A periodical local slippage of ash deposits followed by accumulation at cleaned areas might explain some of the variations in the ash. This is substantiated by the observation that the thickness of the ash deposits and the weight of ash recovered from the tube walls after runs 11, 12, and 13 did not vary appreciably with the length of runs and total weight of ash charged. This is shown in table 21 where the length of the runs ranged from 438 to 730 hours and the weight of ash charged to the retort changed from 13,000 to 20,000 pounds, whereas the weight of ash collected after the run varied from 50.5 to 59.5 pounds. This also indicates that with the 310-alloy retort tube under normal experimental conditions, no difficulty would be encountered due to ash buildup.

TABLE 21. - Weight of ash deposits collected from inner wall of 310-alloy tube

Run number	Approximate weight of ash fed to retort, pounds1/	Total hours of operation	Ash collected from tube wall, pounds
11	20,000	694	59.5
12	13,000	438	50.5
13	19 500	730	53.0

1/ Based on lignite fed to retort and percentage of ash in feed.

The preliminary information obtained from investigation of the behavior of the sulfur during the gasification process may be summarized as:

1. The sulfur content of the product gas is low, being only 35 to 140 grains per 100 c.f. of which 1.5 to 2.3 grains per 100 c.f. is organic sulfur.

2. The percentage of the sulfur charged present in the product gas is directly proportional to the fraction of unreacted steam.

3. The percentage of sulfur charged present in the product gas increases uniformly when only the steam rate to the char zone is progressively increased.

4. Sulfur balances are occasionally erratic because of the difficulty of obtaining char samples corresponding to the gas samples used for sulfur determination.

SUMMARY AND CONCLUSIONS

From January 1949 to the end of the fiscal year June 30, 1950, the Grand Forks Pilot Plant was operated 1,915 hours with a nominal 3-1/4-inch-wide annulus, during which 20 million cubic feet, SGC, of product gas at hydrogen-carbon monoxide ratios varying from 1.85 to 6.50 was produced in gasifying some 428 tons of natural and steam-dried Dakota Star lignite during 4 runs. Gas-production rates ranged from 7.8 to 16.4 M c.f., SGC, per hour, and the heat-transfer rates through the alloy-tube wall were from 2,100 to 4,400 B.t.u. per square foot per hour of surface. The hydrogen to carbon monoxide ratio of 1.85 was the lowest ratio, and 16.4 M c.f., SGC, of product gas per hour was the highest rate yet reached. Both of these were obtained with dried lignite.

A centrifugally cast reaction tube of HK alloy cracked along the horizontal weld seam after 53 hours of erratic operation. Examination of the broken sections indicated that the failure was due to improper fusion of the weld and unsatisfactory fitting of the two separately cast sections of the tube. No evidence of corrosion was observed after 151 hours of operation.

A 310-alloy, rolled-plate tube was operated 1,862 hours without incident. Careful inspection and measurements after each run indicated that corrosion is no longer a major problem but that the deformation or creep at operating temperature might be the limiting factor in the tube life.

From the data of run 11, in which the lignite feed rate was the only variable, it was found that:

1. The percentage of carbon gasified varied inversely with the feed rate.

2. The gas yield per ton of natural lignite decreased with an increase in the lignite feed rate.

3. The temperatures of the inner tube, measured at approximately 1 foot and 5 feet above the gas offtake, decreased with increasing feed rate. As the average reaction temperature is related to the inner tube temperatures, this temperature should also decrease.

4. The hydrogen-carbon monoxide ratio of the gas and the amount of undecomposed steam per M c.f. of gas generally increased with increasing feed rate. However, at the higher ratios the change was small.

Comparison of the gasification in run 12 of natural Dakota Star lignite of approximately 37 percent moisture with Dakota Star lignite dried by the Fleissner Process to 12 to 15 percent moisture under equivalent experimental conditions showed that dried lignite was a superior gasification material because:

1. A greater gas-production rate could be reached using dried lignite as a feed at normal combustion space temperatures.

2. A considerably higher amount of moisture- and ash-free lignite originating from dried lignite could be fed to the retort and a high percentage of gasification maintained.

3. With equal feed rates of moisture- and ash-free lignite, the percentage of carbon gasified, and consequently the gas yield per ton of moisture- and ash-free lignite, were substantially higher when dried lignite was gasified.

4. The hydrogen-carbon monoxide ratio of the product gas was lower and the percentage steam decomposition higher when dried lignite was gasified.

5. The heat consumption per cubic foot of product gas was decreased when dry lignite was gasified.

6. The average reaction temperature and the portion of the reaction space actually used for gasification were increased with dried lignite as the feed.

7. The average particle size of the residue was larger and the pressure drop through the annulus was less when dried lignite was used.

It was found during run 12, in addition to the comparison of steam-dried with natural lignite reported above, that:

1. Steam-dried lignite could be used to produce a gas with a hydrogen-carbon monoxide ratio of 1.85 without using excessive combustion space temperatures.

2. Reduction of the feed size of the charge from 1-1/2 by 3/8 inch to 1-1/2 by 1/16 inch increased the portion of the dried lignite recovered after screening from approximately 45 to 93 percent and caused no difficulty in the operation of the retort.

3. Under comparable experimental conditions, the percentage of carbon gasified increased slightly and the hydrogen-carbon monoxide ratio of the product gas decreased when the smaller sized feed was gasified.

Correlation and analysis of the data obtained during run 13, in which constant combustion-space temperatures and an average feed rate of 470 pounds per hour of natural Dakota Star lignite were used, may be summarized as follows:

1. With equal amounts of water available per ton of moisture- and ash-free lignite, the gas yield per ton and the percentage of carbon gasified were higher when at least part of the live steam was admitted to the upper reaction zone. (1) (2)

2. With equal amounts of water available per ton of moisture- and ash-free lignite, the hydrogen-carbon monoxide ratio of the product gas was not influenced greatly by the location of steam introduction except at very high steam rates to the char zone. (3) (4)

3. Equal increments of live steam resulted in higher percentages of gasification and gas yields per ton of moisture- and ash-free lignite when admitted to the upper reaction zone. (5)

4. Extrapolation of the plotted results indicated that, without addition of any steam, 1 ton of natural Dakota Star lignite of 37 percent moisture and 5.5 percent ash would have approximately 53 percent of the available carbon gasified in the production of 32,000 cubic feet of gas at a 2.0:2.1 hydrogen-carbon monoxide ratio. (6) (7)

5. Efficient utilization of the lower reaction zone does not occur except at very high steam additions to that zone.

Material balances for the streams entering and leaving the annular space were within the usual engineering standards, the accounted for material being 94.7 to 103.0 percent of the input.

Heat requirements for the gasification process were shown by heat balances to be between 24.6 and 32.4 percent of the total heat in the entering materials, with the actual percentage as a function of the hydrogen-carbon monoxide ratio of the gas and the moisture content of the lignite used. The potential heat in the product gas, which is related to the percentage carbon gasified and the H_2-CO ratio of the gas, was in the range of 49.1 to 65.5 percent of the heat input. Addition of the potential heat in the char and dust to that in the gas increased the percentage of potential heat in the products of gasification to 71.8 to 83.6 percent of the total heat input. The value of 83.6 percent heat recovered in the products of gasification was the highest ever reached. Radiation, convection, and unaccounted-for losses ranged from 5 to 13 percent. Also, it was noticed that a higher percentage of heat was removed from the retort as sensible and latent heat in the unreacted steam with the production of a higher ratio gas.

Numerous determinations of the sulfur in the product gas showed the concentration to be low, in the range of 35 to 140 grains per 100 c.f. of which 1.5 to 2.3 grains were organic sulfur. Sulfur in this concentration does not present any difficulty in purification. The percentage of the original sulfur found in the product gas was determined to be directly proportional to the fraction of unreacted steam. A better correlation was obtained when only the steam rate to the lower reaction zone was progressively increased. Sulfur balances occasionally were erratic due to the difficulty of obtaining char samples corresponding to the gas samples used for the determination of sulfur.

BIBLIOGRAPHY

(1) PARRY, V. F., GERNES, D. C., GOODMAN, J. B., WAGNER, E. O., KOTH, A. W., PATTY, W. L., and YEAGER, E. C. Gasification of Lignite and Subbituminous Coal: Progress Report for 1944. Bureau of Mines Rept. of Investigations 3901, 1946, 50 pp.

(2) PARRY, V. F., GERNES, D. C., WAGNER, E. O., GOODMAN, J. B., and KOTH, A. W. Gasification of Lignite and Subbituminous Coal: Progress Report for 1945-46. Bureau of Mines Rept. of Investigations 4128, 1947, 69 pp.

(3) PARRY, V. F., WAGNER, E. O., KOTH, A. W., and GOODMAN, J. B. Gasification of Subbituminous Coal and Lignite in Externally Heated Retorts. Ind. Eng. Chem., vol. 40, 1948, pp. 627-641.

(4) BURR, A. C., HOLTZ, J. C., KOTH, A. W., and OPPELT, W. H. Gasification of Lignite in a Commercial-Scale Pilot Plant: Progress Report for 1947-48. Bureau of Mines Rept. of Investigations 4940, 1953, 28 pp.

(5) CHETRICK, M. H. Undecomposed steam in Lignite Gasification. Bureau of Mines Rept. of Investigations 4738, 1950, 11 pp.

(6) HARRINGTON, L. C., PARRY, V. F., and KOTH, A. Technical and Economic Study of Drying Lignite and Subbituminous Coal by the Fleissner Process. Bureau of Mines Tech. Paper 633, 1942, 84 pp.

(7) REYNOLDS, D. A., DAVIS, J. D., ODE, W. H., WOLFSON, D. E., and BIRGE, G. W. Carbonizing Properties of Velva Lignite from Ward County, N. Dak., and Monarch Coal from Sheridan County, Wyo. Bureau of Mines Tech. Paper 695, 1946, figure 1, p. 9.

APPENDIX

A summary of that portion of the experimental data and calculated results that are of primary interest are included in the appendix. Additional detailed experimental data and calculated results from runs 11 through 13, as listed below, are available upon request from the Charles R. Robertson Lignite Research Laboratory, Grand Forks, N. Dak.

1. Analyses of product gas from natural and steam-dried lignite.
2. Proximate and ultimate analyses of natural and dried lignite tested.
3. Size consist of lignite tested.
4. Proximate and ultimate analyses of chars.
5. Size consist of chars.
6. Size consist of dust collected in steam chest.
7. Static pressures, retort dimensions, and steam flow in reaction zones.
8. Combustion side temperatures of alloy tube.
9. Rate of heat transfer through alloy tube wall.

TABLE 22. - Summary data on gasification of natural and dried lignite runs 11 through 13[1]

Runs 11-A through 11-MN

Run and period number	(1)	11-A	11-AB	11-C	11-D	11-E	11-F	11-G	11-H	11-I	11-J	11-K	11-L	11-M	11-MN
Date	(2)	5/7/49	5/8/49	5/10/49	5/12/49	5/14/49	5/16/49	5/18/49	5/20/49	5/22/49	5/25/49	5/27/49	5/29/49	5/31/49	6/1/49
Duration[2] hr.	(3)	23.9	21.9	23.3	24.0	23.8	23.5	23.5	24.0	20.6	23.3	23.5	24.7	23.6	20.4
Lignite charged lb. per hr.	(4)	641	783	500	395	482	422	389	468	571	306	359	404	343	395
Moisture as charged[3] percent	(5)	36.2	-	36.4	36.4	36.6	36.0	35.6	36.0	34.6	35.2	34.4	36.2	36.8	-
Ash as charged do.	(6)	5.0	-	6.1	6.8	6.2	7.6	7.7	7.0	6.3	5.8	7.3	8.6	7.3	-
Carbon gasified do.	(7)	57.3	52.7	69.4	77.7	68.4	69.1	75.0	67.3	64.4	72.9	68.4	67.2	86.6	80.9
Lb. per M c.f. of gas (SGC)	(8)	50.8	56.0	42.9	39.3	44.4	41.9	38.0	42.0	44.5	39.2	42.3	44.1	32.3	34.5
Dry residue[4] lb. per hr.	(9)	154	206	97	62	96	88	72	100	125	54	76	91	39	62
Char out of bottom do.	(10)	124	167	79	47	75	63	63	78	94	49	52	69	45	45
Blown over at gas offtake do.	(11)	0.6	4.3	0.3	0.2	0.8	1.1	1.0	1.2	4.5	0.2	0.5	0.4	1.4	-
Dust with gas do.	(12)	3.0	-	2.0	0.6	0.9	1.6	2.5	1.8	1.3	2.4	2.5	0.7	-	-
Ash in total residue[2] percent	(13)	29.8	-	47.3	66.2	51.3	39.6	59.2	50.1	-	32.6	41.0	53.5	60.9	-
Gas made, SGC:[6]	(14)														
M c.f. per ton of raw lignite	(15)	39.4	34.5	46.7	51.0	43.1	48.7	52.7	47.6	45.0	51.0	47.2	45.3	61.8	58.0
M c.f. per hour from displacement meter	(16)	12.6	13.5	11.7	10.1	10.8	10.2	10.2	11.1	12.8	7.8	8.5	9.2	10.6	11.4
Gross heating value (calc.) B.t.u./cu.ft.	(17)	284	291	282	288	283	283	283	287	288	271	272	269	253	251
Net heating value (calc.)[7] do.	(18)	252	259	251	257	251	250	251	254	254	239	240	236	221	219
Specific gravity (calc.)[8]	(19)	.55	.56	.54	.53	.54	.55	.55	.55	.55	.56	.56	.56	.56	.56
Ratio H_2-CO	(20)	3.04	2.82	2.75	2.30	2.73	4.82	4.84	4.63	4.40	3.38	3.57	3.99	5.59	6.48
Steam used:	(21)														
Upper reaction zone lb. per hr.	(22)	68	80	55	55	55	215	215	233	288	100	118	132	309	334
Lower reaction zone do.	(23)	210	238	150	102	150	245	245	273	328	102	117	136	308	332
Undecomposed steam[9] lb./M c.f. dry gas	(24)	22.3	-	12.8	9.8	16.4	37.1	35.6	38.4	39.2	20.3	21.1	24.9	27.3	28.9
Heating-system data:	(25)														
Product gas used, SGC M c.f./hr.	(26)	6.10	6.34	5.60	5.00	5.31	5.30	5.30	5.70	6.40	4.20	4.47	4.76	5.70	6.01
Net B.t.u. used per cu. ft. product gas	(27)	122	122	120	120	123	118	120	120	116	130	127	123	119	115
Heat released[10] M B.t.u. per cu. ft.	(28)	13.4	14.3	12.2	11.2	11.6	10.6	10.8	11.6	12.9	8.8	9.3	9.8	11.0	11.4
CO_2 in POC[11] percent	(29)	16.4	16.2	15.8	15.6	16.4	14.4	13.7	15.3	15.2	14.2	15.8	14.5	13.7	13.5
Primary air M c.f./hr.	(30)	14.0	14.8	12.6	11.0	11.9	11.3	11.5	12.5	13.9	8.4	9.1	9.8	12.4	13.1
POC recirculated do.	(31)	26.2	27.0	27.4	27.9	28.2	28.5	30.7	28.9	27.2	32.4	31.8	30.6	29.1	27.5
Temperatures, °F.:	(32)														
Average combustion chamber[12]	(33)	1,784	1,778	1,774	1,775	1,776	1,641	1,660	1,659	1,656	1,647	1,645	1,647	1,648	1,646
Bottom of combustion chamber No. 1	(34)	1,926	1,918	1,926	1,925	1,926	1,750	1,791	1,749	1,751	1,718	1,750	1,750	1,750	1,749
Middle of combustion chamber 2	(35)	1,893	1,848	1,844	1,850	1,851	1,791	1,851	1,850	1,833	1,799	1,799	1,802	1,802	1,799
Top of combustion chamber 3	(36)	1,758	1,747	1,730	1,726	1,726	1,569	1,579	1,576	1,580	1,577	1,570	1,574	1,579	1,578
Outlet from combustion chamber 4	(37)	1,600	1,600	1,596	1,599	1,600	1,432	1,460	1,459	1,461	1,462	1,460	1,460	1,462	1,459
Inlet to fan 5	(38)	958	849	868	861	871	829	818	811	802	845	839	828	812	809
Air and POC to recuperator 7	(39)	472	455	492	512	501	484	490	507	447	520	516	503	466	438
Air and POC to furnace 8	(40)	1,153	1,265	1,267	1,286	1,274	1,163	1,132	1,157	1,154	1,205	1,190	1,177	1,171	1,170
Steam supply for process	(41)	245	266	244	240	244	246	245	248	255	241	241	243	246	250
Superheated steam to upper reaction zone	(42)	507	536	487	471	485	355	340	551	547	531	540	540	539	544
Superheated steam to lower reaction zone	(43)	996	934	1,053	1,116	1,065	914	920	898	882	1,098	1,070	1,027	914	921
Stack 5a	(44)	677	656	684	695	683	567	566	582	576	632	630	623	573	576
Gas leaving offtake 9	(45)	1,193	1,068	1,193	1,202	1,200	1,135	1,123	1,109	1,119	1,218	1,184	1,149	1,136	1,140
Gas leaving retort 12	(46)	628	608	634	660	640	654	645	655	660	654	654	627	685	701
Inner tube opposite D 14	(47)	1,060	941	1,113	1,181	1,124	1,051	1,043	1,025	988	1,151	1,122	1,070	1,069	1,068
Inner tube opposite F 16	(48)	671	581	761	918	765	772	770	724	691	952	867	773	851	856

See Footnotes at end of table.

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...and dried lignite runs 11 through 13[1] (Cont.)

Inner tube opposite F 16	(48)	671	581	761	918	785	772	770	724	691	952	867	773	951	856

See footnotes at end of table.

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TABLE 22. - Summary data on gasification of natural and dried lignite runs 11 through 13[2] (Cont.)

Runs 12 through 13-D

Run and period number	(1)	12-A	12-B	12-C	12-D	12-E	12-F	12-G	12-H	12H&I	12-IJ&J	13-A	13-B	13-C	13-D
Date	(2)	9/10/49	9/12/49	9/14/49	9/16/49	9/18/49	9/20/49	9/22/49	9/23/49	9/24-/49	9/25/49	11/20/49	11/22/49	11/24/49	11/26/49
Duration[2] ..... hr.	(3)	24.47	22.83	23.08	24.07	24.60	24.00	21.27	21.23	23.72	22.62	24.32	24.37	24.30	23.98
Lignite charged ..... lb. per hr.	(4)	481	570	445	489	339	391	307	370	301	405	487	481	467	480
Moisture as charged[3] ..... percent	(5)	12.8	12.3	14.3	13.3	15.4	12.6	12.6	12.8	13.6	13.8	36.5	36.0	36.9	36.8
Ash as charged ..... do.	(6)	8.8	6.3	8.6	6.6	8.1	5.8	7.1	6.5	5.1	6.8	5.7	6.5	5.7	5.9
Carbon gasified ..... do.	(7)	65.3	69.3	76.1	76.0	77.8	71.0	77.5	77.7	80.6	72.8	59.4	60.2	61.8	63.0
Lb. per M c.f. of gas (SGC)	(8)	34.4	36.2	30.4	29.9	29.5	31.4	27.9	28.0	28.1	31.0	54.3	52.7	50.4	49.7
Dry residue[4] ..... lb. per hr.	(9)	137.1	153.7	98.9	101.2	65.7	89.4	62.1	75.1	52.3	91.0	111.1	112.0	102.0	103.1
Char out of bottom ..... do.	(10)	123.0	139.8	70.9	78.8	52.2	79.2	43.6	69.0	46.9	76.2	94.2	90.2	86.1	87.4
Blown over at gas offtake ..... do.	(11)	0.0	0.6	1.5	1.6	0.4	1.1	1.6	1.6	0.8	1.8	0.0	0.5	0.6	0.8
Dust with gas ..... do.	(12)	0.33	0.53	0.34	0.49	0.23	0.45	0.56	0.73	0.31	0.63	0.00	0.00	0.10	0.40
Ash in total residue[5] ..... percent	(13)	37.6	33.4	53.2	43.8	47.6	27.6	34.4	38.8	34.4	33.9	31.6	34.9	30.9	32.8
Gas made, SGC:[6]	(14)														
M c.f. per ton of raw lignite	(15)	58.1	55.2	65.6	66.9	67.8	63.7	71.7	71.4	71.2	64.5	36.8	37.9	39.7	40.2
M c.f. per hour from displacement meter	(16)	14.0	15.7	14.6	16.4	10.8	12.4	11.0	13.2	10.7	13.0	9.0	9.1	9.3	9.7
Gross heating value (calc.) .....B.t.u./cu. ft.	(17)	296	300	285	284	277	274	262	265	277	279	290	282	278	278
Net heating value (calc.)[7] ..... do.	(18)	266	270	255	254	246	243	232	233	246	244	259	251	247	246
Specific gravity (calc.)[8]	(19)	0.54	0.53	0.54	0.54	0.54	0.56	0.56	0.55	0.55	0.55	0.56	0.56	0.56	0.56
Ratio H_2-CO	(20)	1.85	1.85	2.30	2.29	2.87	3.68	3.71	3.55	2.69	2.93	2.49	2.77	2.98	3.07
Steam used:	(21)														
Upper reaction zone ..... lb. per ton	(22)	147	183	222	257	227	299	300	377	287	299	0.0	0.0	0.0	0.0
Lower reaction zone ..... do.	(23)	136	158	174	198	132	174	232	279	131	180	103	150	200	250
Undecomposed steam[9] .....lb./M c.f. dry gas	(24)	8.1	9.1	13.7	12.7	18.1	21.2	29.2	30.2	16.8	19.1	14.5	17.3	22.7	25.1
Heating-system data:	(25)														
Product gas used, SGC .....M c.f./hr.	(26)	5.6	6.0	6.2	6.2	4.7	5.1	5.0	5.6	4.6	5.2	4.9	5.1	5.2	5.3
Net B.t.u. used per cu. ft. product gas.....	(27)	106	103	108	98	106	101	105	98	107	98	142	141	140	136
Heat release[10] .....M B.t.u. per cu. ft.	(28)	12.8	14.1	13.8	13.6	10.0	10.9	10.1	11.3	10.0	11.1	11.1	11.2	11.3	11.4
CO_2 in POC[11] .....percent	(29)	15.7	16.1	15.6	16.4	14.3	15.3	14.3	14.7	15.7	15.8	13.2	12.9	13.3	13.3
Primary air .....M c.f./hr.	(30)	12.7	13.2	12.8	13.7	10.2	11.1	11.0	12.4	10.2	12.6	11.1	11.0	11.1	11.4
POC recirculated ..... do.	(31)	25.3	27.7	25.6	25.5	32.2	32.1	32.1	29.9	31.1	30.9	26.7	29.9	26.6	28.4
Temperatures, °F.:	(32)														
Average combustion chamber[12]	(33)	1,782	1,781	1,766	1,766	1,642	1,643	1,647	1,645	1,644	1,645	1,770	1,771	1,767	1,767
Bottom of combustion chamber No. 1	(34)	1,927	1,924	1,925	1,926	1,750	1,752	1,751	1,752	1,751	1,751	1,923	1,926	1,926	1,925
Middle of combustion chamber ... 2	(35)	1,896	1,900	1,892	1,850	1,801	1,800	1,803	1,800	1,800	1,799	1,852	1,851	1,850	1,851
Top of combustion chamber 3	(36)	1,700	1,701	1,687	1,690	1,555	1,561	1,573	1,571	1,566	1,572	1,702	1,704	1,690	1,690
Outlet from combustion chamber . 4	(37)	1,603	1,599	1,502	1,597	1,460	1,461	1,462	1,459	1,459	1,460	1,601	1,603	1,600	1,601
Inlet to fan 5	(38)	883	872	881	865	830	823	824	817	835	818	887	890	886	888
Air and POC to recuperator 7	(39)	452	443	447	437	467	466	468	445	470	455	612	603	605	607
Air and POC to furnace 8	(40)	1,286	1,265	1,273	1,260	1,184	1,180	1,162	1,154	1,175	1,171	1,277	1,292	1,277	1,282
Steam supply for process	(41)	242	243	246	247	242	245	246	250	245	248	238	242	235	255
Superheated steam to upper reaction zone	(42)	576	580	585	576	540	532	537	532	555	537	-	-	-	-
Superheated steam to lower reaction zone	(43)	1,218	1,222	1,125	1,133	1,091	1,108	1,070	1,027	1,129	1,108	1,148	1,064	1,010	976
Stack 5a	(44)	667	607	636	615	580	558	567	558	594	567	774	761	752	761
Gas leaving offtake 9	(45)	1,329	1,337	1,266	1,278	1,226	1,239	1,248	1,218	1,257	1,226	1,208	1,184	1,170	1,161
Gas leaving retort 12	(46)	768	765	748	761	714	735	740	744	748	752	639	607	605	613
Inner tube opposite D 14	(47)	1,265	1,266	1,197	1,222	1,180	1,154	1,175	1,145	1,210	1,184	1,156	1,124	1,114	1,110
Inner tube opposite F 16	(48)	1,053	1,070	1,019	1,044	1,006	1,006	1,045	905	1,078	1,053	826	792	788	802

See footnotes at end of table.

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TABLE 22. - Summary data on gasification of natural and dried lignite runs 11 through 13[1/] (Cont.)

Runs 13-E through 13-M

Run and period number	(1)	13-E	13-F	13-G	13-H	13-I	13-J	13-K	13-L	13-M	13-N
Date	(2)	11/28/49	11/30/49	12/3/49	12/5/49	12/7/49	12/9/49	12/11/49	12/13/49	12/15/49	12/17/49
Duration[2/] ..... hr.	(3)	23.97	23.93	23.97	27.05	23.25	23.88	24.18	24.18	24.00	23.20
Lignite charged ..... lb. per hr.	(4)	458	475	458	442	481	405	469	454	451	458
Moisture as charged[3/] ..... percent	(5)	37	37.7	35.1	33.4	36.2	35.7	36.8	36.8	35.7	35.8
Ash as charged ..... do.	(6)	5.4	5.5	5.2	8.4	5.7	6.2	6.3	5.7	6.0	6.2
Carbon gasified ..... do.	(7)	65.8	53.1	62.5	60.2	62.5	68.2	75.4	76.0	77.5	66.3
Lb. per M c.f. of gas (SGC)	(8)	47.3	60.0	50.1	45.1	50.4	46.1	42.1	40.3	38.5	47.1
Dry residue[4/] ..... lb. per hr.	(9)	90.8	124.0	101.7	97.6	104.8	94.9	82.8	75.2	73.8	94.0
Char out of bottom ..... do.	(10)	79.9	103.1	85.5	89.1	86.9	74.2	63.4	53.5	52.1	82.7
Blown over as gas offtake ..... do.	(11)	1.0	0.1	0.3	0.3	0.5	0.6	0.7	0.8	1.0	0.6
Dust with gas ..... do.	(12)	0.6	0.3	0.8	0.9	1.0	1.1	1.3	1.0	1.0	1.1
Ash in total residue[5/] ..... percent	(13)	36.3	27.4	33.6	46.4	39.6	41.3	41.7	51.5	49.6	34.1
Gas made, SGC:[6/]	(14)										
M c.f. per ton of raw lignite	(15)	42.2	33.4	39.9	44.3	39.7	43.4	47.5	49.6	51.9	42.4
M c.f. per hour from displacement meter	(16)	9.7	7.9	9.3	9.8	9.6	10.4	11.1	11.3	11.7	9.7
Gross heating value (calc.) ..... B.t.u./cu.ft.	(17)	277	301	292	284	284	281	275	272	271	286
Net heating value (calc.)[7/] ..... do.	(18)	245	269	260	253	252	249	243	240	234	254
Specific gravity (calc.) [8/]	(19)	.56	.55	.55	.55	.56	.56	.56	.56	.56	.56
Ratio H_2-CO	(20)	3.38	2.28	2.64	2.88	3.08	3.10	3.39	3.63	3.77	3.04
Steam used:	(21)										
Upper reaction zone ..... lb. per hr.	(22)	0	0	54	103	103	140	200	250	293	103
Lower reaction zone ..... do.	(23)	293	49	103	103	103	103	103	103	103	103
Undecomposed steam[9/] ..... lb./M c.f. dry gas	(24)	29.2	13.0	16.6	16.1	23.2	21.6	25.0	27.7	29.3	22.0
Heating-system data:	(25)										
Product gas used, SGC ..... M c.f./hr.	(26)	5.4	4.5	5.0	5.2	5.2	5.4	5.7	5.9	5.9	5.1
Net B.t.u. used per cu. ft. product gas	(27)	137	132	102	135	137	130	129	126	120	133
Heat released[10/] ..... M B.t.u. per cu.ft.	(28)	11.5	10.4	11.4	11.3	11.5	11.8	12.1	12.4	12.2	11.3
CO in FGC[11/] ..... percent	(29)	13.3	14.1	13.4	13.9	13.9	14.3	14.4	13.9	15.2	15.6
Primary air ..... M c.f./hr.	(30)	11.6	9.1	10.5	11.1	12.5	12.0	12.7	13.2	13.0	10.9
FGC recirculated ..... do.	(31)	28.3	32.2	29.4	30.7	30.8	28.5	28.2	30.3	29.5	30.5
Temperatures, °F.:	(32)										
Average combustion chamber[12/]	(33)	1,768	1,767	1,772	1,766	1,764	1,772	1,775	1,775	1,778	1,774
Bottom of combustion chamber No. 1	(34)	1,929	1,923	1,927	1,926	1,926	1,926	1,927	1,927	1,929	1,926
Middle of combustion chamber ... 2	(35)	1,852	1,851	1,859	1,850	1,846	1,850	1,851	1,851	1,850	1,850
Top of combustion chamber 3	(36)	1,691	1,694	1,707	1,687	1,682	1,710	1,725	1,720	1,732	1,722
Outlet from combustion chamber . 4	(37)	1,601	1,599	1,600	1,602	1,601	1,600	1,602	1,603	1,599	1,599
Inlet to fan 5	(38)	886	896	893	882	884	879	873	873	897	877
Air and FGC to recuperator 7	(39)	605	659	620	618	602	590	576	577	577	515
Air and FGC to furnace 8	(40)	1,273	1,295	1,290	1,273	1,269	1,265	1,260	1,260	1,243	1,260
Steam supply for process	(41)	245	224	240	239	238	240	238	237	237	239
Superheated steam to upper reaction zone	(42)	-	-	500	562	552	590	600	600	570	564
Superheated steam to lower reaction zone	(43)	932	1,056	1,118	1,112	1,098	1,102	1,104	1,114	1,110	1,104
Stack 5a	(44)	752	756	727	694	690	671	649	636	603	675
Gas leaving offtake 9	(45)	1,151	1,081	1,181	1,181	1,154	1,166	1,179	1,190	1,182	1,165
Gas leaving reactor 12	(46)	623	613	636	658	645	667	702	720	727	661
Inner tube opposite D 14	(47)	1,100	1,171	1,152	1,154	1,126	1,144	1,156	1,168	1,164	1,139
Inner tube opposite F 16	(48)	802	846	864	906	824	844	886	936	1,110	1,104

Footnotes

1/ Steam-dried Dakota Star lignite used in run 12; natural Kincaid lignite used in period 13-H; natural Dakota Star used for all others.

2/ Testing periods were usually 24 hours, but some runs, as indicated, were for longer or slightly shorter periods.

3/ Representative liquid samples consisting of approximately 3 percent of the total weight charged were taken for the official periods.

4/ Total residue was calculated from ash and carbon balances and usually is greater than the sum of (12),(13), and (14) because all losses are not accounted for.

5/ Figures are percentage ash in a composite sample of char, blowover dust and sump residue, as determined by ASTM methods at the Pittsburgh laboratory; no correction has been made for sulfates or carbonates retained as ash during analysis.

6/ Gas volume measured by displacement meter standard gas conditions, saturated gas at 60° F. and 30 inches of mercury.

7/ Calculated net B.t.u. was determined by deducting mol fraction of total hydrogen times 49.5 from the calculated gross B.t.u.

8/ Specific gravity was calculated from average gas analyses.

9/ Dry gas at 60° F. and 30 inches of mercury.

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

11/ Carbon dioxide percentage is average value from chart of Republic meter.

12/ Average of points 1, 2, and 3.

TABLE 23. - Experimental data and calculations converted to moisture and ash-free basis for runs 11 through 13

Runs 11-A through 13-M[1/]

Inner tube opposite F 16	(ft)	1,100	600	1,171	846	1,152	854	1,176	866	1,126	814	1,142	844	1,150	888	1,158	936	1,164	1,110	1,139	1,001

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TABLE 24. - Experimental data and calculations converted to moisture and ash-free basis for runs 11 through 13

Runs 11-A through 12-J&K

Run and period	11-A	11-AB	11-C	11-D	11-E	11-F	11-G	11-H	11-I	11-J	11-K	11-L	11-M	12-A	12-B	12-C	12-D	12-E	12-F	12-G	12-H	12-H&I	12-J&K
Lignite charged, lb./hr.	390	476	205	232	284	247	225	275	344	286	213	230	197	401	464	343	332	244	318	247	298	241	381
Percent carbon gasified	57.3	52.7	69.4	77.7	68.4	69.1	75.0	67.3	64.4	75.0	68.4	67.2	86.6	65.3	65.3	76.2	76.0	77.8	72.0	77.5	89.6	80.6	72.8
Gas made, M c.f./hr.1/	12.6	13.5	11.7	10.1	10.8	10.3	10.2	11.	12.8	7.8	8.5	9.2	10.6	14.0	15.7	11.6	16.4	10.8	12.4	11.0	13.2	10.7	14.0
Lbs. lignite per M c.f. gas	30.9	35.3	29.3	23.0	26.2	24.1	22.0	24.8	26.8	23.8	25.1	25.1	18.6	28.7	29.5	23.4	23.9	22.6	25.6	22.1	22.6	22.5	27.6
Gas made, M c.f./ton of lignite	64.7	56.7	79.1	86.8	76.3	83.1	91.0	80.6	74.6	84.9	79.6	79.6	107.7	69.7	67.8	85.5	83.7	88.6	78.1	89.3	88.5	88.9	81.3
Lb. char/hr. out of bottom	85.2	114.9	40.5	19.1	31.5	35.9	28.7	37.8	45.6	79.3	30.1	31.3	20.3	75.5	80.5	32.5	43.3	20.8	56.5	28.0	41.3	30.2	49.7
Lb. residue/hr. with gas2/	2.5	2.9	.7	.3	.8	1.6	1.0	1.4	2.7	1.9	1.1	.5	.5	.2	.7	.9	.8	.3	1.1	1.0	1.4	.7	1.6
Lb. char/hr. calculated3/	123	166	66.4	35.5	66.1	55.8	41.9	67.0	89.5	36.8	49.5	56.2	14.3	94.0	117.8	60.7	99.0	39.9	56.8	40.3	92.4	34.0	61.5
Ratio H_2:CO	3.04	2.82	2.75	2.50	2.73	4.82	4.34	4.63	4.40	3.38	3.57	3.99	5.56	1.05	1.85	2.30	2.29	2.37	3.08	3.72	3.95	2.69	2.93
Steam added to upper reaction zone, lb./lb. lignite	.17	.16	.19	.24	.19	.87	.96	.84	.83	.94	.52	.57	.57	.37	.49	.65	.66	.93	.94	1.22	1.26	.94	.93
Steam added to lower reaction zone, lb./lb. lignite	.54	.50	.51	.46	.53	.99	1.09	.99	.95	.55	.53	.59	1.56	.54	.34	.51	.50	.54	.52	.94	.94	.54	.56
Moisture and water of formation, lb./lb. lignite3/	.80	.85	.83	.89	.81	.81	.82	.80	.80	.79	.81	.82	.84	.15	.15	.18	.17	.20	.16	.16	.16	.17	.17
Total steam, lb./lb. lignite2/	1.51	1.48	1.53	1.50	1.53	2.67	2.86	2.63	2.59	1.88	1.91	1.98	2.97	.85	.89	1.34	1.33	1.67	1.65	2.32	2.36	1.65	1.66
Total steam, lb./ M c.f. of gas	46.7	5.22	38.7	34.5	38.6	64.3	62.9	65.2	69.4	44.7	47.9	49.7	55.2	24.3	26.1	31.4	31.7	37.8	42.1	51.8	53.2	37.2	45.9
Lbs. excess steam per lb. of lignite	.71	-	.54	.42	.62	1.31	1.59	1.52	1.44	.84	.82	.97	2.50	.28	.30	.58	.52	.79	.81	1.28	1.31	.73	.76
Moles of excess steam per mole of gas	.47	-	.29	.21	.34	.78	.75	.81	.82	.42	.40	.52	.99	.17	.19	.29	.27	.38	.40	.62	.65	.35	.40
Moles excess steam per mole of carbon gasified	1.14	-	.72	.50	.84	2.02	1.94	2.06	1.84	1.04	1.04	1.32	2.65	.38	.43	.70	.64	.94	1.07	1.54	1.59	.86	.98
M c.f. hydrogen per ton of lignite	34.5	30.9	41.2	48.3	42.6	59.3	54.1	47.7	43.9	47.1	46.9	45.7	63.9	36.7	36.4	47.6	46.2	50.9	44.0	51.3	51.7	56.0	45.3
Potential hydrogen (H_2:CO) M c.f. per ton of lignite	47.6	41.8	60.3	59.4	56.3	59.5	65.3	58.0	53.9	61.1	57.5	57.2	75.3	56.6	56.1	68.3	66.9	67.4	58.3	65.2	64.8	68.2	60.6

Runs 13-A through 13-N

Run and period	13-A	13-B	13-C	13-D	13-E	13-F	13-G2	13-H	13-I	13-J	13-K	13-L	14-M	14-N
Lignite charged, lb./hr.	201	277	209	275	264	204	200	277	282	275	207	261	203	266
Percent carbon gasified	59.4	60.2	61.8	63.0	65.8	53.1	62.5	68.2	62.5	68.2	75.4	76.0	77.5	66.3
Gas made, M c.f./hr.1/	8.81	8.96	9.11	9.49	9.91	7.72	9.18	9.65	9.43	10.26	10.94	11.08	11.56	9.59
Lbs. lignite per M c.f. gas	31.9	30.9	29.5	29.0	27.7	36.5	30.5	25.7	29.6	26.8	21.4	23.6	22.9	27.8
Gas made, M c.f./ton of lignite	62.7	64.7	67.8	69.0	75.2	57.8	65.5	71.9	67.1	74.5	82.0	84.7	87.3	71.9
Lb. char/hr. out of bottom	63.6	58.1	58.7	58.6	56.2	71.0	54.9	47.3	51.9	43.1	35.4	25.7	25.9	51.0
Lb. residue/hr. with gas2/	.1	.4	.4	.7	.9	.2	.7	.4	.6	.8	.8	.5	.6	.8
Lb. char/hr. calculated3/	83.3	80.7	75.5	74.8	66.1	97.4	77.3	69.4	77.2	65.1	53.2	49.3	46.7	66.1
Ratio H_2:CO	2.49	2.77	2.98	3.07	3.28	2.28	2.84	2.88	3.08	3.10	3.39	3.63	3.77	3.04
Steam added to upper reaction zone, lb./lb. lignite	-	-	-	-	-	-	.19	.40	.37	.51	.75	.96	1.11	.39
Steam added to lower reaction zone, lb./lb. lignite	.37	.54	.74	.87	1.11	.17	.37	.40	.37	.38	.39	.39	.38	.39
Moisture and water of formation, lb./lb. lignite	.88	.87	.87	.87	.88	.82	.83	.81	.87	.87	.89	.98	.84	.85
Total steam, lb./lb. lignite2/	1.24	1.41	1.62	1.75	2.00	1.00	1.40	1.61	1.69	1.79	2.03	2.23	2.35	1.63
Total steam, lb./ M c.f. of gas	39.5	43.6	47.8	50.8	55.4	36.5	42.7	43.0	47.7	46.9	49.3	52.6	53.8	45.0
Lbs. excess steam per lb. of lignite	.49	.56	.76	.86	1.05	.36	.54	.68	.78	.8_	1.02	1.17	1.28	.79
Moles of excess steam per mole of gas	.30	.36	.46	.52	.61	1.26	.35	.38	.49	.46	.52	.58	.62	.46
Moles excess steam per mole of carbon gasified	.70	.86	1.16	1.26	1.46	.64	.82	.58	1.15	1.10	1.26	1.43	1.53	1.10
M c.f. hydrogen per ton of lignite	33.7	35.5	37.4	38.3	40.4	29.3	36.2	37.4	37.4	41.6	46.7	46.6	50.4	45.2
Potential hydrogen (H_2:CO) M c.f. per ton of lignite	47.2	48.3	49.9	50.8	53.1	42.1	49.9	56.6	49.5	55.1	60.4	62.0	63.7	53.4

1/ Gas measured dry at 60° F. and 30 inches of mercury.
2/ Residue with gas includes blowover dust, sump residue, and dust with waste water.
3/ Calculated char is residue determined from ash and carbon balance.
4/ Moisture and water of formation calculated from the oxygen and equivalent hydrogen from ultimate analysis.
5/ Total steam includes added steam, moisture, and water of formation.

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TABLE 24. - Material balances for runs 11 through 13[1/]

Runs 11-A through 11-M

Run and period	11-A		11-C		11-D		11-E		11-F		11-G		11-H		11-J		11-J		11-K		11-L		11-M	
Material in:	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent
Natural lignite as charged	681	67.6	503	68.1	395	67.9	481	67.2	421	46.2	389	44.3	466	46.5	571	46.9	305	56.9	359	50.5	404	57.6	343	34.6
Process steam	278	29.3	205	27.9	157	27.0	205	28.6	460	50.5	460	52.3	506	50.5	616	50.6	202	37.6	225	36.6	268	38.2	617	62.4
Purge gas[2/]	30	3.1	30	4.0	30	5.1	30	4.2	30	3.4	30	3.4	30	2.9	30	2.5	30	5.5	30	4.9	30	4.2	30	3.0
Total in	949	100.0	738	100.0	582	100.0	716	100.0	911	100.0	879	100.0	1,004	100.0	1,217	100.0	538	100.0	614	100.0	702	100.0	990	100.0
Material out:																								
Char and dusts	150	15.2	97	13.2	62	10.7	96	13.4	80	9.7	72	8.2	100	10.0	125	10.3	54	10.1	76	12.4	91	13.0	46	4.7
Undecomposed steam	277	29.2	156	21.5	102	17.5	173	24.4	378	41.4	358	40.8	420	41.8	495	40.7	156	29.0	176	28.7	221	31.9	493	49.8
Product gas	529	55.8	479	65.2	404	69.5	446	62.3	424	46.6	425	48.4	469	46.0	532	43.7	330	61.4	358	58.5	385	54.8	447	45.2
Total out	960	101.2	734	99.9	568	97.7	717	100.1	886	97.4	855	97.4	989	97.8	1,152	94.7	540	100.5	610	99.4	700	99.7	986	99.9

Note: Period 11-B not reported as it was discontinued due to excessive amounts of air in gas.

Runs 12-A through 12-I&J

Run and period	12-A		12-B		12-C		12-D		12-E		12-F		12-G		12-H		12-HI&I		12-I&J	
Material in:	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent
Natural lignite as charged	509	61.7	570	60.6	445	51.3	459	50.2	319	45.1	395	41.7	337	35.3	370	39.0	301	43.7	405	44.3
Process steam	283	34.6	341	36.2	396	45.5	452	46.7	359	50.7	473	58.9	592	61.2	556	58.1	356	38.6	479	52.5
Purge gas[2/]	30	3.7	30	3.2	30	3.4	30	3.1	30	4.2	30	3.4	30	3.5	30	2.9	30	4.3	30	3.3
Total in	818	100.0	941	100.0	871	100.0	974	100.0	708	100.0	894	100.0	869	100.0	1,056	100.0	689	100.0	914	100.0
Material out:																				
Char and dusts	137	16.7	154	16.4	99	11.4	101	10.4	66	9.3	89	10.0	62	7.1	72	6.8	52	7.6	91	9.9
Undecomposed steam	111	13.6	140	14.9	196	22.5	204	20.9	199	27.1	258	28.9	315	36.4	391	37.0	177	25.7	244	26.7
Product gas	573	70.1	632	67.2	591	67.9	669	68.7	446	63.0	522	58.4	465	53.5	551	52.1	444	64.4	538	58.9
Total out	821	100.4	926	98.4	886	101.8	974	100.0	704	99.4	869	97.3	843	97.0	1,014	95.9	673	97.7	873	95.5

Runs 13-A through 13-G

Run and period	13-A		13-B		13-C		13-D		13-E		13-F		13-G	
Material in:	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent
Natural lignite as charged	497	78.5	481	72.8	467	67.0	480	64.0	458	58.7	470	85.8	468	71.5
Process steam	103	16.6	150	22.7	200	28.7	240	32.0	293	37.5	49	8.8	157	24.0
Purge gas[2/]	30	4.9	30	4.5	30	4.3	30	4.0	30	3.8	30	5.4	30	4.5
Total in	620	100.0	661	100.0	697	100.0	750	100.0	781	100.0	549	100.0	655	100.0
Material out:														
Char and dusts	111	17.9	112	17.0	102	14.6	103	13.7	91	11.7	121	22.4	102	15.6
Undecomposed steam	108	20.6	155	23.4	206	29.5	236	31.7	277	35.5	101	18.2	153	23.4
Product gas	369	58.5	386	58.4	394	56.6	411	54.8	419	53.6	333	60.1	389	59.4
Total out	601	97.0	653	98.8	702	100.6	752	100.2	778	99.8	558	100.7	644	98.4

Runs 13-H through 13-M

Run and period	13-H		13-I		13-J		13-K		13-L		13-M		13-M	
Material in:	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent	Pound	Percent
Natural lignite as charged	442	65.2	484	67.3	481	63.8	459	58.4	454	54.2	451	51.4	456	66.0
Process steam	206	30.4	206	28.6	243	32.2	293	37.8	355	42.2	396	45.2	206	29.7
Purge gas[2/]	30	4.4	30	4.1	30	4.0	30	3.8	30	3.6	30	3.4	30	4.3
Total in	678	100.0	720	100.0	754	100.0	602	100.0	837	100.0	877	100.0	692	100.0
Material out:														
Char and dusts	98	14.4	105	14.6	95	12.6	83	10.4	75	9.0	74	8.4	94	13.5
Undecomposed steam	174	25.7	219	30.4	222	29.4	273	34.0	307	35.7	337	38.4	210	30.2
Product gas	408	60.2	406	56.5	444	58.9	470	58.6	476	56.9	493	56.2	407	58.7
Total out	680	100.3	730	101.5	761	100.9	826	103.0	858	102.6	904	103.0	711	102.4

1/ Hourly basis, material entering and leaving combustion.
2/ Calculated as an average 30 lb. per hr.

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TABLE 25. - Heat balances for runs 11 through 13[1/]

	11-E		11-F		12-G		11-H		11-J		11-K		11-L		11-M	
							B.t.u.,	Per-	B.t.u.,	Per-	B.t.u.,	Per-	B.t.u.,	Per-	B.t.u.,	Per-
																cent

TABLE 29. - Heat balances for runs 11 through 31/

Period	11-A		11-C		11-E		11-F		11-I		11-G		11-H		11-J		11-K		11-L		11-M	
	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent
Heat in:																						
Potential heat natural lignite as charged	4,770	70.1	3,540	66.0	2,612	63.3	3,439	66.6	2,977	60.7	2,740	58.7	3,371	61.0	2,248	61.8	2,956	63.4	2,820	63.8	2,403	57.7
Potential heat, product gas used	1,733	25.5	1,580	29.4	1,340	32.4	1,477	28.6	1,397	28.3	1,397	29.8	1,570	28.4	1,145	31.5	1,217	29.7	1,280	29.0	1,343	31.6
Sensible and latent heat2/ in process steam	287	4.2	233	4.3	178	4.0	233	4.5	523	10.7	523	11.2	576	10.4	225	6.3	267	5.5	305	6.9	720	15.9
Sensible heat in purge3/ gas, air, lignite, and product gas used	15	.2	15	.3	15	.3	15	.3	15	.3	15	.3	15	.2	9	.1	15	.4	15	.3	15	.3
Total in	6,805	100.0	5,368	100.0	4,145	100.0	5,164	100.0	4,902	100.0	4,675	100.0	5,532	100.0	3,637	100.0	4,995	100.0	4,420	100.0	4,562	100.0
Heat out:																						
Potential heat of product gas	3,980	58.6	3,290	61.3	2,900	69.3	3,070	59.6	2,690	55.0	2,698	57.7	2,970	53.7	2,118	58.2	2,800	56.2	2,465	55.8	2,680	58.8
Potential heat,4/ char and dusts	1,625	23.9	839	15.6	398	9.8	862	16.7	791	16.1	498	10.6	787	14.2	545	15.0	751	17.1	715	16.1	302	6.6
Sensible and latent heat2/ undecomposed steam	339	5.0	170	3.2	130	2.9	233	4.5	491	10.0	379	8.1	558	10.1	209	5.8	235	5.7	297	6.7	668	14.7
Sensible heat of char2/	20	.3	23	.4	15	.3	23	.4	21	.4	18	.4	23	.4	13	.4	18	.4	21	.5	11	.2
Sensible heat of product gas, dry	143	2.1	147	2.7	131	3.0	140	2.7	139	2.8	126	2.7	149	2.6	104	2.8	113	2.8	117	2.7	147	3.6
Sensible heat of stack gas, dry	222	3.3	173	3.2	151	3.4	166	3.2	130	2.7	128	2.7	142	2.6	107	2.9	113	2.8	122	2.8	140	3.1
Sensible and latent heat, water in stack gas	193	2.8	227	4.2	202	4.5	272	5.1	209	4.3	205	4.4	243	4.4	177	4.9	188	4.6	204	4.6	230	5.1
Radiation, convection, unaccounted for	603	10.0	506	9.4	526	11.8	454	8.8	427	8.7	699	13.4	664	12.0	364	10.0	427	10.4	479	10.8	380	8.3
Total out	6,805	100.0	5,368	100.0	4,145	100.0	5,160	100.0	4,902	100.0	4,675	100.0	5,532	100.0	3,637	100.0	4,909	100.0	4,420	100.0	4,562	100.0

Period	12-A		12-B		12-C		12-D		12-E		12-F		12-G		12-H		12-H&I		12-I&J	
	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent	B.t.u., thousands	Percent
Heat in:																				
Potential heat dried lignite as charged	4,633	69.9	5,630	71.9	4,176	65.0	4,735	67.3	2,959	63.2	3,730	65.7	2,930	59.9	3,552	61.1	2,660	61.6	3,880	66.1
Potential heat, product gas used	1,657	25.0	1,802	23.0	1,786	27.6	1,774	25.2	1,304	27.8	1,387	24.6	1,310	26.7	1,470	25.4	1,275	27.5	1,130	24.4
Sensible and latent heat2/ in process steam	322	4.9	368	4.9	450	7.0	518	7.3	408	8.7	538	9.5	641	13.1	771	13.3	491	10.6	546	9.3
Sensible heat in purge3/ gas, air, lignite, and product gas used	15	.2	15	.2	15	.2	15	.2	15	.3	15	.2	15	.3	15	.2	15	13	15	.2
Total in	6,627	100.0	7,835	100.0	6,427	100.0	7,042	100.0	4,686	100.0	5,690	100.0	4,896	100.0	5,812	100.0	4,042	100.0	5,871	100.0
Heat out:																				
Potential heat of product gas	4,150	62.6	4,730	60.4	4,210	65.5	4,650	66.0	2,992	63.9	3,410	60.0	2,880	58.9	3,505	60.3	2,967	63.9	3,587	61.0
Potential heat,4/ char and dusts	1,356	20.5	1,475	18.9	813	12.6	934	13.3	582	12.4	963	16.9	592	12.1	696	12.0	525	11.2	896	15.3
Sensible and latent heat 2/ undecomposed steam	154	2.3	196	2.5	275	4.2	283	4.0	263	5.6	356	6.3	437	8.9	543	9.3	244	5.2	339	5.8
Sensible heat of char2/	32	.5	36	.5	23	.4	24	.3	15	.3	21	.4	15	.3	17	.3	12	.3	22	.4
Sensible heat of product gas, dry	206	3.1	238	3.0	217	3.4	249	3.5	154	3.3	187	3.3	168	3.4	202	3.5	152	3.3	199	3.4
Sensible heat of stack gas, dry	159	2.6	160	2.0	169	2.6	167	2.4	117	2.5	123	2.2	124	2.5	138	2.4	120	2.6	142	2.4
Sensible and latent heat, water in stack gas	228	3.4	240	3.1	249	3.9	243	3.5	194	4.1	197	3.5	206	4.2	229	3.9	190	4.1	218	3.7
Radiation, convection, unaccounted for	332	5.0	750	9.7	472	7.4	492	7.0	369	7.9	423	7.4	476	9.7	462	8.3	402	9.5	468	8.0
Total out	6,627	100.0	7,835	100.0	6,427	100.0	7,042	100.0	4,686	100.0	5,690	100.0	4,896	100.0	5,812	100.0	4,042	100.0	5,871	100.0

See footnotes at end of table.

TABLE 25. - Heat balances for runs 11 through 13 1/ (Cont.)

Period	13-A		13-B		13-C		13-D		13-E		13-F		13-G		13-H	
Heat in:	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent
Potential heat natural lignite, as charged	3,400	68.6	3,359	67.4	3,230	65.7	3,340	62.3	3,192	63.2	3,498	70.6	3,375	67.1	3,113	64.5
Potential heat, product gas used	1,422	28.7	1,436	28.9	1,446	29.4	1,472	28.8	1,495	29.5	1,357	28.0	1,460	29.1	1,479	30.4
Sensible and latent heat 2/ in process steam	117	2.4	170	3.4	227	4.6	285	5.6	351	6.9	55	1.1	178	3.5	234	4.8
Sensible heat in purge 3/ gas, air, lignite, and product gas used	15	.3	12	.3	15	.3	15	.3	15	.3	15	.3	15	.3	15	.3
Total in	4,954	100.0	4,977	100.0	4,918	100.0	5,112	100.0	5,053	100.0	4,925	100.0	5,028	100.0	4,841	100.0
Heat out:																
Potential heat of product gas	2,585	52.2	2,575	51.8	2,580	52.4	2,683	52.6	2,678	53.0	2,282	46.1	2,730	54.3	2,785	57.2
Potential heat, 4/ char and dusts	1,159	23.4	1,134	22.8	1,073	21.8	1,062	20.8	897	17.7	1,364	28.1	994	19.8	765	15.7
Sensible and latent heat undecomposed steam	167	3.3	208	4.1	272	5.5	314	6.1	365	7.2	133	2.7	203	4.0	234	4.8
Sensible heat of char 5/	26	.5	25	.5	24	.5	26	.5	21	.4	29	.6	25	.5	23	.5
Sensible heat of product gas, dry	117	2.4	111	2.2	132	2.3	119	2.3	120	2.4	97	2.0	122	2.4	130	2.7
Sensible heat of stack gas, dry	175	3.5	168	3.4	168	3.4	165	3.2	175	3.4	107	2.2	118	2.3	159	3.2
Sensible and latent heat, water in stack gas	276	5.6	249	5.0	214	4.4	231	4.5	237	4.7	197	4.1	220	4.4	226	4.6
Radiation, convection, unaccounted for	510	10.3	508	10.2	475	9.7	511	10.0	568	11.2	906	18.4	336	6.8	627	13.4
Total out	4,954	100.0	4,975	100.0	4,918	100.0	5,112	100.0	5,056	100.0	4,925	100.0	5,028	100.0	4,841	100.0

Period	13-I		13-J		13-K		13-L		13-M		13-N		13-O		13-P	
Heat in:	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent	B.t.u., thousands	Per-cent
Potential heat natural lignite as charged	3,408	66.4	3,359	65.1	3,230	62.8	3,172	61.1	3,210	60.9	3,235	65.4				
Potential heat, product gas used	1,477	28.8	1,515	29.3	1,567	30.3	1,606	30.9	1,600	30.4	1,460	29.6				
Sensible and latent heat 2/ in process steam	234	4.6	276	5.3	344	6.6	408	7.7	446	8.4	234	4.7				
Sensible heat in purge 3/ gas, air, lignite and product gas used	15	.3	15	.3	15	.3	15	.3	15	.3	15	.3				
Total in	5,134	100.0	5,165	100.0	5,176	100.0	5,193	100.0	5,271	100.0	4,944	100.0				
Heat out:																
Potential heat of product gas	2,726	53.1	2,935	56.9	3,038	59.1	3,065	59.0	3,165	60.1	2,778	56.2				
Potential heat, 4/ char and dusts	1,008	19.6	988	19.2	761	14.7	593	11.5	599	11.4	951	19.2				
Sensible and latent heat undecomposed steam	292	5.7	298	5.8	373	7.2	420	8.1	363	6.9	281	5.7				
Sensible heat of char 5/	23	.5	23	.4	19	.4	18	.3	16	.3	22	.4				
Sensible heat of product gas, dry	126	2.5	141	2.7	159	3.1	166	3.2	175	3.3	129	2.6				
Sensible heat of stack gas, dry	158	3.1	162	3.1	164	3.2	165	3.2	155	2.9	147	3.0				
Sensible and latent heat, water in stack gas	227	4.4	242	4.5	241	4.6	241	4.6	230	4.7	223	4.5				
Radiation, convection, unaccounted for	572	11.1	467	9.1	401	7.7	515	9.9	446	8.5	414	8.4				
Total out	5,134	100.0	5,165	100.0	5,176	100.0	5,193	100.0	5,271	100.0	4,944	100.0				

1/ Gross heat basis, hourly averages, and above 60° F.
2/ Calculated as 1,070 + 0.48 ton B.t.u. per lb.
3/ Approximate figure of 15,000 B.t.u. per hr. used.
4/ Based on theoretical weight of residue recovered.
5/ Temperature of char assumed.

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Int. - Bu. of Mines, Pgh., Pa.