel for gasification purposes owing to its lower moisture content and better physical properties.

The pilot plant for steam-drying lignite was erected in the retort building adjacent to the gasification plant. Figure 19 shows the design of this unit with coal services connecting to the main source of fuel for the gas plant and figure 20 is a picture of part of the drying plant. The conveyor delivers dried coal to the weigh belt above the retort, as shown in figure 18.

11/ Gas Engineers' Handbook: McGraw-Hill Book Co., New York, 1934, pp. 501-506.

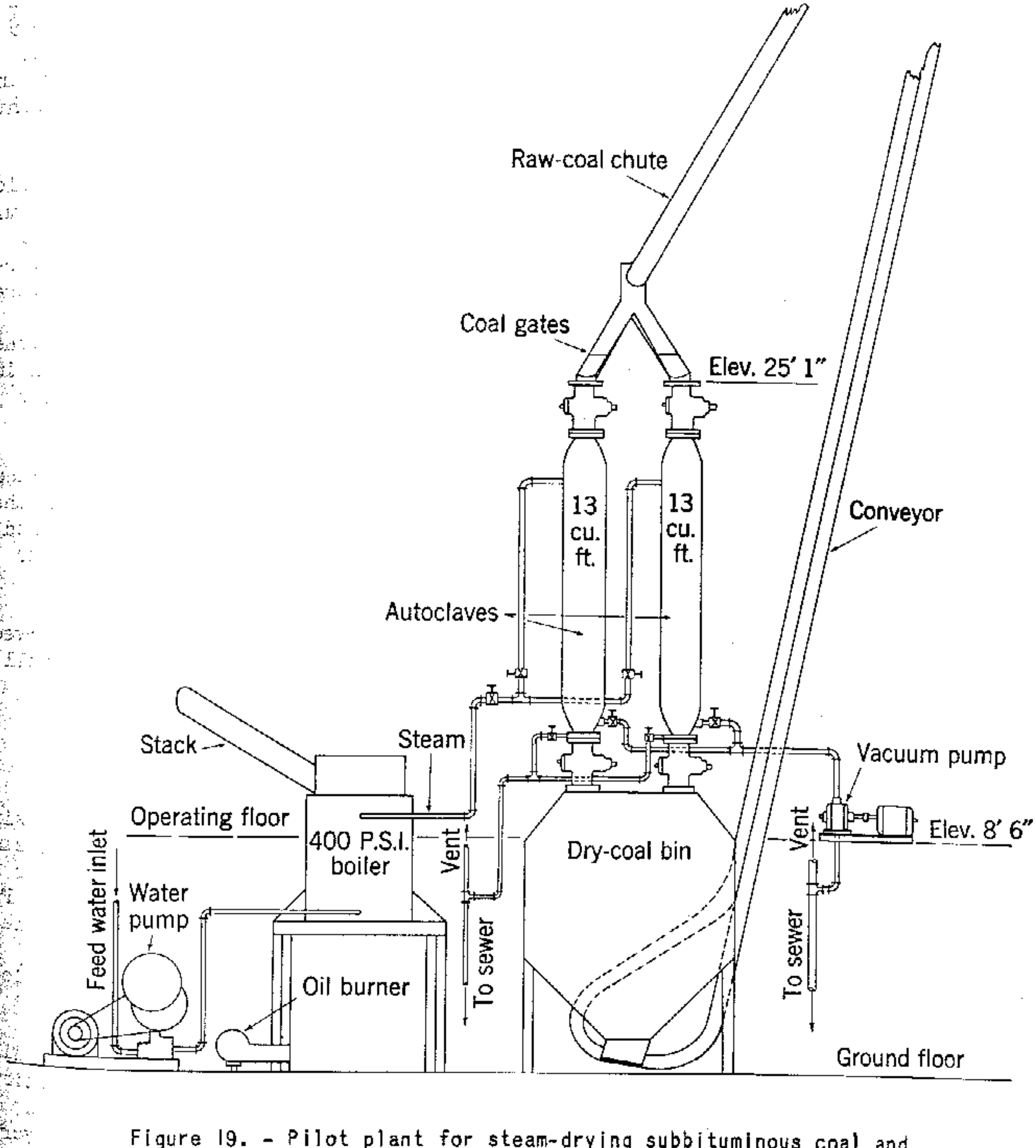


Figure 19. - Pilot plant for steam-drying subbituminous coal and lignite, Grand Forks, N. Dak.

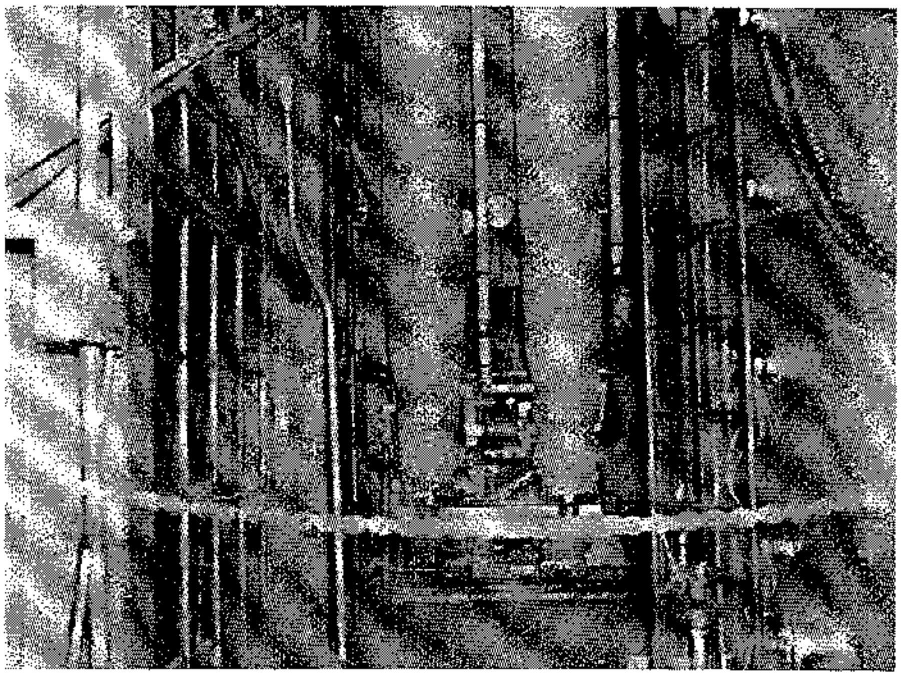


Figure 20. - Steam drying unit, Grand Forks.

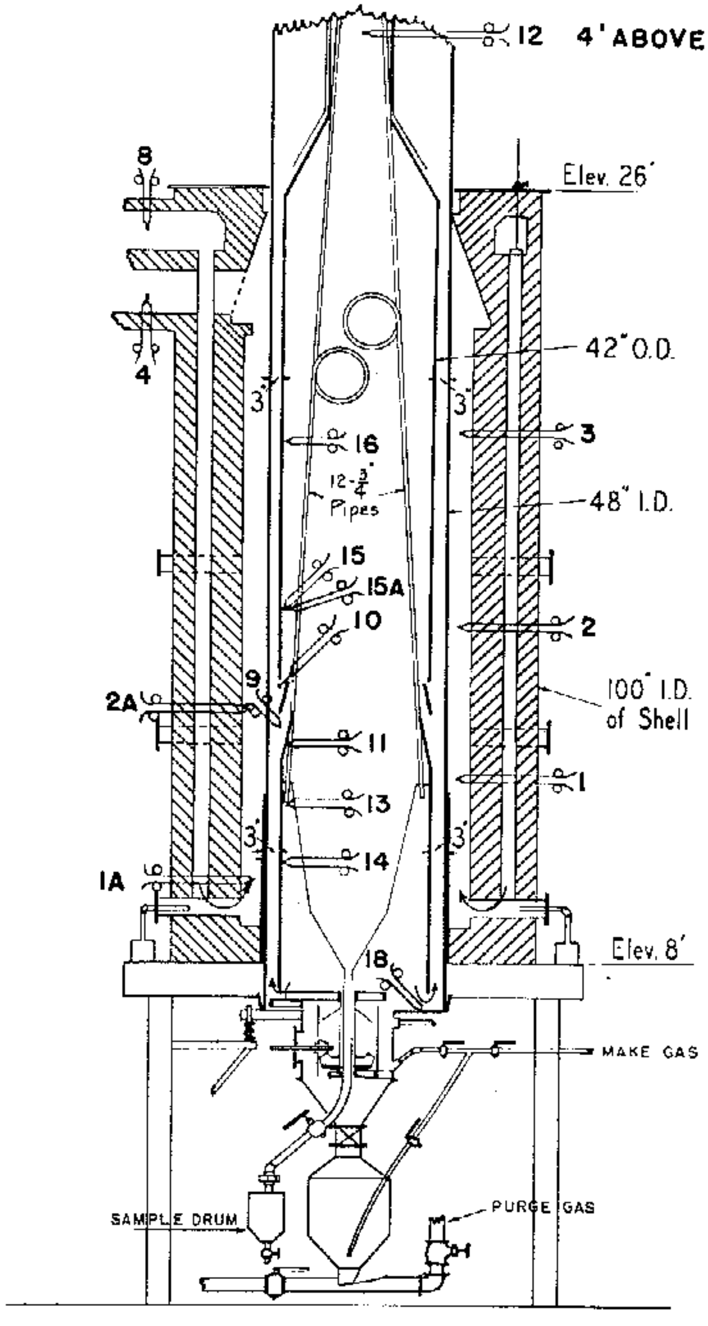
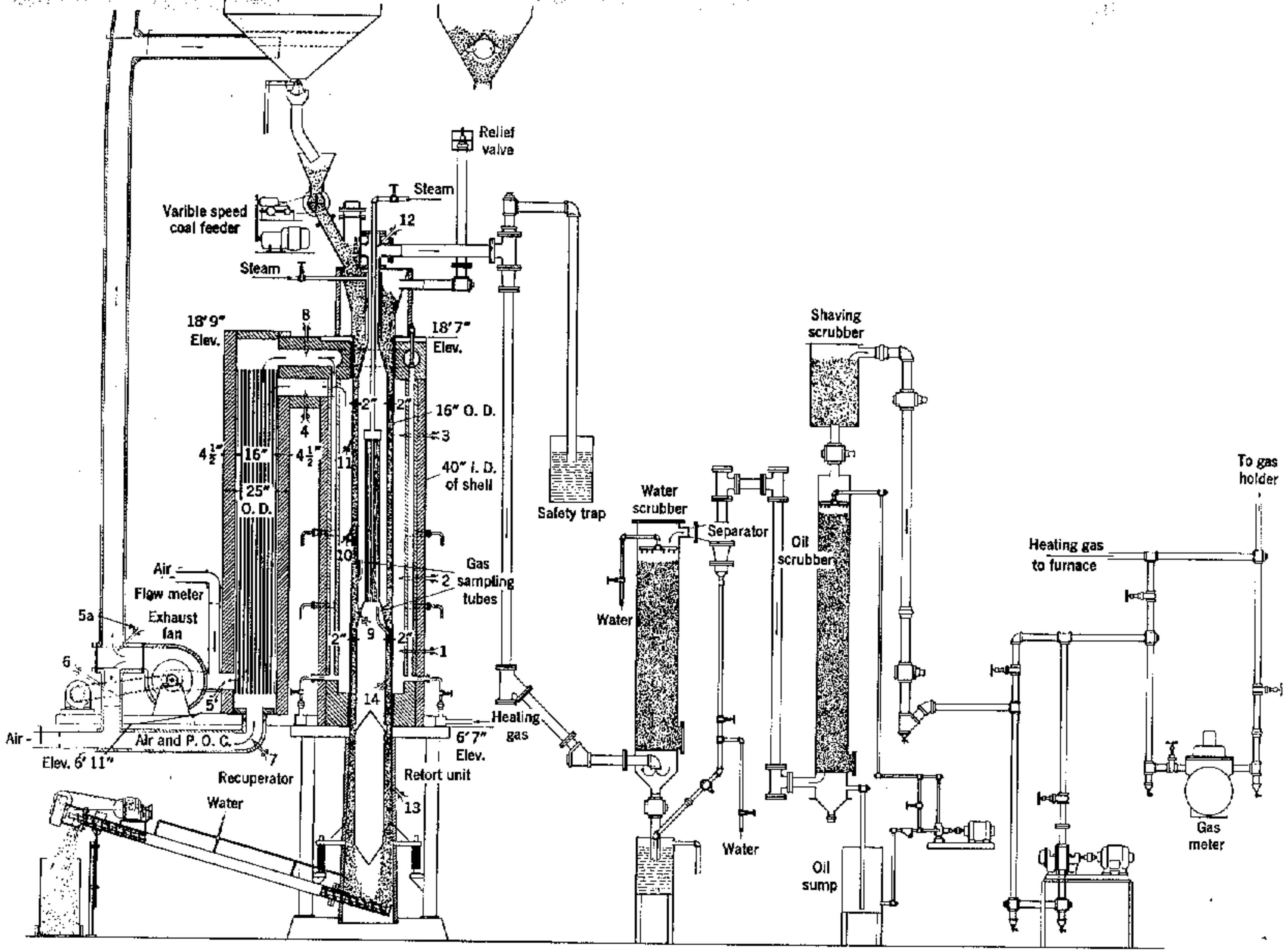


Figure 21. - Arrangement of generator for tests 3 and 4, Grand Forks.



U. S. Bureau of Mines pilot plant for gasification of subbituminous coal and lignite – Parry Retort — Golden, Colorado.

Figure 22. - Arrangement and design of plant as operated during September 1945, test 11.

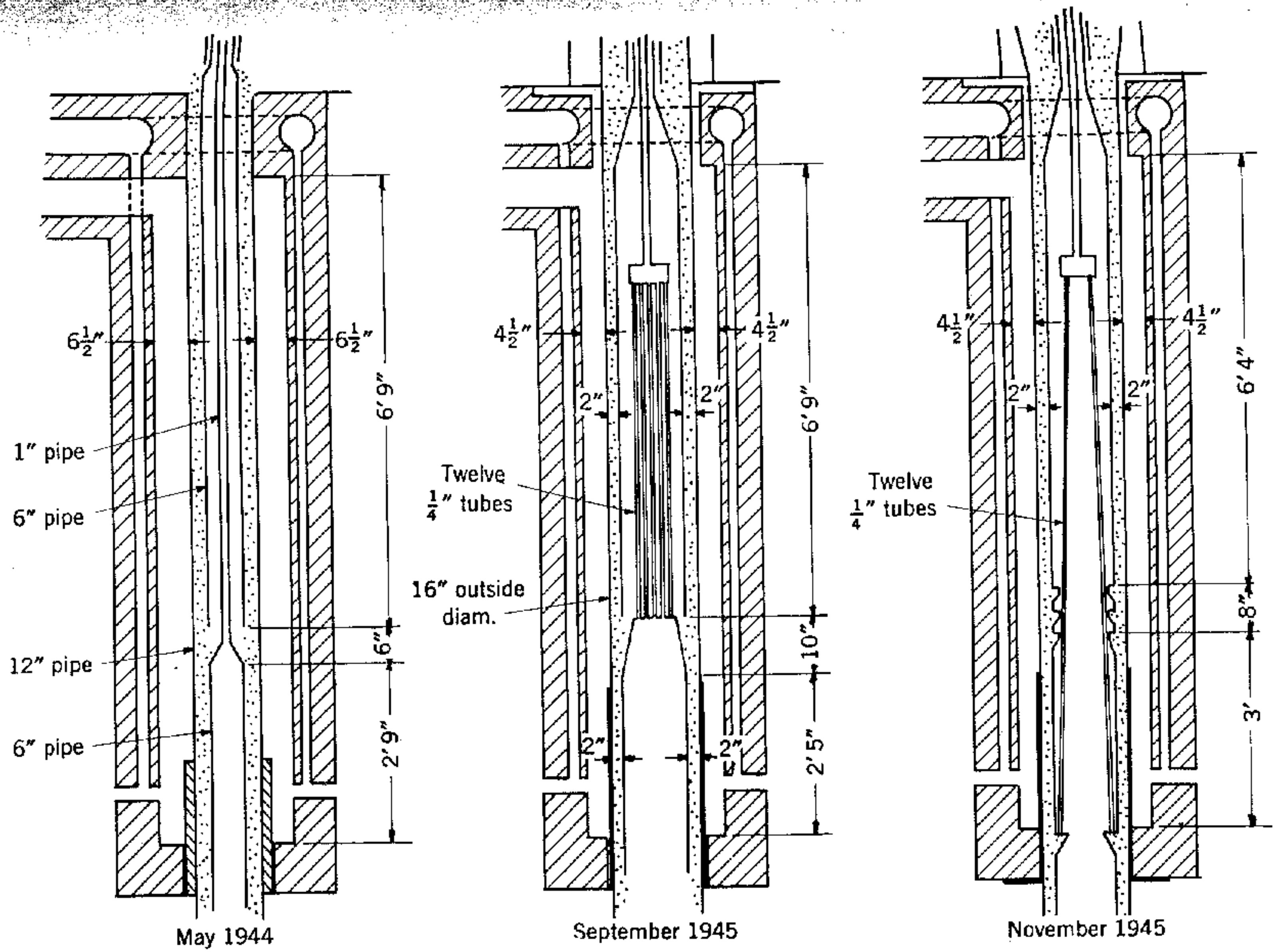


Figure 23. - Golden pilot plant, retort designs.

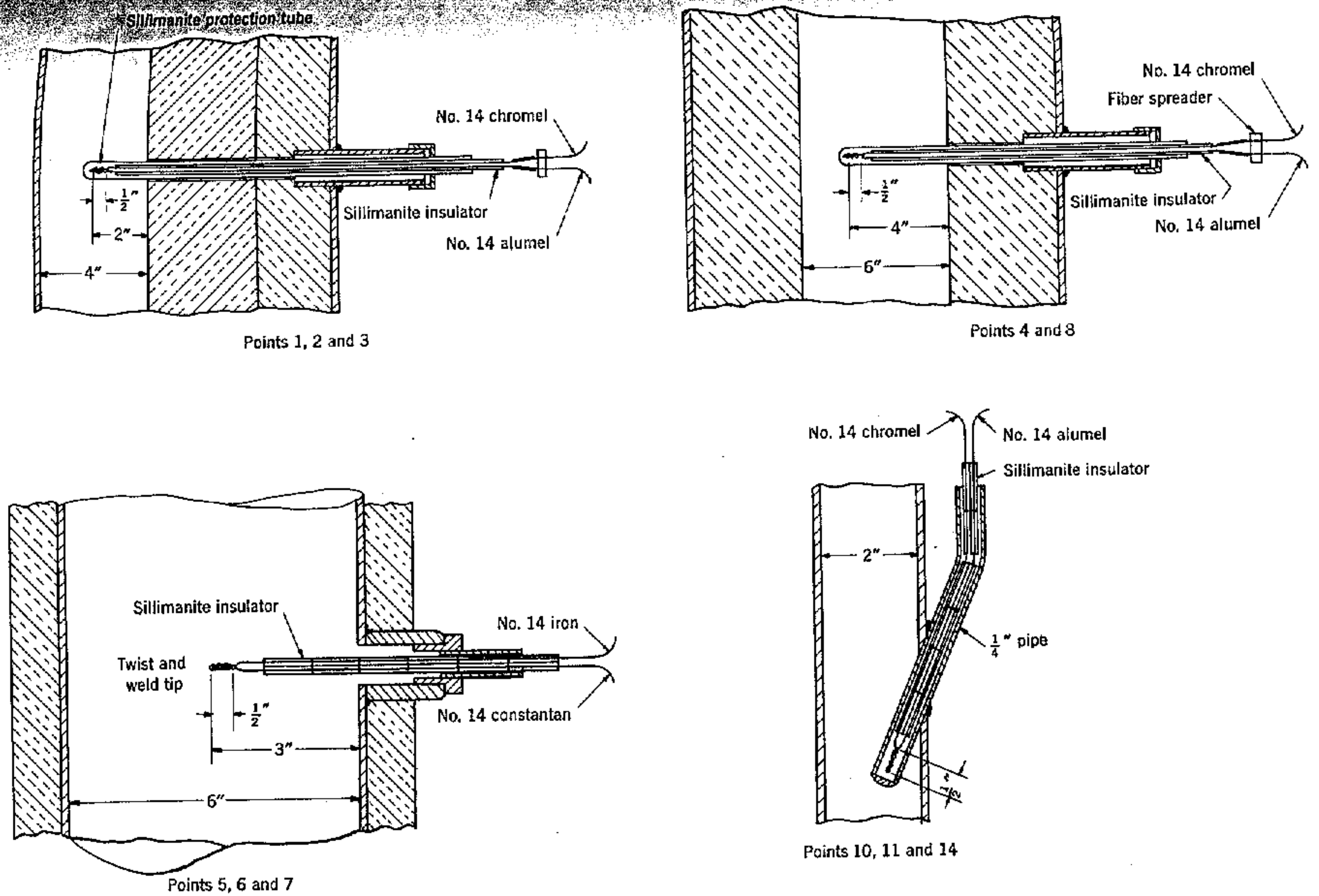


Figure 24. - Detail of thermocouples, Golden pilot plant.

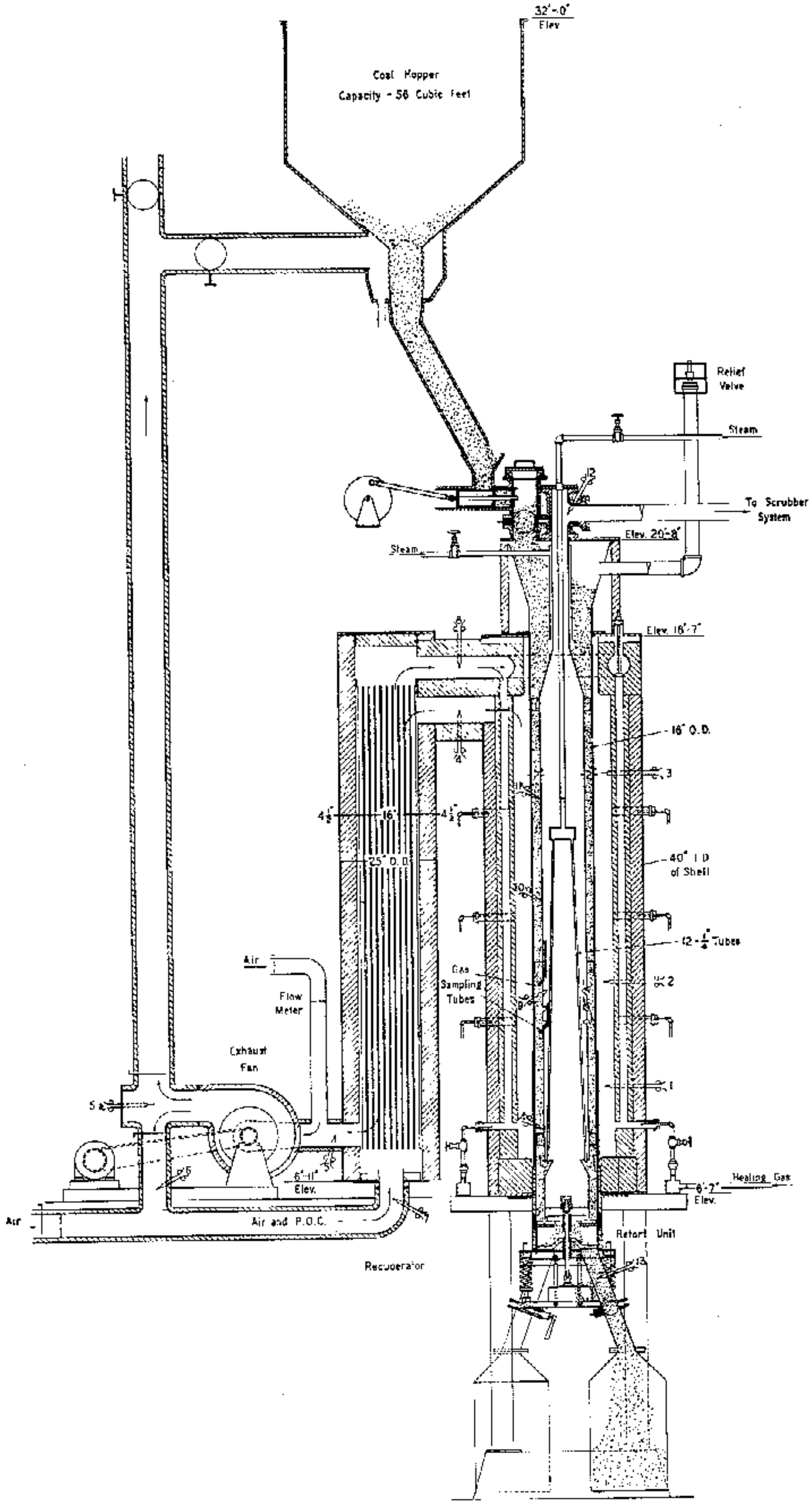


Figure 25. - Arrangement and design of retort, Golden pilot plant, February 1946.

This plant was designed after experience with a smaller pilot plant, which has been described in previous publications.[12] It has a designed capacity of 3,000 pounds per hour. Up to the time of writing this report, the plant had not been operated, except for short test runs, because the flights in the conveying system were not adapted to the physical properties of lignite and fuel could not be handled mechanically. Figure 20 shows the steam-drying unit as installed in one corner of the main retort building.

DESCRIPTION OF THE GOLDEN PILOT PLANT

The basic features of the small pilot plant have been described in a previous report.[13] After run 9, revisions were made to study the effect of decreasing the width of the annular reaction zone, and new ideas on methods of charging and discharging materials were tested. Previous experience had shown that much dust was carried over with the gas through the 6-inch center tube and that the volume of the combustion chamber was greater than necessary. A new steel retort 16 inches in diameter was installed, and the plant was revised to correct certain troubles in the cooling and scrubbing systems.

Figure 22 shows the arrangement of the plant as it was operated during 1945-46. The diameter of the retort was changed from 12 to 16 inches, and the width of the annular reaction zone was reduced from 2.75 to 2 inches. Figure 23 shows the three basic designs of the retort, including the first system tested during 1944. The thermocouples used in measuring temperatures at various places are described in figure 24. All experimental work conducted in the small plant up to December 1945 used a water seal at the base of the retort. This operated very well, but it was a nuisance to handle the wet char residues. Furthermore, it was planned to use the char residues for experimentation in making producer gas for heating the retort; therefore, the discharging system was changed to provide a dry char. These changes are described in figure 25 which shows the design of the system as of February 1946.

OBJECTIVE AND DESCRIPTION OF TESTS

In the development of a process for continuous gasification of coal in an externally heated alloy retort, many problems not encountered in other gasification processes must be solved. In order that the process be successful, it must operate at efficiencies higher than for average processes, and because of relatively low capacity, the operation must be as simple as possible to reduce labor costs. New materials for construction must be investigated. Operational practice must be developed to insure safe heating of the alloy-steel retort.

12/ Harrington, L. C., Parry, V. F., and Koth, Arthur, Technical and Economic Study of Drying Lignite and Subbituminous Coal by the Fleissner Process: Bureau of Mines Tech. Paper 633, 1942, 84 pp.
Parry, V. F., Harrington, L. C., and Koth, Arthur, The Preparation of Stable Nonslacking Fuel by Steam-Drying Subbituminous Coal and Lignite: Trans., Am. Soc. Mech. Eng., Vol. 64, 1942, pp. 177-183.

13/ Work cited in footnote 6.

American lignites and subbituminous coals have not been used for commercial gas production; therefore, much has to be learned about them with respect to their treatment and handling for gas-making purposes. Knowledge of the mechanism of gasification of these fuels must be obtained by experimentation in several pilot-plant steps before design and construction of the final costly commercial-size plant. The properties of the gases and the solid residues obtained during the course of gasification must be studied to provide mechanical means to move them uniformly through the retort and appurtenant equipment. The low-rank fuels have natural tendencies to degrade into fine dusts, which must be separated from gases. This creates problems in operation.

In making the various tests on the pilot plants, the object was not only to make gas and to measure heat and material balances, but principally to find out how to make gas efficiently at a maximum rate. It was important to determine operating conditions for the manufacture of various grades of gas, as well as to measure the properties of the gases, such as composition and sulfur content, and of other minor constituents. It was well-known before development work was started that gas could be made from low-rank fuels by heating them in externally heated retorts. Therefore, the main phase of the development program was to find out how to do it at a reasonable cost.

As previously noted, the major variables that affect yield and quality of gases and the efficiency and rate of gasification by this process are:

1. Temperature of the retort. This depends on the rate of heat release and the distribution of the heating gases and products of combustion.

2. The width of the annular reaction zones.

3. The relative length of top and bottom reaction zones.

4. The amount of steam introduced in each reaction zone.

5. The rate of char removal, which controls the percentage of gasification.

6. The physical and chemical properties of the coal, particularly its moisture and ash content. The size of the fuel is a minor variable if it contains no excessive fine dust and is small enough to move into the narrow annulus.

In operating the pilot plants, it was necessary to develop information on the continuous handling of materials, on the pressures required to move steam through the reaction zones, on the characteristics of the heating system, and on the properties of waste materials.

Because of the many variables that required study, the plant operators were tempted to investigate several factors as quickly as possible. In the small pilot plant, a working knowledge of the effect of any variable could be obtained after 8 or 10 hours' operation, but at least 24 hours were required to determine the effect upon the large plant. Tests of several days' duration are advisable for a complete heat and materials balance, but such tests were not feasible during the relatively short operating periods of the large plant, and 24-hour testing periods were set up in order to gain more knowledge of the effects of different conditions.

At Grand Forks, a 24-hour testing period was preceded by a 24-hour adjustment period. Generally, only one major variable was changed, but in some cases two or more were changed, and the plant was thereafter operated for 48 hours. A balanced equilibrium rate was reached within 24 hours after a change in operating conditions, and then a 24-hour testing period was maintained, during which time no changes were made except in the regulation of temperatures. At the beginning of the testing period or run, the weight or volume of measurable materials was determined. Thereafter, hourly records were made of the flow of gas, air, steam, and water and of temperatures at various places in the plant. Periodically, special measurements were made for the research record. The averages of those measurements are reported as representing the operating condition. During the 15th to 20th hour of operation, gas samples were procured for analysis, and these were considered as representative of the entire 24-hour test period. A log was kept of the operation of the plant during the testing period.

Summary of Runs at Grand Forks

In addition to the preliminary trial, which was started on February 27, 1945, and lasted until March 7, four test runs have been made on the commercial-scale pilot plant. The preliminary run was a test to observe performance of auxiliary equipment, to dry out the system, and to find the relationship of the several controls. It was observed that changes were necessary in the char-removing system, the design of the center gas offtake, the method of supplying steam to the char zone, and the heating gas supply. During the last two days of this trial, balanced conditions were attained, and the preliminary trial test was considered successful. The retort made about 10,000 cubic feet of gas per hour at a rate of about 50 cubic feet per hour per square foot of heated retort surface.

Further improvements were made on the plant, and on June 13 the first official run was started and extended until the 26th. The plant was operated at lower temperatures than those initially employed in the preliminary trial to study operating factors connected with making water gas of high CO_2 content to yield a high H_2 to CO ratio. A capacity of 10,000 cubic feet per hour was attained with a maximum furnace temperature of 1,805°F. The improvements in char removal and in supply of steam to the char zone were responsible for the better operation during this run, but some troubles were experienced from dust and char blown into the center gas offtake. The unit was operated for 192 hours under testing conditions, and approximately 55 tons of natural lignite was gasified. This run revealed the need for improvement in the design of the center gas offtake, but otherwise the generator needed few alterations to prepare it for longer runs.

From July to December 1945, extensive changes were made to improve the plant. The new alloy retort tube had been delivered and was installed with a new steel inner retort to provide a 3-inch annular reaction zone instead of the 4-inch space previously tested. The char-removal system was revised to provide means to extract char dusts carried through the center gas offtake. Experimental work was conducted to study certain factors affecting the carry-over of dust into the center offtake, and this led to a new design. The rotary scrapers in the char-extractor section were improved, and a pneumatic system for handling the spent residues was installed. The coal-handling system was installed, and the plant was made ready to run on the arrangement shown in figure 18.

The object of run 2 was to investigate the factors influencing gasification capacity. The plant was started up on December 6 and continued in operation until the 16th. Six testing periods were established, and a maximum capacity of 15,530 cubic feet of gas per hour was obtained. It was observed that dust carried into the center zone became excessive when the gas-production rate exceeded 14,000 cubic feet of gas per hour.

Following run 2, the total opening of the center gas offtake was enlarged from 2.56 to 4.0 square feet, and some improvements were made in the coal-charging system. Tests were made on the coal-handling system, and it was found that extensive changes would be necessary to adapt the new conveyor system to handle lignite. The plant was made ready for run 3, which was started on March 6, 1946.

The object of run 3 was to study the production of low-CO_2 water gases and at the same time to investigate the characteristics of the new gas offtake. The plant was started on March 6 but had to be shut down on the 8th because of leaks in the mild-steel recuperator tube nest. A new alloy steel recuperator was installed, and the run continued for 265 hours until March 25. Six testing periods were established, which produced data on the production of synthesis-type water gases. By this time the plant operated without difficulties, and the methods of obtaining and reporting operating data were standardized. After closing down the plant on March 25, provisions were made to start an extended test the following month.

Run 4 was started on April 16 and continued without interruption until May 16. The object was to study the production of water gases having H_2/CO ratios of 2.0 to 3.0 and to find the maximum practical capacity without excessive blown-over fuel under fixed temperature limitations. Experimental work was done on the gasification of lignite char during two periods totaling 72 hours, but the main part of the run was on natural lignite, and 185 tons was gasified during 648 hours of operation.

Table 1 summarizes the operating periods of the Grand Forks plant. When run 4 was completed, the plant had been operated 1,714 hours. During the four runs, 381 tons of lignite was gasified and about 16 million cubic feet of water gas was made. A more detailed description of each test is given in a following section entitled "Analysis and Discussion of Tests and Experimental Data."