both the inside and outside. This process produces a built-up, corrosion-resistant coating that consists of 0.015 inch of chromium-nickel alloy on the steel, a second coat of 0.004 inch of pure aluminum, and a thin seal coat of patented composition.

This spray-coated tube was used 449 hours in the preliminary trial and first experimental run. The highest furnace temperature during the preliminary trial was approximately 2,000° F., but in run 1 was about 1,800° F. Examination after these runs showed that the coating had blistered and scaled erratically near the gass offtake and for several feet below in the lower reaction zone. In this general region, a layer of soft ash, varying in thickness from 1/8 to 1 inch, was found on the inside of the tube. The ash deposit does not appear to cause these effects by chemical action but may reduce effective heat transfer, as bubbles, beads, and larger blisters were observed on the outside of the tube in the same region near the middle row of burners. Most of the coating was intact when the tube was discarded.

In addition to this corrosion, the tube had begun to collapse in one place in this same region, and it was obvious that the cross section was no longer circular. The original 4-inch annulus had changed and it was estimated that it varied from 2-3/4 to 5 inches. This distortion indicates that mild steel lacked strength for such service, particularly at the higher temperature.

These observations indicate that a spray-coated steel tube of this size is not satisfactory for this service.

Alloy-Clad Retort Tube

Next an alloy-clad retort tube was used for 3,310 hours. This tube was fabricated from double-armor Pluramelt and consisted of a 1/8-inch integral layer of 446 alloy cladding on each side of a 3/8-inch mild-steel core. All joints were welded with steel rod at the core and then covered with 446 alloy opposite the cladding.

Severe corrosion of this tube probably took place during run 4, when furnace temperatures exceeded 2,000° F., but this condition was not discovered until operational difficulties forced curtailment of run 5, and a careful examination of the tube was made. On the inside, the chief areas of corrosion were from the gass offtake down, where for nearly 3 feet there was a thick, hard, tightly adhering, magnetite scale all around the tube. Below this, extending to within 18 inches of the bottom end, was a soft, flaky, loosely adhering deposit consisting principally of ash. The welded joints in this general area were covered with thick, hard, magnetite scale. A general photograph of the area, looking upward, is shown in figure 12. The photograph to the left in figure 13 is a close view of the scale and ash deposits along a vertical welded seam, and the one to the right is the same area after cleaning. Corrosion of the tube surface and deep pitting at the seam are obvious.

As with the first tube, corrosion on the outside was found near the middle row of burners. A general view of the blisters and scale is shown in figure 14, while figure 15 shows the growth of scale over a seam and the severe corrosion where the scale has broken away. Corrosion and pitting of the welded seams were quite severe and general in this region and were repaired by rewelding on the outside with 310 alloy, but steel was used on the inside. Because of this corrosion, the tube was cleaned and inverted so that the upper part, which had shown little evidence of scaling, became the lower part in the hotter section of the furnace.

Runs 6, 7, and 8 were made with the inverted, reconditioned tube at furnace temperatures up to 2,000° F. No important additional evidence of corrosion was observed, except at the welded seams. As necessary all corroded seams were welded with 310 alloy, and then did not corrode noticeably thereafter. However, the tube continued to increase in diameter, as illustrated in figure 16. The several lines show the nominal inside diameter, the original inside diameter as delivered, and the

Figure 12. - Corrosion, scale, and ash deposits on inside alloy-clad retort tube after run 5.

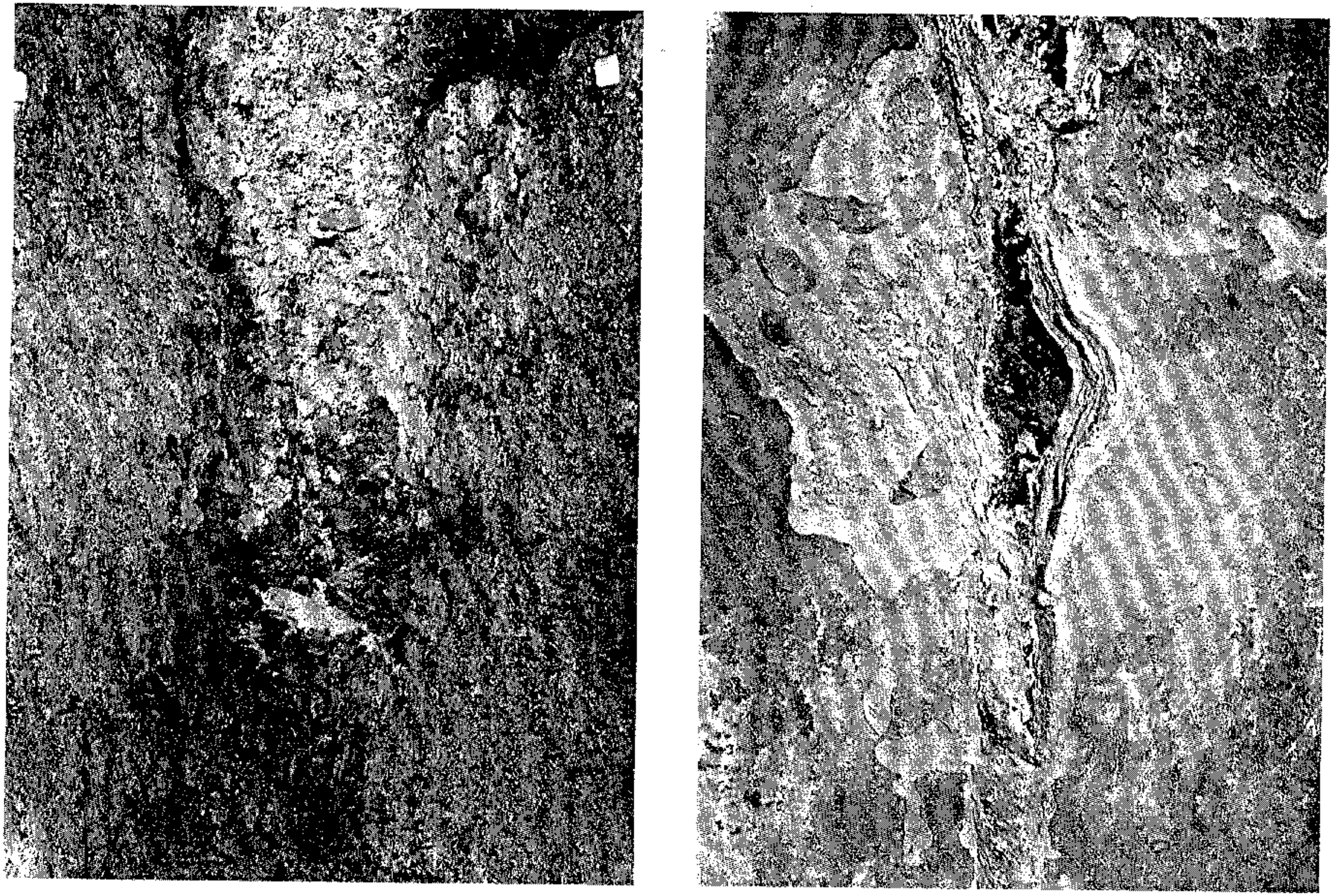

Figure 13. - Scale and ash deposits at vertical weld before cleaning and corroded areas revealed by cleaning on inside of alloy-clad retort tube after run 5.

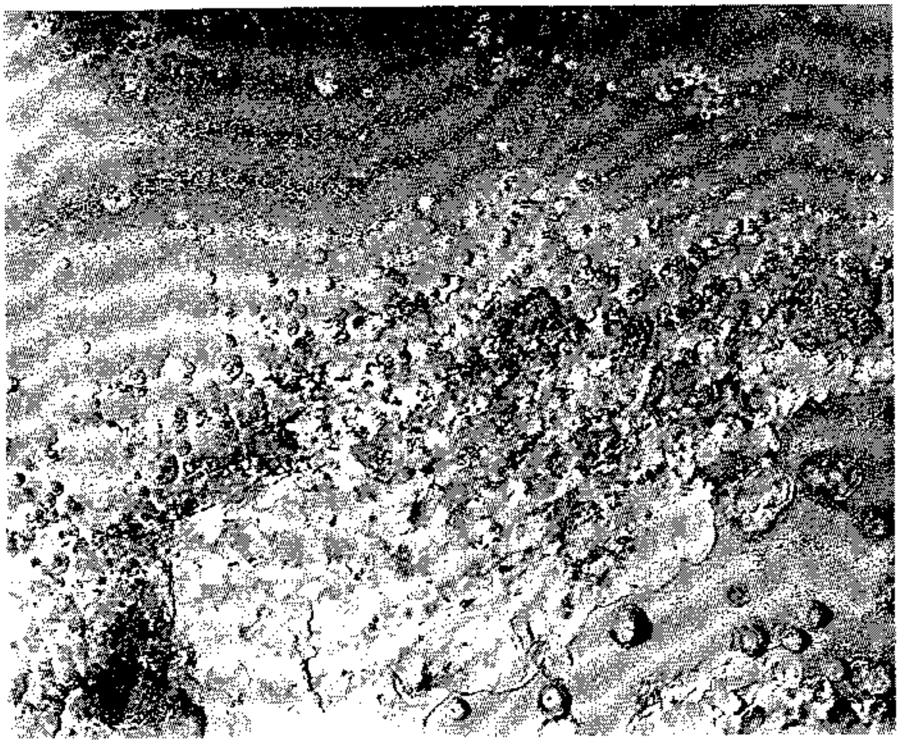

Figure 14. - Blisters and scale on outside of alloy-clad retort tube after run 5.

Figure 15. - Growth of magnetite scale over vertical weld on outside of alloy-clad retort tube after run 5.

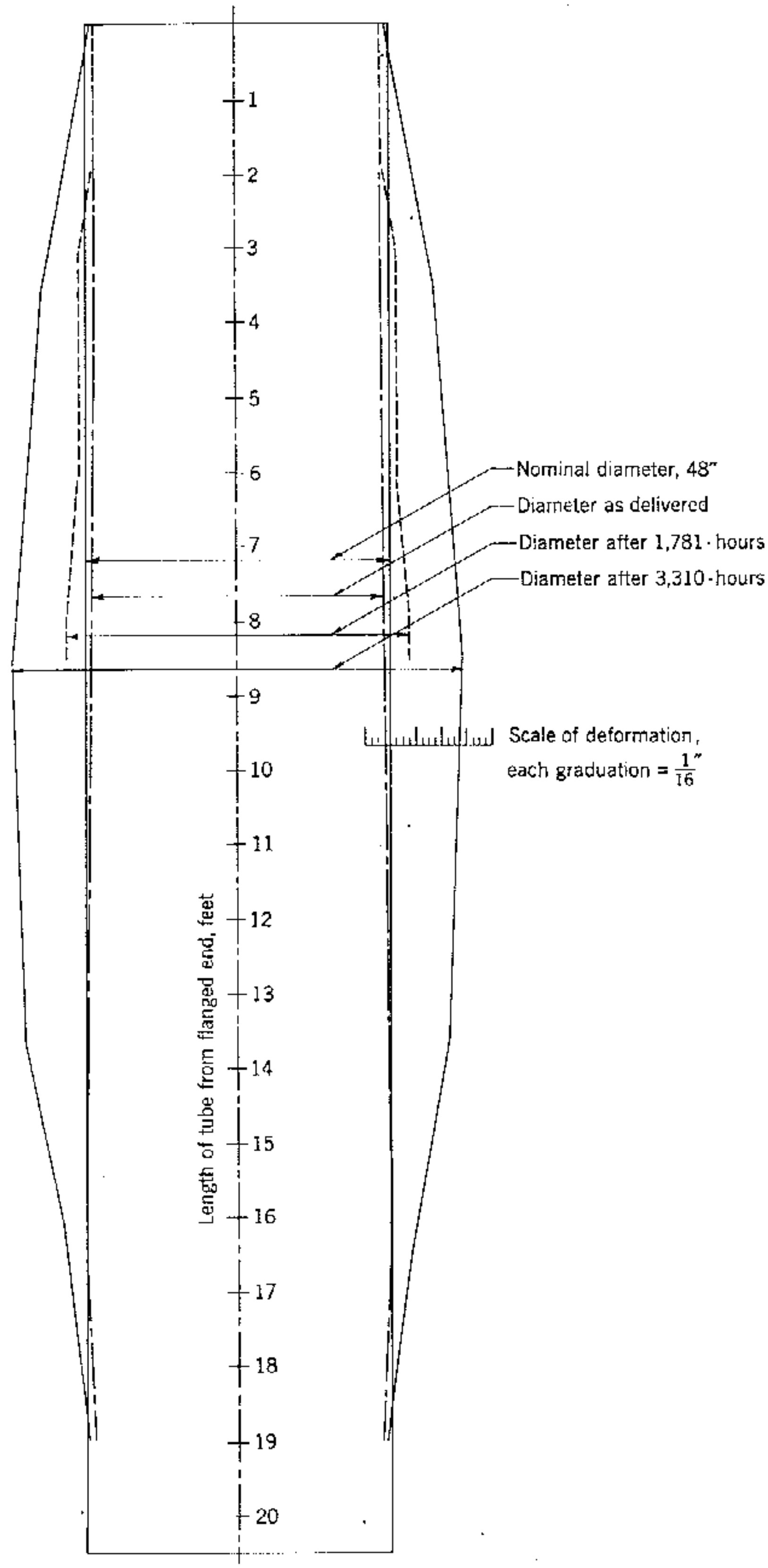

Figure 16. - Deformation of alloy-clad retort tube along axial plane 1-3 during 3,310 hours of service.

inside diameter after 1,781 hours of service and finally after 3,310 hours. These measurements were made along a vertical axial plane designated 1-3, where growth was greatest and reached a maximum of nearly 1-1/2 inches in diameter. A similar set of measurements along an axial plane at right angles to the first set showed a similar increase in diameter. Growth was not uniform either along the axial plane or in any horizontal plane, so that cross sections were not circular after these runs. Possibly this growth may be an effect caused by a difference in the coefficients of thermal expansion of 446 alloy and mild steel. In the temperature range from 70° to 1,300° F. the mean coefficients are 11.6×10^{-6} and 14.8×10^{-6}, respectively. The difference between them is about 28 percent of the lower coefficient.

These observations support the conclusion that a similar alloy-clad tube would not corrode appreciably if the furnace temperature never exceeds 1,900° F. However, 446 alloy cladding on mild steel is not recommended for this service because even at 1,900° F. the tube grows continuously. Although ash is deposited inside the tube in all experiments, the scaly nature of the corrosion, as well as deep pitting, both inside and outside, suggests that chemical action of the ash is not an important cause of corrosion. Ash deposits reduce heat transfer and may cause corrosion through local overheating.

Cast-Alloy Retort Tube

The retort tube for run 9, approximately 3/4 inch thick, was cast from HK alloy in two sections by a centrifugal process. The upper section, 5 feet 8 inches long, was joined to the lower, 14 feet 10 inches long, by a single circumferential weld of 310 alloy. Although the nominal inside diameter was specified as 48-1/2 inches, actual diameters ranged from 48 to 48-13/16 inches, and the cross sections were not circular. The inside surface was rather rough and covered with cavities, grooves, and pits that ranged from 1/16 to 7/16 inch in depth.

The inner tube of 430 alloy had an outside diameter of 44 inches to form a nominal 2-1/4-inch divided annulus. Run 9 was begun with 1-1/2 by 1/2-inch natural lignite, but difficulty in obtaining free flow through the annulus developed immediately. The size of the lignite was decreased in an attempt to correct this condition. After 98 hours when the size had been reduced to 3/4- by 1/4-inch and the difficulty was still apparent in erratic performance, the run was shut down.

The retort was opened for inspection, and measurement of the cold tube indicated variations in annulus width between 1-31/32 and 2-13/32 inches. At the end of the run, as the retort was being dismantled, lignite and char remained in the narrowest part of the annulus until they were prodded loose. It was concluded that the run failed because the annulus was narrow and irregular and its outer wall was rough. The run was too short to develop any operating data or information about corrosion or other deterioration of the tube.

In view of the poor condition of the cast tube and the fact that a rolled-plate tube of approximately the same metal composition was on order, no further gasification tests were made during the balance of 1948, but an apparatus to investigate size of feed versus width of annulus was set up to permit determination of minimum practical annulus widths for various sizes of fuel feed.

Flame Guard

Beginning with run 2, a circular flame guard of 310 alloy, approximately 4 feet in length and 3/16 inch thick has been used to protect the outside of all retort tubes at the lowest row of burners where the temperature is highest. After 3,408 hours of service no deformation, deterioration, or corrosion is apparent.

Inner Retort Tube

During all but run 9, a mild-steel inner retort tube was used. Although no important corrosion has taken place, some blisters with an outer scale of magnetite have been observed in the lower reaction zone where the highest temperatures prevail, but the number and extent of such formations have not been considered serious. A thin, tightly adhering layer of sulfide has been evident in the upper reaction zone, but this condition does not reveal effects of progressive corrosion. Nevertheless, these effects suggest that a low-alloy inner tube should be used in commercial plants, especially with a narrower annulus that would cause the inner tube to be hotter. Mild steel was used for the inner tube in the pilot plant because of the convenience, ease, and economy with which structural changes could be completed.

FLOW OF LIGNITE IN SIMULATED ANNULUS

Because the failure of run 9 was ascribed to effects related to the narrow annulus and the rough outer wall, the flow of lignite was examined in a simulated unheated annulus of rectangular crosssection. One rough wall was simulated with a floor plate that had a wafflelike pattern of 11/32-inch square projections separated on every side by 11/32-inch channels that were 3/32 inch deep. Flow was found to be related to a ratio derived by dividing the size of opening in the smallest screen that would not retain any of the lignite by the width of the annulus. Free flow always was obtained when this ratio was less than 0.33, and the ratio could be increased to 0.50 if both walls were smooth. No difference was detected between the flow of natural- and steam-dried lignite.

These results agree well with experience in run 9, during which free flow was not obtained when the size of the lignite was 3/4 by 1/4 inch. Where the annulus was only 1-31/32 inches in width, the corresponding ratio was about 0.38 without considering shrinkage of the lignite caused by drying.

CONCLUSIONS

During 1947 and 1948 the commercial-scale pilot plant was operated for 1,996 hours on Dakota Star lignite from Mercer County, N. Dak. No major changes in plant equipment were made for these experiments, the general objectives of which were to develop information about the life of the retort tube and the technology of gas making.

The special objective of two runs, 5 and 6, was to determine operating conditions for generation of gas with a high hydrogen-carbon monoxide ratio. For these runs the plant had a 3-inch divided annulus with a double gas offtake on the inner wall. Gas with hydrogen-carbon monoxide ratios between 4 and 9 was generated at rates from 7 to 12 M cu. ft. per hour. The lignite feed rate ranged between 270 and 500 pounds per hour, and the steam rate was controlled between 250 and 1,000 pounds per hour. Capacity performance was not reached at low ratios. At higher ratios near capacity performance was achieved in some periods because the large volume of excess steam present at the higher ratios of hydrogen to carbon monoxide and flowing with the product gas through the fixed area of the offtake limits the capacity of the generator. Otherwise, the chief effect of excess steam was to increase the ratio.

The special objective of runs 7 and 8 was to determine the flexibility and capacity of the plant with a 3-inch continuous annulus. Hydrogen-carbon monoxide ratios ranged between 2.3 and 6 at production rates from 6.5 to 10.5 M cu. ft. per hour. Lignite feed rates were varied from 300 to 500 pounds per hour at steam rates from 100 to 500 pounds per hour. In general, the performance of the continuous annulus did not differ substantially from that of the divided annulus, except that, at equal production rates, the pressure in the charging dome was considerably higher. Higher ratios than 6 were not reached, because it was considered unwise to allow the pressure in the charging dome to exceed about 60 inches of water.

Changes in carbon monoxide content were chiefly responsible for changes in the hydrogen-carbon monoxide ratio, as hydrogen in the product gas varied only between 57 and 62 percent, by volume. Changes in the percentages of carbon monoxide and carbon dioxide were related, and the percentage of carbon dioxide was a useful index to the ratio for plant control. The chief factor in controlling the ratio was the steam rate, and high rates corresponded to high ratios, although furnace temperatures were lowered when high ratios were desired. The lignite feed rate appeared to be a factor controlling the volume of gas.

Four heat and material balances show that the potential heat in the product gas is from 52 to 58 percent of the heat input. Lower percentages are associated with high-ratio gas, which is generated with increased heat losses owing to increased amounts of excess steam. Radiation and unaccounted-for heat losses appear to be related to the furnace temperature. Rates of heat transfer through the metal retort tube were from 1,500 to 3,000 B.t.u. per square foot per hour, or less than one-half the highest rate in earlier tests. No attempt was made to achieve high rates in these tests.

Experience with three retort tubes is discussed. The first was mild steel spray-coated by metcolizing process 45 to protect against corrosion. After 449 hours of service, during part of which furnace temperatures exceeded 2,000° F., the protective coating failed locally and partial collapse of the tube was observed in the lower reaction zone. From this experience it is concluded that a tube of this kind and size is not suitable for this service.

A second tube fabricated from double-armor 446-alloy Pluramelt failed through excessive corrosion after 1,781 hours of service, approximately 40 percent of which was at furnace temperatures above 2,000° F. The most severe corrosion took place at welded seams. After these were rewelded on the inside with steel and on the outside with 310 alloy, the tube was inverted and continued in service for 1,529 hours more at furnace temperatures less than 2,000° F. The reconditioned tube showed little evidence of additional corrosion, but there was a progressive increase in its diameter, which probably is caused by a difference in the coefficients of expansion of 446 alloy and mild steel.

In the divided annulus arrangement layers of ash have been found deposited where corrosion is most severe. As corrosion is observed in this region on the outside of the tube, it is believed that chemical effects from the ash do not influence the corrosion on the inside. The ash probably reduces heat transfer and causes local overheating to accelerate corrosion.

A centrifugally cast HK-alloy tube was in service during run 9 for 98 hours in a retort arrangement with a 2-1/4-inch divided annulus. Erratic performance, which prevented determination of operating results, was caused by roughness of the inside and irregularities in diameter that prevented lignite from flowing freely in the annulus. Tests in a simulated annulus with a rough wall supported this view as free flow was observed whenever the ratio of the size of the largest piece of lignite to the width of the annulus was less than 0.33, and no pieces were smaller than 1/2 inch. The corresponding ratio in run 9 was approximately 0.38 in the narrowest part of the annulus where any shrinkage caused by drying is neglected. When the walls of the annulus are smooth, a ratio as high as 0.50 may be used.

These results and observations support the following conclusions for a plant with a 3-inch annulus:

1. On the basis of present experience, no alloy retort tube should be heated above 2,000° F.

2. A mild-steel tube treated by metcollizing process 45 and the size used in these experiments was unsatisfactory because the coating failed locally and partial collapse was observed in the lower reaction zone.

3. A double-armor 446-alloy Pluramelt tube withstood corrosion well at temperatures up to 1,900° F. but failed to give satisfactory service because of progressive deformation, probably owing to a difference in coefficients of expansion of the cladding alloy and the mild-steel core. Alloys used as integral cladding should have the same coefficient of expansion as the core metal, and the combination should have adequate creep strength at the service temperature.

4. Layers of ash on the inside of the retort tube in a divided-annulus arrangement do not appear to cause corrosion by chemical effects but reduce heat transfer and thereby cause local overheating and accelerated corrosion.

5. Gas-production rates were influenced chiefly by the lignite feed rates with less pronounced effects from furnace temperature and steam rate. Under the prevailing operating conditions, highest production rates were achieved with the divided annulus arrangement of the retort.

6. The hydrogen-carbon monoxide ratio of gas from Dakota Star lignite ranged from 2.3 to 9. A large excess of steam was the chief operating control for production of the highest ratios, with lower furnace temperature as a secondary control.

7. Excess steam reduces the capacity of the plant as well as the thermal efficiency of gas production.

8. As the product gas from natural lignite contains 57 to 62 percent hydrogen, by volume, regardless of operating conditions, changes in hydrogen-carbon monoxide ratio are achieved chiefly through changes in percentage of carbon monoxide.

9. Satisfactory performance and wide flexibility in gas-production rates were obtained with either the divided- or continuous-annulus arrangement of the retort, but under similar operating conditions the continuous annulus had a lower capacity owing to increased flow resistance of the lower annulus.

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APPENDIX

Complete operating results, as well as all analytical data from runs 5 through 8, are presented in tables 11 through 15 in this appendix. For the convenience of readers who are familiar with the earlier progress report (2), an arrangement similar to that used in presentating those results has been retained.

TABLE 11. - Proximate and ultimate analyses of natural lignite used in commercial-scale pilot plant, runs 5 through 8 1/

Run and period number	Condition 2/	Pittsburgh lab. No.	Proximate, percent: Moisture	Proximate, percent: Volatile matter	Proximate, percent: Fixed carbon	Ash	Ultimate, percent: Hydrogen	Ultimate, percent: Carbon	Ultimate, percent: Nitrogen	Ultimate, percent: Oxygen	Ultimate, percent: Sulfur	B.t.u. per pound	Softening temp. ash, °F.
5ABCDE 3/	(1)	C-67425	36.2	27.3	30.1	6.4	6.7	41.4	0.6	44.2	0.7	6,960	2,310
	(2)			42.7	47.3	10.0	4.2	64.8	1.0	18.8	1.2	10,910	
	(3)			47.5	52.5	-	4.6	72.0	1.1	21.0	1.3	12,110	
6A	(1)	C-82128	36.5	27.2	30.3	6.0	6.9	41.4	.6	44.2	.9	7,020	2,450
	(2)			42.8	47.8	9.4	4.5	65.2	.9	18.6	1.4	11,050	
	(3)			47.3	52.7	-	4.9	71.9	1.0	20.7	1.5	12,190	
6B	(1)	C-82129	35.6	27.0	31.0	6.4	6.8	41.5	.6	44.0	.7	7,060	2,370
	(2)			41.9	48.2	9.9	4.4	64.4	.9	19.3	1.1	10,950	
	(3)			46.5	53.5	-	4.9	71.5	1.0	21.4	1.2	12,150	
6C	(1)	C-82302	36.0	28.3	29.4	6.3	5.9	41.4	.6	44.1	.7	6,990	2,360
	(2)			44.2	46.0	9.8	4.5	64.7	.9	19.1	1.0	10,930	
	(3)			49.0	51.0	-	4.9	71.7	1.0	21.3	1.1	12,110	
6D	(1)	C-82548	35.5	28.2	30.2	6.1	6.7	42.5	.6	43.4	.7	7,070	2,410
	(2)			43.7	46.9	9.4	4.3	65.8	.9	18.4	1.2	10,960	
	(3)			48.2	51.8	-	4.8	72.7	1.0	20.2	1.3	12,090	
6E	(1)	C-82550	36.5	27.1	30.1	6.3	6.8	41.7	.6	43.8	.8	6,980	2,410
	(2)			42.8	47.4	9.8	4.2	65.7	.9	18.1	1.3	10,990	
	(3)			47.4	52.6	-	4.7	72.9	1.0	19.9	1.5	12,190	
6F	(1)	C-82551	36.2	27.6	30.3	5.9	6.8	42.0	.6	44.0	.7	7,040	2,420
	(2)			43.2	47.5	9.3	4.3	65.8	.9	18.6	1.1	11,040	
	(3)			47.6	52.4	-	4.7	72.6	1.0	20.5	1.2	12,180	
6G	(1)	C-82776	35.6	27.2	30.3	5.9	6.8	41.9	.6	44.2	.6	6,980	2,270
	(2)			42.9	47.8	9.3	4.3	66.1	.9	18.4	1.0	11,010	
	(3)			47.3	52.7	-	4.7	72.9	1.0	20.3	1.1	12,140	
6H	(1)	C-83110	35.7	27.6	31.1	5.6	6.8	42.1	.6	44.2	.7	7,120	2,490
	(2)			42.9	48.3	8.8	4.4	65.5	.9	19.3	1.1	11,070	
	(3)			47.0	53.0	-	4.9	71.7	1.0	21.1	1.3	12,140	
6I	(1)	C-83109	34.3	28.4	31.1	6.2	6.7	42.6	.6	43.0	.9	7,190	2,360
	(2)			43.2	47.3	9.5	4.4	64.9	.8	19.1	1.3	10,950	
	(3)			47.8	52.2	-	4.9	71.7	.9	21.0	1.5	12,100	
7A	(1)	C-86542	36.6	26.5	29.9	7.0	6.8	40.9	.5	44.1	.7	6,880	2,310
	(2)			41.8	47.2	11.0	4.3	64.5	.8	18.3	1.1	10,850	
	(3)			46.9	53.1	-	4.8	72.5	.9	20.6	1.2	12,200	
7B	(1)	C-87078	36.5	27.6	29.9	6.0	6.8	41.4	.6	44.6	.6	6,950	2,420
	(2)			43.5	47.1	9.4	4.4	65.1	.9	19.2	1.0	10,950	
	(3)			48.0	52.0	-	4.8	71.9	1.0	21.2	1.1	12,080	
7C	(1)	C-87079	36.3	28.6	28.9	6.2	6.8	41.6	.6	44.1	.7	7,000	2,360
	(2)			44.8	45.5	9.7	4.4	65.3	.9	18.6	1.1	10,980	
	(3)			49.7	50.3	-	4.9	72.3	1.0	20.6	1.2	12,170	
7D	(1)	C-87081	36.1	27.7	30.4	5.8	6.8	41.8	.6	44.4	.6	7,040	2,280
	(2)			43.4	47.5	9.1	4.4	65.5	.9	19.2	.9	11,020	
	(3)			47.8	52.2	-	4.8	72.0	1.0	21.2	1.0	12,130	
7E	(1)	C-87082	37.1	27.0	29.4	6.5	6.8	41.0	0.6	44.4	0.7	6,880	2,260
	(2)			42.9	46.7	10.4	4.3	65.1	.9	18.1	1.2	10,940	
	(3)			47.8	52.2	-	4.8	72.7	1.0	20.2	1.3	12,200	
7F	(1)	C-87087	36.7	27.3	29.8	6.2	6.8	41.3	.6	44.4	.7	6,950	2,360
	(2)			43.1	47.0	9.9	4.3	65.3	1.0	18.3	1.2	10,980	
	(3)			47.9	52.1	-	4.8	72.4	1.1	20.4	1.3	12,180	
7G	(1)	C-87086	36.4	27.5	29.3	6.8	6.7	41.2	.6	43.9	.8	6,960	2,310
	(2)			43.2	46.1	10.7	4.2	64.8	1.0	18.0	1.3	10,940	
	(3)			48.4	51.6	-	4.7	72.6	1.1	20.1	1.5	12,250	
7H	(1)	C-87088	36.4	27.7	29.4	6.5	6.9	41.6	.6	43.7	.7	7,000	2,230
	(2)			43.7	46.1	10.2	4.4	65.4	1.0	17.9	1.1	11,010	
	(3)			48.6	51.4	-	4.9	72.8	1.1	20.0	1.2	12,270	
8ABCDE FGH 3/	(1)	C-90062	35.9	27.6	30.3	6.2	6.8	41.5	.6	44.2	.7	6,970	2,260
	(2)			43.1	47.2	9.7	4.3	64.6	.9	19.4	1.1	10,880	
	(3)			47.7	52.3	-	4.8	71.6	1.0	21.4	1.2	12,040	

1/ Samples obtained by reducing increment samples aggregating 1 percent of total lignite charged. Dakota Star lignite from Mercer County, N. Dak., used in all runs.
2/ Condition: (1) As received; (2) moisture free; (3) moisture and ash free.
3/ Composite sample representing all periods.

TABLE 12. - Summary data on gasification of natural lignite in the commercial-scale pilot plant, runs 5 through 8

Run and period number:	(1)	5A	5B	5C	5D	6A	6B	6C	6D	6E	6F	6G	6H	6I	7A	7B	7C	7D	7E	7F
Date 1/	(2)	16-18	20-22	23-25	26-27	12-14	16-19	20-21	23-24	25-26	27-28	29-30	1-2	3-4	8-9	10-11	12-13	14-15	16-17	18-19
Duration 2/ ... hr.	(3)	52.8	45.8	49.3	24.0	48.5	76.6	26.5	23.3	25.6	24.1	25.5	23.3	26.8	25.9	24.8	24.8	24.5	24.1	23.2
	(4)																			
Lignite charged ... lb. per hr.	(5)	380	325	295	380	323	369	448	501	459	429	316	375	273	333	431	492	420	324	294
Moisture as charged 3/ ... percent	(6)	36.2	36.2	36.2	36.2	36.5	35.6	36.0	35.5	36.5	36.2	36.6	35.7	34.3	36.6	36.5	36.3	36.1	37.1	36.7
Ash as charged ... do.	(7)	6.4	6.4	6.4	6.4	6.0	6.4	6.3	6.1	6.3	5.9	5.9	5.6	6.2	7.0	6.0	6.2	5.8	6.5	6.2
Carbon gasified ... do.	(8)	53.4	69.0	69.0	56.7	65.7	76.1	73.9	67.9	70.5	68.0	71.9	67.0	75.4	64.3	61.0	65.8	68.3	72.2	65.3
Lb. per M cu. ft. of gas ...	(9)	55.2	41.7	41.7	53.0	45.5	38.1	39.7	42.1	41.0	41.8	39.0	41.3	36.9	48.3	49.7	46.2	43.8	40.8	44.5
Dry residue 4/ ... lb. per hr.	(10)	99.2	63.2	57.6	93.8	66.3	60.4	77.6	100.3	86.3	84.1	56.6	74.1	46.2	71.9	96.7	101.9	81.6	58.8	61.2
Char out of bottom ...	(11)	68.5	42.3	31.6	68.7	43.7	47.4	53.5	68.2	57.7	44.4	42.9	52.6	36.9	58.0	62.3	62.6	63.8	43.7	41.1
Blown over at gas offtake ...	(12)	1.0	1.6	3.9	2.5	-	1.0	1.7	6.5	3.6	4.4	2.0	5.0	1.5	-	-	-	-	-	-
Dust with gas ...	(13)	0.9	0.3	0.4	1.2	0.1	0.3	0.6	1.8	1.5	0.8	0.6	1.4	-	0	0.3	0.2	0.3	0.3	0.2
Ash in total residue 5/ ... percent	(14)	23.4	25.9	29.8	20.4	39.8	41.0	46.6	31.8	29.5	38.8	30.2	25.4	32.6	30.5	38.7	38.7	33.6	38.6	37.1
Gas made SGC 6/:	(15)																			
M cu. ft. per ton ...	(16)	36.74	47.96	47.93	37.74	44.00	52.45	50.32	47.49	48.78	47.85	51.24	48.38	54.20	41.43	40.21	43.25	45.65	49.00	44.93
M cu. ft. per hour (orifice meter) ...	(17)	6.89	7.79	7.08	7.17	7.11	9.68	11.27	11.90	11.18	10.26	8.08	9.06	7.39						
(displacement meter) ...															6.90	8.56	10.64	9.59	7.93	6.60
B.t.u. per cu. ft. gross (calc.) ...	(18)	269	270	263	270	265	262	265	265	264	260	254	252	256	281	281	282	279	272	271
B.t.u. per cu. ft. (calc.) net 7/ ...	(19)	238	239	232	241	237	232	235	235	232	229	224	222	226	253	252	253	248	242	241
Specific gravity, (calc.) 8/ ...	(20)	0.540	0.545	0.547	0.548	0.561	0.556	0.555	0.554	0.556	0.557	0.556	0.560	0.560	0.552	0.546	0.545	0.547	0.548	0.544
Ratio H_2:CO ...	(21)	5.25	7.21	7.02	5.05	4.04	5.20	5.07	5.44	5.72	6.34	7.77	8.99	7.19	3.35	3.82	3.91	4.31	5.59	5.18
Steam used:	(22)																			
Upper reaction zone ... lb. per hr.	(23)	145	243	220	145	96	190	245	350	350	350	350	535	250	148	248	350	350	350	248
Lower reaction zone 9/ ... do.	(24)	235	260	395	245	155	250	265	330	330	330	330	465	250	-	-	-	-	-	-
Undecomposed steam 10/ lb. per M cu. ft. ...	(25)	32.9	57.1	76.5	52.6	27.0	39.8	35.6	52.7	48.8	52.7	79.5	99.7	59.4	20.7	21.7	25.1	29.8	34.8	30.1
Heating-system data:	(26)																			
Product gas used, SGC ... M cu. ft. per hr.	(27)	4.08	4.32	4.42	4.23	3.10	3.49	3.98	4.63	4.20	3.69	3.16	3.18	2.83	3.81	4.50	5.09	4.33	4.24	3.70
Net B.t.u. used per cu. ft. product gas ...	(28)	141	133	145	142	103	84	83	92	87	82	88	78	88	140	131	121	125	129	135
Heat released 11/ M B.t.u. per cu. ft. ...	(29)	8.43	8.98	8.93	8.85	6.37	7.04	8.13	9.46	8.47	7.33	6.16	6.13	5.58	8.40	9.85	11.20	10.44	8.93	7.77
CO_2 in POC 12/ ... percent	(30)	-	-	-	-	18.0	18.6	18.1	17.5	17.9	18.3	16.5	17.7	16.4	15.2	15.1	16.6	16.1	14.7	15.1
Primary air ... M cu. ft. per hour	(31)	9.68	9.71	9.73	9.03	10.02	8.99	10.28	11.58	10.65	9.51	8.41	9.08	7.74	9.29	10.82	12.09	11.03	9.66	8.11
POC recirculated ... do.	(32)	37.99	38.44	38.02	38.49	39.79	38.47	35.67	36.74	38.50	40.25	45.84	44.02	43.81	40.61	39.02	35.86	40.94	43.21	44.24
Temperatures, °F.:	(33)																			
Average combustion chamber 13/ ...	(34)	1,497	1,531	1,532	1,536	1,612	1,597	1,625	1,578	1,583	1,561	1,475	1,473	1,484	1,590	1,586	1,581	1,518	1,473	1,470
Bottom of combustion chamber No. 1 ...	(35)	1,766	1,749	1,748	1,771	1,778	1,720	1,748	1,765	1,765	1,725	1,659	1,666	1,659	1,777	1,773	1,778	1,701	1,651	1,650
Middle of combustion chamber ... 2 ...	(36)	1,606	1,717	1,648	1,651	1,716	1,723	1,756	1,685	1,677	1,666	1,572	1,582	1,573	1,677	1,668	1,658	1,605	1,567	1,546
Top of combustion chamber ... 3 ...	(37)	1,366	1,394	1,428	1,421	1,520	1,520	1,539	1,481	1,488	1,467	1,387	1,376	1,401	1,514	1,512	1,507	1,443	1,394	1,357
Outlet from combustion chamber .. 4 ...	(38)	1,248	1,265	1,303	1,301	1,432	1,426	1,446	1,382	1,401	1,387	1,281	1,269	1,302	1,350	1,389	1,381	1,324	1,283	1,288
Inlet to fan ... 5 ...	(39)	698	692	701	699	814	841	863	823	832	812	758	745	763	783	771	761	746	734	748
Air and POC to recuperator ... 7 ...	(40)	519	522	531	538	632	638	629	599	620	618	608	591	612	601	582	567	559	578	600
Air and POC to furnace ... 8 ...	(41)	995	1,010	1,030	1,025	1,195	1,193	1,239	1,158	1,167	1,129	1,049	1,023	1,057	1,120	1,103	1,099	1,074	1,044	1,055
Stack ... 5a ...	(42)	497	480	490	495	602	576	598	559	537	519	489	466	502	555	528	515	502	480	484
Steam to reaction zones:	(43)																			
Upper ... 17 ...	(44)	480	475	485	480	479	542	559	532	524	506	475	449	493	498	502	493	475	462	467
Lower, entering 9/ ...	(45)	248	273	-	249	248	256	268	264	263	261	262	272	251	-	-	-	-	-	-
Lower, superheated 9/ ... 13 ...	(46)	-	-	-	-	1,087	1,053	1,040	1,002	1,006	1,006	977	960	1,020	-	-	-	-	-	-
Gas leaving offtake ... 9 ...	(47)	1,090	1,117	1,108	1,112	1,202	1,189	1,192	1,157	1,154	1,143	1,130	1,120	1,148	1,212	1,197	1,201	1,177	1,176	1,177
Gas leaving retort ... 12 ...	(48)	600	655	650	605	642	658	675	671	650	658	650	653	545	637	675	697	675	575	654

TABLE 12. - Summary data on gasification of natural lignite in the commercial-scale pilot plant, runs 5 through 8 (Cont.)

Run and period number:	(1)	7G	7H	8A	8B	8C	8D	8E	8F	8G	8H
Date 1/	(2)	20-21	22-23	29-30	31-1	2-3	4-5	6-7	8-9	10-11	12-13
Duration 2/	(3)	23.7	22.0	22.3	24.3	23.1	24.3	26.4	24.0	22.9	23.4
	(4)										
Lignite charged ... lb. per hr.	(5)	353	353	381	304	369	436	346	380	415	401
Moisture as charged 3/ ... percent	(6)	36.4	36.4	35.9	35.9	35.9	35.9	35.9	35.9	35.9	35.9
Ash as charged ... do.	(7)	6.8	6.5	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Carbon gasified ... do.	(8)	74.3	60.3	59.4	58.7	73.3	72.8	67.2	69.8	71.0	68.0
Lb. per M cu. ft. of gas	(9)	39.3	30.1	52.9	45.6	41.6	41.3	46.8	44.4	43.1	46.2
Dry residue 4/ ... lb. per hr.	(10)	62.1	82.4	89.0	59.1	64.6	77.2	69.5	72.1	76.7	95.1
Char out of bottom	(11)	47.3	59.3	79.1	48.6	51.2	58.8	49.4	54.2	57.8	66.4
Blown over at gas offtake	(12)	-	-	-	-	-	-	-	-	-	-
Dust with gas	(13)	0.4	0	0.1	0.5	0	0.2	0.1	0.4	0.4	0.5
Ash in total residue 5/ ... percent	(14)	42.5	33.4	33.6	36.7	40.5	42.4	34.5	40.2	40.1	31.6
Gas made SGC 6/	(15)										
M cu. ft. per ton	(16)	50.88	39.88	38.87	46.60	45.72	47.39	43.93	45.08	46.35	43.25
M cu. ft. per hour (displacement meter)	(17)	8.97	7.04	7.20	6.58	8.86	10.54	7.39	8.56	9.63	10.40
B.t.u. per cu. ft. gross (calc.)	(18)	270	289	287	290	280	279	294	281	275	286
B.t.u. per cu. ft. (calc.) net 7/	(19)	239	260	259	262	251	248	266	253	247	258
Specific gravity, (calc. 8/)	(20)	0.546	0.531	0.546	0.536	0.540	0.537	0.532	0.546	0.554	0.539
Ratio H_2:CO	(21)	5.95	3.43	2.66	2.49	2.87	3.32	2.30	2.78	3.28	2.49
Steam used:	(22)										
Upper reaction zone ... lb. per hr.	(23)	455	148	100	100	195	300	100	195	300	195
Lower reaction zone 9/ ... do.	(24)	-	-	-	-	-	-	-	-	-	-
Undecomposed steam 10/ ... lb. per M cu. ft.	(25)	39.8	17.3	13.1	12.1	15.6	20.5	11.4	16.6	21.9	13.4
Heating system data:	(26)										
Product gas used, SGC ... M cu. ft. per hr.	(27)	4.59	4.02	3.03	3.60	4.37	5.10	4.09	4.46	4.84	5.24
Net B.t.u. used per cu. ft. product gas	(28)	122	148	138	141	124	120	147	132	124	130
Heat released, M B.t.u. per cu. ft. 11/	(29)	9.55	9.09	8.64	6.19	9.55	10.99	9.47	9.82	10.38	11.77
CO_2 in POC 12/ ... percent	(30)	15.6	15.1	16.2	15.9	17.2	16.8	16.5	16.8	17.3	17.5
Primary air ... M cu. ft. per hour	(31)	10.26	9.46	8.95	8.39	9.36	11.21	9.45	9.83	10.42	12.12
POC recirculated ... do.	(32)	42.27	39.71	40.93	40.62	40.06	38.96	37.68	37.55	36.80	31.24
Temperatures, °F.:	(33)										
Average combustion chamber 13/	(34)	1,471	1,580	1,603	1,601	1,600	1,604	1,709	1,707	1,707	1,849
Bottom of combustion chamber No. 1	(35)	1,650	1,775	1,850	1,851	1,849	1,850	1,950	1,948	1,950	1,999
Middle of combustion chamber 2	(36)	1,553	1,629	1,650	1,649	1,649	1,651	1,754	1,750	1,751	1,898
Top of combustion chamber 3	(37)	1,395	1,510	1,513	1,503	1,501	1,515	1,629	1,628	1,624	1,798
Outlet from combustion chamber .. 4	(38)	1,284	1,404	1,400	1,399	1,400	1,401	1,501	1,501	1,502	1,700
Inlet to fan 5	(39)	736	802	806	811	815	801	852	850	844	896
Air and POC to recuperator 7	(40)	578	608	612	614	611	590	621	614	608	606
Air and POC to furnace 8	(41)	1,042	1,141	1,137	1,141	1,150	1,141	1,219	1,222	1,210	1,355
Stack 5a	(42)	475	585	589	594	563	546	633	591	550	632
Steam to reaction zones:	(43)										
Upper 17	(44)	453	506	471	484	529	515	484	533	524	563
Lower, entering 9/	(45)	-	-	-	-	-	-	-	-	-	-
Lower, superheated 9/ 13	(46)	-	-	-	-	-	-	-	-	-	-
Gas leaving offtake 9	(47)	1,160	1,202	1,223	1,242	1,220	1,220	1,253	1,257	1,233	1,265
Gas leaving retort 12	(48)	697	650	624	636	675	701	654	701	718	731

Footnotes

1/ The figures shown are days of the month; run 5 was made during December 1946, run 6 during September and October 1947, run 7 during December 1947 and run 8 during January and February 1948.

2/ The testing periods were usually 24 hours; but some runs, as indicated, were for a longer or slightly shorter period.

3/ A composite lignite sample was used for analysis in runs 5 and 8; in runs 6 and 7 representative samples were taken for each period.

4/ Total residue was calculated from ash and carbon balance and always is greater than the sum of (11), (12), and (13) because all losses, such as fine dust carried away in cooling water, are not accounted for.

5/ The figures are the percentage of ash in a composite sample of char, blow-over dust, and sump residue, as determined by A.S.T.M. methods at the Pittsburgh Laboratory; no correction has been made for sulfates or carbonates retained in ash during analysis.

6/ Gas volume in runs 5 and 6 from orifice meters; in runs 7 and 8 from displacement meter; standard gas conditions, saturated gas at 60° F. and 30 in. of mercury.

7/ The calculated net B.t.u. was determined by deducting the mol fraction of total hydrogen times 49.6 from the observed gross B.t.u.

8/ Specific gravity calculated from the average gas analyses.

9/ No lower reaction zone in runs 7 and 8 with continuous annulus.

10/ Dry gas at 60° F. and 30 in. of mercury.

11/ This figure is based upon a furnace volume of 115 cu. ft. and the net heating value of the gas.

12/ Not determined during run 5; average value from chart of Republic meter for runs 6, 7, and 8.

13/ Average of points 1, 2, 3, and 4.

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TABLE 13. - Static pressures, retort dimensions, and steam flow in reaction zones of commercial-scale pilot plant, runs 5 through 8

Run and period number	5A	5B	5C	5D	6A	6B	6C	6D	6E	6F	6G	6H	6I	7A	7B
Gas produced..................M cu. ft. per hr.	6.9	7.8	7.1	7.2	7.1	9.7	11.3	11.9	11.2	10.3	8.1	9.1	7.4	6.9	8.7
Static pressures, in. of water:															
Charging dome..............................	6.9	9.3	9.0	7.5	10.8	10.4	13.8	14.4	14.9	14.6	14.6	18.5	14.2	21.2	33.0
Char discharge.............................	5.4	6.4	8.7	5.8	5.3	6.8	7.9	11.2	10.6	10.4	8.6	10.9	6.6	1.2	1.3
Gas offtake................................	2.0	2.0	2.0	2.0	1.9	2.2	2.1	3.8	3.2	2.1	2.1	2.0	2.0	2.1	2.0
Drop through upper reaction zone 1/.........	4.9	7.3	7.0	5.5	8.9	8.2	11.7	10.6	11.7	12.5	6.0	16.5	12.2	19.1	31.0
Drop through lower reaction zone 2/.........	3.4	4.4	6.7	3.8	3.4	4.6	5.6	7.4	7.4	8.3	6.5	8.9	4.6	-	-
Retort dimensions, in.:															
Width of annulus............................	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Length of upper reaction zone 3/4/.........	133	133	133	133	133	133	133	133	133	133	133	133	133	198	198
Length of lower reaction zone 2/...........	63	63	63	63	63	63	63	63	63	63	63	63	63	-	-
Steam, lb. per hr.:															
Upper reaction zone........................	145	243	220	145	96	190	245	350	350	350	350	535	250	148	248
Moisture in lignite........................	138	118	107	138	118	131	161	178	168	155	116	134	94	122	157
Total to upper reaction zone 5/............	283	361	327	283	214	321	406	528	518	505	466	669	344	270	405
Lower reaction zone 2/.....................	235	250	395	245	155	250	265	330	330	330	330	465	250	-	-

Run and period number	7C	7D	7E	7F	7G	7H	8A	8B	8C	8D	8E	8F	8G	8H
Gas produced..................M cu. ft. per hr.	10.6	9.6	7.9	6.6	9.0	7.0	7.2	6.7	8.9	10.5	7.4	8.6	9.6	10.4
Static pressures, in. of water:														
Charging dome..............................	62.2	46.9	41.6	26.6	62.8	19.8	16.1	15.7	24.6	40.1	20.4	35.4	65.5	47.5
Char discharge.............................	1.5	1.1	1.1	1.1	1.2	0.9	1.7	1.6	1.9	1.6	1.6	1.9	1.8	1.8
Gas offtake................................	2.3	2.1	2.0	2.0	2.0	2.0	1.8	1.8	2.0	2.0	2.0	2.0	2.0	2.0
Drop through upper reaction zone 1/.........	59.9	44.8	39.6	24.6	60.8	17.8	14.3	13.9	22.6	38.1	18.4	33.4	63.5	45.5
Drop through lower reaction zone 2/.........	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Retort dimensions, in.:														
Width of annulus............................	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Length of upper reaction zone 3/4/.........	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Length of lower reaction zone 2/...........	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steam, lb. per hr.:														
Upper reaction zone........................	350	350	350	248	455	148	100	100	195	300	100	195	300	195
Moisture in lignite........................	178	152	120	108	128	128	137	109	132	156	124	136	149	173
Total to upper reaction zone 2/............	528	502	470	356	583	276	237	209	227	456	224	331	449	368
Lower reaction zone 2/.....................	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ Pressure drop reported for runs 7 and 8 is total in continuous annulus.
2/ No lower reaction zones in runs 7 and 8 with continuous annulus.
3/ From inside top edge of upper reaction zone to upper edge of gas offtake (see fig. 4).
4/ Length of continuous annulus in runs 7 and 8.
5/ Total to continuous annulus in runs 7 and 8.

TABLE 14. - Analyses of product gas from natural lignite in commercial-scale pilot plant, runs 5 through 8

Run and period	Analysis, percent								Specific gravity (air = 1.0)		B.t.u. per cu. ft.			Remarks
	CO_2	Ill.1/	CO	H_2	CH_4	C_2H_6	N_2	O_2	Ranarex	Calc.	Thomas gross	Calc. gross	Calc. net	
5A	23.6	0.2	11.7	61.4	2.4	0.4	0.3	0	0.557	0.540	274	269	238	(2, 4)
5B	24.7	.2	8.5	61.3	3.2	.6	1.4	.1	.546	.545	262	270	239	(2, 4)
5C	25.3	.2	8.8	61.8	2.3	.6	.9	.1	.567	.547	257	263	232	(2, 4)
5D	23.7	.2	11.9	60.1	3.3	.2	.6	0	.550	.548	269	270	241	(2, 4)
6A	21.6	.1	14.2	57.3	3.3	.1	3.3	.1	.561	.561	270	265	237	(2)
	21.8	.1	14.7	59.4	3.4	.1	.5	-		.543		274		(3)
6B	23.4	.2	11.4	59.3	3.0	.1	2.4	.2	.556	.556	254	262	232	(2)
	23.8	.2	11.6	60.7	3.1	.1	.5	-		.544		268		(3)
6C	23.2	.3	11.7	59.3	3.0	.1	2.2	.2	.558	.555	258	265	235	(2)
	23.5	.3	11.9	60.6	3.1	.1	.5	-		.543		270		(3)
6D	23.8	.3	11.0	59.8	2.9	.2	1.8	.2	.559	.554	258	265	235	(2)
	24.1	.3	11.2	60.7	3.0	.2	.5	-		.547		269		(3)
6E	24.2	.3	10.5	60.1	2.5	.4	1.8	.2	.559	.556	251	264	232	(2)
	24.5	.3	10.7	61.1	2.5	.4	.5	-		.547		267		(3)
6F	24.8	.4	9.5	60.2	2.6	.2	2.1	.2	.550	.557	250	260	229	(2)
	25.1	.4	9.7	61.4	2.7	.2	.5	-		.548		266		(3)
6G	26.0	.3	7.8	60.6	2.6	.2	2.3	.2	.543	.556	245	254	224	(2)
	26.4	.3	8.0	61.9	2.7	.2	.5	-		.550		260		(3)
6H	26.8	.2	6.8	61.1	2.6	.3	2.0	.2	.560	.560	246	252	222	(2)
	27.2	.2	6.9	62.3	2.6	.3	.5	-		.550		256		(3)
6I	25.6	.3	8.4	60.4	2.7	.2	2.3	.1	.559	.560	245	256	226	(2)
	25.9	.3	8.6	61.7	2.8	.2	.5	-		.549		262		(3)
7A	18.8	.1	16.9	56.6	3.1	.8	3.4	.3	.564	.552	287	281	253	(2)
	19.2	.1	17.5	58.7	3.2	.8	.5	-		.536		291		(3)
7B	20.1	.2	15.2	58.0	3.6	.4	2.3	.2	.550	.546	279	281	252	(2)
	20.4	.2	15.5	59.3	3.7	.4	.5	-		.536		287		(3)
7C	20.5	.2	15.0	58.6	3.1	.7	1.8	.1	.550	.545	274	282	253	(2)
	20.6	.2	15.2	59.6	3.2	.7	.5	-		.536		287		(3)
7D	21.6	.2	13.6	58.6	4.3	.1	1.4	.2	.550	.547	283	279	248	(2)
	21.8	.2	13.7	59.3	4.4	.1	.5	-		.540		283		(3)
7E	23.0	.1	10.8	60.4	2.0	1.3	2.2	.2	.545	.548	265	272	242	(2)
	23.3	.1	11.0	61.7	2.1	1.3	.5	-		.537		278		(3)
7F	22.4	.1	11.5	59.6	3.5	.4	2.4	.1	.545	.544	254	271	241	(2)
	22.7	-	11.7	61.0	3.6	.4	.5	-		.532		277		(3)
7G	23.7	.2	10.2	60.7	2.5	.8	1.8	.1	.545	.546	263	270	239	(2)
	23.9	.2	10.3	61.7	2.6	.8	.5	-		.538		274		(3)
7H	18.3	.1	16.9	58.0	4.6	.1	1.8	.2	.540	.531	279	289	260	(2)
	18.5	.1	17.1	59.0	4.7	.1	.5	-		.524		293		(3)
8A	16.4	.1	21.0	55.9	3.1	.5	2.9	.1	.550	.546	296	287	259	(2)
	16.5	.1	21.6	57.6	3.2	.5	.5	-		.531		295		(3)
8B	15.0	.1	22.5	56.0	3.4	.2	2.7	.1	.540	.536	295	295	262	(2)
	15.2	.1	23.1	57.4	3.5	.2	.5	-		.522		297		(3)
8C	17.1	.1	19.9	57.1	2.7	.3	2.7	.1	.540	.540	286	280	251	(2)
	17.2	.1	20.5	58.6	2.8	.3	.5	-		.527		287		(3)
8D	18.8	.2	17.6	58.4	2.9	.2	1.7	.2	.539	.537	281	279	248	(2)
	19.0	.2	17.9	59.3	2.9	.2	.5	-		.531		283		(3)
8E	13.4	.1	24.3	55.8	2.6	.6	3.0	.2	.538	.532	293	294	266	(2)
	13.5	.1	25.1	57.5	2.7	.6	.5	-		.516		303		(3)
8F	17.0	.1	20.3	56.4	2.6	.5	3.0	.1	.535	.546	284	281	253	(2)
	17.1	.1	21.0	58.1	2.7	.5	.5	-		.530		290		(3)
8G	19.3	.1	17.4	57.0	2.7	.5	2.8	.2	.544	.554	285	275	247	(2)
	19.5	.1	17.9	58.7	2.8	.5	.5	-		.539		283		(3)
8H	15.5	.1	22.6	56.2	2.8	.3	2.3	.2	.550	.539	289	285	258	(2)
	15.7	.1	23.1	57.4	2.9	.3	.5	-		.528		293		(3)

1/ Assumed to have the average composition of $C_{2.3}H_{5.6}$.
2/ Averaged original data.
3/ Calculated air- and purge gas-free analysis. All O_2 is assumed to be derived from air. Composition of purge gas assumed 17 percent CO_2 and 83 percent N_2. Gas assumed to contain 0.5 percent N_2 from lignite.
4/ Air and purge gas considered negligible in run 5.

TABLE 15. - Proximate and ultimate analyses of chars and residues from commercial-scale pilot plant, runs 5 through 8[1]

Run and period	Pittsburgh lab. No.	Proximate, percent: Moisture	Proximate, percent: Volatile matter	Proximate, percent: Fixed carbon	Ash[2]	Ultimate, percent: Hydrogen	Ultimate, percent: Carbon	Ultimate, percent: Nitrogen	Ultimate, percent: Oxygen	Ultimate, percent: Sulfur	Ultimate, percent: SO_3[3/4]	Ultimate, percent: CO_2[3]	B.t.u. per pound	Softening temp. ash, °F.
5A	C-67825	1.3	10.3	65.0	23.4	1.6	71.4	0.6	1.8	1.2	-	-	11,130	2,450
5B	C-67823	1.3	9.7	63.1	25.9	1.6	68.0	.6	3.1	.8	-	-	10,580	2,450
5C	C-67826	1.4	11.0	57.8	29.8	1.5	64.2	.5	3.1	.9	-	-	9,990	2,470
5D	C-67824	1.0	9.3	69.3	20.4	1.6	73.5	.6	2.9	1.0	-	-	11,480	2,520
6A	C-82131	1.2	10.3	48.7	39.8	1.3	59.5	.4	-	3.2	7.79	3.20	9,340	2,370
6B	C-82130	1.2	10.9	46.9	41.0	1.3	56.4	.4	-	2.3	5.54	3.66	8,840	2,360
6C	C-82383	.8	10.8	41.8	46.6	1.2	51.5	.4	-	2.5	5.92	3.83	8,120	2,330
6D	C-82549	1.0	11.8	55.4	31.8	1.5	62.3	.5	-	1.2	3.67	4.54	9,720	2,310
6E	C-82694	1.3	11.7	57.5	29.5	1.5	64.6	.5	-	1.3	2.70	4.07	10,070	2,360
6F	C-82693	1.1	11.8	48.3	38.8	1.4	56.0	.5	-	1.4	3.03	4.59	8,730	2,420
6G	C-82777	1.4	11.8	56.6	30.2	1.6	62.7	.5	-	.8	1.84	4.38	9,740	2,410
6H	C-83112	1.5	12.3	60.8	25.4	1.8	66.8	.6	-	.6	2.87	4.63	10,410	2,380
6I	C-83111	1.1	10.6	55.7	32.6	1.4	62.1	.5	-	1.1	1.31	4.30	9,590	2,330
7A	C-86543	.6	9.3	59.6	30.5	1.6	67.8	.5	-	2.6	6.38	2.31	10,760	2,180
7B-C	C-87080	.6	9.8	50.9	38.7	1.1	61.2	.4	-	3.1	6.78	3.86	9,420	2,410
7D	C-87084	.6	9.6	56.2	33.6	1.1	64.2	.5	-	2.4	5.34	4.31	9,950	2,450
7E	C-87083	.6	10.7	50.1	38.6	1.1	59.8	.4	-	2.6	5.48	4.42	9,260	2,420
7F	C-87085	.7	10.1	52.1	37.1	1.2	61.7	.4	-	2.5	6.32	4.33	9,500	2,260
7G	C-87090	.6	10.8	46.1	42.5	1.0	56.1	.4	-	2.7	6.09	4.94	8,660	2,350
7H	C-87089	.5	8.1	59.0	33.4	1.1	66.0	.5	-	2.9	6.85	3.16	10,210	2,350
8A	C-89412	.5	7.8	58.1	33.6	1.1	67.6	.5	-	3.1	7.76	2.32	10,500	2,170
8B	C-89414	.3	7.4	55.6	36.7	.9	64.9	.5	-	3.3	8.16	2.45	10,010	2,230
8C	C-89413	.8	8.4	50.3	40.5	.9	60.3	.4	-	3.4	8.49	3.07	9,380	2,210
8D	C-89707	.5	8.9	48.2	42.4	.8	59.0	.4	-	3.5	8.0	3.9	9,120	2,230
8E	C-89863	.3	6.9	58.3	34.5	.8	67.3	.4	-	3.1	7.2	2.3	10,370	2,310
8F	C-89864	.5	7.4	51.9	40.2	.9	62.6	.4	-	3.8	8.6	2.5	9,770	2,390
8G	C-89865	.5	8.8	50.6	40.1	.9	62.0	.4	-	3.7	6.2	3.2	9,650	2,420
8H	C-89866	.6	7.0	60.8	31.6	1.0	68.7	.4	-	2.9	8.5	2.9	10,590	2,420

1/ Samples prepared as composite of char, blow-over dust, and sump residue.
2/ Ash uncorrected for sulfur and carbon reported as SO_3 and CO_2.
3/ In ash; reported as percent of original char.
4/ Sulfur reported as equivalent SO_3; some results are inconsistent with total sulfur in char.