TABLE 1. - Record of operations, Grand Forks plant

Run	Date From-	Date To-	Total hours	Lignite processed, tons	Gas made, Mcf
Preliminary .	2/27/45	3/7/45	192	1/	2/
1	6/13/45	6/24/45	240	55	1,665
2	12/6/45	12/16/45	240	3/56	4/2,590
3	3/6/46	3/25/46	5/312	6/85	7/3,800
4	5/16/46	6/16/46	8/780	9/185	10/8,180
Total			1,714	381	16,235

1/ Lignite measured by volume and charged at rates of 550 to 640 pounds per hour for 75 hours.
2/ Gas made was not measured for entire period, but rate ranged from 9,000 to 10,680 cubic feet per hour for 75 hours.
3/ At an average rate of 594 pounds per hour during testing periods.
4/ At an average rate of 13,450 cubic feet per hour.
5/ Excludes 2 days for installation of alloy recuperator.
6/ At an average rate of 544 pounds per hour.
7/ At an average rate of 12,200 cubic feet per hour.
8/ Includes 72 hours operation on char.
9/ 648 hours at 573 pounds per hour average.
10/ At 12,620 cubic feet per hour average.

Summary of Runs at Golden

Run 10 was the first operation to employ the 16-inch retort tube and the 2-inch annular reaction zone. The object was to study operating characteristics with respect to handling materials. Previous experimental work with the 12-inch retort had shown that not more than 2,000 cubic feet of gas per hour could be handled without excessive carry-over of ungasified carbon due to the high velocity in the center gas offtake pipe. The revised retort for run 10 provided four times more area in the offtake pipe and 33 percent more heated tube surface than that of the 12-inch retort. A further object of the test was to study improvements in the char-discharging arrangement. The test lasted about 100 hours, during which time many combinations of variables were studied to find the effects of temperature, steam concentration, and rate of removal of char. The plant operated smoothly, and gas was made at rates of 3,260 cubic feet per hour, but it was indicated that certain changes were necessary to improve char and gas-handling procedures.

Run 11 was made after revisions in the system provided for continuous removal of char through a water-sealed screw discharge.

The arrangement of the plant for this run is shown in figure 22. It was observed, however, that dusts blown into the center offtake increased the pressure drop through the system after 50 hours' operation, and it was indicated that provisions would have to be made to remove dusts at this point. The run continued for about 100 hours, and several variables were studied, particularly the effect of rate of gasification upon carry-over of char into the gas offtake.

The interior arrangement of the retort was revised for run 12, as shown in the November diagram of figure 23. For this test the annular gas offtake was changed to a number of individual ports or louvres spaced diagonally around the inner cylinder and having a total area equal to that of the center gas offtake pipe. Furthermore, provisions were made to dispose of the char dusts that were carried into the center gas zone. These changes were quite satisfactory, and the generator operated smoothly for several days, during which time natural lignite, subbituminous coals, and predried fuels were gasified and gas was made at high rates, as shown in the summary of operating results.

EXPERIMENTAL AND OBSERVED DATA

Coals Tested

Natural lignite from the Velva mine was used in the preliminary test and in run 1. This lignite was selected because of its relatively low ash and sulfur contents. Its physical and chemical properties are typical of the North Dakota lignites, which contain an average of about 37 percent moisture and 6.0 percent ash. The heating value of 6,830 B.t.u. per pound is close to the average of lignite mined in North Dakota. Table 2 gives the proximate and ultimate analyses of the several samples gasified in the large pilot plant during 1945-46.

Lignite from the Dakota Star mine was used for all runs subsequent to No. 1 because of its favorable size consist as delivered from the mine. Less over- and under-size lignite was discarded when using coal from this mine. As shown in table 2, Dakota Star lignite is slightly higher in sulfur content, and the heating value is also 1 to 2 percent higher.

Caprock subbituminous coal from the northern Colorado field and a sample of Velva lignite were used in runs on the small pilot plant at Golden. Table 3 gives the proximate and ultimate analyses of these fuels as well as the analyses of chars and dusts from the several runs.

The size consists of lignites used in runs 2 and 3 in the large pilot plant are given in table 4. For run 2, no screening facilities were available and the run-of-car lignite was gasified. The size range is considerably greater than was used in run 3. No size-consist data were obtained on the lignite used in run 4, but it can be assumed that it is close to that shown for run 3 in table 4, because the same screening facilities were used and the lignite was prepared at the same mine. Table 5 gives the size-consist data on all coals tested in the small pilot plant at Golden. It should be noted that the size range is predominantly 0.5 by 1.0 inch, which is considered to be the best size for the 2.0-inch retort annulus.

TABLE 2. - Proximate and ultimate analyses of natural lignites used in Grand Forks pilot plant.[1/]

Description	Run and period	Condition[2/]	Pittsburgh lab. No.	Proximate, percent				Ultimate, percent					B.t.u. per pound	Softening temp. ash, °F.
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		
Velva lignite	Prelim.	1	C-37614	37.5	27.3	29.2	6.0	6.9	40.5	0.7	45.6	0.3	6,830	2,450
		2			43.7	46.8	9.5	4.4	64.8	1.1	19.8	.4	10,910	
		3			48.3	51.7		4.9	71.6	1.2	21.9	.4	12,070	
Dakota Star lignite	1-AB	1	C-44344	37.8	26.6	30.4	5.2	6.9	40.7	.6	46.2	.4	6,810	2,460
		2			42.8	48.9	8.3	4.3	65.4	1.0	20.3	.7	10,960	
		3			46.7	53.3		4.7	71.3	1.1	22.2	.7	11,950	
Velva lignite	1-C	1	C-36714	37.5	27.3	29.2	6.0	6.9	40.5	.7	45.6	.3	6,830	2,450
		2	3/		43.7	46.8	9.5	4.4	64.8	1.1	19.8	.4	10,910	
		3			48.3	51.7		4.9	71.6	1.2	21.9	.4	12,070	
Dakota Star lignite	2-ABCDE	1	C-52394	38.0	26.3	29.7	5.8	7.0	40.6	.6	45.3	.7	6,880	2,400
		2			42.6	48.1	9.3	4.4	65.7	.9	18.6	1.1	11,090	
		3			47.0	53.0		4.9	72.4	1.0	20.5	1.2	12,230	
Dakota Star lignite	3-ABDFGH	1	C-56522	37.3	27.1	29.7	5.9	6.9	41.1	.5	45.0	.6	6,940	2,380
		2			43.2	47.4	9.4	4.3	65.5	.7	19.0	1.1	11,070	
		3			47.6	52.4		4.7	72.3	.8	21.0	1.2	12,210	
Dakota Star lignite	4-B to N, inc.	1	C-58174	36.0	27.7	30.5	5.8	6.8	41.8	.6	44.1	.9	7,060	2,420
		2			43.3	47.6	9.1	4.4	65.4	.9	18.8	1.4	11,040	
		3			47.7	52.3		4.9	71.9	1.0	20.7	1.5	12,150	
Dakota Star lignite	4-H	1	C-57635	35.2	27.9	31.5	5.4	6.8	42.6	.5	44.0	.7	7,170	2,470
		2			43.1	48.6	8.3	4.5	65.7	.8	19.6	1.1	11,070	
		3			47.0	53.0		4.9	71.7	.9	21.3	1.2	12,080	

1/ Composite increment sampling aggregating 1 percent of total lignite charged.
2/ Condition: (1) As received; (2) moisture-free; (3) moisture-and-ash free.
3/ The analysis of lignite for run 1-C was not determined. It was assumed to be the same as previous shipment for the preliminary run.

TABLE 3. - Proximate and ultimate analyses of coals, chars, and dusts, Golden pilot plant, runs 10, 11, and 12.

Description	Run	Condition1/	Pittsburgh lab. No.	Proximate, percent				Ultimate, percent					B.t.u. per pound	Softening temp. ash, °F.
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		
Caprock subbituminous coal	10-AB	1	C-46248	23.0	33.5	38.0	5.5	6.1	53.3	0.8	33.6	0.7	9,010	2,090
		2			43.6	49.2	7.2	4.6	69.1	1.0	17.2	.9	11,700	
		3			47.0	53.0		5.0	74.5	1.1	18.4	1.0	12,600	
Char out bottom of retort	10-A	2	C-46759		8.2	76.3	15.5	1.2	79.0	.8	2.8	.7	11,990	2,030
		3			9.7	90.3		1.4	93.5	1.0	3.3	.8	14,190	
	10-B	2	C-46760		9.5	65.1	25.4	1.0	70.7	.6	.6	1.7	10,670	2,220
		3			12.8	87.2		1.3	94.8	.7	.9	2.3	14,300	
Caprock subbituminous coal	11-A	1	C-48608	23.0	32.3	38.5	6.2	6.3	52.4	.8	33.6	.7	8,900	2,080
		2			42.0	50.1	7.9	4.7	68.1	1.0	17.4	.9	11,560	
		3			45.6	54.4		5.1	73.9	1.1	18.9	1.0	12,560	
Char out bottom of retort	11-A	2	C-48942		11.0	59.1	29.9	1.2	65.5	.6	1.0	1.8	9,990	2,190
		3			15.7	84.3		1.7	93.5	.8	1.4	2.6	14,260	
Caprock subbituminous coal	12-A	1	C-50387	21.2	33.1	40.2	5.5	6.0	54.2	.8	33.0	.5	9,270	2,080
		2			42.1	50.9	7.0	4.6	68.8	1.0	18.0	.6	11,760	
		3			45.8	54.8		4.9	73.9	1.1	19.4	.7	12,650	
Caprock subbituminous coal predried	12-B	1	2/	12.9	36.5	44.2	6.4	5.4	59.6	.9	27.1	.6	10,200	2,080
		2			41.9	50.8	7.3	4.6	68.8	1.0	18.0	.6	11,760	
		3			45.2	54.8		4.9	73.9	1.1	19.4	.7	12,650	

See footnotes on page 23.

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TABLE 3. - Proximate and ultimate analyses of coals, chars, and dusts, Golden pilot plant, runs 10, 11, and 12. (cont'd.)

Description	Run	Condition 1/	Pittsburgh lab. No.	Proximate, percent				Ultimate, percent					B.t.u. per pound	Softening temp. ash, °F.
				Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		
Velva lignite	12-C	1	C-24720	34.5	28.6	32.2	4.7	6.8	43.0	.7	44.6	.2	7,190	2,490
		2	3/		43.9	49.4	6.7	4.6	66.0	1.0	21.4	.3	11,020	
		3			47.0	53.0		4.9	70.8	1.1	22.9	.3	11,820	
Char out bottom of retort	12-A	2	C-50937		11.3	70.0	18.7	1.0	77.1	0.5	1.6	1.1	11,640	2,070
		3			13.9	86.1		1.3	94.8	.6	2.0	1.3	14,310	
	12-B	2	C-50939		10.5	70.0	19.5	1.1	76.5	.6	1.2	1.1	11,550	2,100
		3			13.0	87.0		1.4	95.0	.7	1.5	1.4	14,350	
Char out bottom of retort (lignite)	12-C	2	C-50941		11.7	72.1	16.2	1.2	76.6	.7	4.8	.5	11,520	2,450
		3			13.9	86.1		1.5	91.4	.9	5.5	.7	13,750	
Dust with gas	12-A	2	C-50938		26.5	38.8	34.7	2.0	60.1	.5	.6	2.1	9,610	2,280
		3			40.6	59.4		3.0	92.0	.7	1.1	3.2	14,710	
	12-B	2	C-50940		21.1	39.8	39.1	1.3	54.1	.4	2.5	2.6	8,210	2,300
		3			34.6	65.4		2.2	88.9	.7	4.0	4.2	13,490	

1/ Condition: (1) As received, (2) moisture-free, (3) moisture-and-ash-free.
2/ Based upon Pittsburgh analysis adjusted to moisture-and-ash determined at time of run.
3/ Based upon Pittsburgh analysis adjusted to moisture determined during run.

TABLE 4. - Size consist of lignites and chars, Grand Forks pilot plant.

Lignite[1]			Char from retort			
Screen size, inches[2]	Percent retained		Screen size, inches[2]	Percent retained		
	2-B and 2-C	3[3]		1-A	1-B	1-C
1.05	48.5	17.2	0.530	1.1	0.8	0.0
.742	26.3	39.0	.263	7.3	13.9	5.0
.525	18.3	26.9	.131	28.0	42.0	24.5
.263	4.0	13.8	.065	26.9	27.5	30.2
-.263	2.9	3.1	-.065	36.7	15.8	40.3
Total ...	100.0	100.0	Total ...	100.0	100.0	100.0

1/ Sampled from cars, representing 1 percent of lignite charged.
2/ Square-mesh screen sizes.
3/ All periods of run 3.

TABLE 5. - Size consist of coals used in Golden pilot plant.

Screen size, inches[1]	Percentage retained				
	Run number and period				
	10-A and B	11-A	12-A	12-B[2]	12-C[3]
1.06	0.0	0.0	0.0	0.0	0.0
.750	5.9	14.0	9.0	2.0	8.0
.530	52.2	56.0	46.0	17.0	22.0
.263	38.1	28.0	41.0	45.0	53.0
.131	2.4	1.5	3.0	19.0	9.0
-.131	1.4	.5	1.0	17.0	8.0
Total	100.0	100.0	100.0	100.0	100.0

1/ Standard square-mesh screen sizes, coarse series.
2/ Coal used in all periods of runs 10, 11, and through 12-B was Caprock subbituminous B. Coal for 12-B was preheated and partly dried before charging.
3/ Velva lignite.

Operating Data

A summary of the operating data obtained in runs 10, 11, and 12 in the Golden pilot plant is given in table 6. As shown, these data are usually reported on an hourly basis, even though the runs may have lasted 24 hours. The table summarizes the operating records taken every hour during the course of the run and averages the observations during the test period studied.

Table 7 presents operating data for all runs on the pilot plant, which total 1,714 hours' operation. The average hourly rates are reported for testing periods lasting 24 hours. The operating data taken during the 24-hour transition periods when a variable was changed are not reported, as several hours are required to reach balanced conditions.

TABLE 6. - Summary data on gasification of subbituminous coal and natural lignite in the Golden pilot plant.

Run and period number:	(1)	10-A	10-B	11-A	12-A	12-B	12-C
Date[1]	(2)	7	7-8	18-19	6-7	7-8	9
Duration, hours	(3)	6	19	24	24	24	4
	(4)						
Coal charged, pounds per hour:	(5)	104	118	105	116	117	130
Moisture as charged, percent[2]	(6)	22.0	21.8	23.0	22.1	12.9	34.5
Ash as charged, percent	(7)	5.6	5.6	6.2	5.4	6.4	4.7
Percentage gasified	(8)	78.5	73.4	78.6	71.8	64.3	64.2
Pounds of coal per Mcf of gas	(9)	33.5	36.2	33.0	36.7	35.5	51.4
Dry residue, pounds per hour:[3]	(10)	20.4	25.7	18.7	26.1	33.8	27.9
Char out of bottom	(11)	16.6	19.2	16.5	24.0	32.1	23.8
Blown over at gas offtake	(12)						
Dust with gas	(13)	1.7	3.1	2.2	1.2	1.7	1.3
Ash in total residue, percent[4]	(14)	20.9	24.4	32.6	20.6	21.8	17.9
	(15)						
Gas made SGC, Mcf per ton:	(16)	59.62	55.25	60.57	54.48	56.41	38.92
Mcf per hour	(17)	3.10	3.26	3.18	3.16	3.30	2.53
B.t.u. per cu. ft. observed, gross	(18)	313	315	300	314	302	309
B.t.u. per cu. ft. calculated, net[5]	(19)	281	284	268	282	271	277
Specific gravity, calculated	(20)	.508	.518	.522	.520	.521	.531
Ratio H_2/CO	(21)	1.92	2.00	2.14	2.26	2.16	2.11
	(22)						
Steam used, pounds per hour:	(23)						
With coal	(24)	18.8	30.0	29.0	29.2	51.0	15.9
In char zone	(25)	43.2	49.0	49.0	48.6	48.6	48.6
Undecomposed steam, lb. per Mcf	(26)	8.2	13.4	12.4	12.9	16.9	25.9
	(27)						
Heating-system data:	(28)						
Net B.t.u. used per cu. ft. gas made	(29)	138	142	132	143	131	167
Heat released, M B.t.u. per cu. ft.[6]	(30)	24.1	25.3	22.8	24.7	23.7	23.2
Make gas used, Mcf per hour	(31)	1.57	1.63	1.56	1.60	1.60	1.53
CO_2 in Poc, percent[7]	(32)	16.7	17.1	16.6	16.1	15.9	15.4
Primary air, Mcf per hour	(33)	4.23	4.33	4.23	4.48	4.43	4.56
Poc recirculated, Mcf per hour.	(34)	9.02	9.23	5.47	6.55	7.65	8.32
	(35)						

See footnotes on page 26.

TABLE 6. - Summary data on gasification of subbituminous coal and natural lignite in the Golden pilot plant. (cont'd.)

Temperatures, °F.:		(36)						
Average combustion chamber 8/		(37)	1,805	1,800	1,760	1,755	1,750	1,750
Bottom of combustion chamber	No. 1	(38)	2,000	2,025	2,010	2,000	1,960	2,010
Middle of combustion chamber	2	(39)	2,060	2,035	1,890	1,955	1,965	1,965
Top of combustion chamber	3	(40)	1,680	1,650	1,610	1,565	1,590	1,560
Outlet from combustion chamber	4	(41)	1,480	1,480	1,540	1,500	1,490	1,465
Inlet to fan	5	(42)	810	820	880	870	835	825
Air and Poc to recuperator	7	(43)	475	480	505	510	505	505
Air and Poc to furnace	8	(44)	1,015	1,035	1,110	1,055	1,020	1,005
Gas leaving retort	12	(45)	705	705	805	740	810	645
Stack	5a	(46)	490	510	800	815	790	780

1/ The figures shown are the day of the month. Run 10 was made during August 1945, run 11 during September 1945, and run 12 during November 1945.

2/ The moisture was determined for each period.

3/ Residue calculated from ash and carbon balance; includes losses such as dusts carried away in cooling water.

4/ From analyses of chars and dusts determined at Golden using A.S.T.M. method for coal and coke. No corrections were made for sulfates, carbonates, or iron.

5/ Determined by deducting the mol fraction of total hydrogen times 49.6 from the observed gross B.t.u.

6/ Calculated on net basis using furnace volume of 18.3 cu. ft.

7/ Calculated from the analyses of the heating gas and the volume of air and gas used.

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

TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant.

Run and period number:	(1)	Pre-A	Pre-B	1-A	1-B	1-C
Date,[1]	(2)	7	7	18-19	19-20	22-24
Duration, hours[2]	(3)	7	3/4	24	21	42
	(4)					
Coal charged, pounds per hour:	(5)	600	638	600	690	540
Moisture as charged, percent[3]	(6)	37.5	37.5	37.8	37.8	37.5
Ash as charged, percent	(7)	6.0	6.9	5.2	5.2	6.0
Percentage gasified	(8)	48.7	55.0	47.0	47.0	48.8
Pounds of coal per Mcf of gas	(9)	65.1	58.2	70.8	68.6	65.0
Dry residue, pounds per hour[4]	(10)			165.6	194.6	145.8
Char out of bottom	(11)	153	159	152	152	138
Blown over at gas offtake	(12)					
Dust with gas	(13)					
Ash in total residue, percent[5]	(14)	22.1	24.0	16.3	15.4	18.0
	(15)					
Gas made SGC, Mcf per ton:	(16)	30.73	34.36	28.23	29.12	30.78
Mcf per hour	(17)	9.22	10.96	8.47	10.06	8.31
B.t.u. per cu. ft. observed, gross	(18)	281	282	289	280	279
B.t.u. per cu. ft. calculated, net[6]	(19)	249	252	255	247	245
Specific gravity, calculated[7]	(20)	.562	.550	.572	.565	.550
Ratio H_2/CO	(21)	3.47	3.13	3.65	4.58	4.49
	(22)					
Steam used, pounds per hour:	(23)					
With coal	(24)	198	296	0	165	0
In char zone	(25)	198	296	400	400	190
Undecomposed steam, lb. per Mcf	(26)			56.3	63.8	28.3
	(27)					
Heating-system data:	(28)					
Net B.t.u. used per cu. ft. gas made	(29)	144	151	135	130	125
Heat released, M B.t.u. per cu. ft.[8]	(30)			5.6	6.4	5.0
Make gas used, Mcf per hour	(31)	5.29	6.39	4.77	5.30	4.23
CO_2 in Poc, percent[9]	(32)			17.9	17.9	16.2
Primary air, Mcf per hour	(33)	16.23	17.17	11.27	12.68	10.48
Poc recirculated, Mcf per hour	(34)	41.48	38.05	37.40	37.50	38.00
	(35)					
Temperatures, °F.	(36)					
Average combustion chamber[10]	(37)	1,825	1,885	1,705	1,670	1,695
Bottom of combustion chamber No. 1	(38)	1,980	1,995	1,815	1,805	1,800
Middle of combustion chamber 2	(39)	1,885	1,935	1,775	1,745	1,765
Top of combustion chamber 3	(40)	1,780	1,875	1,675	1,630	1,670
Outlet from combustion chamber 4	(41)	1,655	1,730	1,560	1,505	1,545
Inlet to fan 5	(42)	730	765	755	720	725
Air and Poc to recuperator 7	(43)	495	505	545	520	545
Air and Poc to furnace 8	(44)	1,250	1,360	1,250	1,190	1,225
Gas leaving retort 12	(45)	600	645	615	605	580
Stack 5a	(46)					
Steam to char zone	(47)					
Steam with coal	(48)					
	(49)					

See footnotes on page 34.

TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Run and period number:	(1)	2-A	2-B	2-C	2-D	2-E
Date,[1]	(2)	9	10	12	13	15
Duration, hours[2]	(3)	1	5	3	2-1/2	3
	(4)					
Coal charged, pounds per hour:	(5)	436	486	560	800	729
Moisture as charged, percent[3]	(6)	38.0	38.0	38.0	38.0	38.0
Ash as charged, percent	(7)	5.8	5.8	5.8	5.8	5.8
Percentage gasified	(8)	85.1	85.7	84.0	65.5	74.9
Pounds of coal per Mcf of gas	(9)	39.8	39.4	41.2	53.8	46.9
Dry residue, pounds per hour[4]	(10)	63.2	59.5	71.5	167.2	122.5
Char out of bottom	(11)	59.5	57.3	57.9	122.6	90.0
Blown over at gas offtake	(12)	1.1	1.6	3.2	33.9	26.2
Dust with gas	(13)	0.6	0.6	0.7	5.5	6.3
Ash in total residue, percent[5]	(14)	40.0	47.4	45.3	27.8	34.5
	(15)					
Gas made SGC, Mcf per ton:	(16)	50.25	50.78	48.55	37.16	42.61
Mcf per hour	(17)	10.95	12.34	13.59	14.86	15.53
B.t.u. per cu. ft. observed, gross.	(18)	297	296	303	309	308
B.t.u. per cu. ft. calculated, net[6]	(19)	264	264	271	276	275
Specific gravity, calculated[7]	(20)	.527	.536	.528	.541	.533
Ratio H_2/CO	(21)	3.05	2.41	2.15	2.41	2.48
	(22)					
Steam used, pounds per hour:	(23)					
With coal	(24)	100	65	65	0	0
In char zone	(25)	200	200	200	200	250
Undecomposed steam, lb. per Mcf	(26)	21.0	15.6	15.0	14.5	13.5
	(27)					
Heating-system data:	(28)					
Net B.t.u. used per cu. ft. gas made	(29)	129	126	128	131	127
Heat released, M B.t.u. per cu. ft.[8]	(30)	12.3	13.6	15.1	17.0	17.1
Make gas used, Mcf per hour	(31)	5.37	5.91	6.40	7.08	7.16
CO_2 in Poc, percent[9]	(32)	17.8	17.4	17.6	18.5	17.1
Primary air, Mcf per hour	(33)	12.67	14.92	16.18	17.60	18.95
Poc recirculated, Mcf per hour	(34)	30.88	31.18	29.27	28.66	32.27
	(35)					
Temperatures, °F.	(36)					
Average combustion chamber[10]	(37)	1,715	1,770	1,880	1,780	1,790
Bottom of combustion chamber No. 1	(38)	1,705	1,800	1,915	1,790	1,925
Middle of combustion chamber 2	(39)	1,820	1,895	2,020	1,960	1,890
Top of combustion chamber 3	(40)	1,750	1,800	1,905	1,800	1,775
Outlet from combustion chamber 4	(41)	1,580	1,590	1,690	1,570	1,580
Inlet to fan 5	(42)	730	715	750	760	695
Air and Poc to recuperator 7	(43)	550	510	520	510	480
Air and Poc to furnace 8	(44)	1,190	1,170	1,250	1,280	1,130
Gas leaving retort 12	(45)	680	710	745	660	685
Stack 5a	(46)	460	495	540	635	595
Steam to char zone	(47)					
Steam with coal	(48)	460	445	455		
	(49)					

See footnotes on page 34.

TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Run and period number:	(1)	3-A	3-B	3-D	3-F	3-G
Date,[1]	(2)	9-10	14-15	16-17	18-19	20-21
Duration, hours[2]	(3)	17	28	21-1/2	24	24
	(4)					
Coal charged, pounds per hour:	(5)	400	660	528	539	539
Moisture as charged, percent[3]	(6)	37.5	37.8	37.4	37.8	36.8
Ash as charged, percent	(7)	5.9	5.8	5.9	5.8	5.9
Percentage gasified	(8)	58.8	77.4	78.3	75.1	74.6
Pounds of coal per Mcf of gas	(9)	52.4	44.1	41.5	44.8	45.0
Dry residue, pounds per hour[4]	(10)	91.6	105.6	80.3	90.2	92.7
Char out of bottom	(11)	78.9	98.0	73.0	81.0	83.4
Blown over at gas offtake	(12)	2.3	6.3	4.9	2.4	1.9
Dust with gas	(13)	1.6	1.3	1.9	0.9	0.9
Ash in total residue, percent[5]	(14)	25.8	36.2	38.8	34.7	34.3
	(15)					
Gas made SGC, Mcf per ton:	(16)	38.17	45.40	48.19	44.69	44.43
Mcf per hour	(17)	7.63	14.98	12.72	12.04	11.98
B.t.u. per cu. ft. observed, gross	(18)	271	299	286	295	300
B.t.u. per cu. ft. calculated, net[6]	(19)	238	266	255	265	267
Specific gravity, calculated[7]	(20)	.564	.538	.547	.543	.538
Ratio H_2/CO	(21)	5.43	2.71	2.84	2.46	2.18
	(22)					
Steam used, pounds per hour:	(23)					
With coal	(24)	500	50	50	50	0
In char zone	(25)	300	300	300	150	150
Undecomposed steam, lb. per Mcf	(26)	104.2	18.1	21.8	12.8	9.3
	(27)					
Heating-system data:	(28)					
Net B.t.u. used per cu. ft. gas made	(29)	201	123	117	124	121
Heat released, M B.t.u. per cu. ft.[8]	(30)	13.3	16.0	13.0	13.0	12.6
Make gas used, Mcf per hour	(31)	6.43	6.94	5.84	5.62	5.41
CO_2 in Poc, percent[9]	(32)	18.5	17.0	16.8	17.5	17.5
Primary air, Mcf per hour	(33)	16.39	16.16	13.99	13.42	13.13
Poc recirculated, Mcf per hour	(34)	47.03	25.82	30.09	30.45	28.83
	(35)					
Temperatures, °F.	(36)					
Average combustion chamber[10]	(37)	1,345	1,785	1,740	1,770	1,810
Bottom of combustion chamber No. 1	(38)	1,645	1,885	1,865	1,925	1,925
Middle of combustion chamber 2	(39)	1,540	1,880	1,785	1,825	1,875
Top of combustion chamber 3	(40)	1,190	1,760	1,725	1,740	1,795
Outlet from combustion chamber 4	(41)	1,015	1,620	1,595	1,595	1,650
Inlet to fan 5	(42)	390	835	845	845	850
Air and Poc to recuperator 7	(43)	295	585	625	625	630
Air and Poc to furnace 8	(44)	545	1,530	1,315	1,315	1,355
Gas leaving retort 12	(45)	615	635	645	655	665
Stack 5a	(46)	290	630	595	580	645
Steam to char zone	(47)	270	250	250	245	240
Steam with coal	(48)	285	465	455	450	
	(49)					

See footnotes on page 34.

TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Run and period number:	(1)	3-H	4-A	4-B	4-C
Date,[1]	(2)	22-23		18-19	20-21
Duration, hours[2]	(3)	24		24	24
	(4)				
Coal charged, pounds per hour:	(5)	600	334	604	604
Moisture as charged, percent[3]	(6)	37.9		36.9	36.8
Ash as charged, percent	(7)	5.8		5.7	5.7
Percentage gasified	(8)	70.3		71.5	74.3
Pounds of coal per Mcf of gas	(9)	48.6	40.8	45.7	44.2
Dry residue, pounds per hour:[4]	(10)	112.8	193.2	104.5	102.7
Char out of bottom	(11)	100.8	132.6	91.7	85.8
Blown over at gas offtake	(12)	5.1	60.6	4.0	4.1
Dust with gas	(13)	2.6	0.0	1.7	1.8
Ash in total residue, percent[5]	(14)	30.9		21.0	25.5
	(15)				
Gas made SGC, Mcf per ton:	(16)	41.16	48.96	43.77	45.25
Mcf per hour	(17)	12.35	8.18	13.22	13.67
B.t.u. per cu. ft. observed, gross	(18)	299	265	290	292
B.t.u. per cu. ft. calculated, net[6]	(19)	265	258	259	260
Specific gravity, calculated[7]	(20)	.542	.533	.550	.530
Ratio H_2/CO	(21)	2.42	2.67	2.55	2.83
	(22)				
Steam used, pounds per hour:	(23)				
With coal	(24)	0	150	100	100
In char zone	(25)	200	200	200	200
Undecomposed steam, lb. per Mcf	(26)	14.8		20.1	18.1
	(27)				
Heating-system data:	(28)				
Net B.t.u. used per cu. ft. gas made	(29)	130	165	120	116
Heat released, M B.t.u. per cu. ft.[8]	(30)	13.9	11.6	13.8	13.7
Make gas used, Mcf per hour	(31)	6.05	5.22	6.13	6.08
CO_2 in Poc, percent[9]	(32)	19.0	17.4	18.3	18.3
Primary air, Mcf per hour	(33)	14.32	12.61	15.00	14.62
Poc recirculated, Mcf per hour	(34)	28.07	31.54	27.89	27.61
	(35)				
Temperatures, °F.:	(36)				
Average combustion chamber[10]	(37)	1,790			
Bottom of combustion chamber No. 1	(38)	1,915	1,935	1,940	1,965
Middle of combustion chamber 2	(39)	1,830			
Top of combustion chamber 3	(40)	1,785	1,660	1,765	1,795
Outlet from combustion chamber 4	(41)	1,635	1,545	1,620	1,645
Inlet to fan 5	(42)	840	770	790	805
Air and Poc to recuperator 7	(43)	605	535	520	545
Air and Poc to furnace 8	(44)	1,335	1,195	1,265	1,290
Gas leaving retort 12	(45)	640	710	675	680
Stack 5a	(46)	645	550	600	610
Steam to char zone	(47)	245	245	250	250
Steam with coal	(48)			547	
	(49)				

See footnotes on page 34.

TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Run and period number:	(1)	4-D	4-E	4-F	4-G
Date,[1] ..... [2]	(2)	23-24	25-26	27-28	29-30
Duration, hours[2]	(3)	24	24	24	24
	(4)				
Coal charged, pounds per hour:	(5)	587	685	502	477
Moisture as charged, percent[3]	(6)	35.8	35.6	34.8	35.6
Ash as charged, percent	(7)	5.8	5.9	5.9	5.9
Percentage gasified	(8)	72.3	65.3	78.1	78.5
Pounds of coal per Mcf of gas	(9)	44.7	50.0	40.9	41.4
Dry residue, pounds per hour:[4]	(10)	114.4	147.9	85.8	84.4
Char out of bottom	(11)	91.8	120.5	74.4	74.1
Blown over at gas offtake	(12)	4.8	6.2	3.2	3.1
Dust with gas	(13)	1.4	2.9	0.9	1.0
Ash in total residue, percent[5]	(14)	24.7	23.3	28.3	26.3
	(15)				
Gas made SGC, Mcf per ton:	(16)	44.72	40.00	48.92	48.32
Mcf per hour	(17)	13.13	13.70	12.28	11.53
B.t.u. per cu. ft. observed, gross ..	(18)	292	296	295	294
B.t.u. per cu. ft. calculated, net[6] .	(19)	252	264	260	263
Specific gravity, calculated[7]	(20)	.530	.537	.525	.523
Ratio H_2/CO	(21)	2.97	2.76	2.60	2.75
	(22)				
Steam used, pounds per hour:	(23)				
With coal	(24)	49	49	50	50
In char zone	(25)	250	250	250	250
Undecomposed steam, lb. per Mcf	(26)	18.4	19.8	18.3	20.5
	(27)				
Heating-system data:	(28)				
Net B.t.u. used per cu. ft. gas made.	(29)	117	126	124	126
Heat released, M B.t.u. per cu. ft.[8]	(30)	13.3	15.0	13.2	12.7
Make gas used, Mcf per hour	(31)	6.09	6.52	5.86	5.54
CO_2 in Poc, percent[9]	(32)	17.4	18.2	18.3	17.8
Primary air, Mcf per hour	(33)	14.66	15.30	13.65	13.04
Poc recirculated, Mcf per hour	(34)	27.01	26.98	27.82	27.43
	(35)				
Temperatures, °F.:	(36)				
Average combustion chamber[10]	(37)				
Bottom of combustion chamber No. 1 ..	(38)	2,015	2,020	2,055	1,995
Middle of combustion chamber 2 ..	(39)				
Top of combustion chamber 3 ..	(40)	1,810	1,835	1,840	1,840
Outlet from combustion chamber 4 ..	(41)	1,650	1,670	1,675	1,675
Inlet to fan 5 ..	(42)	795	805	810	815
Air and Poc to recuperator 7 ..	(43)	505	505	535	540
Air and Poc to furnace 8 ..	(44)	1,285	1,290	1,295	1,305
Gas leaving retort 12 ..	(45)	640	630	675	670
Stack 5a ..	(46)	625	620	625	625
Steam to char zone	(47)	250	250	245	250
Steam with coal	(48)		475	490	490
	(49)				

See footnotes on page 34.

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TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Run and period number:		4-H	4-I	4-J	4-K
Date,[1]	(1)				
Duration, hours[2]	(2)	1-2	3-4	5-6	7-8
	(3)	24	24	24	24
	(4)				
Coal charged, pounds per hour:	(5)	614	544	549	495
Moisture as charged, percent[3]	(6)	36.4	37.2	37.1	35.1
Ash as charged, percent	(7)	5.3	5.7	5.7	5.9
Percentage gasified	(8)	74.8	68.7	73.6	72.9
Pounds of coal per Mcf of gas	(9)	43.8	48.3	44.5	43.9
Dry residue, pounds per hour:[4]	(10)	104.0	106.2	97.2	90.6
Char out of bottom	(11)	97.5	97.3	85.9	74.9
Blown over at gas offtake	(12)	3.8	2.6	2.6	2.8
Dust with gas	(13)	1.9	.8	.9	.5
Ash in total residue, percent[5]	(14)	29.1	21.1	24.3	39.7
	(15)				
Gas made SGC, Mcf per ton:	(16)	45.68	41.40	44.91	45.54
Mcf per hour	(17)	14.02	11.26	12.33	11.27
B.t.u. per cu. ft. observed, gross	(18)	294	293	290	292
B.t.u. per cu. ft. calculated, net[6]	(19)	261	260	258	261
Specific gravity, calculated[7]	(20)	.528	.539	.532	.524
Ratio H_2/CO	(21)	3.06	2.47	2.72	2.47
	(22)				
Steam used, pounds per hour:	(23)				
With coal	(24)	200	50	100	50
In char zone	(25)	150	150	150	150
Undecomposed steam, lb. per Mcf	(26)	20.2	15.8	16.5	13.8
	(27)				
Heating-system data:	(28)				
Net B.t.u. used per cu. ft. gas made	(29)	118	134	122	129
Heat released, M B.t.u. per cu. ft.[8]	(30)	14.4	13.1	13.2	12.5
Make gas used, Mcf per hour	(31)	6.33	5.81	5.84	5.66
CO_2 in Poc, percent[9]	(32)	17.8	19.0	17.5	17.9
Primary air, Mcf per hour	(33)	14.95	13.70	14.37	13.48
Poc recirculated, Mcf per hour	(34)	25.65	28.61	28.32	28.39
	(35)				
Temperatures, °F.:	(36)				
Average combustion chamber[10]	(37)				
Bottom of combustion chamber No. 1	(38)	2,000	2,010	2,025	2,035
Middle of combustion chamber 2	(39)				
Top of combustion chamber 3	(40)	1,855	1,820	1,815	1,845
Outlet from combustion chamber 4	(41)	1,690	1,660	1,655	1,685
Inlet to fan 5	(42)	810	800	795	810
Air and Poc to recuperator 7	(43)	510	520	510	530
Air and Poc to furnace 8	(44)	1,315	1,285	1,270	1,295
Gas leaving retort 12	(45)	730	685	705	695
Stack 5a	(46)	570	625	595	630
Steam to char zone	(47)	245	245	245	245
Steam with coal	(48)	555	485	540	490
	(49)				

See footnotes on page 34.

TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Run and period number:	(1)	4-L	4-M	4-N	4-O
Date,[1]	(2)	9-10	11-12	13-14	15-16
Duration, hours[2]	(3)	24	24	24	24
	(4)				
Coal charged, pounds per hour:	(5)	577	629	618	312
Moisture as charged, percent[3]	(6)	35.5	34.2	35.1	6.0
Ash as charged, percent	(7)	5.9	6.0	5.9	
Percentage gasified	(8)	72.7	68.6	71.3	
Pounds of coal per Mcf of gas	(9)	44.1	44.9	43.8	38.1
Dry residue, pounds per hour:[4]	(10)	103.2	120.7	117.5	169.6
Char out of bottom	(11)	85.1	92.0	83.7	156.7
Blown over at gas offtake	(12)	2.7	5.0	5.6	12.3
Dust with gas	(13)	1.0	1.6	1.9	0.6
Ash in total residue, percent[5]	(14)	32.7	24.9	22.3	27.0
	(15)				
Gas made SGC, Mcf per ton:	(16)	45.34	44.59	45.63	52.3
Mcf per hour	(17)	13.08	14.02	14.10	8.19
B.t.u. per cu. ft. observed, gross	(18)	291	285	285	268
B.t.u. per cu. ft. calculated, net[6]	(19)	260	253	252	240
Specific gravity, calculated[7]	(20)	.538	.541	.540	.524
Ratio H_2/CO	(21)	2.62	2.99	3.12	2.55
	(22)				
Steam used, pounds per hour:	(23)				
With coal	(24)	200	200	200	200
In char zone	(25)	100	200	200	107
Undecomposed steam, lb. per Mcf	(26)	18.9	24.0	23.5	16.7
	(27)				
Heating-system data:	(28)				
Net B.t.u. used per cu. ft. gas made	(29)	125	118	118	133
Heat released, M B.t.u. per cu. ft.[8]	(30)	14.2	14.4	14.4	9.7
Make gas used, Mcf per hour	(31)	6.34	6.55	6.57	4.55
CO_2 in Poc, percent[9]	(32)	18.4	18.0	17.8	17.3
Primary air, Mcf per hour	(33)	14.98	15.49	15.49	10.99
Poc recirculated, Mcf per hour	(34)	27.42	26.58	26.48	27.08
	(35)				
Temperatures, °F.:	(36)				
Average combustion chamber[10]	(37)				
Bottom of combustion chamber No. 1	(38)	2,045	2,050	2,055	1,960
Middle of combustion chamber 2	(39)				
Top of combustion chamber 3	(40)	1,855	1,835	1,820	1,715
Outlet from combustion chamber 4	(41)	1,675	1,665	1,660	1,600
Inlet to fan 5	(42)	800	790	785	785
Air and Poc to recuperator 7	(43)	495	480	480	570
Air and Poc to furnace 8	(44)	1,280	1,260	1,250	1,205
Gas leaving retort 12	(45)	750	695	710	725
Stack 5a	(46)	565	560	560	525
Steam to char zone	(47)	240	245	250	245
Steam with coal	(48)	550	550	545	520
	(49)				

See footnotes on page 34.

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TABLE 7. - Summary data on gasification of natural lignite in the Grand Forks pilot plant. (cont'd.)

Footnotes

1/ The figures shown are the day of the month. The preliminary run was made during March 1945, run 1 during June 1945; run 2 during December 1945, run 3 during March 1946, and run 4 during April and May 1946.

2/ Each of the testing periods lasted for at least 24 hours, but due to irregularities in operation, the static balances on some of these periods were determined for the shorter time enumerated.

3/ For the preliminary run and for runs 1 and 2, a composite sample was used for the coal analysis, whereas for runs 3 and 4 daily moisture determinations were made.

4/ Total residue calculated from ash and carbon balance; includes losses such as char dust from cyclone and fine dusts carried away in cooling water.

5/ For the preliminary run and for run 1, the figures shown are the percentage ash in chars only as determined at Golden by A.S.T.M. methods, no corrections being made for sulfates or carbonates. For runs 2 and 3, the percentage ash in total residue was calculated from the carbon and ash balance. For run 4, the percentage ash in total residue was determined at Golden by A.S.T.M. methods, no corrections being made for sulfates or carbonates.

6/ For the preliminary run, the net B.t.u. per cu. ft. was estimated from similar data on the small pilot plant. For the rest of the runs, 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.

7/ For the preliminary run, the specific gravity reported is the observed value.

8/ For the preliminary run and for run 1, this figure is based upon a furnace volume of 206 cu. ft. and the net heating value of the gas. For runs 2, 3, and 4, this figure is based upon a furnace volume of 115 cu. ft. and the net heating value of the gas.

9/ Determined by Orsat for the preliminary run and for runs 1, 2, and 3. Calculated from the analysis of the heating gas and the volume of air and gas used for run 4.

10/ Averages of points 1, 2, 3, and 4.