Each test period of approximately 24 hours was preceded by a preliminary or transition period, also of 24 hours. The actual time of these periods was not constant, depending on the cutoff time, but was never shorter than 20 hours. During test periods, the only changes made were slight adjustments to maintain the selected conditions.

Since all instruments were maintained in good operating condition and were, when possible, carefully calibrated before each run, their accuracy was believed to be within the generally accepted limits for each instrument.

TEST RUNS, OPERATING CONDITIONS, AND LIGNITE GASIFIED

Run 10

The retort was blown into operation at 4 p.m. January 17, 1949, and the heating system was shifted from city gas to product gas about 33 hours later. Experimental conditions were set for the first stabilization period, and attempts were made to bring the unit into balance. Erratic performance resulted with marked fluctuation in gas flow, static pressures, and temperatures. At 9:00 p.m. on January 19, the rate of gas production dropped sharply from approximately 12,000 to 9,000 cubic feet per hour; the pressure in the combustion space increased rapidly and could not be controlled by opening the stack damper. The temperature of the P.O.C.-primary air mixture leaving the recuperator increased from 1,300° to 1,600° F., and the temperature of the P.O.C. leaving the recuperator to the exhaust fan went from 900° to more than 1,000° F. The temperature of the P.O.C. at the outlet of the furnace advanced from 1,300° to 2,070° F. within 9 minutes, whereas the temperatures in the combustion space remained low. These observations indicated that the cast alloy tube must have broken in the upper section, giving the product gas direct access to the combustion space. Emergency procedure was put into effect, and the plant was rapidly shutdown.

When the inner tube was removed, a horizontal crack was discovered running along the circumferential weld seam 5 feet, 8 inches from the flanged end of the cast-alloy tube. Approximately 128 inches of the 150-inch weld had separated, the 2 sections of the tube being held together by only 22 inches of intact weld. More detailed information concerning the inspection of the tube may be found in the section on behavior of the various tubes.

Owing to the failure of the cast tube, run 10 lasted only 53 hours without steady-state conditions being reached; consequently, no testing period could be established. Approximately 253,000 cubic feet of gas was made during gasification of 12,000 pounds of natural lignite.

Before the HK-cast alloy tube cracked, the erratic behavior of the gas generator was similar to that of run 9, when actual bridging or hangup of the charge occurred. However, it is believed that hangup as such did not take place during run 10, because before the run, tests were made in which 1-1/2- by 1/2-inch lignite was fed through the 3-1/4-inch wide annulus at various rates without any indication of bridging. Also, no difficulty was encountered when the lignite remaining at the end of the run was removed. In addition, temperature, pressure, and gas-rate variations indicated that the apparent obstruction occurred at or near the gas offtake where gasification had taken place to such an extent that the size of the lignite was so reduced that bridging was not liable to occur. It was thought that char picked up by the gas leaving the gas offtake would accumulate between the 4-foot, 1/4-inch-mesh screen fastened in the cone of the gas offtake and the wall of the inner tube. This accumulated char was periodically lifted by the gas, causing surges and uneven operation of the retort. The screen was therefore removed for the the succeeding runs.

Run 11

Since no testing period was completed during run 10, the experimental program initiated for that run was kept for run 11. Four sets of hydrogen-carbon monoxide ratios ranging from approximately 2.5 to 6 were to be investigated. The combustion space temperatures, as well as the total steam admitted based on the percentage of natural lignite fed to the generator, were kept constant for each set of experiments, as the lignite feed rate was the variable under investigation. The 310-alloy, rolled-plate outer tube was first used in this run.

During periods A through E a low-ratio gas of approximately 2.5 was produced at various feed rates. The combustion space temperatures used for this series of experiments were:

	°F.
Thermocouple 1.	1,925
2.	1,850
4.	1,600

Steam admitted to the upper reaction zone was 10 percent of the weight of the raw lignite charged, whereas 30 percent of the feed weight was blown into the lower reaction zone. The range of feed rates tested was from 395 to 780 pounds per hour.

The objective of the periods F through I was to produce a gas having a ratio between 4.5 and 5. The lignite feed rate ranged from 411 to 579 pounds per hour, whereas the steam to the upper reaction zone was 53 to 55 percent of the weight of the raw lignite, and the steam to the lower reaction zone was approximately 60 percent. The combustion space temperatures for period F were:

	°F.
Thermocouple 1.	1,759
2.	1,790
4.	1,450

However, with this temperature distribution, the inner tube temperature was low, so the temperature at the middle row of burners was increased 60° F. This resulted in the following distribution of temperature for periods G through I:

	°F.
Thermocouple 1.	1,750
2.	1,850
4.	1,460

For periods J through L, the specific objective was to produce a medium ratio gas of about 3.5. The feed rate range was from 306 to 409 pounds per hour with combustion space temperatures adjusted to:

	°F.
Thermocouple 1.	1,750
2.	1,800
4.	1,480

Steam amounting to 33 percent of the weight of lignite charged was admitted to the upper reaction zone, and the same amount was sent into the lower zone.

Production of an H_2-CO ratio of the gas of approximately 6 was the objective of periods M and MN. In addition, more information concerning the appearance of gas surges at high steam rates was sought. The combustion space temperatures used during these periods were:

	°F.
Thermocouple 1.	1,750
2.	1,800
4.	1,480

The lignite feed rate was nearly constant at 389 and 395 pounds per hour for periods M and MN, respectively. The total steam admitted, equally distributed between the lignite zone and the char zone, was 159 and 169 percent respectively, of the weight of the raw lignite.

The stoker-size lignite of 1-1/2- by 3/8-inch size used for these experiments was obtained from the Dakota Star mine at Hazen, Mercer County, N. Dak., and was rescreened to 1-1/2- by 1/2-inch. This material was very uniform in composition, as shown in table 1, which contains the proximate and ultimate analyses of the lignite feed for the first, the eighth, and the last test periods of run 11.

TABLE 1. - Typical analyses of natural Dakota Star lignite as charged during run 11

Run and period number	11A	11H	11M
Proximate analyses, percent:			
Moisture	34.2	34.1	35.3
Volatile matter	28.5	27.9	28.1
Fixed carbon	32.3	31.0	29.3
Ash	5.0	7.0	7.3
Ultimate analysis, percent:			
Hydrogen	6.7	6.6	6.7
Carbon	44.1	42.9	41.6
Nitrogen	.7	.6	.6
Sulfur	.5	.9	1.0
Oxygen	43.0	42.0	42.8
Ash	5.0	7.0	7.3
Heating value, B.t.u. per lb.	7,440	7,210	7,010
Ash-softening temperature, °F.	2,490	2,360	2,280

Table 2 gives the size consist of the lignite charge again for the first, the eighth, and last test periods. This table shows that no significant difference existed in the size distribution of the lignite charged during the run.

TABLE 2. - Size consist of natural Dakota Star lignite as charged during run 11

Percentage retained

Run and period		11A	11H	11M
U. S. mesh No.1/	Opening, inches2/			
	1.50	0.0	0.0	0.0
	1.05	24.5	21.7	24.2
	.742	39.0	38.5	37.5
	.525	24.4	25.8	25.3
	.371	9.0	9.7	9.1
4	.185	1.8	2.8	2.4
8	.093	.7	.9	.8
16	.046	.3	.3	.4
Minus-16	-.046	.3	.3	.3
Average size, inches		.864	.838	.854

1/ Numbers are U. S. Standard series.
2/ Standard square-mesh openings.

Run 12

The major specific objective was to gasify steam-dried lignite of 12 to 15 percent moisture under conditions similar to those of gasification run 11 so that comparisons could be made of the behavior of the retort when operated with dried lignite, as opposed to the behavior when natural lignite was used. In addition, the gasification program called for production of a gas with a hydrogen-carbon monoxide ratio of less than 2, because this ratio had not been previously produced by the gasification of natural lignite. Numerous determinations of hydrogen sulfide and organic sulfur in the product gas were also made to obtain additional information on the distribution of the original lignite sulfur in the product gas and char.

To accomplish the major specific objective of this run, it was necessary to maintain the following conditions approximately equal: The lignite feed rate based on moisture- and ash-free material, the combustion space temperatures, and the total steam available per unit weight of moisture and ash-free lignite in each reaction zone. It was necessary that the total steam available be based on moisture- and ash-free lignite because the natural lignite contains approximately 37 percent moisture and 5 to 8.5 percent ash, whereas the steam-dried material has 12 to 15 percent moisture and 6 to 9 percent ash. If equal weights of dried and natural lignite were used, there would not be equivalent amounts of carbon available. Therefore, the operating conditions for periods C and D, E and F, HI and I, and IJ and J, were calculated on the basis of equivalent carbon to correspond, respectively, to the 2.5, 3.5, and 4.5 ratio conditions of run 11. The conditions of periods A and B of run 12 were calculated to give a hydrogen-carbon monoxide ratio of about 1.8. Table 3 summarizes the experimental conditions under which run 12 was made.

TABLE 3. - Summary of experimental conditions for run 12

Period	Combust. space temp., °F.1/	Feed rate, lb. per hr.	Steam, upper reaction zone	Percent of feed2/ to lower reaction zone
12-A	Thermocouple 1. 1,925 2. 1,900 4. 1,600	481	30	27
12-B	Same	570	32	28.4
12-C	Thermocouple 1. 1,925 2. 1,850 4. 1,600	445	49.6	52.1
12-D	Same	489	39.5	40.9
12-E	Thermocouple 1. 1,750 2. 1,800 4. 1,460	319	70.6	76.8
12-F	Same	391	40.8	44.8
12-G	Thermocouple 1. 1,750 2. 1,800 4. 1,460	307	98.1	98.7
12-H	Same	370	75.1	75.7
12-HI + I	Thermocouple 1. 1,750 2. 1,800 4. 1,460	301	75	44
12-JH+J	Same	405	75	44

1/ Thermocouple numbers refer to location in combustion space. 1 is near the bottom, 4 at junction box. Nominal temperature given.

2/ Approximate percentage.

The feed for run 12 was Dakota Star lignite, which had been steam-dried to 12 to 15 percent moisture at 400 p.s.i.a. by a modified Fleissner process (6) at the Grand Forks Station. Approximately 250 tons of raw lignite, 1-1/2- by 1/2-inch, was dried, yielding 144.5 tons of dried lignite, plus-1/2-inch, and 45.8 tons of minus -1/2-inch size. Steam drying of the 250 tons of lignite represents the largest drying operation of this type ever completed in the United States. Table 4 gives analyses of the dried lignite from periods 12A, 12E, and 12HI and I, and table 5 presents the particle-size distribution for the same periods. These results may be considered representative of the entire run. The composition of the feed was quite uniform, the greatest variation occurring in the moisture and sulfur contents. The percentage of moisture ranged from 11.8 to 15.4, and the sulfur percentages varied from 0.7 to 2.2. The higher sulfur percentages, even when calculated to conditions of natural lignite, were greater than that usually observed in lignite from Mercer County, N. Dak. Variations in moisture content were due to changes in the drying cycle and in the length of storage.

TABLE 4. - Typical analyses of steam-dried Dakota Star lignite as gasified during run 12

Run and period number	12-A	12-E	12-IJ + J
Proximate analysis, percent:			
Moisture	11.8	15.4	13.8
Volatile matter	38.5	36.7	38.6
Fixed carbon	40.9	39.8	40.8
Ash	8.8	8.1	6.8
Ultimate analysis, percent:			
Hydrogen	5.1	5.3	5.3
Carbon	56.9	55.2	56.5
Nitrogen	.7	.7	.8
Sulfur	2.2	1.7	.9
Oxygen	26.3	29.0	29.7
Ash	8.8	8.1	6.8
Heating value, B.t.u. per lb.	9,630	9,280	9,580
Ash-softening temperature, °F.	2,310	2,310	2,420

TABLE 5. - Size consist of steam-dried Dakota Star lignite as charged during run 12

		Percentage retained		
Run and period		12-A	12-E	12-HI + I 3/
U. S. mesh No.1/	Opening, inches2/			
	1.50	-	-	-
	1.05	-	3.6	3.5
	.742	11.1	32.0	13.8
	.525	37.4	34.9	30.8
	.371	31.1	18.0	21.4
4	.185	18.7	10.0	21.8
8	.093	1.1	.9	6.7
16	.046	.3	.5	1.8
Minus-16	-.046	.3	.1	.2
Average size, inch		.530	.664	.531

1/ Numbers are U. S. Standard series.
2/ Standards square-mesh screen openings.
3/ Period 12-HI + I reported as the screen sample for 12 IJ + J was not considered representative.

Run 13

The major specific objective was to determine the influence of the location of steam admission on the behavior of the retort with respect to gas yield, percentage of carbon gasified, and hydrogen-carbon monoxide ratio. The rate of steam admission to the upper or lignite zone and to the lower or char reaction zones was varied in 50-pound-per-hour increments, whereas the lignite feed rate and combustion-space temperatures were kept essentially constant. The nominal combustion space temperatures for run 13 were:

		°F.
Thermocouple	1.	1,925
	2.	1,850
	4.	1,600

By following a strict schedule of greasing the feed valve, an almost uniform number of strokes per hour of the reciprocating feeder was maintained throughout the entire run. However, because the reciprocating feeder controlled the volume rather than the actual weight of material charged, fluctuations in the bulk density of the natural lignite resulted in slight variations of the feed rate. The average feed rate during the run was 470 pounds of lignite per hour with a ± 5-percent deviation.

As usual, natural Dakota Star lignite from Mercer County, N. Dak., was used in the experiments, except for period 13-H. Owing to delay in shipment of Dakota Star lignite from the mine to the station, it was necessary to use Kincaid lignite from the University bunkers for this period. This Kincaid lignite was originally obtained from Burke County, N. Dak. The results obtained during this period were not used for the correlation of the experimental data, although little difference in gasification characteristics was observed. The tests were based on Dakota Star lignite with an average moisture content of 36.2 percent, which had been rescreened from the regular as-received stoker size to 1-1/2- by 3/8-inch. Table 6 summarizes the experimental conditions for run 13.

In addition to the influence of the location of the steam admission, the investigation of the distribution of the original sulfur in the lignite between product gas and residue was continued.

The Dakota Star lignite from Mercer County, N. Dak., used as feed for run 13 was quite uniform in composition. Table 7 presents the proximate and ultimate analyses on an as-received basis for the first, the median, and the last period.

Table 8 shows the size consist of the feed for the same periods for which the analyses were given and indicates variations between the periods. The percentage of charge retained on the 1.05-inch-mesh was from 11.8 to 20.4, and the average size was 0.789 to 0.852 inch. With these variations in the size consist, fluctuations in the bulk density of the lignite occurred, and these were reflected in changes of weight of lignite charged by the feeder operating on a volumetric basis.

TABLE 6. - Experimental conditions for run 13

Period	13-A	13-B	13-C	13-D	13-E	13-F	13-G	13-H1/	13-I	13-J	13-K	13-L	13-M	13-N
Natural lignite feed rate, lb. per hr.	487	481	467	480	458	475	468	442	484	481	469	454	451	458
Combustion-space temperatures:2/														
Thermocouple 1	1,923	1,926	1,926	1,925	1,925	1,923	1,927	1,926	1,926	1,926	1,925	1,927	1,929	1,926
2	1,852	1,851	1,850	1,851	1,854	1,851	1,852	1,850	1,846	1,850	1,851	1,851	1,850	1,850
4	1,601	1,603	1,600	1,601	1,601	1,599	1,600	1,602	1,601	1,600	1,601	1,600	1,599	1,599
Steam to upper reaction zone, lb. per hr.	0.0	0.0	0.0	0.0	0.0	0.0	54	103	103	140	200	250	293	103
Steam to lower reaction zone, lb. per hr.	103	150	200	240	293	49	103	103	103	103	103	103	103	103
Water available from moisture and water of formation, lb. per hr.4/	246	239	234	240	232	233	233	209	243	238	237	228	222	226
Total steam entering, lb. per hr.	349	389	434	480	525	282	390	415	449	481	540	581	618	432
Total steam entering, lb. per lb. M.a.f. lignite	1.24	1.40	1.61	1.75	2.00	1.00	1.40	1.61	1.60	1.75	2.02	2.22	2.36	1.62

1/ Kincaid lignite used for 13-H. All other periods were run on Dakota Star lignite.
2/ Thermocouple numbers refer to location in combustion space. No. 1 is near the bottom. No. 4 at junction box.
3/ No steam added to upper reaction zone during periods A through F.
4/ Calculated from total oxygen and equivalent hydrogen from ultimate analysis.

TABLE 7. - Typical analyses of natural Dakota Star lignite as gasified during run 13

Run and period number	13-A	13-G	13-N
Proximate analysis, percent:			
Moisture	36.5	35.1	35.8
Volatile matter	27.7	28.1	27.4
Fixed carbon	30.1	31.6	30.7
Ash	5.7	5.2	6.1
Ultimate analysis, percent:			
Hydrogen	6.8	6.7	6.8
Carbon	41.3	42.7	41.9
Nitrogen	.5	.6	.6
Oxygen	44.9	44.2	43.8
Sulfur	.8	.6	.8
Ash	5.7	5.2	6.1
Heating value, B.t.u. per lb.	6,990	7,210	7,060
Ash-softening temperatures, °F.	2,440	2,450	2,420

TABLE 8. - Size consist of natural Dakota Star lignite as charged during run 13

Percentage retained on screen

Run and period		13-A	13-G	13-N
U. S. mesh No.1/	Opening, inches2/			
	1.50	-	-	-
	1.05	11.8	14.6	20.4
	.742	42.0	41.9	42.5
	.525	34.2	28.9	26.3
	.371	9.1	11.8	8.7
4	.185	2.6	2.6	1.7
8	.093	.1	.1	.2
16	.046	.0	.0	.1
Minus-16	-.046	.2	.1	.1
Average size, inch		.789	.805	.852

1/ Numbers are U. S. Standard series.
2/ Standard square-mesh screen openings.

RESULTS AND DISCUSSION OF TESTS

General

The results and observations for 4 runs, including one of only 53 hours during which 20 million cubic feet of gas was generated from some 428 tons of natural or steam-dried lignite, are discussed herein. All the pertinent information is included in the appendix, and selected portions of the data and their correlation appear with the text.

Run 10

Owing to the failure of the cast-alloy tube, no results were obtained during this run.

Run 11

The gas generator was blown in on May 4, 1949, and the run ended on June 2, 1949. During the 694 hours of operation, 7,304 M c.f. of gas containing 4,200 M c.f. of hydrogen was produced at a rate of 7.8 to 13.5 M c.f. per hour from 344,000 pounds of natural lignite.

Figures 8 through 10 summarize the information obtained during these tests. These curves were constructed from data included in table 22 in the appendix and illustrate the influence of the lignite feed rate on the performance of the unit at the three sets of hydrogen to carbon monoxide ratios of the product gas investigated. Each set of ratios is presented in separate figures, since the operating conditions, except for the variable feed rate, were constant within each series.

Consideration of the influence of the feed rate on the percentage carbon gasified shows that, for each set of curves, the percentage of gasification was reduced with an increase of the feed rate. For the low-ratio series (fig. 8, hydrogen to carbon monoxide ratios 2.30-3.04) the percent carbon gasified decreased from 77.7 to 52.7 percent with an increase in feed rate from 395 to 783 pounds per hour, whereas, with the medium range of ratios (fig. 9, hydrogen-carbon monoxide ratio 3.38-3.99), a drop from 72.9 to 67.2 percent was observed, with an increase in feed rate from 306 to 404 pounds per hour. With an increase in feed rate from 389 to 571 pounds per hour, the percentage carbon gasified was reduced from 75 to 64.4 percent during the high-ratio experiments (fig. 10, hydrogen-carbon monoxide ratios 4.40-4.84).

An inverse relationship was also noticed when the influence of feed rate on the gas yield was examined. For the low-ratio series, the gas yield varied from 60.0 to 34.5 M c.f. per ton of natural lignite, with an increase of feed rate from 395 to 783 pounds per hour. At the medium-ratio range, the change in gas yield was from 51.0 to 45.0 M c.f. per ton of natural lignite for feed variations between 306 and 404 pounds per hour. A slightly smaller change was noted at the higher ratios, where the gas yield decreased from 52.7 to 45.0 M c.f. per ton when the feed rate was increased from 389 to 571 pounds per hour.

Changes in the inner tube temperatures as measured at 1 foot (point D) and 5 feet (point F) (see fig. 4) above the gas offtake are indications of variations in the average reaction temperature in the annulus at these points and thus may also be correlated with the changing feed rate. The same general trends as shown for the percent gasification and gas yield were followed by these inner-tube temperatures for each set of ratios. At the low ratios the temperature at point D dropped from 1,181° to 941° F. and the temperature at point F dropped from 918° to 581° F. when the feed rate was increased from 395 to 783 pounds per hour, a change in rate of 388 pounds per hour during the production of a low-ratio gas. At the medium ratios, the temperature at D dropped from 1,151° to 1,070° F., and the temperature at F dropped from 952° to 773° F., when the feed rate was increased from 306 to 404 pounds per hour, a change of 98 pounds per hour in rate. At the high ratios, a temperature drop of 63° from 1,051° to 988° F. was observed at D, and an 81 drop from 772° to 691° F. was noticed at F when a 182-pound-per-hour change from 389 to 571 pounds per hour was made in the feed rate.

Figure 11 shows the performance of the gas generator as a function of the feed rate for all periods of run 11. When taking the lowest lignite feed rate for each set of experiments as an index of 100 and expressing the higher lignite feed rates on a percent basis of the lowest, the percent carbon gasified for all periods of run 11 can be represented by a straight line, as shown on the plot. With a decrease of the

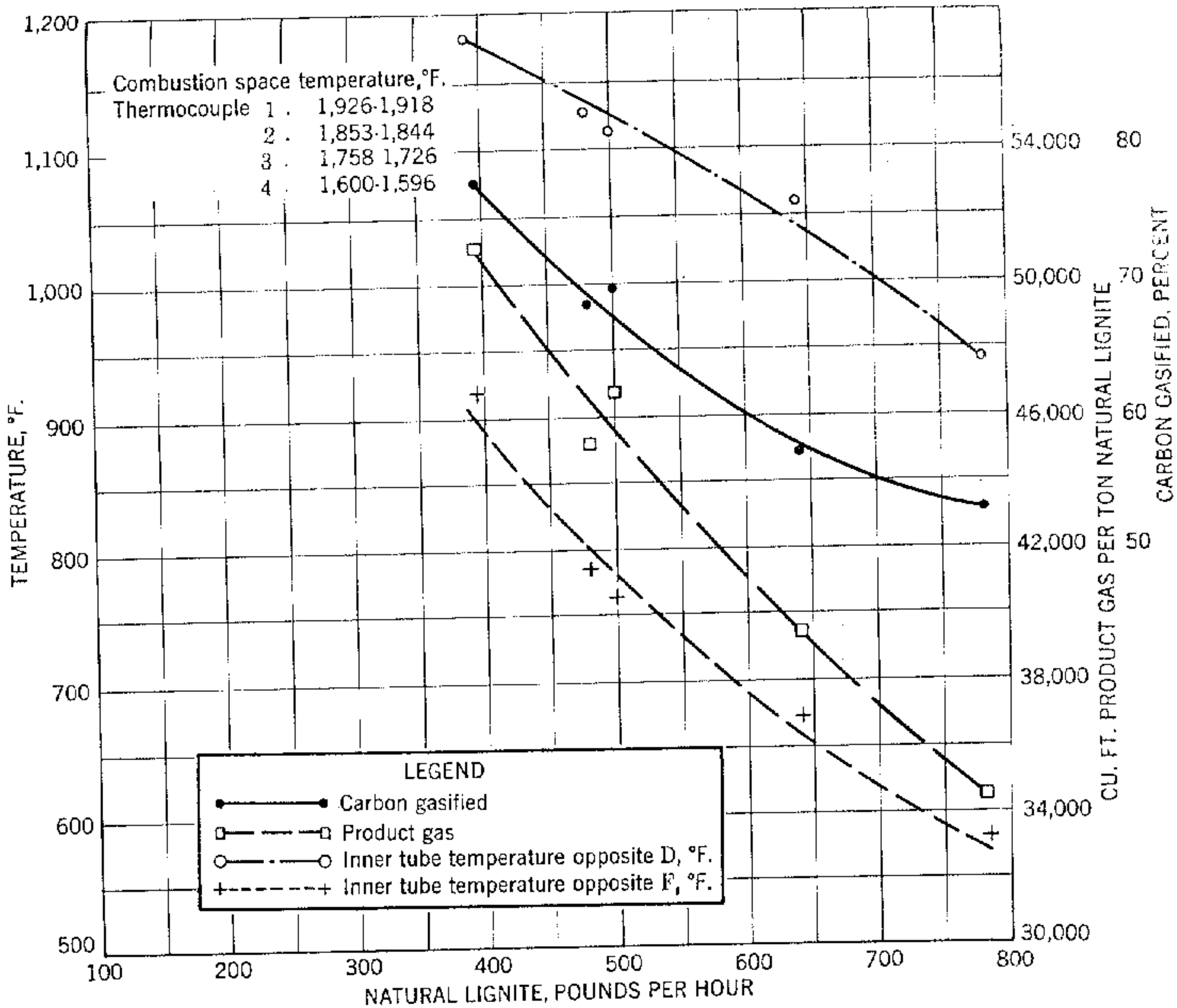

Figure 8. - Influence of lignite feed rate on performance of gas generator H_2-CO ratio 2.30 : 3.04.

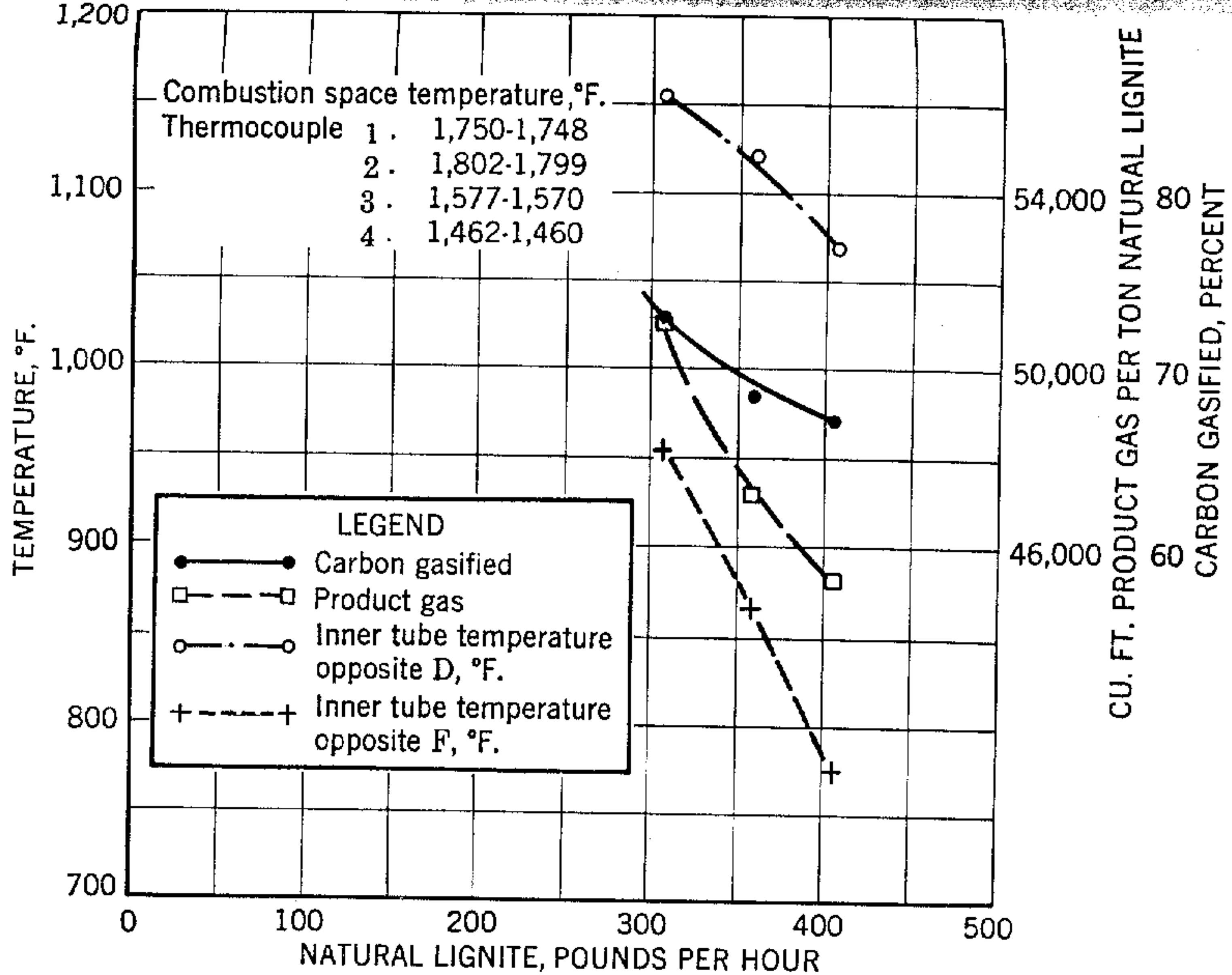

Figure 9. - Influence of lignite feed rate on performance of gas generator H_2-CO ratio 3.38 : 3.99.

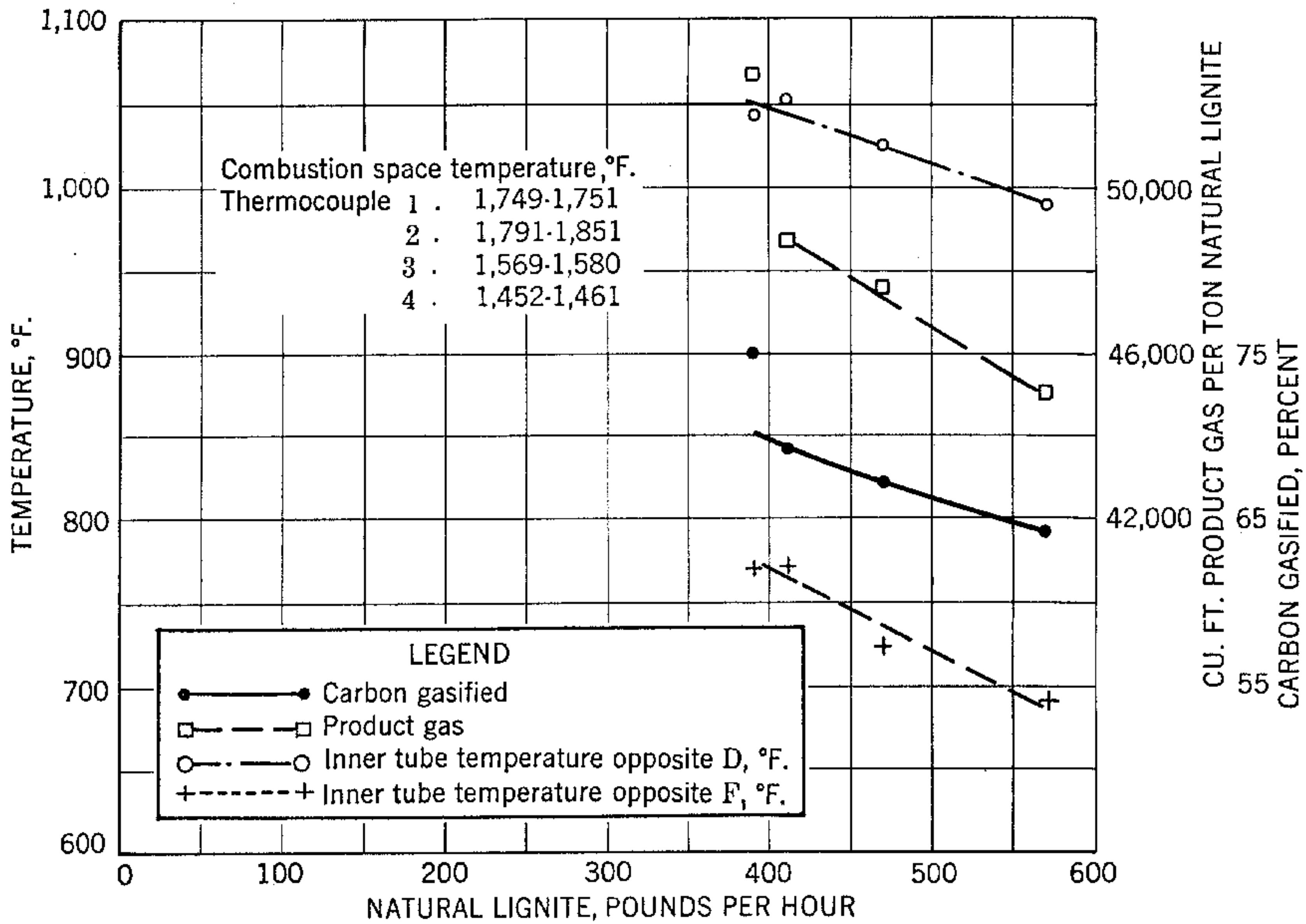

Figure 10. - Influence of lignite feed rate on performance of gas generator H_2-CO ratio 4.40 : 4.84.

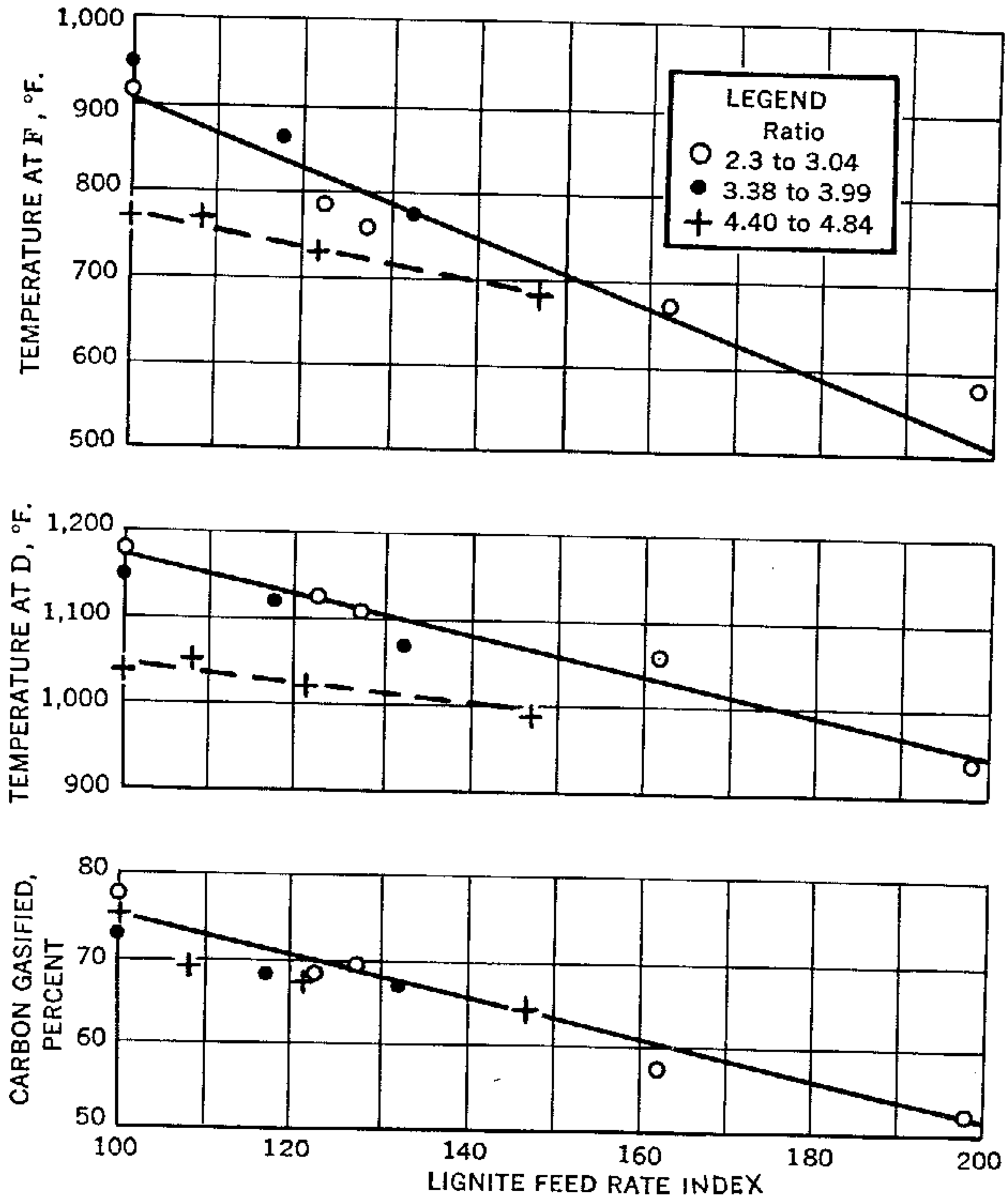

Figure 11. - Performance of the gas generator as a function of the lignite feed rate - run 11. Lowest feed rate for each series of experiments - 100.

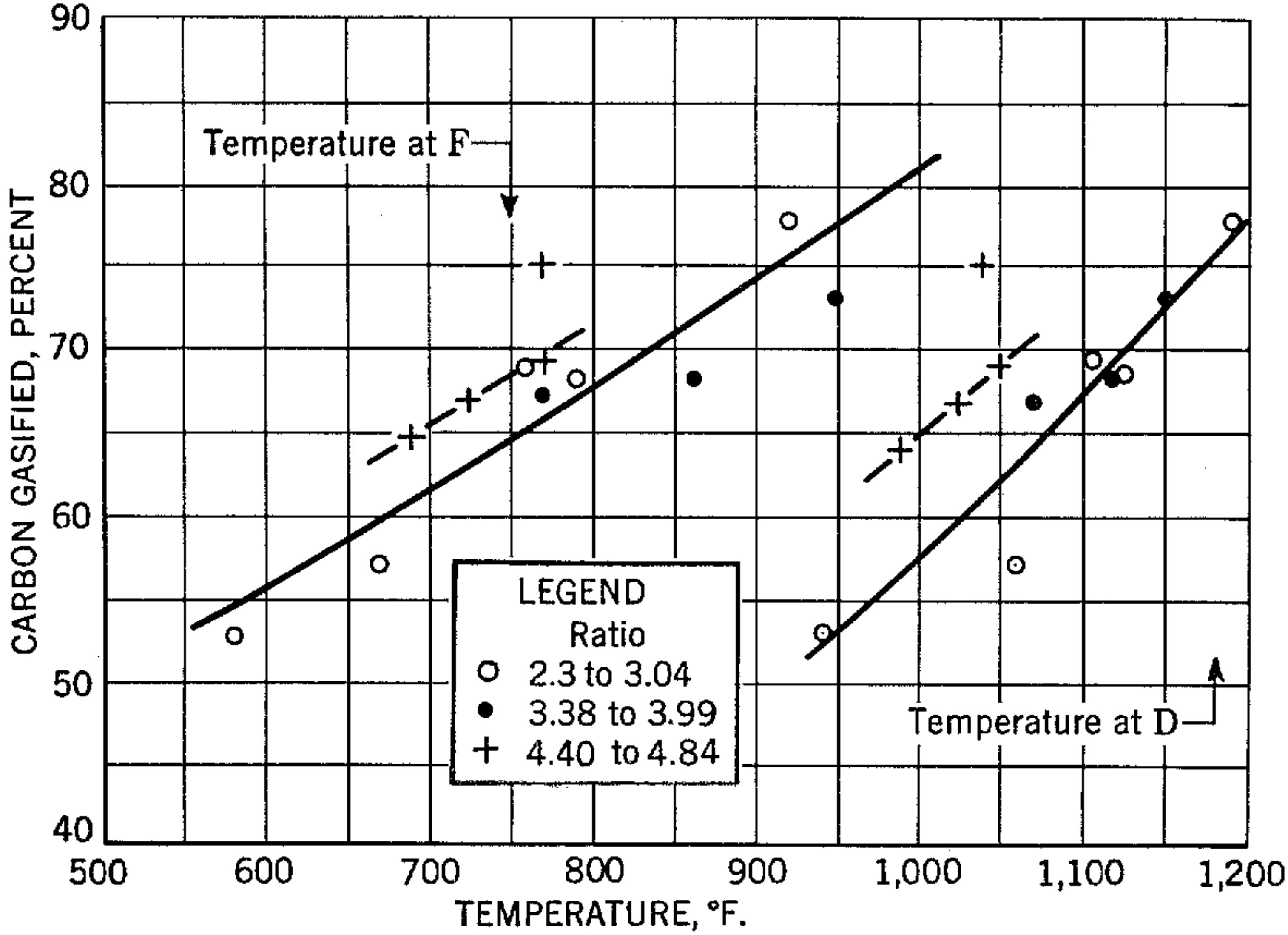

Figure 12. - Percentage carbon gasified as a function of the inner tube temperature.

percent carbon gasified, the temperature of the wall of the inner tube decreases simultaneously, as shown by the curves of figure 11, which represent the variation of the temperature at points D and F on the wall of the inner tube.

The percentage of carbon gasified as a function of the temperature of the inner tube is shown by figure 12. Despite different combustion space temperatures, the percentage of carbon gasified is closely related to the temperature of the wall of the inner tube. However, with a higher H_2-CO ratio of the product gas, the percentage of carbon gasified is higher at equal temperatures of the inner tube wall.

In addition to the correlations presented in the curves, a general increase of the hydrogen-carbon monoxide ratio was noticed with an increasing feed rate. However, at the higher ratios the change was slight, and within the limits of the experimental error of the operation. At the lowest set of ratios an increase in the hydrogen-carbon monoxide ratio from 2.30 to 3.0 occurred when the feed rate was varied from 395 to 641 pounds per hour. Because the concentration of undecomposed steam in the gas is directly related to the hydrogen-carbon monoxide ratio, this also increased with the feed rate.

Again, the variation in the amount of unreacted steam in the product gas was smaller at the higher ratios. The maximum variation of 12.5 pounds of undecomposed steam per M c.f. of gas (9.8 to 22.3 pounds of undecomposed steam per M c.f. gas) occurred again in the low-ratio experiments when the feed rate changed from 395 to 641 pounds per hour.

Periods M and MN, with ratios of 5.6 and 6.5 and a gas production of 10.6 and 11.4 M c.f. per hour, respectively, had the highest mass velocity of gas and steam at the gas offtake of any periods in this run. Because the chief purpose of these two periods was to obtain information concerning the effect of the velocity of the gases leaving the gas offtake on the operation of the unit, the results of these tests will be later correlated with data from runs 12 and 13.

The effect of the feed rate on the percentage of carbon gasified, gas yield, and other characteristics of the gasification process may generally be explained by the fact than an increased portion of the upper reaction zone was being used chiefly for drying and carbonization at the higher feed rates, with less space remaining for gasification. Increasing feed rates would reduce the contact time between the steam and lignite. Also, at the high feed rates with natural lignite, it was impossible to bring the lignite charged to a relatively high temperature. Thus, with a reduced reaction space and a lowered reaction temperature, less gasification would take place. With less gasification, the percentage of carbon gasified would be lower, and the resulting gas yield based on the feed would necessarily also be lower.

Tar carryover was particularly noticed during period AB, which had the highest feed rate and consequently the lowest annular space temperatures of any period of run 11. Considerable quantities of tar vapors escaped with the product gas and were later condensed in the scrubbing system, causing operational difficulties. Condensation of some of the higher boiling point tar vapors in the colder part of the annulus near the inner tube wall agglomerated char particles into briquetlike masses that interfered with the proper flow of the charge. Because of the excessive tar a test period B was not attempted, and the transition period AB, which for the purpose of comparison was stabilized enough, was taken as the test period.

Analyses of the residue, or char, showed marked differences, depending on the percentage of carbon gasified. Table 9 illustrates the change in composition at the highest, a medium, and the lowest percentage gasification. The residue samples analyzed were composites containing proportional amounts of char, blowover dust, and residue from the water-separating system. This table shows that the ash and volatile matter decrease and the carbon increases with a decreasing percentage of gasification. The volatile-matter content dropped from 13.0 to 9.2 percent, the carbon content increased from 41.1 to 67.8 percent, and the ash decreased from 60.5 to 29.8 percent when the percentage of carbon gasified decreased from 86.6 to 57.3 percent.

TABLE 9. - Analyses of residue from the gasification process at various percentages of carbon gasified during run 11

Run and period number	11-M	11-F	11-A
Carbon gasified, percent	86.6	69.1	57.3
Proximate analysis, percent:			
Moisture	1.0	1.4	1.5
Volatile matter	13.0	11.8	9.2
Fixed carbon	25.5	47.2	59.5
Ash1/	60.5	39.6	29.8
Ultimate analysis, percent:			
Hydrogen	1.0	1.4	1.3
Carbon	41.1	56.8	67.8
Nitrogen	.4	.4	.5
Sulfur	4.2	2.5	2.5
Oxygen	-	-	-
Ash1/	60.5	39.6	29.8
$SO_3$2/3/	8.13	5.36	5.97
$CO_2$2/	3.35	3.21	1.75
Heating value, B.t.u./lb.	6,550	8,990	10,550
Softening temperature of ash, °F.	2,300	2,360	2,420

1/ Ash uncorrected for sulfur and carbon reported as SO_3 and CO_2.
2/ In ash, reported as percent of original residue.
3/ Sulfur reported as equivalent SO_3.

Table 10 is a comparison of the size consist of the char for the same experiments as used in the preceding table. The comparison shows an increase of the particle size with decreasing percentage of gasification. The percentage retained on the 4-mesh screen increased from 21.2 to 33.9 percent, and the average particle size increased from 0.122 to 0.172 inch when the percentage of carbon gasified decreased from 86.6 to 57.3 percent.