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INFLUENCE OF FLUE TEMPERATURE AND COAL PREPARATION ON COKE QUALITY IN 460-mm TECHNICAL-SCALE COKE OVEN

J.F. GRANSDEN AND W.R. LEEDER

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INFLUENCE OF FLUE TEMPERATURE AND COAL PREPARATION ON COKE QUALITY IN 460-mm TECHNICAL-SCALE COKE OVEN

by

J.F. Gransden* and W.R. Leeder**

ABSTRACT

A 460-mm technical-scale coke oven operated by the Coal Resource and Processing Laboratory (CRPL) of CANMET was recently rebuilt. The silicon carbide heating walls were replaced by silica brick walls of the type used in industry to more closely approximate the heat transfer characteristics of commercial ovens.

The effect of oven flue temperature, coal moisture and pulverization level on oven operating characteristics and coke quality was determined for a typical industrial coal blend used for making blast furnace coke. Coke strength was found to increase as the coal bulk density in the oven increased and was higher for the more finely ground coal. Coke-size distribution was influenced mainly by flue temperature, narrowing as the temperature was raised.

From results of the test program the following standard oven operating conditions were selected: flue temperature - 1125°C; coal moisture - 6%; coal size - 80% minus 3.25 mm.

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L'INFLUENCE DE LA TEMPERATURE DU CARNEAU ET LA PREPARATION DU CHARBON SUR LA QUALITE DU COKE DANS UN FOUR A COKE D'ENVERGURE TECHNIQUE DE 460 MM

par

J.F. Gransden* et W.R. Leeder**

RESUME

Un four d'envergure technique de 460 mm en opération au Laboratoire des ressources et du traitement du charbon (LRTC) du CANMET a été reconstruit récemment. Les parois de chaleur en carbure de silicium ont été remplacés par des parois en briques de silice pour ressembler à ce qu'emploie l'industrie afin de déterminer plus précisément les caractéristiques d'échange de chaleur des fours commerciaux.

L'effet de la température du carneau du four, de la teneur d'eau du charbon et du degré de pulvérisation sur les caractéristiques de fonctionnement du four et sur la qualité du coke a été déterminé pour un mélange industriel de charbon marchand habituellement employé pour la fabrication du coke dans le haut-fourneau. On s'est aperçu que la résistance du charbon augmentait en fonction de l'augmentation de la densité du charbon en vrac dans le fourneau et était plus élevée pour le charbon broyé plus fin. La distribution granulométrique du coke est influencée principalement par la température du carneau; elle diminue lorsque la température diminue.

On a choisi les conditions normalisées de fonctionnement du fourneau à partir des résultats du programme d'essai: température du carneau, 1125°C; teneur d'humidité du charbon, 6%; granulométrie du charbon, 80% à moins 3.25 mm.

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INTRODUCTION

The Energy Research Laboratories (ERL) of CANMET operate four technical-scale slot-type coke ovens (1). These are the only ovens of this size in Canada and are relied upon by Canadian mining companies, commercial coke makers and government agencies for evaluating coking coals. Testing at this scale is necessary to fully evaluate coking properties. The ovens are therefore essential in evaluating coking coal resources, in choosing blends of coals for industrial use and in carbonization research and development.

The largest oven has a movable wall, a 460-mm wide coking chamber, similar to commercial ovens, and a charge capacity of 325 kg. This oven was recently rebuilt, and design improvements were made. The main modification was replacing the silicon carbide bricks of the heating walls with silica bricks similar to those in industrial ovens. The test oven now duplicates more closely the heat transfer characteristics of industrial ovens and should better simulate commercial cokemaking.

The test program reported here determined the oven's operating characteristics. This information was used to choose standard oven operating conditions simulating industrial cokemaking practice as closely as possible. Most oven tests are carried out at standard conditions so the quality of cokes produced from different coal blends are comparable.

A typical industrial coal blend for producing blast furnace coke was used in the test program. The results demonstrated the effect of operating variables on the quality of coke produced. They will also help determine non-standard operating conditions for research programs and to gauge the sensitivity of coke quality parameters to deviations from standard conditions.

OVEN OPERATION

The walls of the oven are heated electrically by twelve silicon carbide resistance elements contained in heating chambers. A constant temperature during coking is maintained by four temperature controllers each of which controls three resistance elements. Industrial ovens are heated by gas burning in flues, and by analogy the heating chamber temperature of the technical-scale oven is referred to as flue temperature.

The coal blend used in the test program was supplied by a member company of the Canadian Carbonization Research Association (CCRA), which sponsored the program. It consisted of three component coals identified as A, B and C for which chemical analyses are given in Table 1. The blend was composed of 25% A, 37.5% B, and 37.5% C. The thermal rheological properties of the component coals and of the blend are shown in Table 2.

In practice the crushed and weighed coal blend is charged at a predetermined moisture content into the top of the oven. The charge is levelled in the oven by raking out excess coal through the levelling door. The bulk density is calculated from the amount of blend charged and removed during levelling, and the volume of the oven. The coke is discharged from the oven by an electrically operated pusher. Current practice is to push the coke out half an hour after the temperature at the centre of the charge has reached 1000°C. The coke is immediately quenched with water in a quench box and dropped 3 m to a concrete floor to simulate coke handling in a commercial operation. It is then oven dried and screened.

EFFECT OF CARBONIZATION VARIABLES ON OVEN OPERATION

The carbonization variables investigated were coal moisture content, degree of pulverization and flue temperature. Oven charges were carbonized at three moisture levels, nominally 3, 5 and 7%, at two levels of coal pulverization, 75 and 90% passing a 3.35-mm sieve as seen in Table 3, and three different flue temperatures, 1025, 1075, and 1150°C. These three independent variables are usually considered in terms of two further variables - coking rate and coal bulk density calculated on a dry basis. Coking rate,

Table 1 - Chemical analyses of component coals

Identification			
Laboratory Number	2478-77	2479-77	2480-77
Description	J-6401 Component Coal A	J-6402 Component Coal B	J-6403 Component Coal C
Classification			
Rank (ASTM)	lvb	hvAb	mvb
International System	334	635	535
Specific Volatile Index	219	175	184
Carbon (dmmfb) %	91.0	87.1	88.3
Proximate Analysis (db)			
Ash %	6.2	5.1	6.8
Volatile Matter %	17.5	32.1	28.7
Fixed Carbon %	76.3	62.8	64.5
Gross Calorific Value (db)			
Btu per pound	14735	14625	14500
Ultimate Analysis (db)			
Carbon %	84.7	82.2	81.7
Hydrogen %	4.5	5.3	5.1
Sulphur %	0.82	0.79	0.80
Nitrogen %	1.2	1.6	1.6
Ash %	6.2	5.1	6.8
Oxygen (by difference) %	2.6	5.0	4.0
Ash Analysis (db)			
SiO_2 %	50.0	52.7	49.0
Al_2O_3 %	30.1	28.4	29.1
Fe_2O_3 %	11.5	10.0	9.7
TiO_2 %	2.1	1.5	1.5
P_2O_5 %	0.1	0.1	0.2
CaO %	1.8	1.9	2.2
MgO %	0.4	0.9	1.2
SO_3 %	1.9	1.8	2.4
Na_2O %	0.5	0.5	0.6
K_2O %	1.2	1.5	2.4

Table 2 - Thermal rheological properties of component coals and blend

Identification				
Laboratory Number	2478-77	2479-77	2480-77	2257-77
Description	J-6401 Component Coal A	J-6402 Component Coal B	J-6403 Component Coal C	J-6335 A 25% B 37.5% C 37.5%
Linear Expansion				
Bd. 52 lb/ft^3 at 2% moisture...%	-	-	-	-2.3
Gieseler Plasticity				
Start ....°C	445	397	405	406
Fusion Temp. ....°C	461	411	418	417
Max. Fluid Temp. ....°C	485	438	444	442
Final Fluid Temp. ....°C	505	476	484	486
Solidification Temp. ....°C	512	483	487	489
Melting Range ....°C	60	79	79	80
Max. Fluidity ....dd/m	42.8	25750	8950	2448
Torque ....g.in.	40	40	40	40
Dilatation				
Ti - Softening Temp. ......°C	419	347	359	362
Tii - Max. Contraction Temp. °C	463	417	425	427
Tiii - Max. Dilatation Temp. .°C	493	462	473	468
Contraction ....%	24	25	26	24
Dilatation ....%	56	184	197	102
Free Swelling Index				
F.S.I.	8.5	7	7.5	7

Table 3 - Sieve analyses of typical coarse and fine coke oven charges

Size range	Coarse grind %	Fine grind %
plus 6.3 mm	5.4	0.2
6.3-3.35 mm	18.3	7.7
3.35-1.70 mm	20.1	24.2
1.70 mm-850 μm	18.7	24.5
minus 850 μm	37.5	43.4
Total minus 3.35 mm	76.3	92.1

defined as oven width in millimetres divided by time in hours for the centre of the coal charge to reach a specified temperature, depends on the coal moisture content, pulverization level, and oven flue temperature. Coal bulk density varies with moisture and pulverization levels.

Results from the 25 carbonized oven charges are given in Table 4. The relationships between the dependent and independent coking variables are discussed below.

EFFECT OF PULVERIZATION AND MOISTURE CONTENT ON BULK DENSITY OF COAL IN THE OVEN

Bulk density is affected by a number of factors related to the physical condition of the coal and the manner of oven charging. Because the latter is standardized, only the factors associated with the condition of the coal are considered - moisture and pulverization levels. Their effect on coal bulk density after charging, calculated on a dry basis, is shown in Fig. 1. Increases in moisture content decrease bulk density over the range used in this investigation. At 7% moisture, the finer grind has a bulk density of about 16 kg/m^3 less than the coarse-ground coal. In industrial practice, oil is often added to the oven charges. This increases bulk density and minimizes the effect of moisture variations (2).

FLUE TEMPERATURE AND COKING RATE

Figure 2 shows the relationship between flue temperature and coking rate calculated from the time required for the centre of the charge to reach 900°C. As expected, higher flue temperatures decrease coking time or increase coking rate. Two other trends in the data are apparent. First, the higher the moisture content, the faster the coking rate at a particular flue temperature. Secondly, the coking rate of the coarse grind is generally slower at a particular flue temperature.

Figure 3 shows the same relationship except

Table 4 - Oven test results

Test no.	Oven flue temp °C	Coal moisture %	Grind fine/ coarse	Oven bulk density kg/m^3	Wall pressure kPa	ASTM stability	ASTM hardness	JIS DI^{15}_{30}	Coke-size distribution (mm)							Apparent specific gravity	Coking-time (h)	
									+100	+75	+50	+38.1	+25	+19	+12.5		900°C	1000°C
195	1075	5.1	F	762		54.8	59.9	94.0	7.3	28.5	71.6	88.0	94.9	95.7	96.4	-	16.2	-
198	1075	3.3	F	824		59.0	65.0	95.2	5.2	23.9	68.4	87.3	94.1	94.7	95.5	0.876	17.2	20.5
199	1075	7.2	F	716		55.1	60.6	94.5	7.1	30.3	72.9	87.9	95.6	96.6	97.2	0.835	16.0	17.3
201	1025	5.0	F	770		56.4	60.3	94.4	13.2	39.4	75.6	89.0	95.8	96.5	97.2	0.821	19.0	-
202	1025	7.2	F	716		52.9	57.1	94.1	11.3	35.7	76.2	89.5	95.0	95.8	96.8	0.824	19.6	-
203	1025	2.5	F	833		59.8	64.8	94.7	16.7	39.4	77.2	90.5	94.9	95.8	96.7	0.882	22.2	-
205	1150	3.3	F	822		58.9	66.9	94.8	3.2	24.4	63.9	85.1	94.4	95.1	95.8	0.905	16.1	17.9
206	1150	5.2	F	748		55.1	62.1	94.1	4.3	23.5	65.0	84.1	95.2	96.0	96.7	0.844	15.4	16.8
207	1150	7.3	F	722		52.0	60.0	94.5	4.7	24.1	64.6	87.4	95.0	96.0	96.7	0.828	14.0	15.3
208	1150	2.6	C	807		56.0	65.2	95.3	5.1	23.3	62.4	84.2	95.9	96.8	97.6	0.902	16.2	18.0
209	1150	5.0	C	764		51.9	60.1	93.7	7.5	26.0	67.8	86.8	94.9	95.8	96.6	0.822	15.4	17.2
210	1150	7.4	C	734		51.4	59.8	92.8	3.9	23.5	66.3	87.2	94.3	95.4	96.3	0.811	15.3	16.8
211	1075	7.4	C	732		51.6	57.9	93.1	5.1	34.7	74.0	88.3	95.1	95.9	96.8	0.848	17.2	20.2
212	1075	5.2	C	761		54.1	62.2	94.2	6.2	28.1	69.9	87.9	95.1	95.9	96.5	0.857	16.4	19.0
213	1075	3.3	C	826	11.0	57.7	65.7	94.4	14.9	31.3	71.0	88.8	95.3	96.1	97.1	0.921	18.9	21.0
214	1025	2.9	C	830	7.8	59.3	67.0	95.2	20.3	47.4	80.4	91.6	95.9	96.7	97.4	0.931	21.9	25.0
215	1025	5.0	C	778	2.3	55.5	62.3	94.0	16.3	39.2	78.9	90.0	95.3	96.1	96.9	0.860	20.3	-
216	1025	6.9	C	730	2.1	50.6	56.8	93.7	20.6	42.1	79.4	90.3	94.3	95.2	96.2	0.815	19.9	-
217	1025	5.0	C	769	3.9	54.1	60.5	94.9	15.6	38.2	77.9	90.5	95.3	96.1	97.0	0.849	19.5	-
218	1075	7.0	F	674	3.9	51.2	56.2	94.3	4.9	23.7	70.0	87.3	94.3	95.3	96.2	0.809	15.3	19.8
219	1150	5.0	C	761	3.4	51.8	61.1	94.1	2.9	25.1	64.7	85.3	94.8	95.9	96.9	-	-	-
220	1150	7.3	C	729		51.7	62.1	94.4	3.7	23.8	64.9	86.1	94.8	95.9	96.7	0.813	-	-
221	1150	7.0	F	713		51.7	57.8	94.3	6.6	26.3	71.1	87.7	94.9	95.6	96.4	-	-	-
222	1075	6.6	F	713		51.0	56.6	94.2	12.2	30.5	71.9	84.7	94.6	95.5	96.3	0.820	-	-
223	1150	2.6	C	830	4.1	55.7	67.3	95.0	3.2	17.1	58.7	84.0	95.4	96.6	97.3	-	-	18.25

that the coking rate is calculated from the time to reach a centre temperature of 1000°C. This temperature was not reached in all tests, especially those at the lower flue temperature which was only 25°C higher than 1000°C.

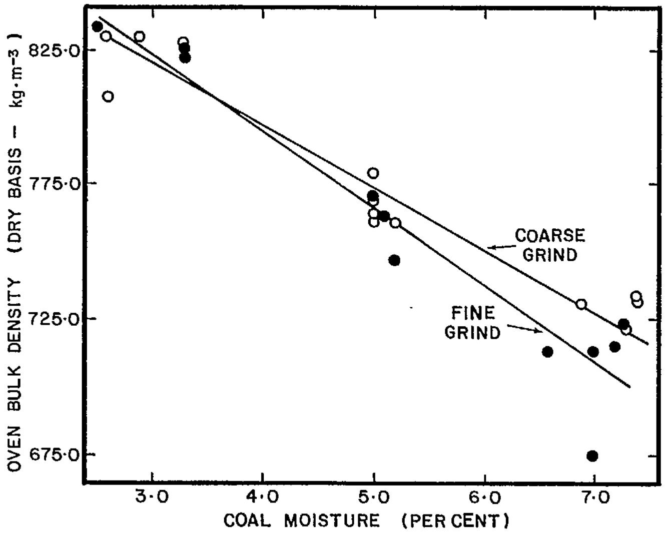

Fig. 1 - Effect of coal moisture content on coal bulk density in oven

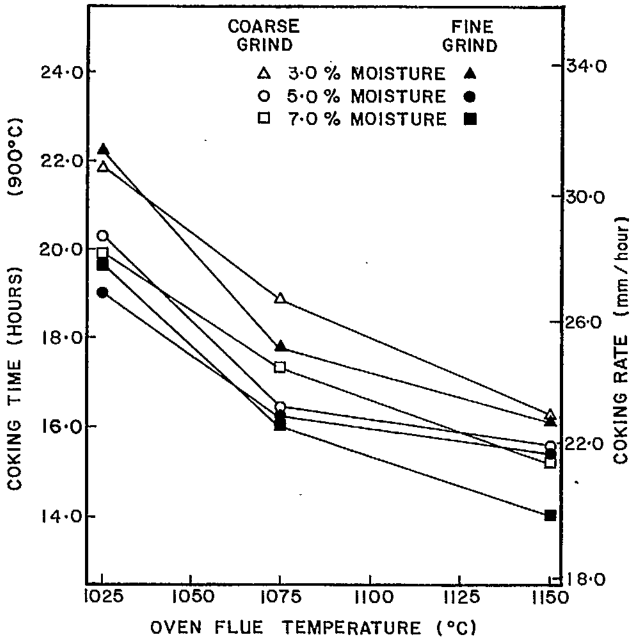

Fig. 2 - Effect of oven flue temperature on coking rate for a centre temperature of 900°C

COKING TIME AND COAL BULK DENSITY

At each flue temperature a linear relationship appears to exist between coking time and coal bulk density. This is shown in Fig. 4, where coking time is based on 900°C.

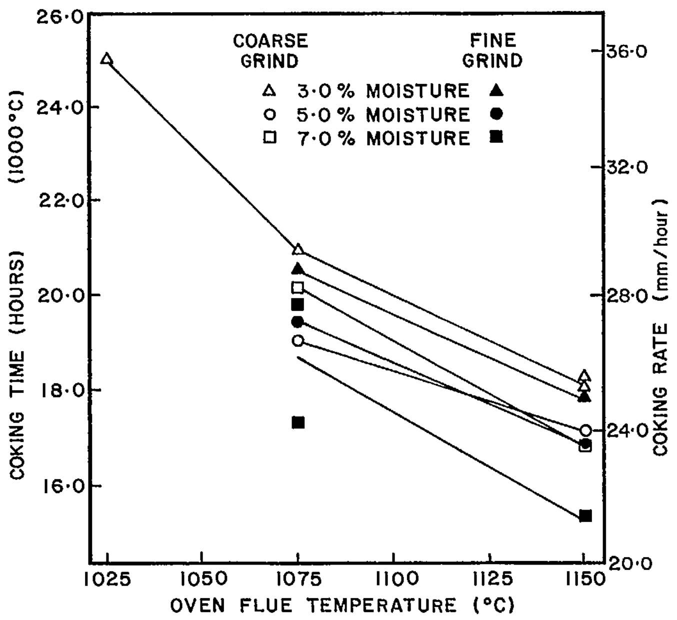

Fig. 3 - Effect of oven flue temperature on coking rate for a centre temperature of 1000°C

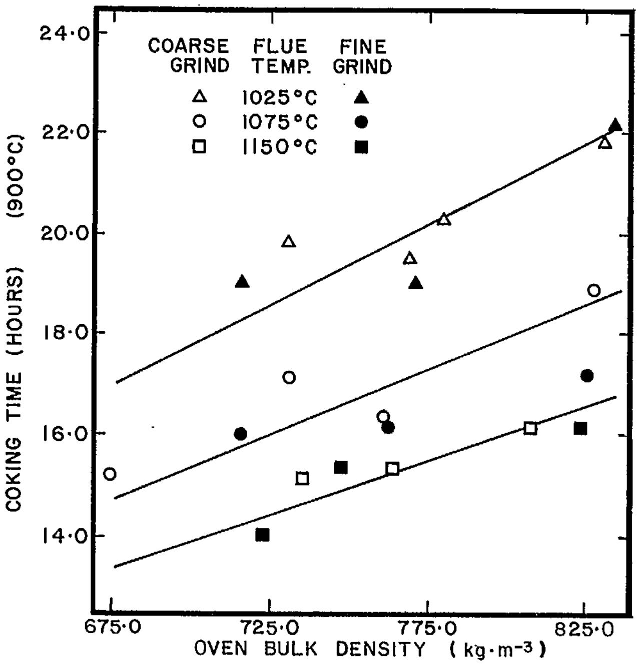

Fig. 4 - Relationship between coal bulk density and coking time for a centre temperature of 900°C

WALL PRESSURE

Wall pressure measurements are important in technical-scale movable-wall oven tests as they can help avoid possible damage to industrial ovens. It is generally agreed that coal blends that develop a wall pressure less than 14 kPa can be safely carbonized in commercial equipment (3).

Wall pressure is measured by four load cells at the ends of four water-cooled tie-rods joining the four corners of the two walls. However, problems occurred with some of the electrical components of the system during the first part of this program. The eight values recorded in Table 4 were obtained after the problems had been solved and the equipment calibrated satisfactorily. The pressures ranged from 2.0-4.0 kPa at bulk densities below 778 kg/m^3, and from 4.0-11.0 kPa at higher bulk densities.

EFFECT OF CARBONIZATION VARIABLES ON COKE PROPERTIES

ASTM COKE TUMBLER STRENGTH TEST

This ASTM test is used to determine coke stability, an index commonly used to indicate coke strength and regarded by North American coke oven operators as the most important index of coke quality (4). Briefly, the test consists of tumbling 10 kg of coke screened to 50 mm by 75 mm for 1400 revolutions at 2.51 rad/s ± 0.1 (24 ± 1 rpm in a 914 mm diam by 457 mm long cylindrical drum having two equispaced 50-mm lifters. The tumbled coke is screened at 25 and 6.3 mm, and the percentages remaining on these screens are called the stability and hardness indices, respectively.

Figure 5 shows that coke stability of the industrial coal blend is influenced significantly by pulverization and moisture levels and to a lesser extent by oven flue temperature. In Fig. 6, where coke stability is plotted against bulk density, the effect of pulverization on stability is seen more clearly. Stability increases with bulk density and is higher for the finer grind. Figure 7 shows the relationship between coke stability and oven flue temperature.

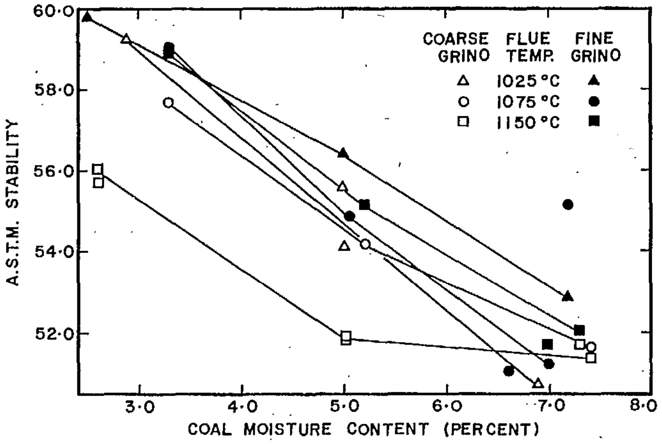

Fig. 5 - Relationship between coal moisture and ASTM stability index

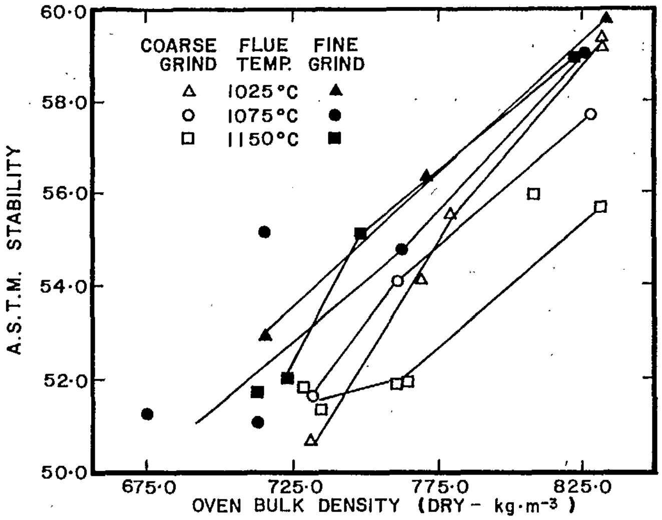

Fig. 6 - Relationship between coal bulk density and ASTM stability index

The effect of flue temperature is seen to be small, particularly when compared with the influence of bulk density. No clear trend is apparent for all the moisture and pulverization levels, but most show minor decreases in stability as the flue temperature is increased from 1025°C to 1150°C.

Coke hardness is a measure of abrasion resistance. Figure 8 shows this property decreases with increased coal moisture. The linear regression lines further suggest that hardness is also influenced by flue temperature.

At 7% moisture, hardness is increased by about three points as flue temperature is increased from 1025 to 1150°C.

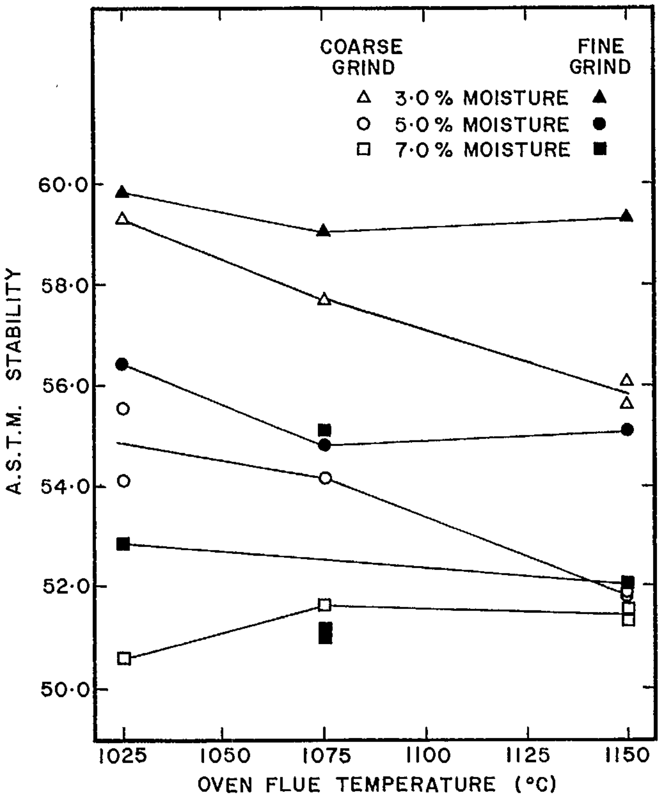

Fig. 7 - Effect of oven flue temperature on ASTM stability index

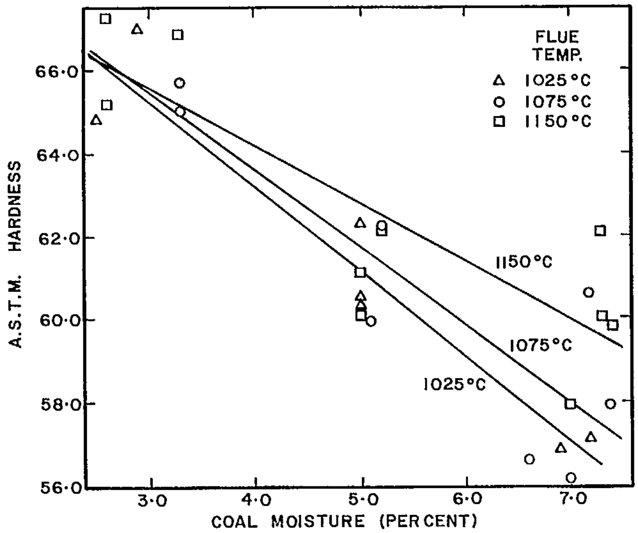

Fig. 8 - Relationship between coal moisture and ASTM hardness

JAPANESE COKE TUMBLE TEST, JIS DI^{30}_{15} INDEX

A Japanese coke tumble test has been routinely used by ERL for the last 16 years (5). The cylindrical drum has a 1.5-m diam and is 1.5 m long with six equispaced lifters, 0.25 m high. A 10-kg sample of 50 x 75 mm coke is tumbled for 30 revolutions at 1.57 rad/s (15 rpm) and then screened over square-mesh sieves having 50, 25, and 15 mm openings. The cumulative percentage remaining on the 15-mm sieve is the modified JIS DI^{30}_{15} index. The index is called modified as the sample is 50 x 75 mm coke; the Japanese specification is plus 50-mm coke. Use of the former size fraction allows indices from CRPL's different coke ovens to be compared (5).

Figure 9 plots modified indices versus stability of the cokes made in the 26 tests. The regression line was derived from the modified least squares linear regression method of Visman and Picard (6). This assumes the errors in the X and Y plotted parameters are approximately equal, whereas in the normal least squares regression it is assumed that most of the error appears in the Y data. The regression line gives the following relationship between the two indices: modified JIS DI^{30}_{15} = 87.05 + 0.134 (stability index)

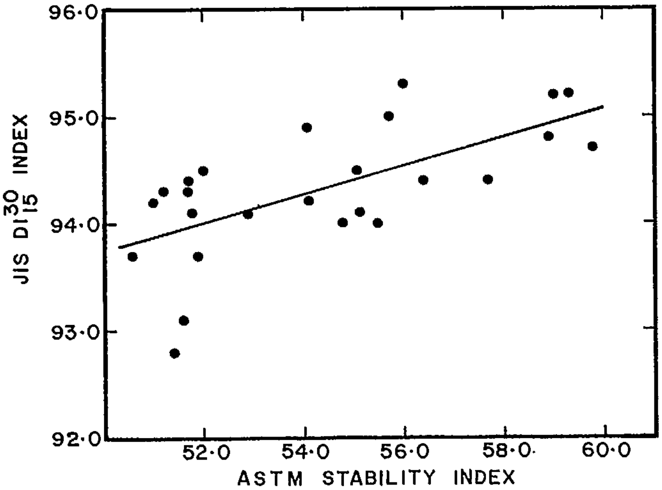

Fig. 9 - Plot of ASTM stability index against modified JIS DI^{30}_{15} INDEX

COKE-SIZE DISTRIBUTION

A narrow coke-size distribution in the blast furnace reduces the resistance of the burden to the passage of gas so that high productivity can be achieved by blowing more air through the furnace. However, the best size distribution depends on the blast furnace practice employed (7).

Figure 10 shows that the percentage of coke larger than 50 mm decreases as the flue temperature is increased. The linear regression lines used to relate the three different nominal charge moisture contents suggests the production of plus 50-mm coke increases with greater coal moisture. The percentage of coke less than 12.5 mm (coke breeze) was found not to correlate with flue temperature, coal moisture or coke hardness.

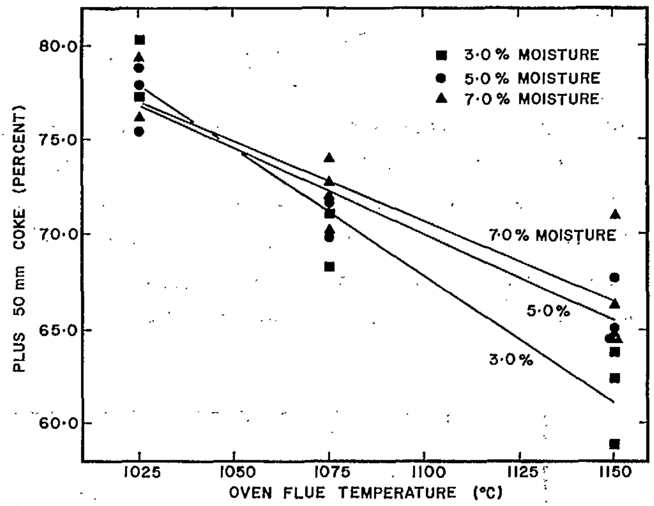

Fig. 10 - Effect of oven flue temperature on percentage plus 50 mm-coke produced

Figure 11 shows the influence of flue temperature on the distribution of coke in several size ranges. The lines were obtained by linear regression from results of the 25 tests. The amount of minus 25-mm coke produced is unaffected by flue temperature. However, the proportions of the 38.1 x 25 mm and 50 x 38.1 mm coke sizes increase at the expense of the larger sizes as the flue temperature is increased. Thus, higher flue temperatures narrow the size range of coke produced.

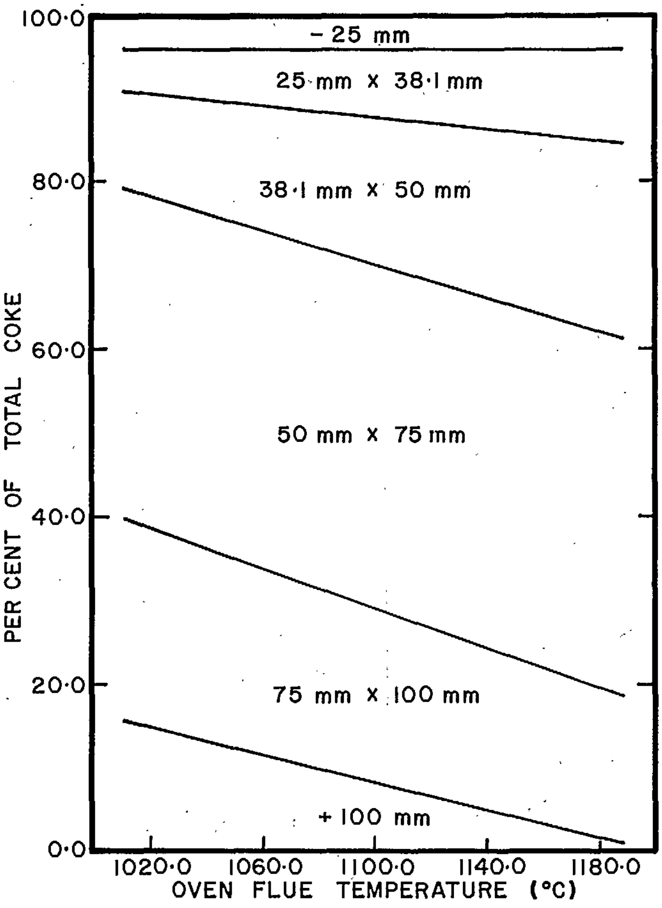

Fig. 11 - Effect of oven flue temperature on coke-size distribution

APPARENT SPECIFIC GRAVITY

The apparent specific gravity of coke is measured by immersing a sample in water. The values obtained indicate coke porosity and were found to depend on the coal bulk density (Fig. 12). Changes in flue temperature had no discernible effect on coke porosity.

PETROGRAPHIC PREDICTION OF COKE STABILITY

Petrographic analyses of the component coals and the calculated petrographic analysis of the blend are given in Table 5. The predicted stability indices shown were calculated using a method similar to that described by Schapiro et al. (8). The predicted stabilities apply to

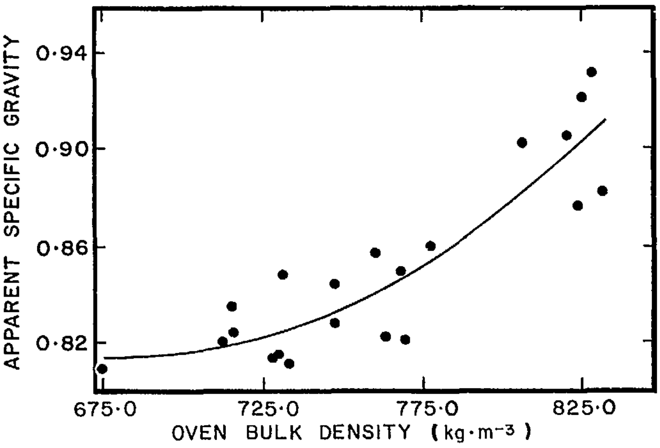

Fig. 12 - Relationship between coal bulk density and coke apparent specific gravity

coke produced in technical-scale ovens from coals crushed to 80% minus 3.35 mm and carbonized at oven bulk density of 881 kg/m^3. When the stability and coal bulk density data for the coarse-ground coal are linearly regressed and the linear regression line extrapolated to an oven bulk density of 881 kg/m^3, an index of 61.0 is obtained (Fig. 6). This compares satisfactorily with the predicted stability of 61.2 for the coal blend.

SELECTION OF STANDARD OPERATING CONDITIONS

This study shows that coke quality produced from a typical industrial coking coal blend varies dramatically with change in oven operating conditions. For example, coke stability varied from 50.6 to 59.8. The lower value represented poor quality blast furnace coke and the upper value extremely good coke. The objective of CRPL is to operate the technical-scale oven under conditions that produce a coke quality similar to that of industrial ovens.

Standard operating conditions were selected by first choosing a coal bulk density as the test results show this variable has the largest influence on coke strength. Canadian companies reported bulk densities in the range of 689-745 kg/m^3 for their ovens and a value of 745 kg/m^3 was selected for the technical-scale oven. As it is impossible to adjust bulk density after the coal is in the oven, it is necessary to standardize the pulverization and moisture levels to achieve the required bulk density. Nevertheless, variations do occur and the bulk density can only be accurately determined after the charge is in the oven. A coal pulverization level of 80% minus 3.35 mm was selected as it approximates industrial practice and could be prepared with existing CANMET crushers. Figure 1 indicates that to achieve the desired 745 kg/m^3 coal bulk density for a blend pulverized to 80% minus 3.35 mm, a charge moisture level of 6% is required. These conditions were adopted as a standard coal preparation method.

After selecting the coal preparation conditions, it was necessary to consider the required oven flue temperature. Because industrial flue temperatures vary depending on oven construction, refractories, etc., and as the coking rate was found to have a greater influence on coke quality, it was used as the other criterion. In keeping with general industrial practice, a coking rate of 25 mm/h, when calculated using the time for the centre of the charge to reach 1000°C, was adopted. The choice of 1000°C was arbitrary; a variety of end temperatures for defining coking rate appear in the literature. However, this temperature allows for thorough coking of the charge and also represents industrial practice. Figure 3 indicates that to achieve a coking rate of 25 mm/h for the coarse-grind charge containing 6% moisture, a flue temperature of approximately 1125°C is required. The coke is discharged 0.5 h after the temperature reaches 1000°C.

CONCLUSIONS

To simulate industrial practice the following oven operating conditions were chosen:

flue temperature:	1125°C
coal moisture:	6%
coal pulverization:	80% minus 3.35 mm

These conditions result in a dry-charge oven bulk density of about 745 kg/m^3 and a coking rate of 25 mm/h to reach a charge centre temperature of 1000°C. The oven is pushed half an hour after the charge centre temperature reaches 1000°C.

The coke quality obtained in this study is peculiar to the blend of coals used, but the following are expected to apply to similar blends: coke strength increased as coal bulk density in the oven increased and was higher for more finely ground coal; coke size distribution was influenced mainly by oven flue temperature and narrowed as the temperature was increased.

Table 5 - Petrographic analysis of component coals

Identification				
Laboratory Number..............	2478-77	2479-77	2480-77	Calculated
Description....................	Component Coal A	Component Coal B	Component Coal C	for blend A 25% B 37.5% C 37.5%
Distribution of Vitrinite Types				
V-6..........................%				
V-7..........................%		1.8		0.7
V-8..........................%		17.9	1.4	8.1
V-9..........................%		33.4	13.9	19.0
V-10.........................%		6.6	32.7	14.5
V-11.........................%			18.8	6.7
V-12.........................%			2.8	1.0
V-13.........................%	0.7			0.2
V-14.........................%	15.3			3.5
V-15.........................%	32.0			7.3
V-16.........................%	24.0			5.5
V-17.........................%	0.8			0.1
V-18.........................%				
Reactive Components				
Total Vitrinite...............%	72.8	59.6	69.6	66.7
Reactive Semi-fusinite (1/3)...%	3.9	4.3	2.1	3.4
Exinite......................%	0.0	10.1	5.4	5.8
Total........................%	76.7	74.0	77.1	75.9
Inert Components				
Inert Semi-fusinite (2/3)......%	7.7	8.6	4.1	6.6
Micrinite....................%	4.5	8.6	10.0	8.1
Fusinite.....................%	7.5	5.8	4.9	5.9
Mineral Matter...............%	3.6	3.0	3.9	3.5
Total........................%	23.3	26.0	22.9	24.1
Petrographic Indices				
Mean Reflectance..............%	1.56	0.91	1.05	1.12
Balance Index..................	2.15	0.93	0.76	0.98
Strength Index.................	7.13	3.44	3.99	4.55
Stability Index................	61.6	44.5	54.3	61.2

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