INTRODUCTION

A commercial-scale pilot plant for gasification of lignite was completed by the Bureau of Mines at Grand Forks, N. Dak., early in 1945 as an extension of work on gasification of low-rank coals initiated in a smaller pilot plant at Golden, Colo., during 1943. The development work on this plant was part of a program to make reducing gases from lignite for beneficiation of low-grade iron ores. The background of this project has been described in a previous report.6/ The present report describes the major features of the large pilot plant, a record of experimental operating data during five runs totaling about 1,800 hours, and results of experimental work on the small pilot plant at Golden during 1945.

This project has created considerable interest because heretofore there has been little success in several attempts to gasify American lignites. Furthermore, the method employed is a departure from conventional processes. Natural lignite is fed continuously into an externally heated annular retort and is converted into water gas by heat conducted through alloy metal walls. Because of the high thermal conductivity of metal, the rate of gasification is several times greater than can be obtained when employing refractory walls. The process has been developed to a point that leaves one major question unanswered - "How long will the alloy retort last under practical operating conditions?" - and this question has aroused the interest of the Coal Division of the Bureau of Mines in this new development.

Owing to the high reactivity of the lower-rank fuels, the water-gas reactions proceed rapidly at medium temperatures of 1,650°F. to 1,800°F. These temperatures can be attained in a reaction zone heated by external means when the temperature of the retort does not exceed 1,900°F. while transferring from 6,000 to 7,000 B.t.u. per hour per square foot. Such rates are several times greater than can be attained through refractory walls as employed in the Didier-Bubaig7/ and the Ahrens processes.7/ Therefore, the investment cost of the gas generator per unit of capacity will be considerably lower for the higher-capacity process. However, the maintenance cost of metal vessels will be higher than that of refractory retorts, and this emphasizes the importance of large-scale operation to determine the life of an alloy retort under practical operating conditions.

It is reasonable to assume that a suitable alloy retort will cost about 60 cents a pound, or about $15 a square foot and will have a useful life of 10,000 to 20,000 hours. When transferring heat at a rate of 6,000 B.t.u. per hour per square foot, 80 to 90 cubic feet of water gas will be made per hour

6/ Parry, V. F., Germes, D. C., Goodman, J. B., Wagner, E. O., Koth, A. W., Patty, W. L., and Yeager, E. C., Gasification of Lignite and Subbituminous Coal, Progress Report for 1944: Bureau of Mines Rept. of Investigations 3901, 1946, 59 pp.

7/ Coke and Smokeless-Fuel Age, Complete Gasification: Vol. 4, May 1942, p. 103.
Coke and Smokeless-Fuel Age, Complete Gasification: Vol. 4, June 1942, p. 127.

per square foot when gasifying natural lignite and subbituminous coal. Therefore, the cost of the alloy will range from 1 to 2 cents per Mcf of gas made, depending on the life of the retort. It is of interest to note that when transferring heat at the above rate, a square foot of metal costing about $15 will transmit, during 10,000 hours, the same energy as can be derived from 150 to 225 Mcf of oxygen when making water gas in an internally heated process. This is equivalent to oxygen costing 6.7 cents to 12.5 cents per Mcf.8/

A major object of large-scale tests is to establish these important economic facts and to solve the practical operating problems involved in the development of a new process.

The large pilot plant was built on the campus of the University of North Dakota during the fall of 1944 and was ready for preliminary tests in March 1945. The design was similar to that of the small pilot plant but expanded approximately six times in capacity. During the course of four runs following the preliminary trial, several changes were introduced, which improved both the capacity and efficiency, and by May 1946 the plant had been operated about 1,800 hours and the design was essentially ready for long-time tests simulating commercial conditions, which are planned to be run during the fiscal year 1947.

The present report does not include the theoretical aspects of gasification and presents only the factual record of development and tests. In a later report, a theoretical analysis of the process of gasification in externally heated retorts will be presented.

Several tests were conducted in the small pilot plant to study some of the problems that would be encountered in operation of the large plant. This report describes results of experiments to find the best width of reaction zone and to study the effects of different designs of gas off-take ports.

Acknowledgments

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The assistance of Walter L. Patty, formerly fuel engineer, Bureau of Mines, Grand Forks, N. Dak., in taking direct charge of construction of the large plant is acknowledged. The research was advanced by the assistance of Velma A. Cook, Earl C. Yeager, and B. G. Gustafson, who analyzed the products of gasification, and G. C. Lammers, who assisted in operating the plant and

8/ 120 Mcf based upon 150 cu. ft. O_2 in Lurgi pressure gasification processes. 225 Mcf based upon 250 cu. ft. O_2 in low-pressure operation.

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The cooperation of the Colorado School of Mines, Ben H. Parker, president, and the University of North Dakota, John C. West, president, in furnishing technical services and facilities is acknowledged.

SUMMARY ABSTRACT

This report presents details of the design, construction, and operation of two pilot plants for gasification of low-rank fuels that employ externally heated retorts. A small pilot plant having a capacity of about 3,000 cubic feet of water gas per hour was operated several hundred hours at Golden, Colo. to obtain data for design of a large plant.

A commercial-size unit about six times the capacity of the small plant was build by the Bureau of Mines on the campus of the University of North Dakota and was operated about 1,800 hours during 1945-46. This plant makes water gas with a heating value of 300 B.t.u. per cubic foot from natural lignite. The results of four tests on the large plant, covering the effects of many variables, are tabulated in the report.

It was proved that the composition of water gases derived from low-rank fuels can be varied over a wide range. By changing the concentration of steam and the temperature around the externally heated retort, water gases having H_2/CO ratios of 2.15 to 5.43 were obtained in the large plant. In the small plant, H_2/CO ratios of 10.0 have been obtained. Operating problems increase with the H_2/CO ratio because of the greater mass of steam required to produce the high-hydrogen water gases. No tar is produced in this process, but the combined hydrogen ordinarily associated with the products of carbonization appear as hydrocarbon gases.

The behavior of the alloy steel retort with respect to its life and cost is an important objective in the operation of the large pilot plant. The retort is 4 feet in diameter and 20 feet in length and is of clad alloy. The inner mild-steel section is "sandwiched" between integral 1/8-inch thick layers of 28 percent chromium heat-resisting alloy steel. It is suspended in a vertical furnace that generates temperatures of 1,500°F. to 2,050°F. by combustion of a mixture of gas with preheated air and products of combustion. Thus far, during 1,300 hours of operation at 2,000°F. maximum temperature, the alloy-clad retort shows no evidence of failure. It is believed that the retort will last several thousand hours under mild heating conditions. The alloy retort tube transmits heat at rates of 5,000 to 6,000 B.t.u. per hour per square foot to make 65 to 80 cubic feet of water gas per hour per square foot from natural lignite.

The investigations have demonstrated the value of pilot-plant steps in the development of a process. The small plant incorporated the major features of the commercial-size plant on a reduced scale. The experience gained from its operation was useful in designing the large unit, which has operated with few troubles. The capacity of the units is in the ratio of about 1 to 6. The operating characteristics of each plant are about the same, and the experimental results obtained on coals tested in the small unit compare well with those obtained in the large unit.

CONCLUSIONS

Experimental data developed as a result of operation of the commercial-size pilot plant for 1,800 hours and the operation of a small pilot plant for about 2,000 hours confirm previous conclusions drawn from operation of the small plant[2/] and support the following additional conclusions with respect to large-scale operation:

1. Various grades of water gas having H_2/CO ratios of 2.1 to 5.4 were made readily from natural lignite in the commercial-scale externally heated retort by adjustment of temperature and concentration of steam. These gases were made at rates ranging from 65 to 80 cubic feet per hour per square foot of heated surface when employing a reaction zone 3 inches wide. In the small plant, gases having H_2/CO ratios up to 10 have been made. Operating problems increase about in proportion to the H_2/CO ratio or the mass rate through the gas off-take ports because of the increased concentration of steam required.

2. The rate of gas formation or the rate of heat transfer in the annular retort is approximately inversely proportional to the width of the reaction zone. In the Grand Forks plant, the maximum rate of heat transfer attained was 5,800 B.t.u. per hour per square foot when employing a 3-inch wide reaction zone. At this rate 75 cubic feet of water gas was made per hour per square foot of surface. When using a 4-inch reaction zone under similar conditions, the maximum rate attained was 50 cubic feet per hour per square foot.

3. It is indicated, from comparison of operation of the small and large pilot plants, that the capacity of the large pilot plant will increase to 90 cubic feet per hour per square foot by reducing the width of the annular reaction zones to 2.5 inches.

4. The indicated over-all efficiency of gasification is 72 percent when it is assumed that producer gas and steam for the process can be generated at efficiencies of 80 and 85 percent, respectively.

2/ Work cited in footnote 6.

5. Fifty to 90 percent of the carbon in natural lignite can be converted to water gas in a single pass through the externally heated retort. The optimum percentage of gasification appears to be 75 to 85 percent.

6. Operating experience thus far indicates that improvements in the design of the gas off-take ports and in the coal-charging mechanisms are necessary. When the hot gas and steam issuing from the present ports exceeds a velocity of 4.7 feet per second, excessive quantities of char and fine dust are carried over with the gas. Gas and steam passing through the off-take ports should not exceed 200 pounds per hour per square foot of port opening in order to reduce the blown-over dusts to less than 1.0 percent of the weight of the gas and steam. Coal must be charged at a constant rate to achieve uniform operation.

DESCRIPTION OF THE GRAND FORKS PILOT PLANT

Plant Site

The Grand Forks pilot-plant site was selected because of the advantages offered at the University of North Dakota, where much experimentation on lignite utilization had been under way prior to this investigation. In addition to the technical advantages from a university environment, the practical advantages of existing power, gas, steam, coal-handling, and shop equipment were important in the building and operation of the pilot plant.

The area of Government property adjacent to the University power plant is shown in figure 1. The University granted 0.681 acre of land without charge to the Government as an inducement to erect the plant. Some buildings on the land were converted into laboratories, shops, storage space, and offices. A new fireproof retort building 25 by 30 feet at the base and 60 feet high was erected near the existing power-plant coal bunkers. The plant area was planned to accommodate future expansion and to permit addition of purification equipment. Figure 2 is an air view of the campus of the University of North Dakota, in the foreground of which is the Government property adjacent to the power plant, and figure 3 shows the plant site from railroad property adjoining the power plant. This property is adequate for extensive development work on pilot plants for demonstration of new methods for utilizing lignite.

Progress of Construction of the Plant

A field office was established at the University of North Dakota in May 1944, and part of the engineering staff of the Subbituminous Coal and Lignite Section was transferred from Golden to Grand Forks to take charge of construction of the plant. The plant site had been designated and most of the detailed designs for the gasification unit were finished from June 1, but approval of War Production Board priorities to begin construction of the plant was not received until June 22, 1944. Although the contract for erection of the retort building was awarded in May, construction was delayed until the latter part of September, when the land deeded to the Government by the University was accepted by the Government.

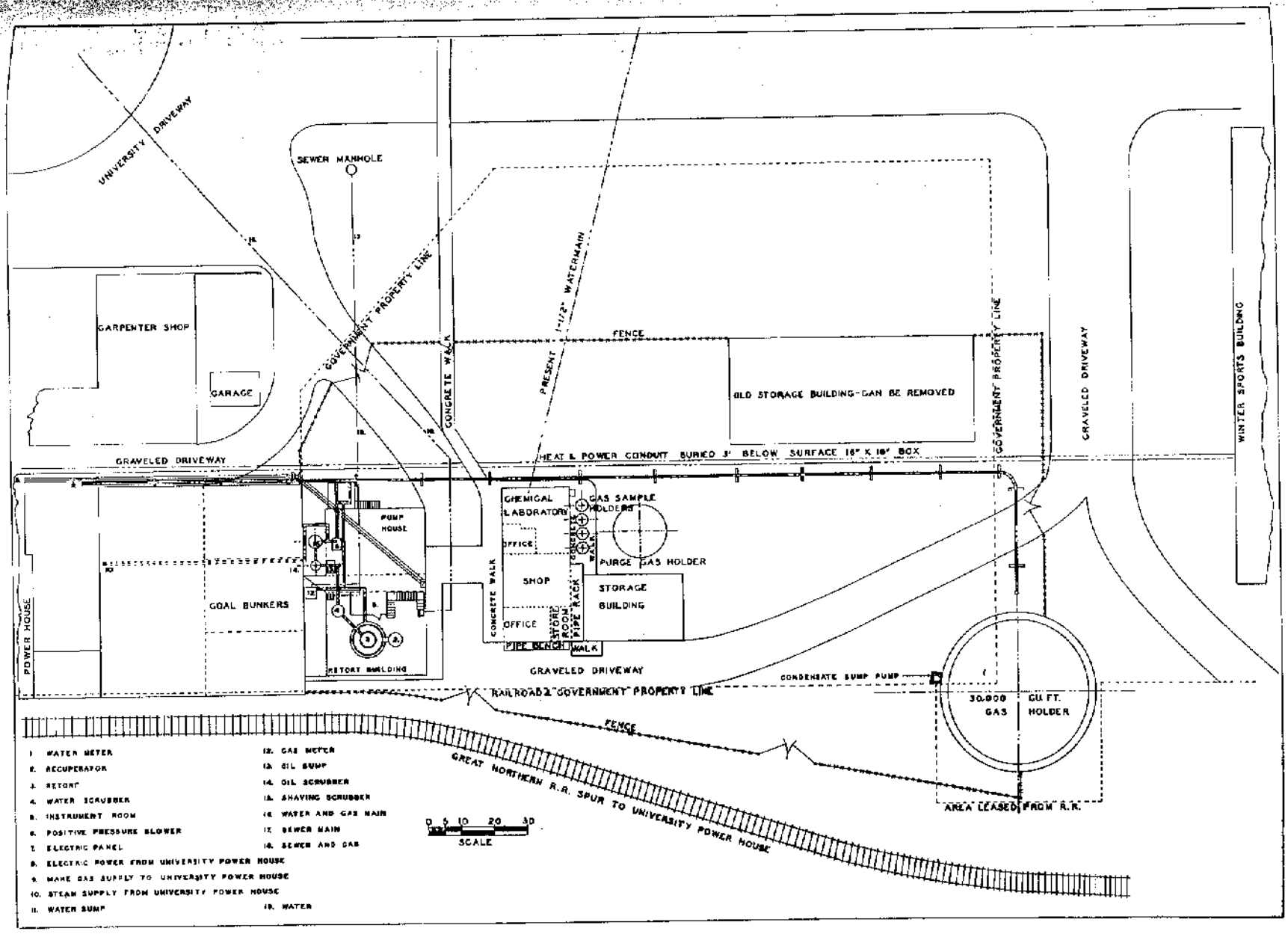


Figure 1. - Plan view of Government property and lignite gasification unit, Grand Forks, N. Dak., 1945.

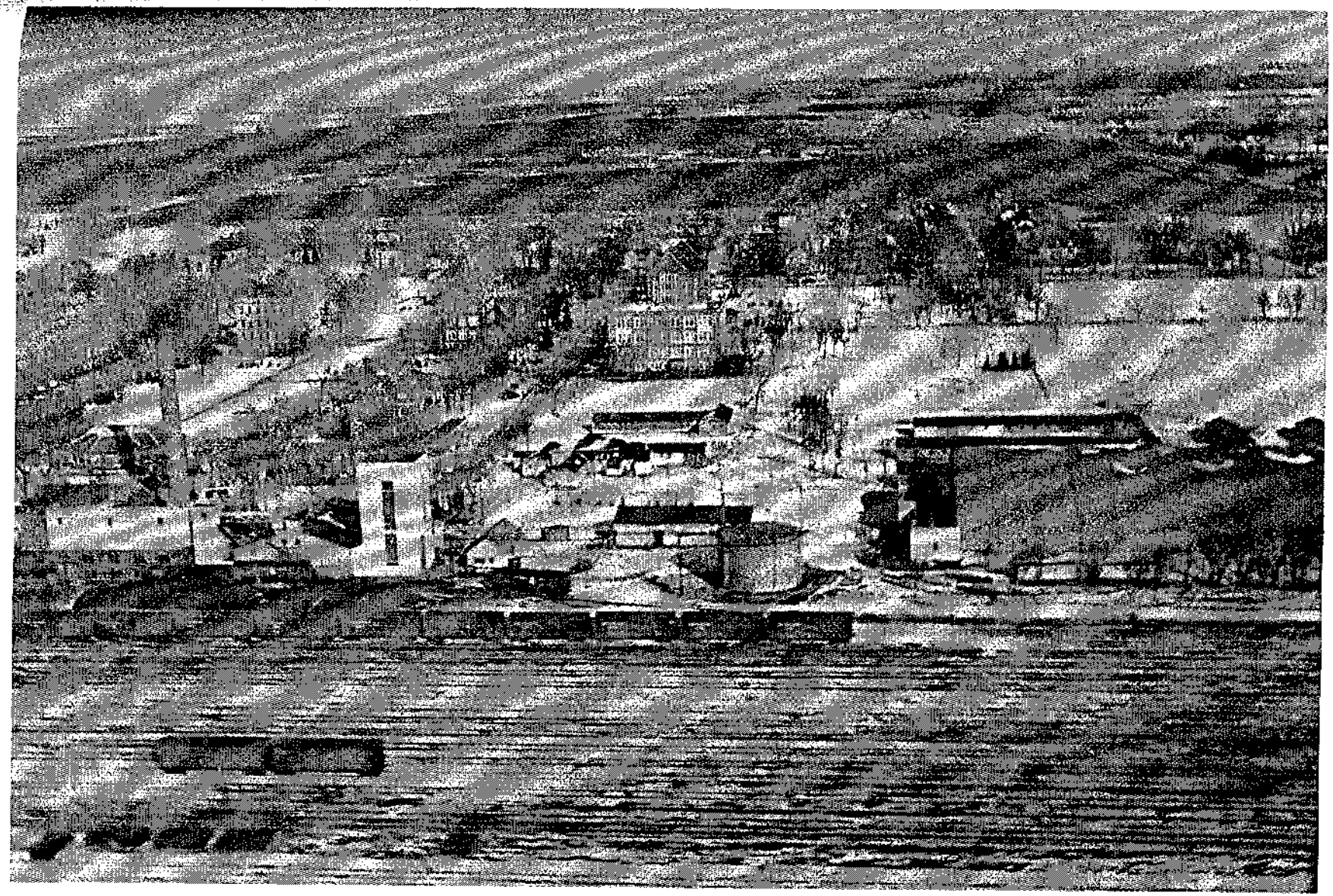


Figure 2. - Aerial view of Government property on University of North Dakota campus.

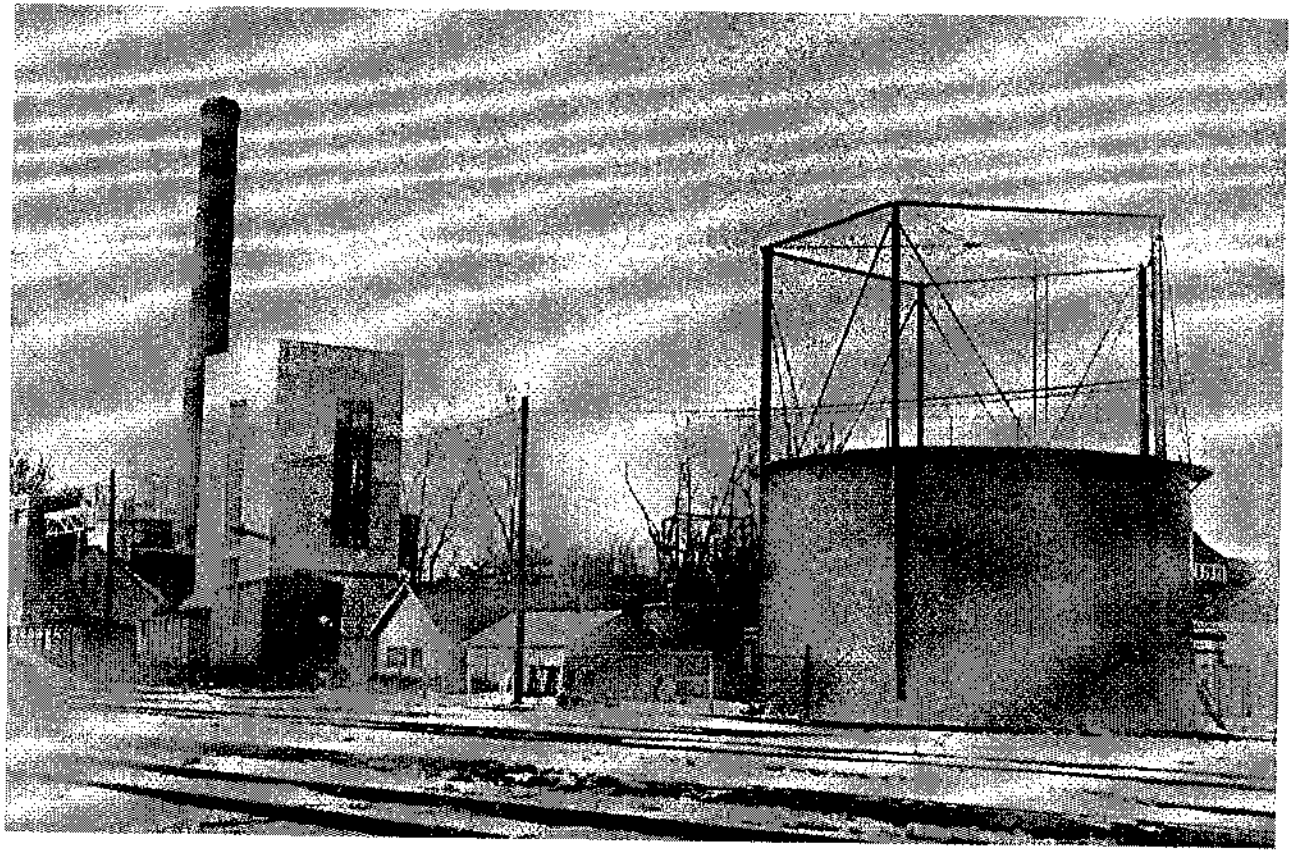


Figure 3. - Grand Forks, N. Dak., pilot plant.

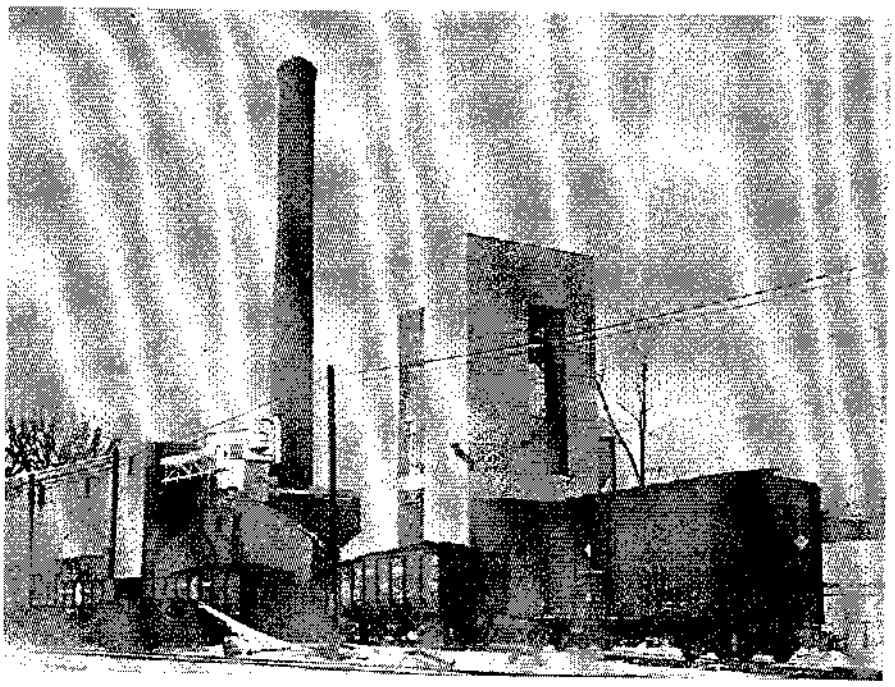


Figure 4. - Retort building February 1945, Grand Forks.

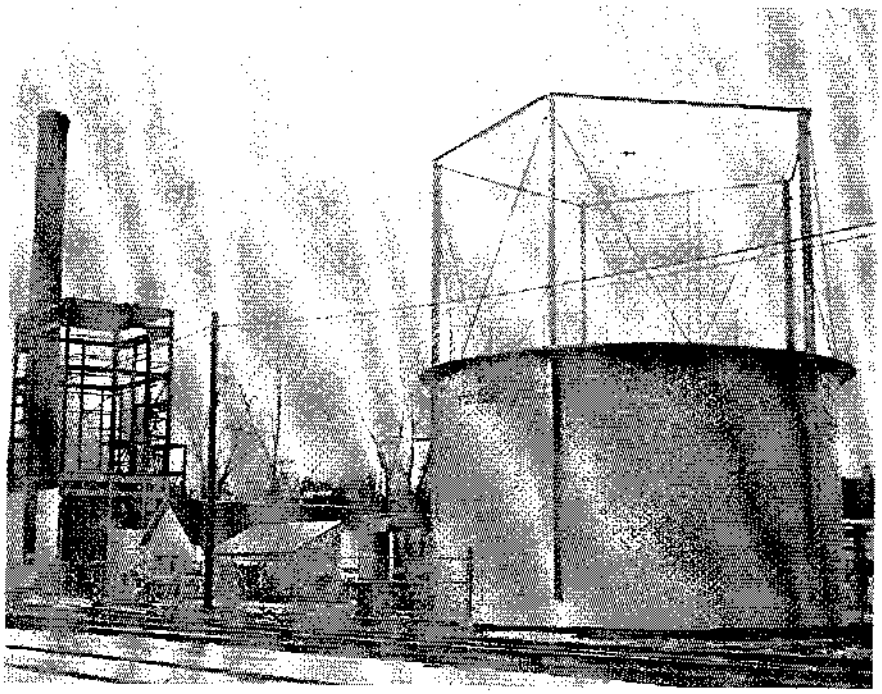


Figure 5. - Construction progress, December 1944, Grand Forks.

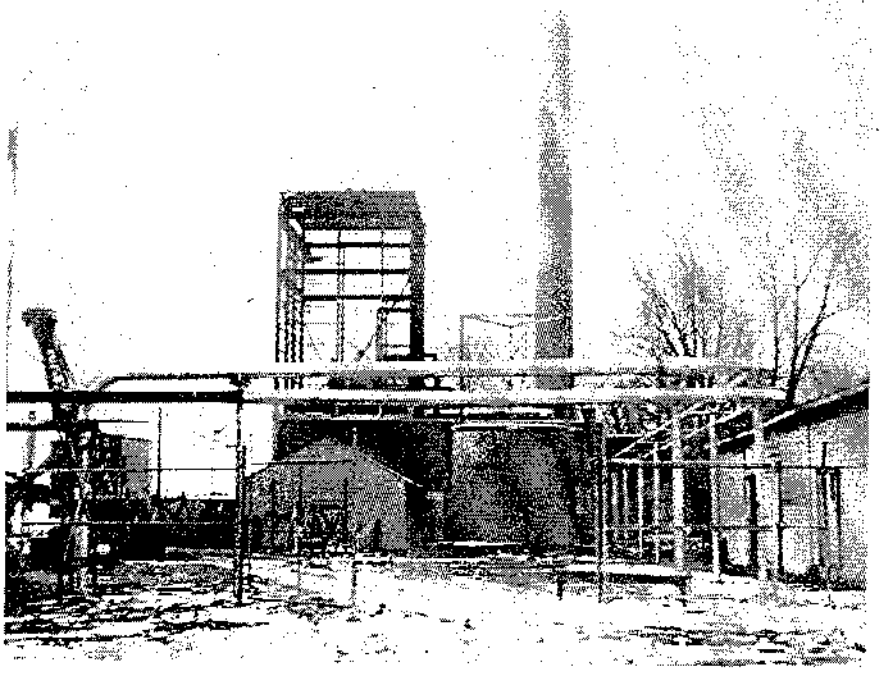


Figure 6. - Retort building and gas piping, Grand Forks, December 1944.

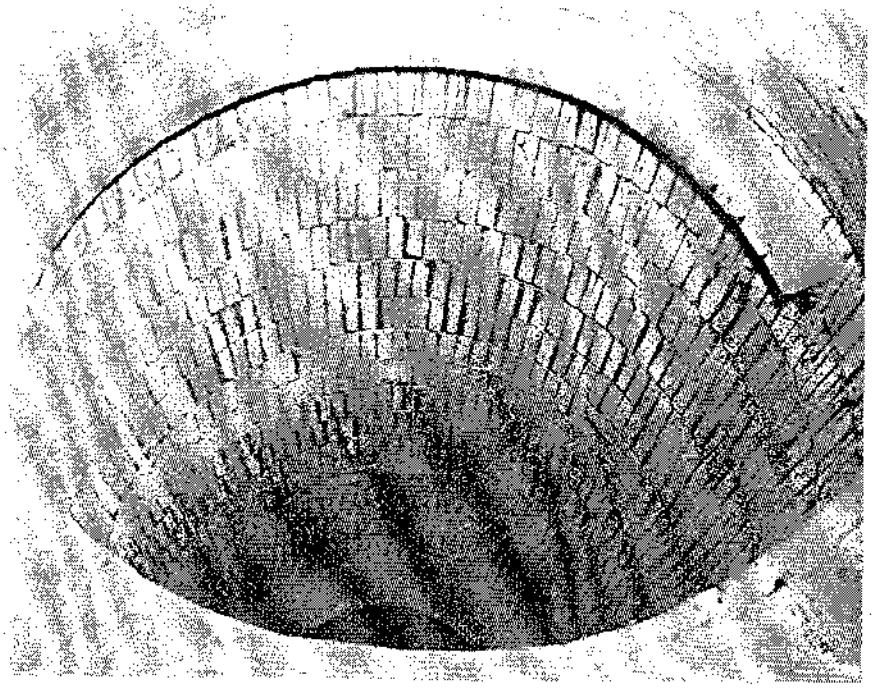


Figure 7. - Brickwork lining of the generator, Grand Forks.

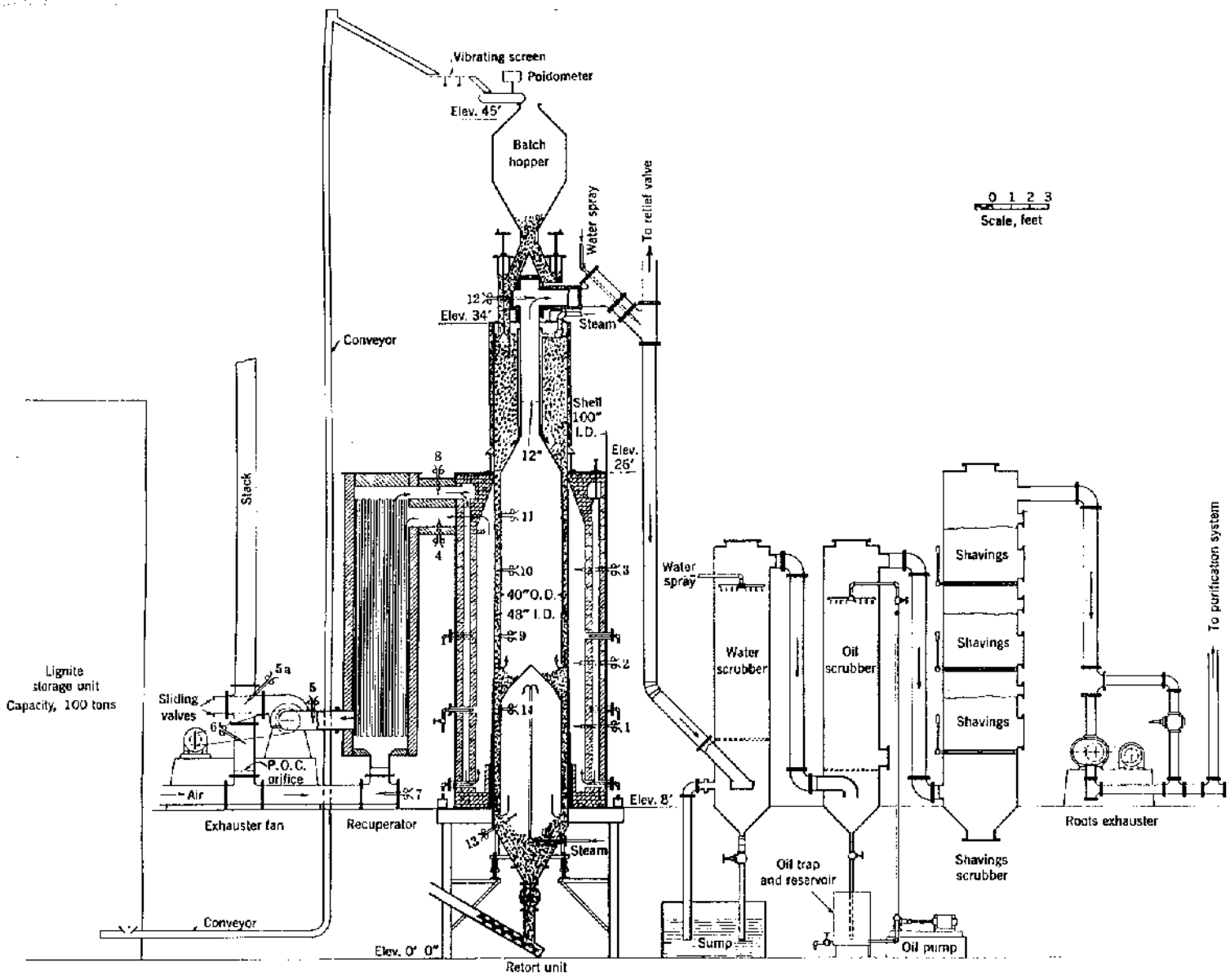
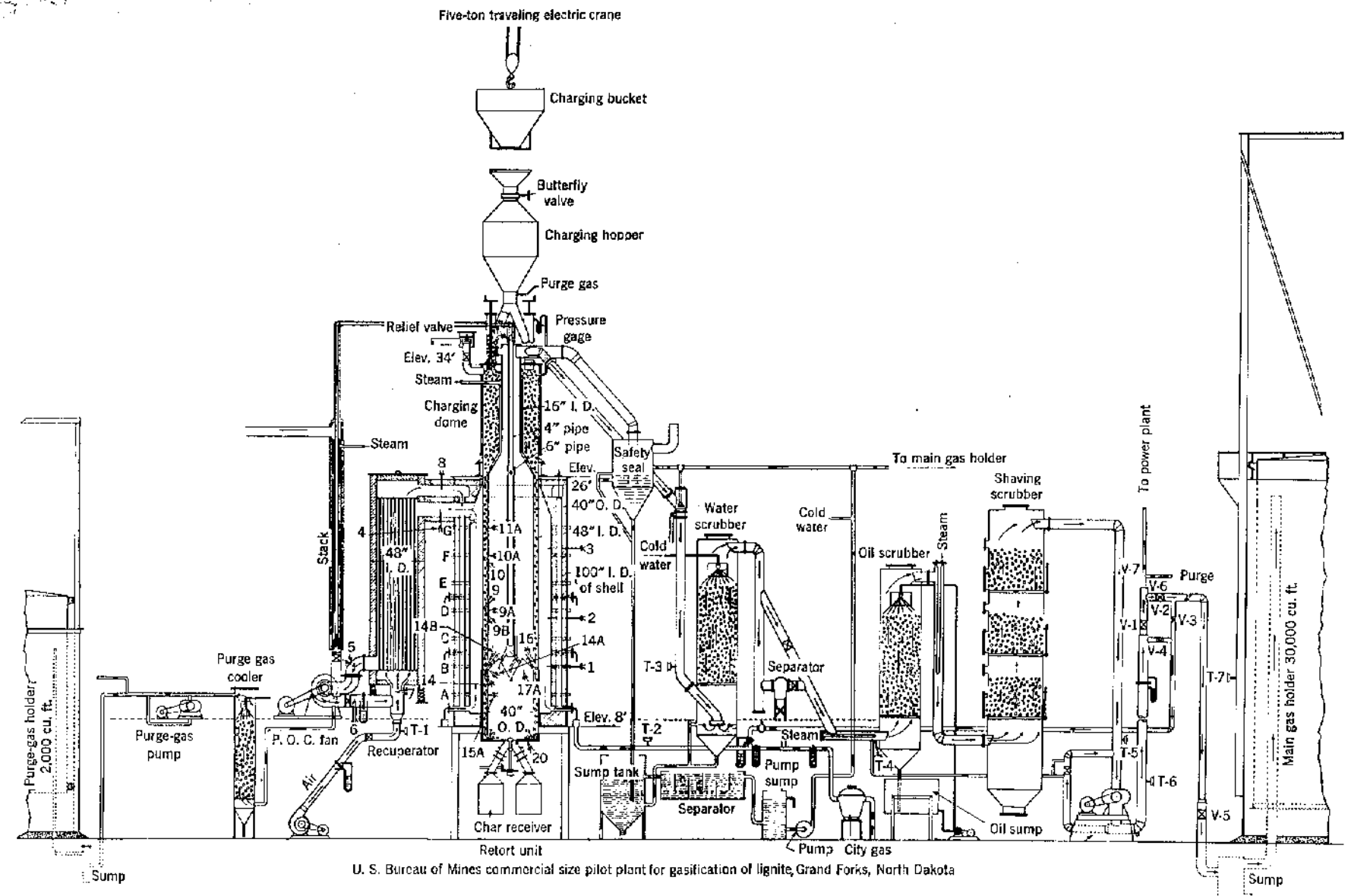


Figure 8. - Pilot plant for complete gasification of coal, Parry retort, Grand Forks.



U. S. Bureau of Mines commercial size pilot plant for gasification of lignite, Grand Forks, North Dakota

Figure 9. - Arrangement of plant as operated during test 1, June 1945.