SUMMARY ABSTRACT

This progress report covers the period from January 1949 to the end of the fiscal year, June 30, 1950. Three runs were successfully completed, and one run was terminated as the result of failure of a cast reaction tube. Including the abbreviated run, the gasifier was operated for 1,915 hours, during which some 428 tons of natural and steam-dried lignite was partly gasified in producing 20 million cubic feet of gas. Gas-production rates varied from 7.8 to 16.4 thousand cubic feet per hour, the latter being the highest production rate yet reached; hydrogen-carbon monoxide ratios of the product gas varied from 1.85, the lowest ratio yet produced, to 6.5; and heat-transfer rates through the heated wall of the outer tube varied from 2,100 to 4,400 B.t.u. per square foot an hour.

The general objective of the project is to establish the technology and economy of the gasification of lignite in an externally heated, metal, annular retort. Specific objectives include determination of the useful life of the metal retort tube, which is a continuing problem, and special objectives that were established for each run as part of the systematic investigation of the basic variables of the gasification process. For runs 10 and 11 the special objective was the influence of the lignite feed rate on gasification; for run 12, a comparison of dried and natural lignite, and the production of gas having a hydrogen-carbon monoxide ratio less than 2; and for run 13, the influence of a gradually increasing steam rate with steam admitted to either the upper or lower reaction zones. In addition, during each run the sulfur distribution and concentration in the product gas and char were investigated.

Experimental results obtained using the lignite feed rate as the variable indicated that the gas yield per ton of natural lignite varied inversely with the feed rate.

Comparison of the gasification of natural and steam-dried Dakota Star lignite indicated that the dried lignite was a superior gasification material because:

1. The hourly gas production was higher at normal combustion space temperatures under nearly equal experimental conditions.

2. On the moisture- and ash-free basis, a considerably higher feed rate could be maintained at a relatively high percentage of carbon gasified.

3. At nearly equal moisture- and ash-free feed rates, the specific gas yield was higher.

The location of steam admission was found to be important because the gas yield per ton of natural lignite was higher when at least a portion of the process steam was admitted to the upper reaction zone.

Heat balances showed the potential heat in the gas and char to be 71.8 to 83.6 percent of the total heat input.

The sulfur concentration in the product gas was low, being in the range of 35 to 140 grains per 100 cu. ft., of which 1.5 to 2.3 grains was organic sulfur.

Careful measurements and inspection of the 310-alloy rolled plate tube following runs 11, 12, and 13 showed no excessive corrosion; however, some radial deformation had occurred indicating that deformation or creep might be the limiting factor in the life of the tube.

INTRODUCTION

This progress report, the fourth of a series, presents the continuation of the work of the Bureau of Mines in cooperation with the University of North Dakota on the gasification of lignite in an externally heated annular retort during 1949 and to the end of the fiscal year, June 30, 1950. Previous publications have covered the history and development of the project (1, 2),8/ theoretical aspects of gasification in externally heated retorts (3, 5), and the progress of the project until the end of 1948 (4).

The research on the gasification of lignite was initiated by the Bureau of Mines in 1943 in an attempt to link the beneficiation of the low-grade Minnesota iron ores with the extensive lignite deposits of western North Dakota. Interest in the gasification project has been sustained by the possibilities of using the product gas as a raw material in the Fischer-Tropsch synthesis for the production of synthetic fuels or as a basis for hydrogen used in the hydrogenation of coal.

The commercial-scale demonstration plant was operated for an additional 1,915 hours from January 1949 to the end of the fiscal year, June 30, 1950. During this period 20 million cubic feet of gas was produced in the course of the systematic investigation of some of the variables of the gasification process. The results of these investigations are presented in this progress report; and the analysis of the various phases of the gasification process is being published in a separate series of reports (5). In addition, the failure of a centrifugally cast retort tube is discussed, and the behavior of a 310-alloy rolled plate tube during approximately 1,900 hours of operation is reported.

Recommendations for the design of commercial plants, as well as cost data, will be presented in a future report.

ACKNOWLEDGMENTS

General direction of this investigation was given by A. C. Fieldner, formerly Chief, Fuels and Explosives Division, and now chief fuels technologist, Bureau of Mines, Washington, D. C. Additional helpful guidance was rendered by L. C. McCabe, formerly chief, Coal Branch, and now chief, Fuels and Explosives Division, and by R. L. Brown, coal technology coordinator, Bureau of Mines, Washington, D. C. Continued encouragement and many suggestions were given by L. C. Harrington, dean, College of Engineering, and M. H. Chetrick, professor of chemical engineering, University of North Dakota, who served as consulting engineers for the project.

Acknowledgment also is made to the regular operating staff, R. A. Axelsen, L. H. Shore, S. Swanson, F. J. Wentz, and R. J. Wills for their cooperation, assistance, and suggestions during operation and maintenance of the plant. Part-time assistance

8/ Underlined numbers in parentheses refer to reference under literature cited.

for operational, analytical, and testing work was given by P. L. Guy, W. W. Halverson, D. A. Houkom, L. A. Navarro, D. K. Nelson, W. C. Olson, H. A. Tannahill, and W. W. Walker.

Analyses of the lignite, char and special samples were done under the supervision of H. M. Cooper, former supervising chemist, Coal Analysis Section, and W. A. Selvig, supervising chemist, Miscellaneous Analysis Section, Bureau of Mines, Pittsburgh, Pa. Graphic services were provided by the Graphic Section, under L. F. Perry, supervising engineer, Bureau of Mines, Pittsburgh, Pa.

OBJECTIVES OF GASIFICATION EXPERIMENTS

General

The general objectives of the investigations remained the same as previously reported (4). For the convenience of the reader, these objectives are again briefly stated as:

1. Development of a continuous process for the gasification of lignite in an externally heated annular metallic retort. This phase was essentially completed before the present report with the successful operation of the demonstration plant.

2. Establishment of the technology and economy of the process, a continuous part of the project.

Specific Objectives

The primary specific objective of the Grand Forks Demonstration Plant is still determination of the useful life of the outer alloy tube under various operating conditions. A satisfactory life is necessary for the success of this gasification process; thus, experimentation must show that heat and corrosion-resistant alloys are available for commercial operation over an extended period and under prevailing operating conditions.

Secondary specific objectives include gathering additional information concerning the technology of the gasification process. Specific objectives were formulated for each run as part of a long-range investigation of the influence of the operating variables on gasification of lignite.

Runs 10 and 11:

The specific objective was to determine the influence of lignite feed rate on the gasification process and on the capacity of the retort under comparable experimental conditions at 4 different hydrogen-carbon monoxide ratios of the product gas, ranging from 2.3 to 4.6. The combustion space temperatures and the steam-lignite ratio were to be kept constant for each set of experiments, whereas the lignite feed rate was changed. As run 10 was of only 53 hours duration, because of the failure of the cast tube, the program established for that run was carried out during run 11.

Run 12:

The specific objective was to investigate gasification of steam-dried lignite under conditions similar to those of run 11, so that the gasification characteristics of the natural and dried lignite could be compared. In addition, the program specified the manufacture of a product gas with a hydrogen-carbon monoxide ratio of less than 2.

Run 13:

The specific objective was to investigate the influence of a gradually increasing steam rate, with steam admission either to the lower or upper reaction zone, on the performance of the gas generator. To provide comparable experimental conditions it was necessary to keep the lignite feed rate and the combustion-space temperature distribution constant.

Special objectives were similar for each run. Projects such as determination of the concentration and distribution of the sulfur in the product gas as hydrogen sulfide and organic sulfur, depending on the operating conditions, were accomplished for the respective periods of each run.

DESCRIPTION OF COMMERCIAL-SCALE PILOT PLANT

General

Detailed descriptions of the Grand Forks Pilot Plant and auxiliaries have been given in previous publications (2, 4). The plant is at the University of North Dakota, Grand Forks, N. Dak., at a site made available by the university. No major changes in the plant or auxiliary equipment have been made since the last report (4). A plan view of the site and facilities and an aerial view of the area are shown in figures 1 and 2.

Flow Diagram of the Demonstration Plant and Description of Operations

The flow diagram of the gasification process given in figure 3 shows the divided annulus arrangement of the retort used for the four runs herein reported.

The only operational change was adjustment of the lignite feed rate. Formerly (4), the char removal rate was set, whereas the feed rate was regulated to maintain a constant height of feed in the charging dome. The present procedure is to set the reciprocating feeder at a predetermined position and then adjust the char removal rate so that the height of charge in the dome remains nearly constant. This change affords closer control and allows the steam admission to be regulated as a function of the feed rate. To obtain good results with this method of operation, the lignite feed rate had to be set accurately. This required calibration of the reciprocating feeder at various settings of the variable speed drive and at different gate heights.

A significant change was also made in the heating-up procedure. Beginning with run 11, crushed and screened gas coke instead of char was used to fill the annular space while the retort was being brought to operating temperature. Little reaction of the gas coke occurred with the steam, and the unit was brought to temperature with no tar formation or dust blow-over.

Retort Unit

Fundamentally the retort unit used for runs 10, 11, 12, and 13 was similar to that previously described (2, 4). Figure 4 shows the various arrangements used for these runs.

Run 10:

The HK-alloy, centrifugally cast outer tube obtained for run 9 was used again. The inner tube for run 10 was made of mild steel and was 42 inches in outside diameter,

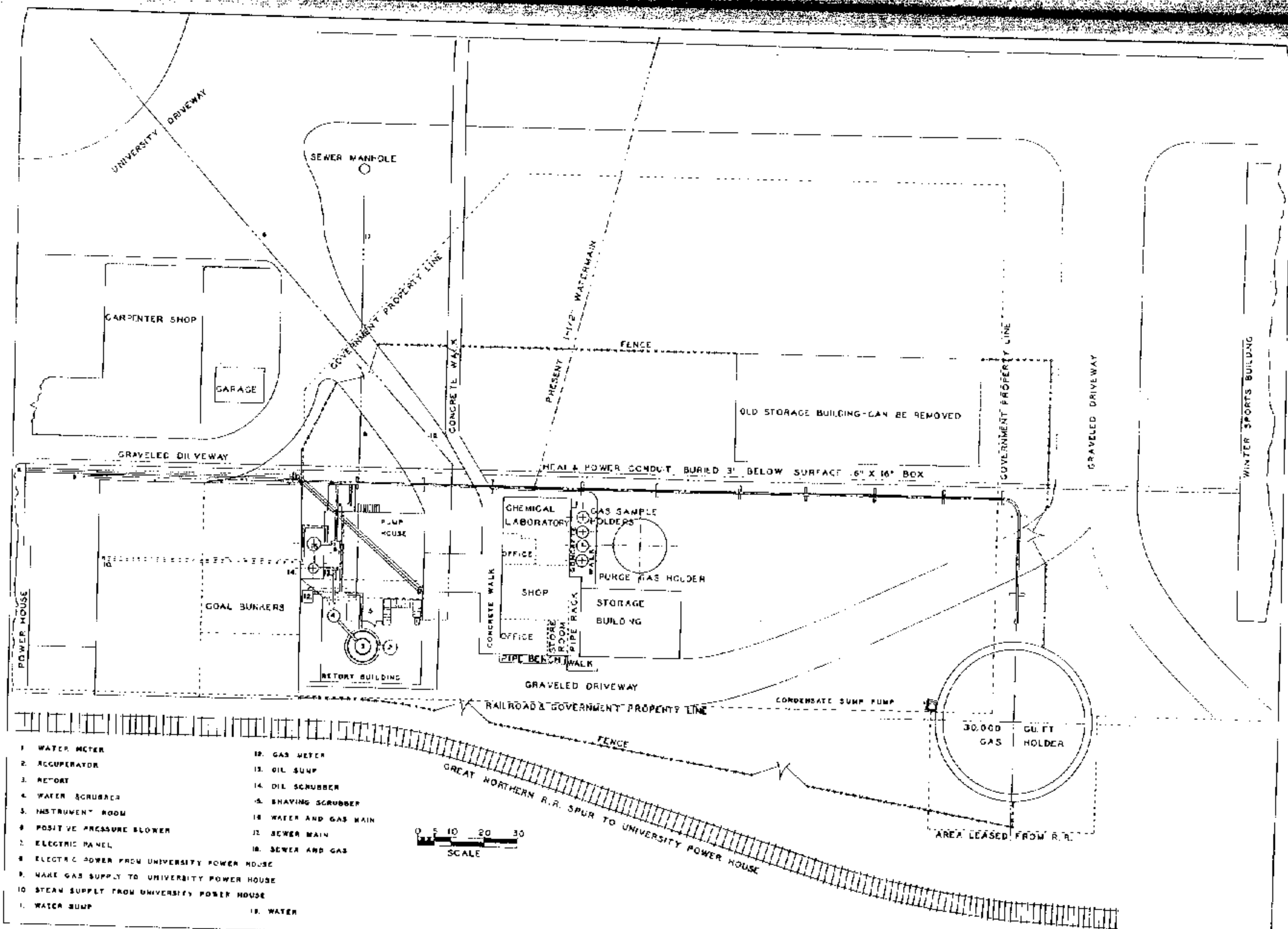

Figure 1. - Plan view of Government property and lignite-gasification unit, Grand Forks, N. Dak.

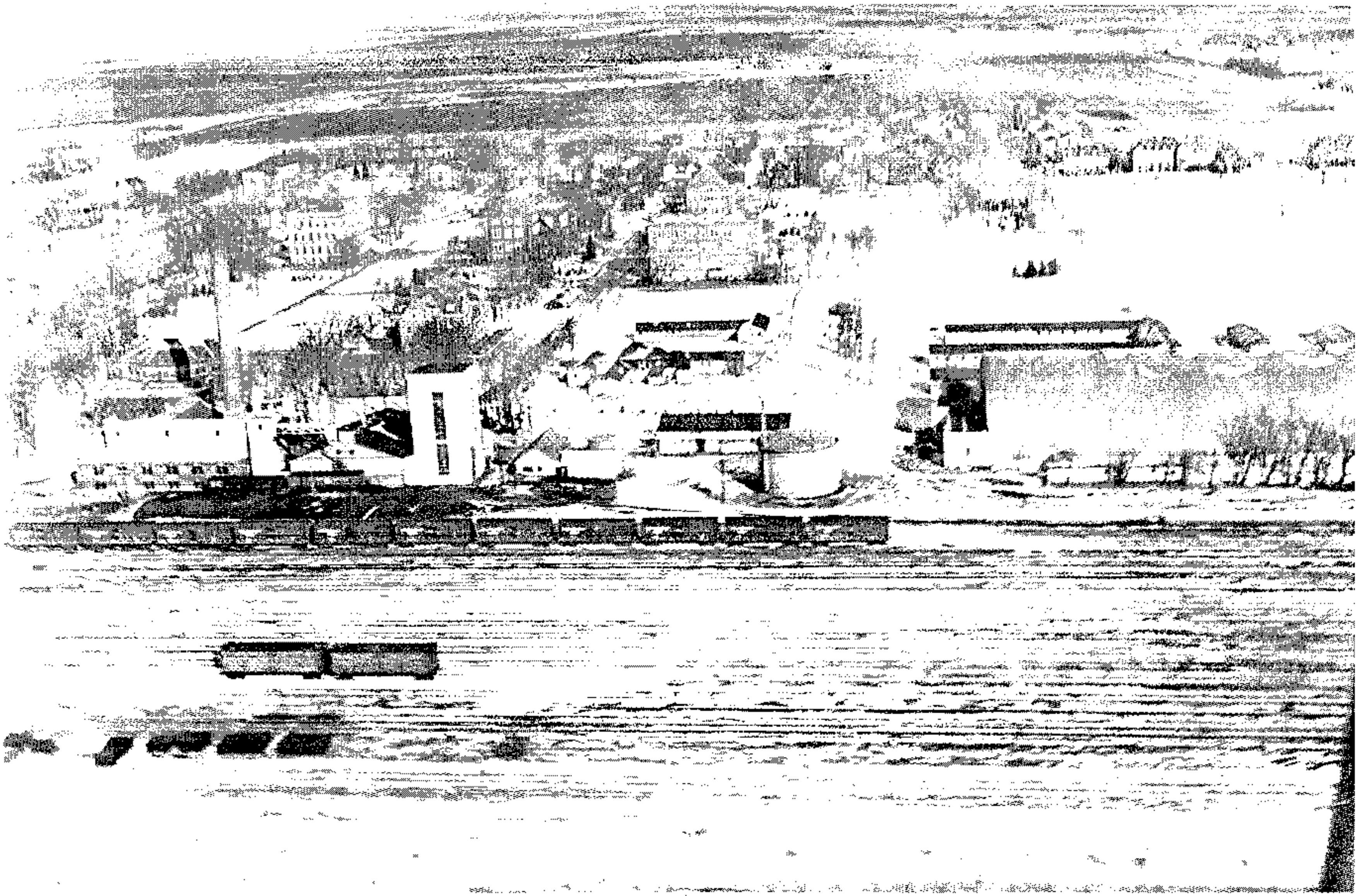

Figure 2. - Aerial view of Government property on University of North Dakota campus.

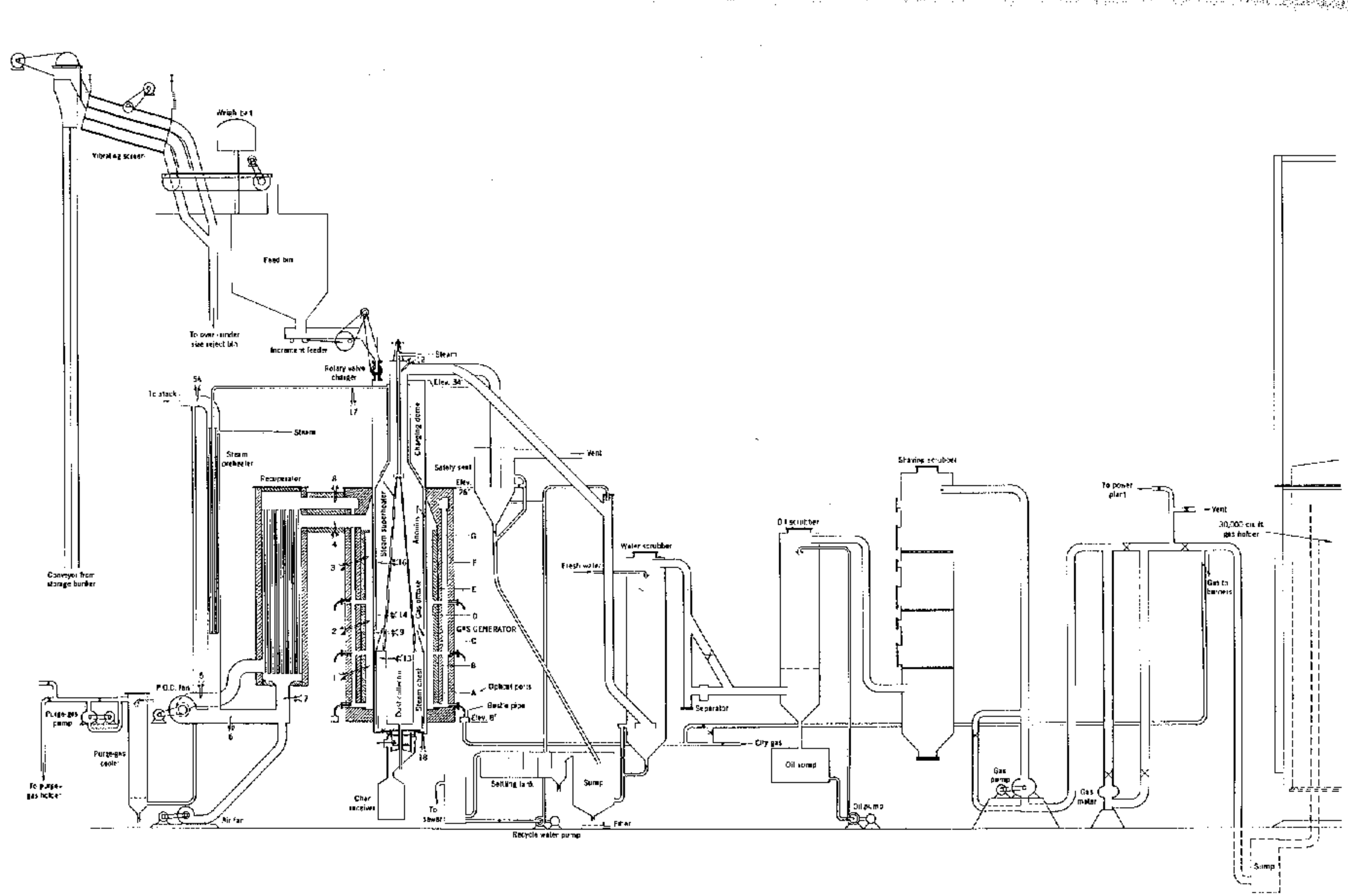

Figure 3. - Flow diagram of Grand Forks lignite-gasification process, showing divided annulus arrangement of retort.

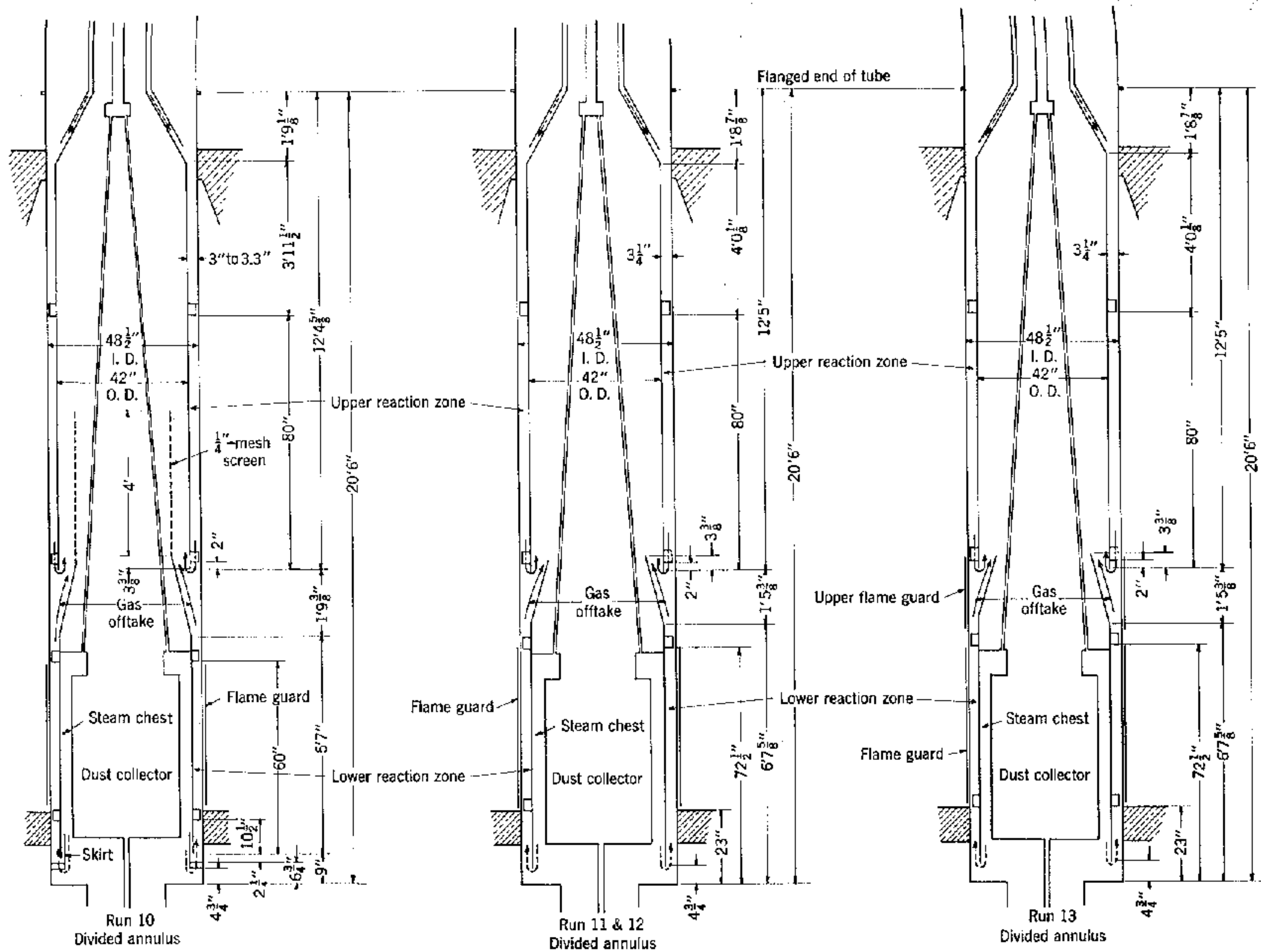

Figure 4. - Arrangement of retort unit for runs 10, 11, 12, and 13.

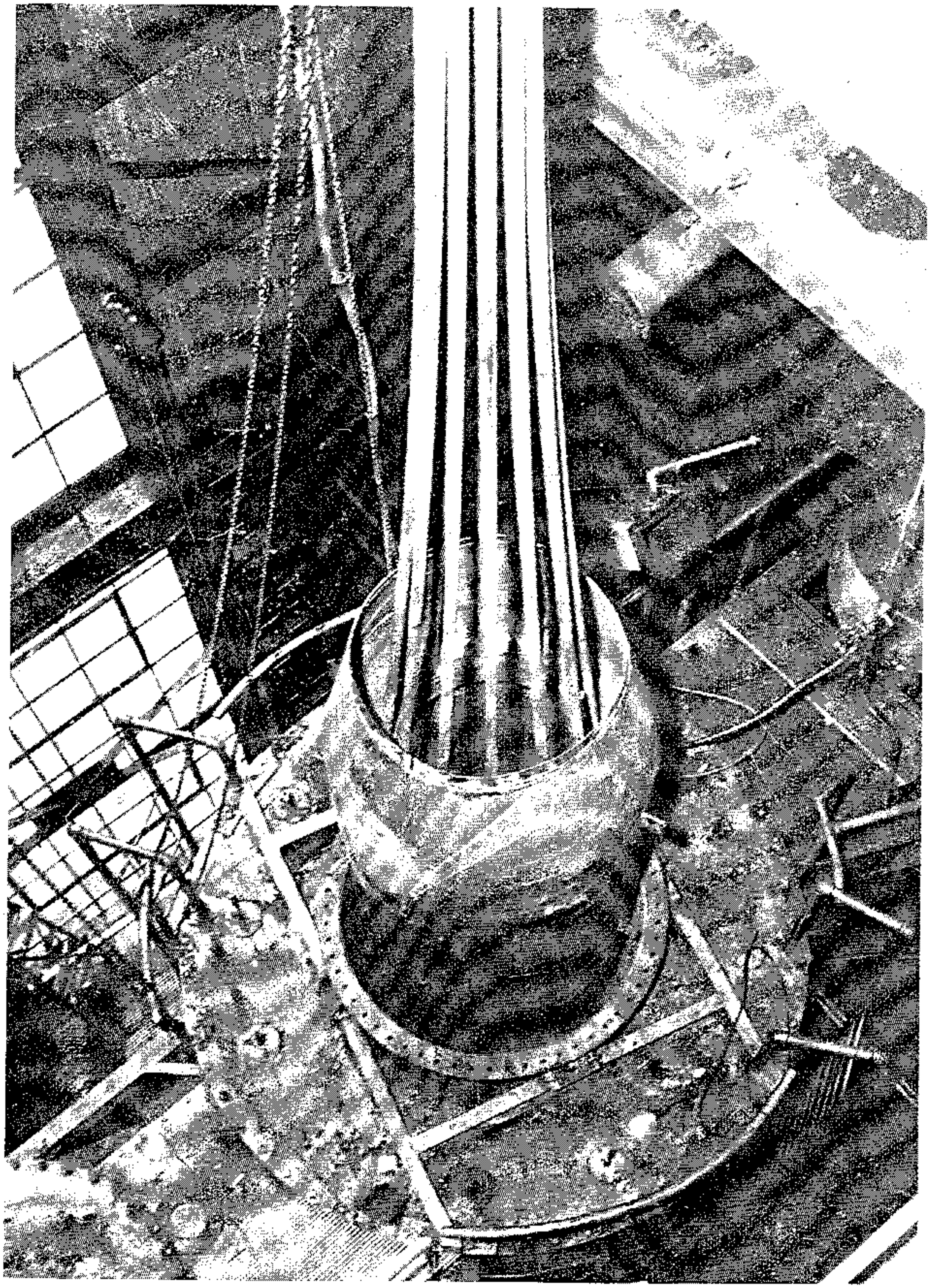

Figure 5. - Steam chest being lowered into retort.

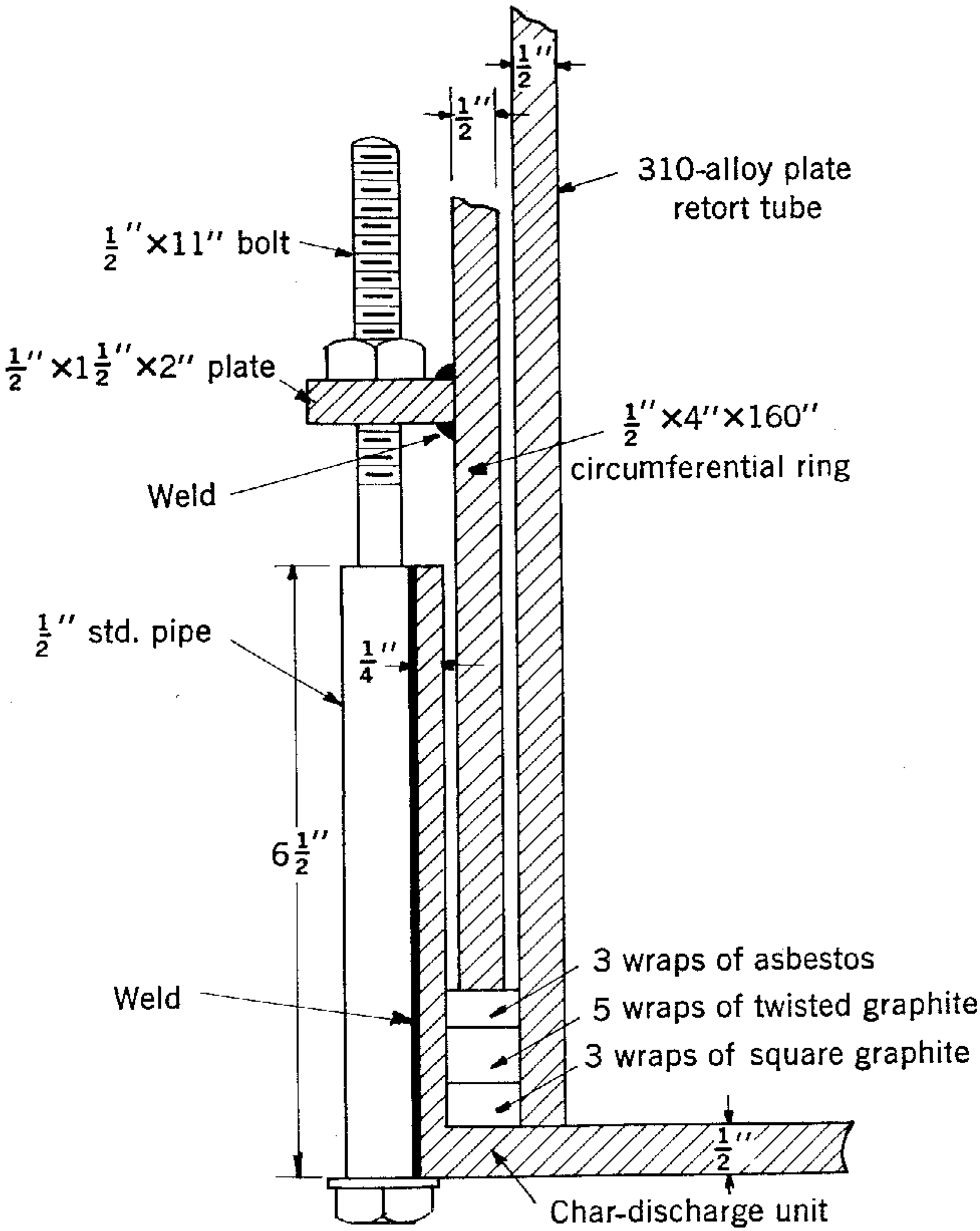

Figure 6. - Packing gland seal connecting retort tube to char-disposal unit.

providing a nominal 3-1/4-inch-wide annulus with the cast outer tube. The annular distance was increased from 2-1/4 inches to 3-1/4 inches, to insure even flow through the rough, irregular annulus. Other features of the unit were the same as for run 9.

Run 11:

A 310 alloy,[9] rolled plate tube having a 48-1/2-inch i.d. and a 1/2-inch wall thickness was used as the outer tube.

The 1/4-inch-mesh screen fastened to the cone of the gas offtake was removed for run 11. Also, the skirt, which previously was welded to the lower end of the outer tube, was taken off. This skirt allowed the width of the gas offtake to be varied without changing the actual length of the inner tube. Because in these runs the gas offtake was to be held at a constant width, there was no necessity for this skirt. To maintain the same length of the reaction zone, 15 feet, a 3-5/8-inch-high ring of mild steel was welded to the steam chest.

The cone on the steam chest was lengthened 2 inches in a vertical plane, so that a 2-3/4-inch overlapping of the cone and the upper section of the inner tube was maintained when the retort was heated. This overlapping was necessary to prevent excessive amounts of partly gasified lignite from falling into the blowover dust collector. Figure 5 shows the reconditioned steam chest being lowered into place.

A large packing gland (fig. 6) was designed to improve the seal between the outer tube and the char-disposal unit. This packing gland was constructed so that it could be adjusted at any time during a run, thereby maintaining a tight seal at any expansion of the outer tube. It consisted of a 1/2- by 4- by 160-inch circumferential ring, which fitted between the collar of the char-disposal unit and the 310-alloy tube. Twelve equidistant plates 1/2 by 1-1/2 by 2 inches were welded to the top of the circumferential ring. The plates were drilled so that a 1/2- by 11-inch standard bolt could pass through. Twelve short pieces of 1-1/2-inch standard pipe were welded to the char-disposal unit so that the bolts would connect the plates with the char unit. The space between the char-disposal unit, the inner tube, and the ring was filled with palmetto packing. Adjustment of the nut on the bolts kept the packing under pressure at all times.

The inner tube and the annular width of the reaction space of 3-1/4 inches were the same for runs 11, 12, and 13. The only change made in the retort unit after run 11 was addition of a second flame guard of 310-alloy plate on the outside of the alloy tube at 12 to 14 feet from the flanged end. This flame guard was to prevent direct impingement of flame from the second row of burners on the gas-offtake area, thus preventing overheating of the tube wall at that point of low heat consumption.

After run 13, the lower row of spacer bars welded to the outside of the inner tube was removed and replaced by a stiffener ring welded to the inside of this tube. This was done because constriction of the annular reaction space near the lower row of spacer bars made it difficult to remove the inner tube.

Auxiliary Equipment

The lignite-handling system, consisting of vane feeder, conveyor, vibrating screen, and weighbelt, operated satisfactorily without modification from the previous runs.

9/ Composition of alloy in percent: Cr, 24.35-24.49; Ni, 20.76-20.80; C, 0.03-0.06; Mn, 1.85-2.00; P, 0.018-0.020; S, 0.008-0.017; Si, 0.50-0.74; Cb, 0.69-0.75.

The method of feeding small increments to the retort, using the rotating plug valve interconnected by an adjustable speed drive to the reciprocating feeder, also was satisfactory. To secure more uniform distribution of lubricant to the valve body, the position of the greasing cups was changed, and a zirk grease fitting was placed at the back. The greasing schedule was slightly modified when the interval between greasings was reduced from 3 hours to 1 hour. The valve was dismantled and cleaned or replaced before each run.

Char and blowover dust were removed from the bottom of the dust collector by the same arrangements as were previously described for run 9 (4). Before run 12, the 1-1/2-inch pipe connecting the blowover dust collector to the blowover dust can was replaced by steel tubing, which had approximately the same outside diameter but had an internal diameter of 2 inches. The increase in internal diameter from 1-1/2 to 2 inches facilitated removal of the dust from the chamber and reduced the tendency of the connecting pipe to plug.

The scrubbing system was not changed, and the only work necessary was preventive maintenance, cleaning of the Raschig rings in the water scrubber, and replacement of the crushed coke in the coke scrubber.

The recuperator in which the primary air and recirculated P.O.C. (Products of Combustion) are heated by the hot flue gas operated satisfactorily after the 18-8 alloy tubes replaced the corroded portion of the Sicromo 5-S tubes after run 5. However, since the Sicromo 5-S, 18-8 combination tubes were considered to be a temporary expedient, new 23-12 tubes were ordered when the recuperator was repaired. After run 13, the recuperator was dismantled and rebuilt, using headerplates, baffles, and tubes fabricated of 23-12 alloy. The lower ring, which supported the recuperator-tube nest, was shortened 3 inches to prevent the top portion of the tube nest from blocking part of the upper duct in the junction box after the recuperator is at operating temperature. Figure 7 shows the reconstructed recuperator-tube nest.

Instrumentation, Methods of Testing, Obtaining Data, and Accuracy of Results

A complete description of the plant instrumentation and methods of testing and obtaining results and a discussion of the accuracy of the observed information have been presented in previous publications (2, 4). Reference should be made to those sources for detailed information.

The volume of product gas was measured by a Roots-Connersville low-pressure positive-displacement meter, and the composition was determined by analyses with a Burrell-Orsat analyzer on a minimum of three samples for each test period. The carbon dioxide content of the product gas and products of combustion (P.O.C.) were recorded by Republic meters. A recording Thomas calorimeter measured the heat value of the product gas, and a recording Ranarex meter recorded the specific gravity. The Orsat analysis and the calculated specific gravity were used in calculations, whereas the instruments were used for plant operation and control.

A belt-type weightometer was used to determine the lignite feed. Previously, calibration of this instrument consisted of weighing a timed sample on a platform scale. Beginning with run 12, the change in the creep load of the weightometer used to determine the lignite feed rate was also taken into consideration. The creep load per unit time was determined before and after the lignite was charged to the feed bin, and an average rate of creep load was calculated. Using this average rate and the loading time, a correction factor to be applied to the indicated weight of lignite was established. This method increased the accuracy of the determination of the weight of lignite fed to the retort.

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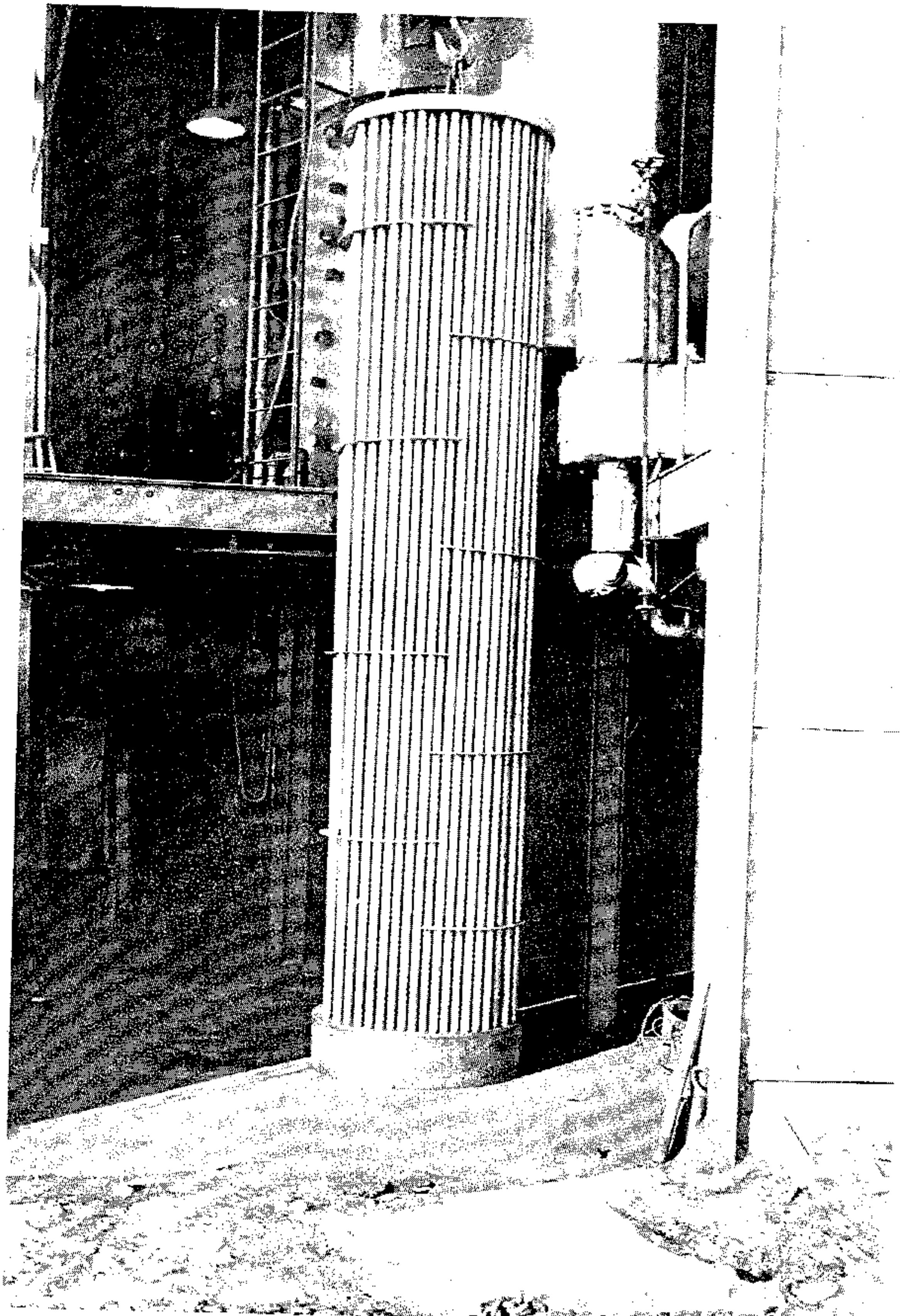

Figure 7. - Recuperator tube nest constructed from 23-12 stainless steel.