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COKEMAKING WITH PREHEATED CANADIAN COALS

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by

J.F. Gransden*, J.T. Price** and W.R. Leeder***

ABSTRACT

Three western Canadian medium-volatile coals, an eastern Canadian high-volatile coal and two blends of these coals were coked in the Koppers oven under three different conditions :-

1. Wet charge, coal contained 5-6% moisture

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2. Air-dry charge, coal contained 1-2% moisture

3. Preheated charge, coal heated to 180-210°C.

Preheating increased productivity by 23-30% compared to wet charging and by 7-17% compared to air-dry charging. The coal bulk denisty in the oven was higher and the coke stronger for preheated charges than for wet charges for all coals and blends. However, although preheated and air-dry charges had similar oven coal bulk densities, preheating decreased the coke strength of the three medium-volatile coal but increased the strength of the high volatile coal and the blends compared to air-dry charging. Further tests on two coals using different coking rates and charges that were cooled after preheating were carried out in an attempt to explain these differences. It was concluded that differences in the temperature history of the coal in the oven, as found by others, must be largly responsible, but in addition the method of preheating was found to produce a detrimental change in the properties of the medium volatile coal.

The improvements in coke strength and productivity observed for the blends of Canadian coal suggest that preheating may be a suitable technology for the proposed merchant coke oven battery in Eastern Canada which presumably would use a high percentage of Eastern Canadian high-volatile coal.

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INTRODUCTION

Blends of coals charged to coke ovens usually have moisture contents in the range 5 to 12%. The term "preheating of coal." refers to the drying and heating of the coal to 150-300°C before charging. Commercial application of preheating steadily increased during the 1970's and is now an established technology.

The coal is dried and preheated by entrainment in hot inert gas (or by fluid-bed/entrainment as developed by Cerchar) and stored in insulated bunkers. It is charged to the ovens by one of three methods, a suitably designed larry car, Redler conveyor, or pipeline which uses superheated steam as the carrier medium (1).

Some advantages of preheating are (1,2):-

Increased productivity: coking times are reduced and oven coal bulk densities are usually higher leading to productivity increases of 30-50%.

Increased coke strength:- higher coal bulk densities and a thermal "preheating effect" (see discussion) result in higher coke strengths. Coke from preheated coal usually has a narrower size distribution and more uniform porosity.

Wider coal range:- since preheating increases coke strength larger amounts of inferior grade coal can be used to produce coke of acceptable strength.

Increased refractory life:- refractories are subjected to less thermal shock

Reduced energy requirement:- thermal efficiency of preheaters for drying and heating is better than coke ovens and an overall energy reduction is claimed.

Emission control:- charging emissions are reduced (mechanical levelling of the charge is eliminated) and pollution during oven pushing is decreased because the charge is more evenly carbonized.

This laboratory has carried out investigations into preheating over the last 20 years, mainly on coals from the U.S.A. which are used to produce coke in Canada. This report describes recent work carried out on three western Canadian medium-volatile coals an eastern Canadian high-volatile coal, and two blends of these coals.

EXPERIMENTAL PROCEDURE

The coals used in the first part of the work reported here were from the same batch of coals coked in previous work and reported in "Cokemaking with commercial Canadian coking coals", and are therefore identified by the same letters A, B, C and E(3). Different samples of coals A and E were used in the second part of the work and are designated A1 and E1. Coal analyses appear in Appendix A.

In the first part coals were carbonized under three different conditions:-

- Wet charge: coal contained 5.6-6.4% moisture, so the coal bulk density in the oven was low, 41.5-44.9 lb/cu ft (dry basis).
- 2. Air-dry charge: coal was air dried and contained 1.1-2.0% moisture, so that coal bulk density in the oven was high 50.2-56.9 lb/cu ft.
- 3. Preheated charge: coal was preheated to 180-210°C and coal bulk densities were 50.8-56.9 lb/cu ft.

Coal was preheated in the charging hopper. The hopper was placed in a gas drying oven controlled at 230°C for periods up to 90 hours. The hopper top was covered and sealed with clay and nitrogen was passed into the centre of the hopper at a flowrate of one litre per minute. The nitrogen first flowed through a five gallon can of coal also situated within the oven in order to remove oxygen that might react with the coal.

In the second part of the work reported here coals A1 and E1 were carbonized at different flue temperatures and coal that had been preheated was allowed to cool in the hopper under nitrogen before charging.

RESULTS

The coking test results appear in Appendix B. Air-dry (high coal bulk density) charges of the three medium-volatile western Cabadian coals A, B and C produced stronger coke than the wet charges (low coal bulk density). This is illustrated in Figure 1 where the coke stability factors are plotted against the coal bulk density in the oven. The slope of these lines are close to one so an increase of one pound per cubic foot in bulk density produces an average increase of one point in the stability factor. Actual averaged values are given in Table 1. The increase was much smaller for the eas-

tern Canadian coal, E, (slope 0.28) and for the blend containing 75% E and 25% C (slope 0.17). The line for the blend containing 75% E and 25% A has a slope of 0.5.

Table 1 - Averaged stability factors for wet, air-dry and preheated charges

Coal	s * w	s _d	S p	$\frac{S_d - S_w}{BD_{\overline{d}}BD_w}$	ΔS = S _p - S _d
Α	44.3	57.4	47.5	0.93	-9.9
В	41.9	58.4	50.3	1.11	-8.1
С	41.1	55.3	51.2	1.19	-4.1
Е	41.2	43.9	51.8	0.28	7.9
75% E-25% A	48.6	54.7	57.6	0.50	2.9
75% E-25% C	43.5	45.4	53.0	0.16	7.6

 ${}^{*}S_{_W},\ S_d$ and S_p are average stability factors for wet, air-dry and preheated charges respectively

******BD and BD are coal bulk densities for wet and air-dry charges

Preheated charges of a coal or coal blend always had a higher coke stability factor than wet charges. However it seems more appropriate to compare cokes made at similar coal bulk densities. Figure 1 shows that the bulk density of air-dry charges were very similar to those of preheated charges. In general they were slightly higher for the single coals but slightly lower for the blends. Differences in the coke stability factors between prehated and air-dry charges, ΔS in Table 1, is therefore attributed solely to preheating and not to bulk density effects. The values of ΔS show that preheating was detrimental to all three western Canadian mediumvolatile coals but advantageous to the eastern Canadian high-volatile coal and both blends. Coal A suffered the largest decrease in the coke stability factor from preheating, $\Delta S = -9.9$ and coal E had the largest gain, $\Delta S = 7.9$.

Figure 2 shows that the coke hardness factors increased with coal bulk density for all coals and blends but the factors for preheated charges were always lower than air-dry charges by 0.3-4.0 points. The mean coke sizes of the preheated medium-volatile coals were unchanged or lower than those for air-dry charges, but were significantly higher for coal E and the blends. The maximum coking pressures of preheated charges were similar to the air-dry charges.

Coking times for preheated charges were shorter than those for air-dry charges but similar to those for wet charges. The advantages of preheating are best illustrated by comparing changes in oven productivity,

$$P = \frac{W}{T}$$

where W is the weight of the charge (dry basis) and T is the gross coking time (time for the coal charge to reach 1010°C at its centre plus 30 minutes). Productivities are given in Table 2 and have been averaged for duplicate tests.

Coal	Produc	tivity, 1	os coal/min	% Productivity increase compared to wet charge			
	wet	air-dry	preheated	air-dry	preheated		
A	0.604	0.695	0.773	15.0	27.9		
В	0.610	0.715	0.765	17.2	25.4		
С	0.650	0.702	0.804	8.0	23.6		
Е	0.679	0.742	0.865	9.2	27.3		
E-25% A	0.658	0.748	0.833	13.6	26.5		
E-25% C	0.672	0.722	0.877	7.4	30.5		

Table 2 - Oven productivity

The percentage change in productivity, also shown in Table 2 has been calculated from

$$\frac{100 (P_d - 1) \text{ or } 100 (P_p - 1)}{\frac{P_w}{P_w}}$$

where P_w , P_d and P_p are the productivities for the wet, air-dry and preheated charges respectively. Charging coal air-dried increased productivity by between 7 and 17% while preheating increased it by 23-30% compared to wet charging.

DISCUSSION

There appears to be a relationship between coal rank as expressed by the mean maximum reflectance, Ro in Table 3, and ΔS the difference in stability factor between preheated and air-dried charges. However Figure 3a further suggests there may be one relationship for the three medium-volatile coals and another for coal E and the blends whose major constituents are coal E. Figures 3b and 3c show further apparent relationships between ΔS and total Ruhr dilatation and between ΔS and the natural logarithm of the maximum Gieseler fluidity.

Table 3 - Mean maximum reflectance Ro, total Ruhr dilatation c+d and maximum Gieseler fluidity of coal and coal blends

Coal	Δs .	Ro	c+d	Fluidity
		ą,	%	dial divisions/min
A	-9.9	1.38	39	20
В	-8.1	1.27	40	79
С	-4.1	1.06	72	435
Ε	7.9	0.99	226	27800
75% E-25% A	2.9	1.09	136	2100
75% E-25% C	7.6	1.01	153	1725

Despite these apparent relationships it is unclear exactly what causes the differences in strength between dry and preheated charges. It has been established that the temperature history of a preheated charge is considerably different from a non-preheated charge. The rate of temperature rise in the plastic zone is lower and the temperature gradient in the semicoke is reduced (4,5). The former may influence the rheological behaviour

of the plastic coal and the latter reduce contraction stresses in the semicoke. It has been found that coke made from preheated coal has a smaller pore-size distribution (6).

Methods of predicting coke strength from rank and coking properties of a coal or blend suggest that maximum strength is obtained when the maximum Gieseler fluidity is 200-1000 dial divisions per minute or the total dilatation is 50-150% (7,8). Now the high-volatile coal E has very high fluidity and dilatation, Table 3, so methods of reducing the values of these properties would be expected to increase its coke strength. One method is to add inert material to the coal, for example coke breeze or char, and the present authors have shown that additions of petroleum coke do substantially increase the strength of 500-1b oven coke made from this coal (9). Another method involves partially oxidizing the coal. Ignasiak et al have shown, on a small scale, that partially oxidizing coals that have high Gieseler fluidities improves their coke strength and they have suggested that it is oxidation during the preheating process that is responsible for the high coke strength of this type of coal when preheated (10). (Kim and Aukrust have observed the charring or coking of very fine coal particles in a commercial preheater and have shown that it increases with gas temperature (11)). Finally it can be argued that as the rate of heating in the plastic layer is smaller for preheated coal its fluid properties are lowered. (Lower rates of heating are known to reduce the numbers obtained from the Gieseler plastometer and the Ruhr dilatometer). Expressed differently the laboratorymeasured ranges of fluidity and total dilatation required for maximum coke strength of wet charges must be moved upwards for preheated coals.

Tests at different coking rates and preheated/cooled charges

Of the western Canadian coals only coal C has a fluidity in the range required for maximum coke strength. The valves for coals A and B are below this range so small amounts of oxidation during preheating or decreases in the fluid behaviour of the coal in the plastic range may be expected to decrease coke strength.

To investigate these possibilities further carbonization tests were carried out on coals A and E. New batches of these coals were used and to denote this they are coded A1 and E1. Each coal was charged dry and carbonized once at a high oven flue temperature (high coking rate) and once at a

low oven flue temperature (low coking rate). Each coal was also preheated and carbonized at a intermediate flue temperature. The coke stability indices, Table 4, are plotted against the oven flue temperature in Figure 4 and against the time required to reach 900°C at the

Coal	Treatment	Flue temperature	Stability factor
A1	air-dry	low	61.0
A1	air-dry	high	54.7
A1	preheated	medium	53.0
A1	preheated-		
	cooled	medium	50.1
A1	preheated-		
	cooled	medium	54.2
E1	air-dry	low	34.6
E1	air-dry	high	34.3
E1	preheated	medium	43.6
E1	preheated-		
	cooled	medium	33.1
E1	preheated-		
	cooled	medium	35.9

Table 4 - Stability factors for coals A1 and E1

centre of the charge (coking rate) in Figure 5. For coal E1 it is seen that the stability index of the coke at the high and low oven flue temperatures (high and low coking rates) is similar, 34.3 and 34.6 respectively, but the preheated charge coked at the intermediate flue temperature (Figure 4) and a coking rate similar to the dry charge at high flue temperature (Figure 5) produced a coke with an index of 43.6. The two other data points in these figures are the indices for charges that were heated and then cooled to room temperature before charging to the oven and coked at the intermediate flue temperture. The coke stability indices 33.1 and 35.9 are similar to the dry charges and significantly different from the preheated charge. The coke

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sieve analysis and hardness indices have values intermediate between the two dry charges. These tests strongly suggest that the improvement in coke strength obtained for a preheated charge is not due to any oxidation that takes place during preheating. Otherwise the heated and cooled charges would be expected to have stability indices closer to that for the preheated charge. In addition the coal rheological properties for fresh, preheated and heated cooled charges, Table 5, show no significant differences.

Oven Test No.	Coal	Sample	Gieseler maximum fluidity	Ruhr total dilatation c+d	FSI
390,391	A1	fresh	7.5	9	6 1/2
394	A1	fresh	5.8	2	6 1/2
394	A1	preheated	7.7	4	6 1/2
397	A1	fresh	5.6	7	6 1/2
397	A1	preheated	5.5	0	6
397	A1	cooled	1.7	0	4
392,393	E1	fresh	13,940	208	8 .
398	E1	fresh	28,000	235	8
398	E1	preheated	19.170	207	8
400	E1	fresh	24,900	221	8
400	E1	preheated	13,840	213	7 1/2
400	E1	cooled	27,300	204	· 8

Table 5 - Rheological properties of charges of coals A1 and E1

These results suggest the reason for the improved coke strength of preheated charges of coal E must be due to the manner in which coking proceeds in the oven i.e., the temperature history of the coal charge. It is interesting to note that the mean coke size and coke sieve analysis of the preheated charge coked at the intermediate flue temperature was similar to the dry charge coked at the high flue temperature. Figure 5 shows that the coking rates for the two charges were also similar and yet the coke stabil-

ity factors significantly different.

The coke stability factor of coal A1 increased from 54.7 at the fast coking rate (high flue temperature) to 61.0 at the slow coking rate (low flue temperature), Figure 4. The coke stability factor of the preheated charge coked at the intermediate flue temperature was 53.0. Now the coking rate for this preheated charge was similar to that for the dry-charge coked fast, and the stability factors 53.0 and 54.7 respectively and coke sieve analysis (Appendix B) are also similar. This single result suggests that the apparent deterioration of coke quality observed for preheated western Canadian coals A, B and C may be attributed, at least in part, to the faster rate at which they were coked. However coking rate is just one manifestation of the charge-temperature history, other aspects of which may be more important, e.g., plastic layer thickness.

Charges that were preheated then cooled before coking at the intermediate flue temperature indicate a further reason for the deterioration. They produced coke with stability indices 3.5-7 points lower than would be expected (see Figure 5). This suggests that oxidation or a chemical change detrimental to coking has taken place while the coal was hot. This view is supported somewhat by the coal rheological properties reported in Table 5 which in general are lower for the preheated and preheated-cooled charges.

CONCLUSION

Preheating increased coke strength and oven productivity compared to conventional charging with 5-6% moisture for all coals and blends tested. The increase in strength can be partly explained by the higher bulk density of coal in the oven. However preheated and air-dry charges had similar bulk densities but produced different coke strengths. This was attributed to differences in the temperature history of the charge, as determined by others, and in the case of one of the medium-volatile coals to deterioration of coal properties during preheating.

The improvements in coke strength and productivity observed for the blends of Canadian coal suggest that preheating may be a suitable technology for the proposed merchant coke oven battery in Eastern Canada which presumably would use a high percentage of Eastern Canadian high-volatile coal.

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Identification					
Laboratory Number		3049-77	3335-77	2090-78	3335-77
Coal		Α	В	С	Е
<u>Classification</u>					
Rank (ASTM)		mvb	mvb	mvb	hvAb
International system		433	433	533	635
Specific volatile index		195	190	182	172
Carbon (dmmfb)	%	90.7	90.4	93.9	86.3
Proximate Analysis (db)					
Ash	%	9.8	8.4	9.5	4.1
Volatile matter	%	21.8	23.5	25.5	33.9
Fixed carbon	%	68.4	68.1	65.0	62.0
Gross Calorific Value (db)					
Btu per pound		13,975	14,175	13,885	14,730
MJ/kg		32.5	33.0	32.3	34.2
<u>Ultimate Analysis (db)</u>					
Carbon	%	80.9	82.0	84.1	82.3
Hydrogen	%	4.4	4.4	4.7	5.4
Sulphur	%	0.32	0.39	0.30	1.25
Nitrogen	%	1.3	1.4	1.0	1.7
Ash	%	9.8	8.4	9.5	4.1
Oxygen (by difference)	%	3.3	3.4	0.4	5.2
<u>Ash Analysis (db)</u>					
Si0 ₂	%	65.1	57.3	52.0	36.9
Al ₂ 03	%	28.4	33.2	25.9	21.4
Fe ₂ 0 ₃	%	2.3	5.8	3.7	35.2
TiO2	%	1.7	1.8	1.5	0.9
^P 2 ⁰ 5	%	0.5	1.0	0.8	0.1
Ca0	%	1.1	1.4	6.1	1.8
MgO	%	0.6	0.5	1.5	1.4
so ₃	%	0.7	0.7	4.3	2.0
Na ₂ 0	%	0.1	0.1	1.4	0.5
к ₂₀	%	0.4	0.7	0.3	1.1

APPENDIX A - Coal Properties

Table A-1 - Chemical analyses of component.coals

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Identification					
Laboratory number		3049-77	3336-77	2090-77	3335-77
Coal		Α	В	С	Е
Gieseler Plasticity					
Start	۰C	438	430	417	390
Fusion temp.	۰C	455	446	429	403
Max. fluid temp.	°C	470	463	454	433
Final fluid temp.	°C	490	479	482	475
Solidification temp.	°C	493	484	486	477
Melting range	°C	52	49	65	85
Max. fluidity	dd/m	20	79	435	27,800
Torque	g.in.	40	40	40	40
Dilatation					
Ti - softening temp.	°C	397	392	377	349
Tii - max. contraction temp.	°C	454	442	427	406
Tiii - max. dilatation temp.	°C	485	472	461	449
Contraction	%	23	24	23	26
Dilatation	%	16	16	49	200
Free Swelling Index					
F.S.I.		7	7-1/2	5	8-1/2

APPENDIX A - (Cont'd)

Table A 2 - Thermal rheological properties of component coals

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Identification			2226 1217	2000 777	2225 88
		3049-77	5550-77	2090-77	5555-77
		A	В	U	E
Distribution of Vitrinite types	đ				
V-0	70 At				
V-7	76 71				
V-8	% a			li e	5.0
V-9	70 71		0 5	4.5	40.0
V-10	%		0.5	36.1	28.7
V-11	%		12.6	9.0	4.7
V-12	%	5.3	14.8	0.5	
V-13	%	27.0	24.7		
V-14	%	16.4	2.2		
V-15	%	4.3			
V-16	%				
V-17	%				
V-18	%				
Reactive components					
Total vitrinite	%	53.0	54.9	50.1	79.6
Reactive semi-fusinite	%	15.0	14.0	14.0	1.0
Exinite	%	0.0	0.3	0.1	5.3
Total	%	68.0	69.2	64.2	86.0
Inert components					
Inert semi-fusinite	%	15.1	14.0	14.0	2.3
Micrinite	%	3.4	2.1	7.5	3.2
Fusinite	%	8.0	10.0	9.0	6.0
Mineral matter	%	5.5	4.7	5.3	2.5
Total	%	32.0	30.8	35.8	14.0
Petrographic indices					
Mean reflectance	%	1.38	1.27	1.06	0.99
Balance index		2.78	1.93	1.53	0.41
Strength index		6.09	5.20	3.85	3.48
Stability index		54.5	56.0	46.0	37.6

APPENDIX A - (Cont'd)

Table A-3 - Petrographic analysis of component coals

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APPENDIX B - Carbonization Results

Test No.	306	315	316	309	318					
Description		COAL A					COAL B			
						Prehea	ted			Pre-
										heated
						188°C	193°C			207°C
Charge wt. (dry)		16	317.3	418.5	428.4	414.2	420.3	312.6	425.2	414.9
Moisture in char	ge	%	6.1	2.0	2.0	` -	-	6.4	1.8	-
ASTM bulk densit	y (w)	lb/ft ³	41.2	52.9	53.9	-	-	40.4	55.9	-
Oven bulk densit	y (d)	16/ft ³	42.0	55.5	56.8	54.9	55.7	41.5	56.4	55.0
Gross coking tim	ne	hr:m	8:45	9:55	10:23	8:41	9:19	8:32	9:54	9:02
Max wall pressur	e	p.s.i.	0.31	1.03	1.40	1.17	0.84	0.30	0.58	0.60
Coke yield		\$	74.8	77.5	77.5	75.3	76.1	78.2	77.8	77.7
Mean coke size		in	2,00	1.99	2.03	1,92	1.57	1.92	1,98	1.89
Coke a.s.g.			0.88	1.02	1.03	1.08	1.07	0.89	1.03	1.04
Coke Screen Ana	lysis									
	+3"		11.9	10.5	11.0	11.8	5.1	7.3	10.3	8.8
	+2"		48.8	43.1	44.6	43.0	31.4	44.1	41.9	40.9
	+1-1/2"		74.4	74.3	77.6	70.0	55.0	71.1	72.7	66.4
	+1"		87.5	91.9	93.0	84.8	73.6	86.0	92.7	86.4
	+3/4"		89.7	94.8	95.2	88.3	77.6	92,6	95.4	90.8
	+1/2"		90.5	95.5	95.9	89.0	79.1	93.4	96.2	92.3
Stability facto	 ,		44.3	57.2	57.6	48.1	46.9	41.9	58.4	50.3
Hardness factor			56.9	68.9	69.6	65.1	67.3	57.0	71.1	69.2
JIS DI ³⁰			87.6	93.7	94.2	90.1	91.2	90.7	93.8	92.1
150 JTS DT			72.3	83.2	83.9	77.4	79.1	75.6	84.3	80.3

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APPENDIX B - (Cont'd)

Test No.		326	322	324	323	325	338	334	336	335	337		
Description			COAL C C								COAL E		
•					Prehe	ated				Prehe	ated		
		to											
					182°C	198°C				185°C	204°C		
Charge wt. (dry)	lb	338.5	427.1	429.3	425.9	428.9	313.1	390.3	378.3	386.5	383.2		
Moisture in charge	¥.	5.6	1.1	1.2	-	-	5.7	1.8	2.0	_	_		
ASTM bulk density (w)	lb/ft ³	41.3	55.6	55.6	-	-	40.5	49.8	49.8	·	-		
Oven bulk density (d)	1b/ft ³	44.9	56.6	56.9	56.5	56.9	41.5	51.8	50.2	51.3	50.8		
Gross coking time	hr:m	8:40	10:13	10:06	9:05	8:38	7:41	8:38	8:38	7:29	7:20		
Max wall pressure	p.s.i.	-	0.73	0.90	0.90	0.73	0.15	0.72	0.60	0.50	0.50		
Coke yield	%	75.2	75.7	75.8	75.0	75.2	68.2	67.5	67.5	68.8	68.2		
Mean coke size	in	2.18	2.25	2.15	2.23	2.16	1.87	1.86	1.89	1.97	2.01		
Coke a.s.g.		0.88	1.04	1.05	1.05	1.04	0.78	0.87	0.83	0.87	0.87		
Coke Screen Analysis .			·····					·····					
+3"		16.1	18.9	15.5	22.2	17.3	2.2	3.0	2.6	7.8	8.6		
+2"		54.2	56.9	51.9	53.8	50.5	38.0	35.4	38.2	41.3	43.5		
+1-1/2"		81.9	81.4	77.3	76.6	78.2	73.1	73.3	74.5	75.1	76.0		
+1"		92.0	94.2	92.5	91.1	91.5	91.6	92.1	92.9	93.3	93.9		
+3/4"		94.2	96.4	95.9	94.1	94.7	95.1	95.5	96.3	96.8	96.5		
+1/2"		95.1	97.3	96.9	95.1	96.0	96.4	96.8	97.1	97.3	97.4		
Stability factor		41.1	55.6	54.9	52.9	49.5	41.2	43.4	44.3	50.7	52.9		
Hardness factor		55.0	70.1	70.3	69,8	67.5	58.0	66.8	65.4	66.7	66.4		
JIS DI ³⁰ 15		90.2	93.8	93.7	93.5	92.3	91.2	91.2	91.9	93,1	93.2		
JIS DI ¹⁵⁰ 15		73.6	82.2	82.4	82.7	80.9	77.9	78.4	79.6	81.8	81.9		

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APPENDIX B = (Cont'd)

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Test No.		326	322	324	323	338	334	336	335	
Description			25% A	- 75% E		25% C - 75% E				
					Pre-			Prehea	at	
					heat					
					196°C			207°C	199°C	
Charge wt. (dry)	1b	321.6	414.7	413.3	419.4	318.7	403.0	414.7	416.5	
Moisture in charge	x	5.7	1.5	1.4	-	6.2	1.1	-	-	
ASTM bulk density (w)	16/ft ³	39.9	54.1	54.1	-	41.5	53.0	-	-	
Oven bulk density (d)	1b/ft ³	42.7	55.0	54.8	55.6	42.3	53.5	55.0	55.2	
Gross coking time	hr:m	8:08	9:24	9:03	8:23	7:54	9:18	7:43	8:04	
Max wall pressure	p.s.i.	0:60	0.70	0.93	0.73	-	0.61	0.65	0.73	
Coke yield	\$	71.9	71.7	71.3	71.1	70.1	70.3	70.0	69.9	
Mean coke size	in	1.99	1.93	1.91	2.05	2.05	1.92	2.05	2.05	
Coke a.s.g.		0.79	0.93	0.94	0.94	0.81	0.93	0.93	0,92	
Coke Screen Analysis								<u>.</u>	·····	
+3"		6.3	5.8	5.0	10.9	8.6	5.8	11.8	11.0	
+2"		45.0	40.1	39.1	47.3	50.7	38.7	46.3	47.3	
+1-1/2"		77.4	74.0	74.0	77.0	78.4	72.4	75.2	75.9	
+1"		92.4	92.4	92.3	93.2	92.4	92.5	93.1	93.4	
+3/4"		95.0	95.2	95.3	95.9	94.7	95.9	95.9	96.2	
+1/2"		96.1	96.4	96.3	97.0	95.9	97.2	97.0	97.2	
Stability factor		48.6	54.4	55.0	57.6	43.5	45.4	52.3	53.6	
Hardness factor		68.8	69.9	70.3	69.3	58.1	70.8	68.6	68.7	
JIS DI ³⁰		93.1	93.3	93.9	94.3	91.5	91.6	93.2	93.1	
JIS DI ¹⁵⁰		80.7	82.7	83.2	84.1	76.9	78.7	80.7	81.5	

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APPENDIX	в –	(Cont	'd)
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Test No.	· .	390	391	394	397	408	392	393	398	400	409
Description		•	COAL A1 COAL E1								
				Pre-	Pre-	Pre-			Pre-	Pre-	Pre-
				heat	heat	heat			heat	heat	heat
					cooled	cooled				cooled	cooled
Charge wt. (dry)	1b	424.8	428.3	422,4	428.1	429.9	416.2	412.9	409.5	406.6	411.5
Moisture in charge	%	1.7	1.7	-	-	-	1.2	1.1	-	-	-
ASTM bulk density (w)	lb/ft ³	55.0	55.7	-	-	-	53.7	52.9	-	-	-
Oven bulk density (d)	1b/ft ³	56.3	56.8	56.0	56.8	57.0	55.2	54.6	54.3	53.9	54.6
Flue temperature	°C	1027	1171	1082	1084	1074	1175	1030	1076	1076	1079
Coking time to 900°C	hr:m	10:02	8:02	8:21	9:05	9:00	7:18	9:07	7:17	8:25	8:38
Gross coking time	hr:m	11:48	8:40	9:05	10:02	10:04	7:38	10:05	8:00	9:06	9:21
Max wall pressure	p.s.i.	1.77	2.52	1.93	1.33	2.37	0.40	-	0.62	0.50	0.63
Coke yield	a.c.	76.9	78.0	77.0	78.1	78.2	66,8	66.4	66.6	66.3	67.5
Mean coke size	in	2,22	1.89	1.90	1.95	2.07	1.81	1.96	2.01	1,86	1.85
Coke a.s.g.		1.09	1.04	1.04	1.08	0.94	0.91	0.91	0.91	0.93	0.90
Coke Screen Analysis											
+3"		15.8	6.6	9.6	11.0	17.0	3.3	9.1	9.1	4.4	3.6
+2"		55.2	38.9	37.2	41.4	44.4	33.7	43.2	43.7	37.2	36.7
+1-1/2"		81.7	68.3	67.4	68.5	71.6	68.2	72.4	75.9	70.1	68.1
+1"		94.0	90.4	88.3	90.0	91.6	89.5	90.7	92.7	90.2	91.8
+3/4"		96.4	95.4	93.2	93.6	94.6	95.1	94.7	95.5	94.9	95.9
+1/2"		97.2	96.7	94.7	94.7	95.5	96.5	96.6	96.9	96.5	96.7
Stability factor		61.0	54.7	53.0	50,1	54.2	34.3	34.6	43.6	33.1	35.9
llardness factor		73.3	73.2	71.8	67.7	70.1	64.6	67.9	66.2	66.7	67.8
JIS DI ³⁰		94.1	93.7	93.0	90.9	93.5	89.5	89.0	92.1	88.6	90:4
JIS DI ¹⁵⁰ 15		84.3	83:5	82,4	78.7	82.7	69.5	71.2	79.7	71.3	76.8



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Figure 1. Relationship between ASTM stability factor and coal bulk density in the oven for wet, air-dry and preheated charges.



Figure 2. Relationship between ASTM hardness factor and coal bulk density in the oven for wet, air-dry and preheated charges.



Figure 3. Relationship between ∆S, the difference in the ASTM stability factor between preheated and air-dry charges and (a) the mean maximum reflectance, Ro, (b) total Ruhr dilatation c+d, and (c) the natural logarithm of the maximum Gieseler fluidity.

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Figure 4. Relationship between the ASTM stability factor and the oven flue temperature for coal Al and El.

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Figure 5. Relationship between the ASTM stability factor and the time required for the centre of the charge to reach $900^{\circ}C$ (coking rate) for coals Al and El.

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