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Blast Furnace Granulated Coal Injection

Quarterly Report
July 1 - September 30, 1998

Work Performed Under Contract No.: DE-FC21-91MC27362

For
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Disclaimer

QUARTERLY REPORT

Plant Operations:

Production levels on each furnace exceeded 7000 NTHM/day during July. The combined production of 14,326 was a result of lower coke rates and below average delay rates on both furnaces. The combined production was at its highest level since September 1997. In August, the combined productivity declined to less than 13,500 NTHM/day. Although D furnace maintained a production rate in excess of 7000 NTHM/day, C furnace was lower because of a castfloor breakout and subsequent five day repair from August 26–30. Despite the lower productivity in August, injected coal and furnace coke rates were very good during the month. During September, the operation was difficult as a result of higher delays on both furnaces. The combined average monthly delay rate was considerably above the twenty-month average of 113 minutes per day and the combined average monthly production was less than 14,000 NTHM/day. Higher furnace coke rates at lower coal injection levels also contributed to the decrease. Additionally, the coke rate on both furnaces was increased substantially and the injected coal rate was decreased in preparation for the high volatile Colorado coal trial that started on September 28. The furnace process results for this quarter are shown in Tables 1A and 1B. In addition, the last twelve months of injected coal and coke rates for each furnace are shown in Figures 1 and 2.

The Colorado coal trial is part of the continuing cooperative agreement with the Department of Energy. The trial is expected to last about five weeks and will consist of three weeks using granular sizing and two weeks using pulverized sizing. For this trial the BALWAX model predicts that a higher coke rate will be necessary due to the lower carbon content of the Colorado coal. Therefore, beginning on September 10, the coke rate on both furnaces was increased by about 45 pounds/NTHM. The increase caused the monthly average coke rate to rise to 702 pounds/NTHM on C and 729 pounds/NTHM on D in September. An evaluation of the effects of injected coal sizing on furnace operating parameters will be made by comparing furnace performance with granular coal to that of pulverized coal.

C Furnace Coke Evaluation:

Since May 17, there have been several changes made to the coke charged to the Burns Harbor furnaces. The timing of these changes provided an opportunity to assess the furnace operation with the different cokes. The analysis is made using a comparative base period on C furnace from April 1 through May 17. C furnace was analyzed since injected coal was used during all of the evaluation periods. The low volatile component of the coal blend at the coke ovens was increased from 25% to 30% on May 18 to start the first evaluation period. On July 5, Chinese coke was charged to the furnace. The rate of use was about 13.8% of the total coke consumed during the second evaluation period. Subsequently, on September 11, the low volatile coal blend component was changed back to the original 25% level. The furnace statistics and the Burns Harbor coke stability are compared for the base period and the three evaluation periods in Table 2. The physical properties of the Chinese coke are also shown on Table 2. Because coke quality, particularly size and stability, can substantially affect the permeability of the furnace, permeability is the variable that is assessed during each evaluation period. Also, since injected natural gas increases furnace permeability, all operating days when natural gas was used on the furnace in excess of 5 pounds/NTHM are deleted from the evaluation data. The t- statistic for differences between means with small sample sizes is used to determine the statistical validity of the evaluation periods. This method determines if the mean value between two samples is statistically different and at some confidence interval. If the t-statistic indicates that the permeability value changed, the period was examined for other process changes that may have affected the permeability besides the coke change. Each of these comparative periods has been examined in such a manner.

The evaluation base period is shown in Figure 3. The average furnace permeability with all home coke at a coal blend using 25% low volatile coal is 1.21. The coal injection rate during this period is 297 pounds/NTHM. The Burns Harbor coke stability is 60.8 and 60.9 measured at the wharf on #1 and #2 batteries.

Figure 4 shows the first evaluation period using Burns Harbor coke after the change to 30% low volatile coal. The average permeability has increased to 1.28. The coke stability increased on both #1 and #2 batteries to 61.6 and 62.1 respectively. This change in stability compared to the base period on each battery is statistically significant at the 99% confidence interval. The injected coal rate of 294 pounds/NTHM is comparable to the base period. The increase in permeability during this period is statistically significant at the 99% confidence interval. Since there were no other discernable process changes in the operation during this period, the increase in the furnace permeability is attributed to the change in coke stability.

Chinese coke was added to the burden on July 7. Table 2 shows that during the period from July 7 through September 11, the second evaluation period, Chinese coke was added at 13.8% of the total coke rate. Figure 5 shows the permeability results during the period. The increase from 1.28 to 1.34 is statistically significant at the 99% confidence level. Since the coal injection rate has not changed, the home coke stability has remained at the previous period's high level and no other process changes are apparent, the increase is attributed to the use of Chinese coke. Table 2 shows the physical properties of the Chinese coke that we believe increased the permeability. The Chinese coke is noticeably larger than home coke and has a higher stability. Also of importance is the small amount of this coke that is minus one inch. The amount of undersized coke that goes into the furnace may be more significant for permeability than the top size. Ultimately, however, the most important attribute of the Chinese coke that affects permeability is the stability value. The higher stability of the Chinese coke is primarily responsible for the increase in permeability. The third comparative period is shown in Figure 6. The low volatile coal in the blend was reduced to the previous level of 25% during this brief period in September but the coke stability did not change. The Chinese coke percentage in the burden increased slightly to 15.1% of the total coke rate and the coal injection rate was reduced by 60 pounds/NTHM. The furnace permeability has increased to 1.40 from 1.34. The increase is statistically significant at the 99% confidence level. The reduction of the coal injection rate and the corresponding increase in the furnace coke rate was made to accommodate the planned Colorado coal trial mentioned previously.

The change in permeability during this period is attributed to the injected coal and coke rate change rather than to a change in coal blend or the increase of Chinese coke

The increase in furnace permeability using higher stability coke with a tighter size range is not surprising. Since the beginning of coal injection, operators have struggled to maintain good furnace permeability. Higher coal injection rates and lower furnace coke rates are limited at the Burns Harbor furnaces by the permeability factor. The surprising result of this analysis is that small, incremental differences in coke properties can significantly affect the permeability.

Plans for Next Quarter:

Complete the Colorado coal trial with granular and pulverized coal.

TABLE 1A
Burns Harbor C Furnace
Summary of Operation

	July 98	August 98	Sept 98
Prod, NTHM/d Rep	7256	6407	6835
Delays, Min/d	45	155	71
Coke Rate, lbs/NTHM	644	666	702
Nat. Gas Rate, lbs/NTHM	8	10	8
Inj. Coal Rate, lbs/NTHM	287	284	254
Total Fuel Rate, lbs/NTHM	938	960	964
Burden %:			
Sinter	35.8	31.8	33.1
Pellets	64.0	68.1	66.7
Misc.	.2	.2	.2
BOF Slag, lbs/NTHM	4	9	9
Blast Conditions:			
Dry Air, SCFM	145,851	146,637	151,533
Blast Pressure, psig	38.3	38.2	38.6
Permeability	1.34	1.33	1.40
Oxygen in Wind, %	26.4	25.9	25.1
Temp, F	2101	2087	2090
Moist., Grs/SCF	22.8	20.4	20.5
Flame Temp, F	3811	3783	3831
Top Temp, F	256	261	257
Top Press, psig	16.7	16.5	17.2
Coke:			
H2O, %	4.9	4.8	5.1
Hot Metal, %:			
Silicon	.51	.55	.53
Standard Dev.	.123	.167	.152
Sulfur	.035	.034	.034
Standard Dev.	.015	.018	.020
Phos.	.058	.058	.060
Mn.	.38	.38	.40
Temp., F	2700	2663	2661
Slag, %:			
SiO2	36.94	36.89	37.02
Al2O3	9.78	9.53	9.63
CaO	40.18	40.22	39.94
MgO	11.39	11.22	11.47
Mn	.34	.34	.37
Sul	1.47	1.47	1.48
B/A	1.10	1.11	1.10
B/S	1.40	1.39	1.39
Volume, lbs/NTHM	438	434	435

TABLE 1B

Burns Harbor D Furnace

Summary of Operation

	July 98	August 98	Sept 98
Prod. NTHM/d Rep	7070	7078	6838
Delays, Min/d	50	42	81
Coke Rate, lbs/NTHM	678	683	729
Nat. Gas Rate, lbs/NTHM	5	2	1
Inj. Coal Rate, lbs/NTHM	243	250	222
Total Fuel Rate, lbs/NTHM	927	935	951
Burden %:			
Sinter	34.9	30.8	32.2
Pellets	65.0	69.0	67.6
Misc.	.2	.2	.2
BOF Slag, lbs/NTHM	5	10	10
Blast Conditions:			
Dry Air, SCFM	145,943	149,599	151,916
Blast Pressure, psig	38.3	37.6	38.1
Permeability	1.32	1.43	1.44
Oxygen in Wind, %	25.9	25.5	25.1
Temp, F	2098	2089	2059
Moist., Grs/SCF	22.9	21.2	21.0
Flame Temp, F	3854	3836	3897
Top Temp, F	265	263	259
Top Press, psig	16.5	16.7	17.0
Coke:			
H2O, %	4.7	4.7	4.9
Hot Metal, %:			
Silicon	.48	.49	.52
Standard Dev.	.102	.104	.097
Sulfur	.040	.041	.036
Standard Dev.	.012	.016	.014
Phos.	.058	.058	.060
Mn.	.37	.37	.39
Temp., F	2661	2652	2681
Slag, %:			
SiO2	37.12	37.30	37.17
Al2O3	9.79	9.47	9.63
CaO	39.92	40.09	39.82
MgO	11.36	11.36	11.49
Mn	.35	.36	.38
Sul	1.46	1.45	1.47
B/A	1.09	1.10	1.10
B/S	1.38	1.38	1.38
Volume, lbs/NTHM	432	430	434

TABLE 2

STATISTICAL ANALYSIS OF C FURNACE PERMEABILITY & COKE CHANGES

Trial Period 1998		Coal Injection Rate	% Chinese Coke	% LV Coal in Blend	Burns Harbor Mean Stability	Coke Std.Dev	Permeability Mean	Standard Deviation	Sample Size	t-Value	Significant @ %
4/1/ - 5/17	BASE	297	0	25	60.8 , 60.9	.78 , .93	1.21	.052	40	-	
5/19 - 6/29	#1	294	0	**30**	61.6 , 62.1	1.31 , .87	**1.28**	.058	34	5.00	99
7/5 - 9/11	#2	300	**13.8**	30	62.8	.73	**1.34**	.067	56	4.29	99
9/13 - 9/30	#3	**240**	15.1	**25**	62.7	.49	**1.40**	.079	12	2.73	99

ATTRIBUTES OF CHINESE COKE

Coke Sizing and Stability

Chinese Coke Sizing (Samples from Indiana Harbor to Burns Harbor)

Date	+4" %	+3" %	+2" %	+1" %	-1" %	Stability
June 1		11.5	48.6	35.0	4.9	68.9
June 2		16.5	62.8	17.5	3.2	70.2
June 9	0.3	13.6	69.2	15.7	1.1	68.0
June 11		13.1	64.0	21.6	1.2	68.9
June 12		10.6	61.9	24.8	2.7	69.3
June 15		9.9	58.5	29.3	2.2	63.6
June 16		9.9	55.2	31.4	3.5	64.5
June 29		5.3	57.3	35.2	2.2	70.4
June 30		7.2	61.2	29.4	1.6	70.9
July 1	0.4	9.6	65.1	23.6	1.3	70.4
July 2		5.4	59.3	33.5	1.8	68.2
July 3		9.5	61.0	26.7	2.7	70.7
July 6		3.5	53.3	38.1	5.1	67.3
July 7		10.4	65.0	22.9	1.3	71.8
July 9		6.6	65.5	26.4	1.5	71.6
July 9	0.4	9.6	65.1	23.6	1.3	70.4
July 14		6.9	64.3	27.6	1.2	68.2
July 16		3.5	53.3	38.1	5.1	67.3
AVERAGE	0.35	9.0	60.6	27.8	2.5	68.9

Chinese Coke Sizing (Samples taken during trucking from Indiana Harbor to Burns Harbor and analyzed by CTE)

FIGURE 1

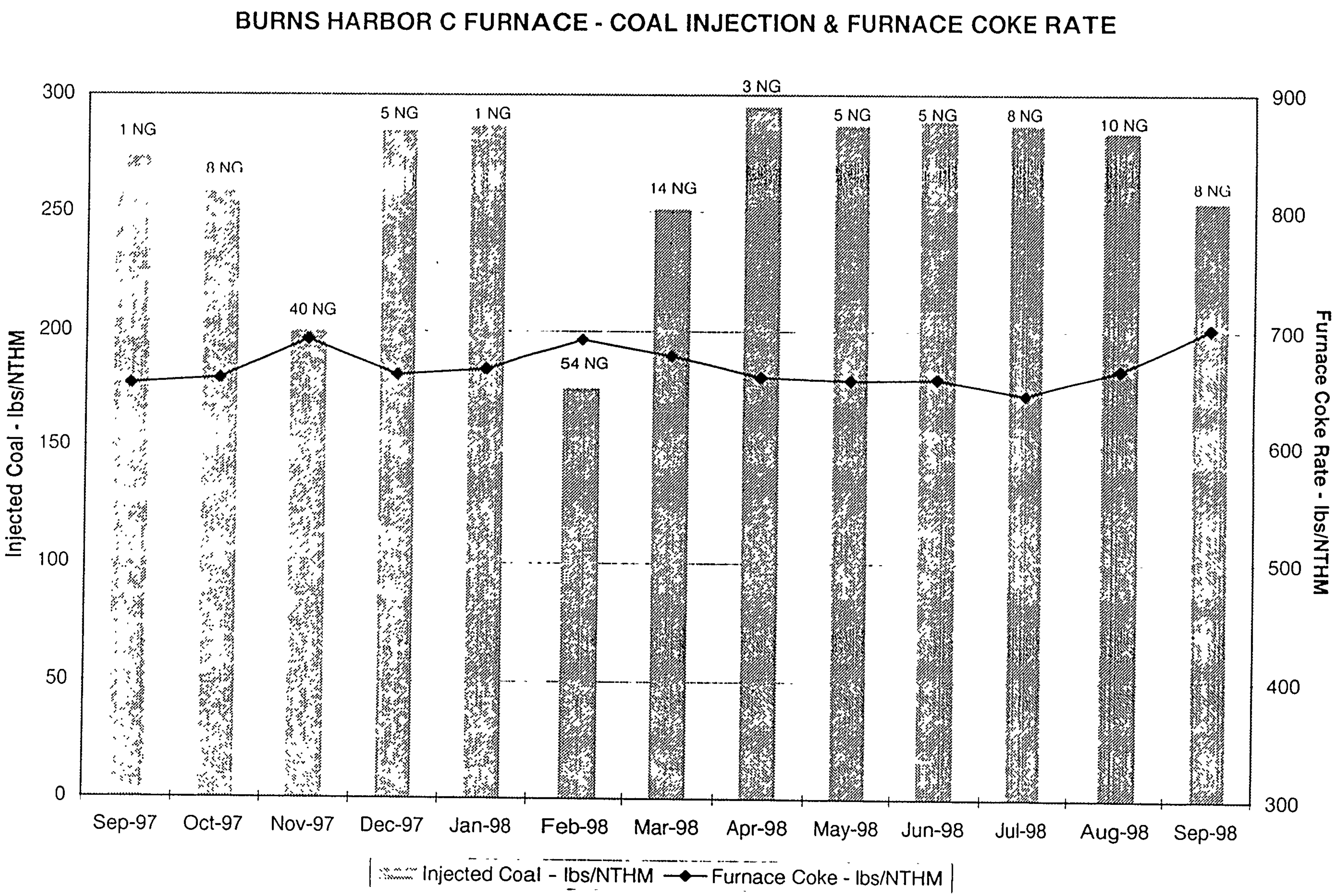
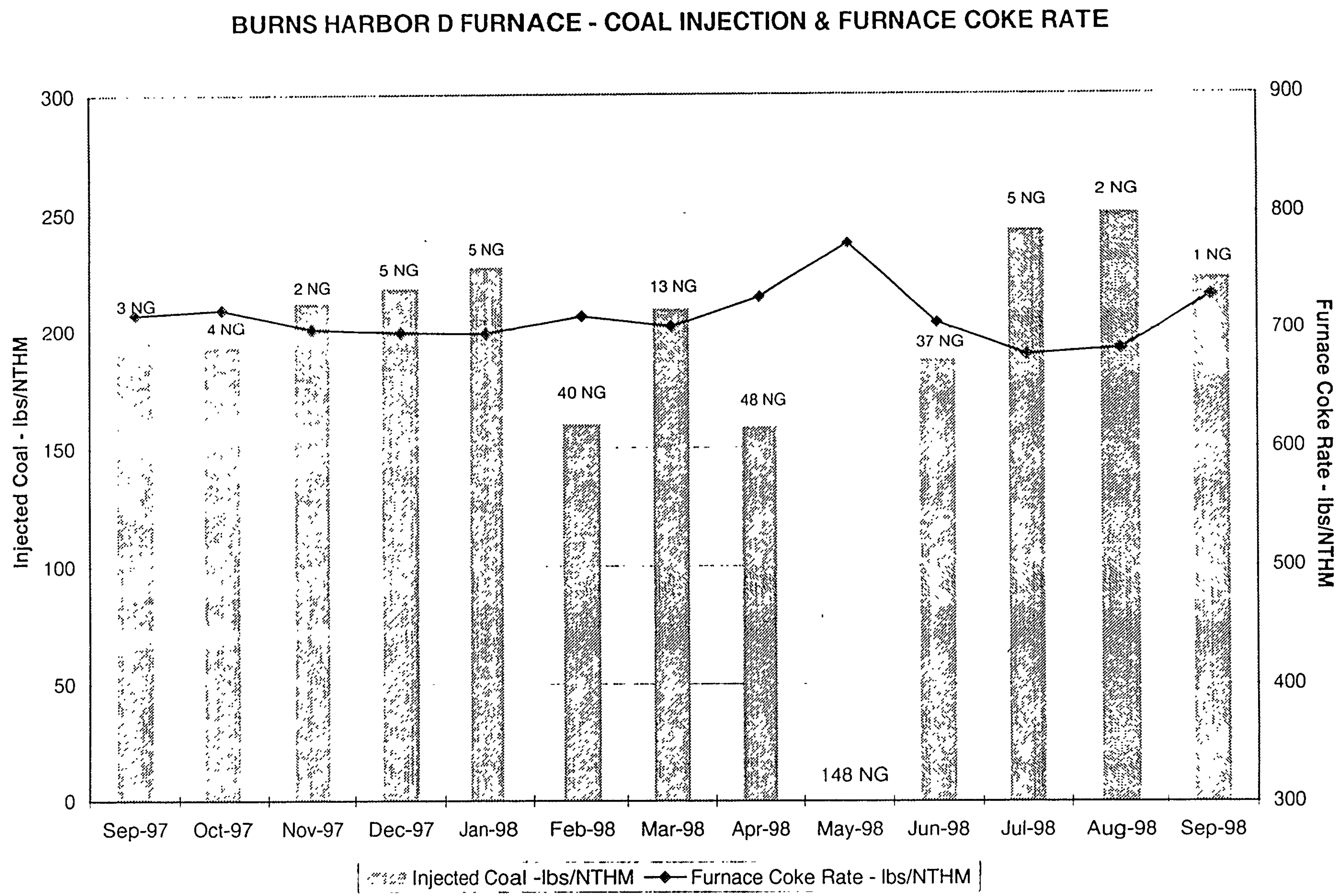

BURNS HARBOR C FURNACE - COAL INJECTION & FURNACE COKE RATE
Injected Coal - lbs/NTHM
Furnace Coke Rate - lbs/NTHM
300
250
200
150
100
50
0
900
800
700
600
500
400
300
1 NG
8 NG
40 NG
5 NG
1 NG
54 NG
14 NG
3 NG
5 NG
5 NG
8 NG
10 NG
8 NG
Sep-97
Oct-97
Nov-97
Dec-97
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Injected Coal - lbs/NTHM
Furnace Coke - lbs/NTHM

FIGURE 2



BURNS HARBOR D FURNACE - COAL INJECTION & FURNACE COKE RATE
Injected Coal - lbs/NTHM
Furnace Coke Rate - lbs/NTHM
300
250
200
150
100
50
0
900
800
700
600
500
400
300
3 NG
4 NG
2 NG
5 NG
5 NG
40 NG
13 NG
48 NG
148 NG
37 NG
5 NG
2 NG
1 NG
Sep-97
Oct-97
Nov-97
Dec-97
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Injected Coal -lbs/NTHM
Furnace Coke Rate - lbs/NTHM

FIGURE 3

C Furnace - Permeability With 25% Low Volatile in the Coal Blend

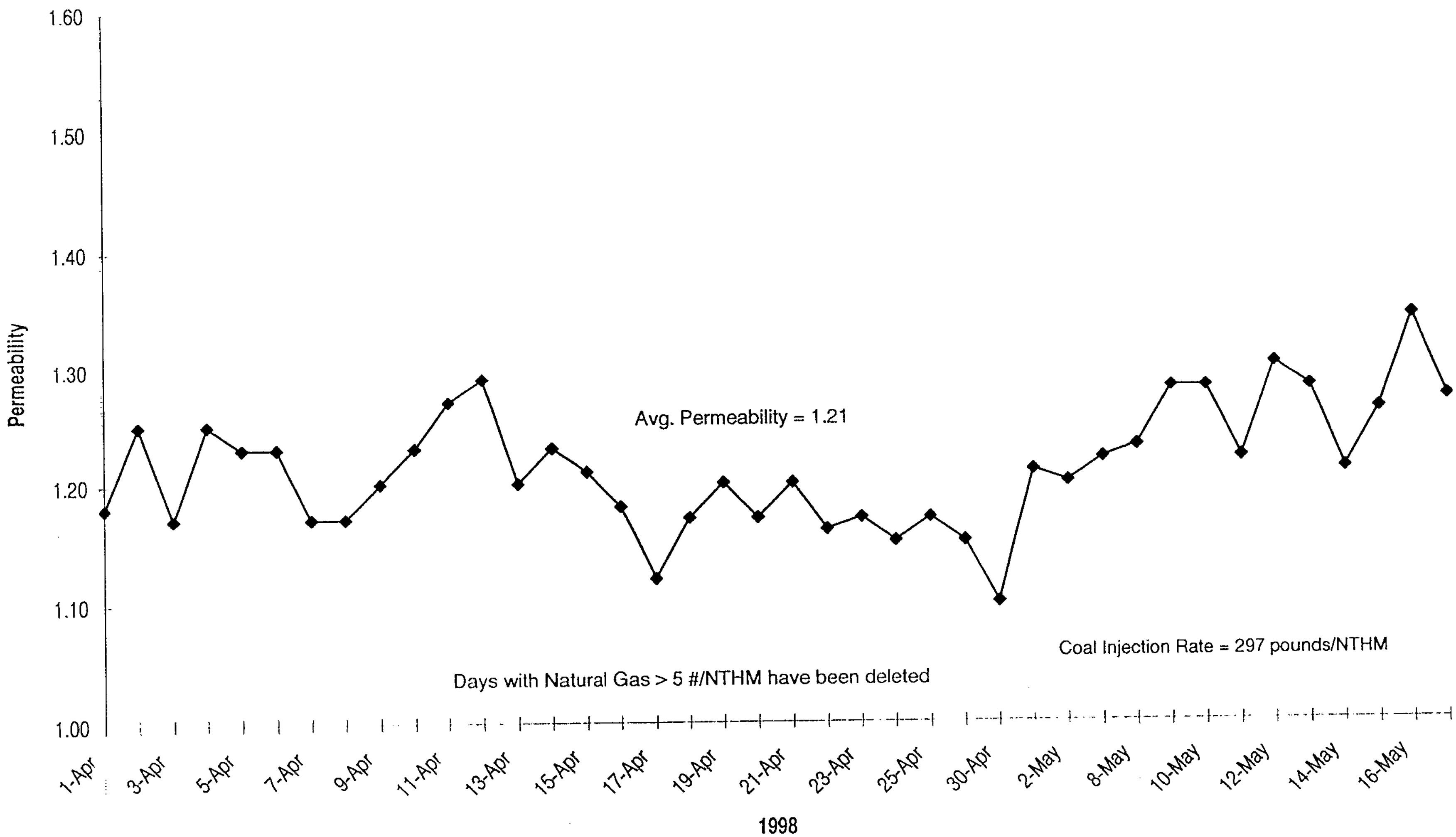


FIGURE 4

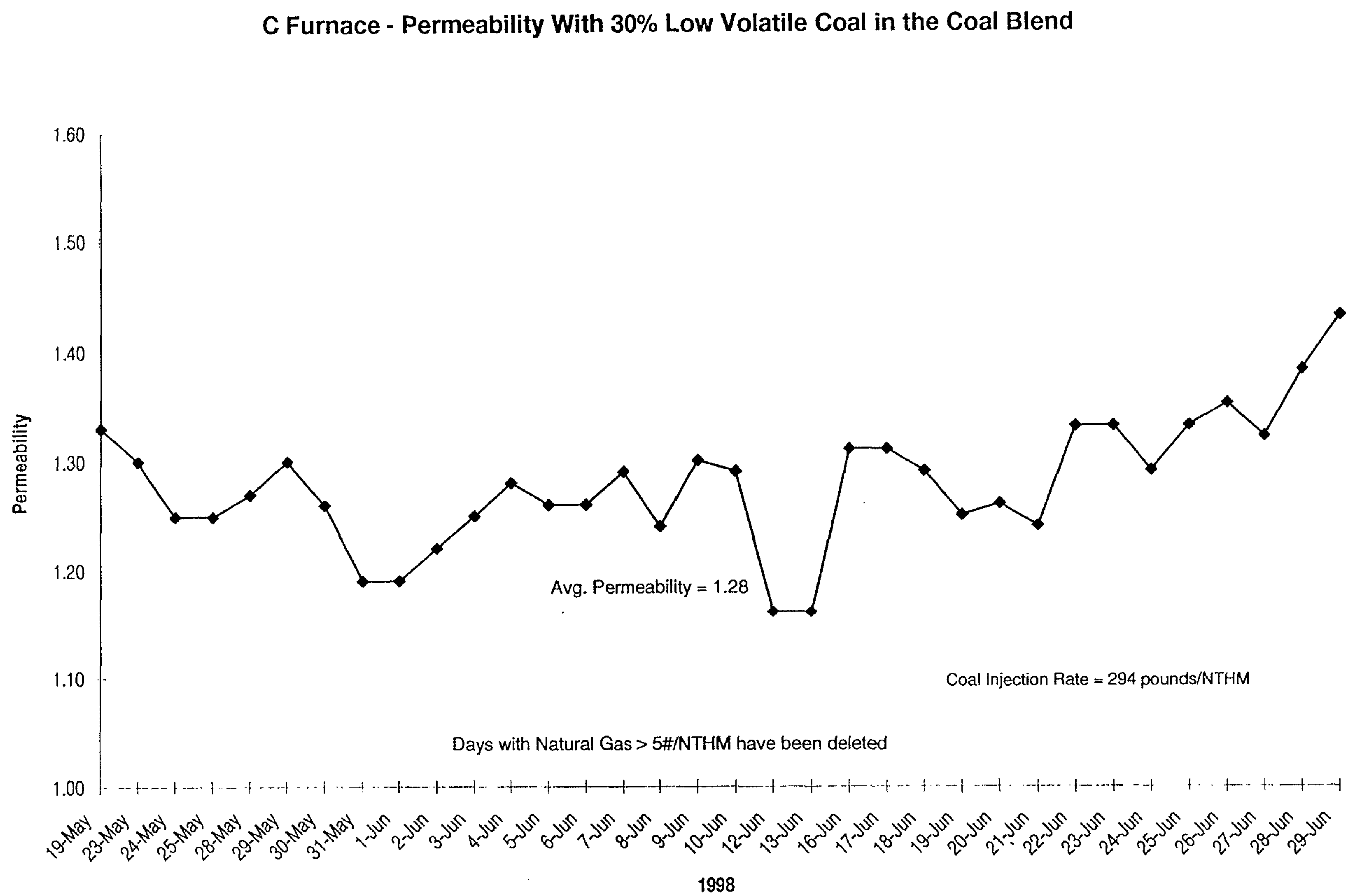

C Furnace - Permeability With 30% Low Volatile Coal in the Coal Blend
Permeability
1.60
1.50
1.40
1.30
1.20
1.10
1.00
Avg. Permeability = 1.28
Coal Injection Rate = 294 pounds/NTHM
Days with Natural Gas > 5#/NTHM have been deleted
19-May
23-May
24-May
25-May
28-May
29-May
30-May
31-May
1-Jun
2-Jun
3-Jun
4-Jun
5-Jun
6-Jun
7-Jun
8-Jun
9-Jun
10-Jun
12-Jun
13-Jun
16-Jun
17-Jun
18-Jun
19-Jun
20-Jun
21-Jun
22-Jun
23-Jun
24-Jun
25-Jun
26-Jun
27-Jun
28-Jun
29-Jun
1998

FIGURE 5

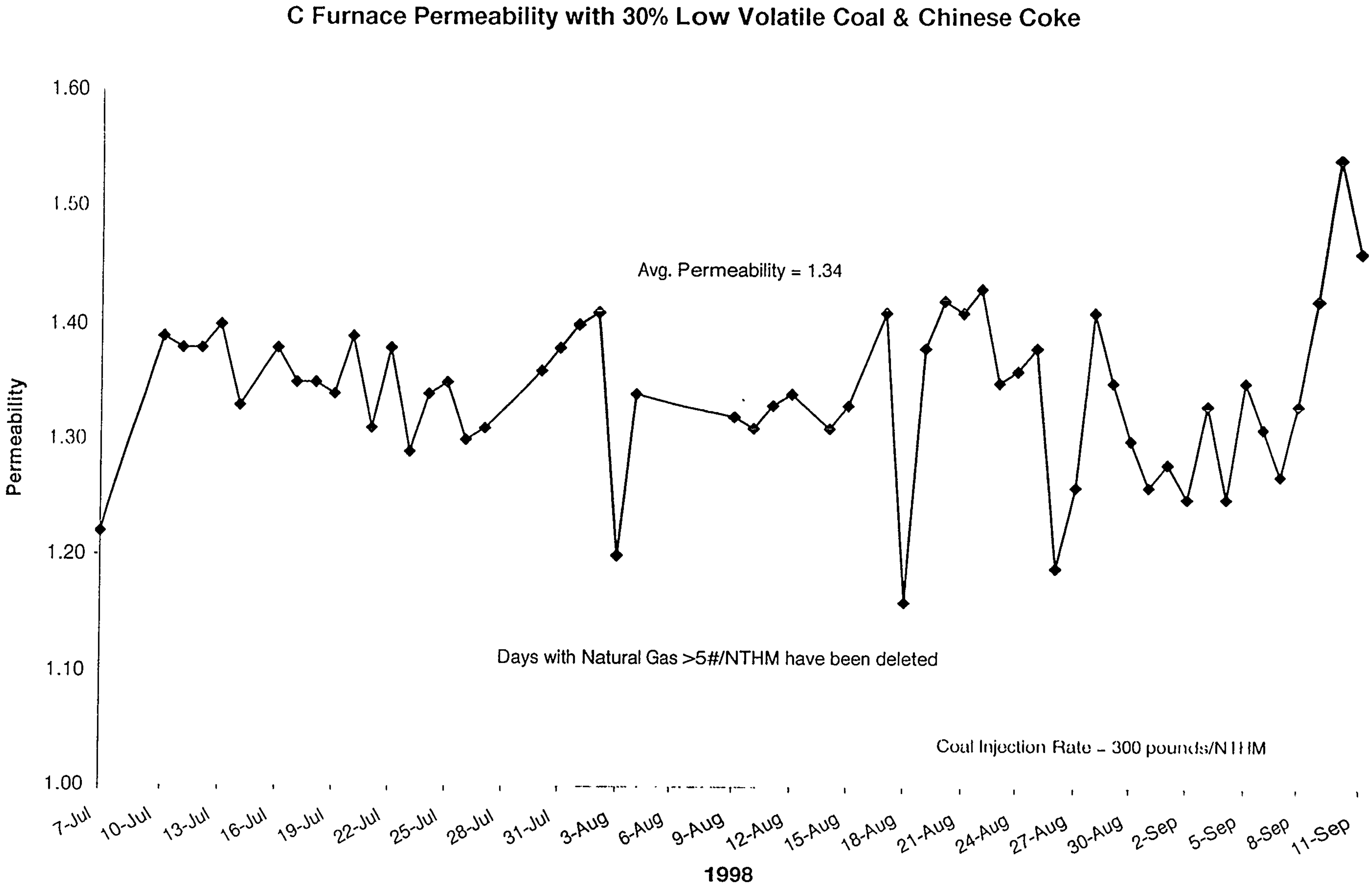
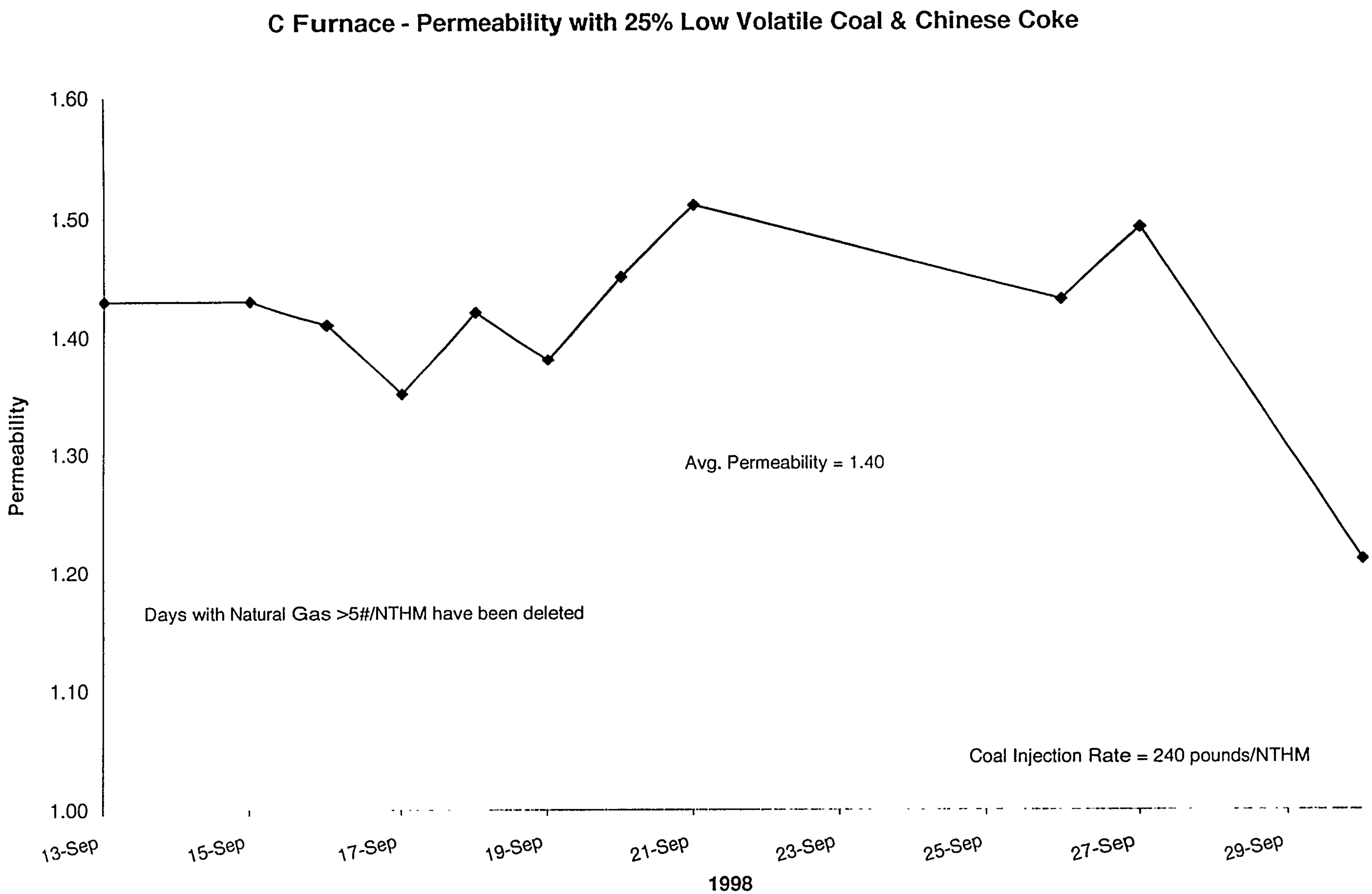

C Furnace Permeability with 30% Low Volatile Coal & Chinese Coke
Permeability
1.60
1.50
1.40
1.30
1.20
1.10
1.00
Avg. Permeability = 1.34
Days with Natural Gas >5#/NTHM have been deleted
Coal Injection Rate - 300 pounds/NTHM
7-Jul
10-Jul
13-Jul
16-Jul
19-Jul
22-Jul
25-Jul
28-Jul
31-Jul
3-Aug
6-Aug
9-Aug
12-Aug
15-Aug
18-Aug
21-Aug
24-Aug
27-Aug
30-Aug
2-Sep
5-Sep
8-Sep
11-Sep
1998

FIGURE 6


C Furnace - Permeability with 25% Low Volatile Coal & Chinese Coke
Permeability
1.60
1.50
1.40
1.30
1.20
1.10
1.00
Avg. Permeability = 1.40
Days with Natural Gas >5#/NTHM have been deleted
Coal Injection Rate = 240 pounds/NTHM
13-Sep
15-Sep
17-Sep
19-Sep
21-Sep
23-Sep
25-Sep
27-Sep
29-Sep
1998