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COMPARISON OF COKE PRODUCED IN DIFFERENT CANMET COKE OVENS – PART 2

J.T. PRICE AND W.R. LEEDER

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COMPARISON OF COKE PRODUCED IN DIFFERENT CANMET COKE OVENS - PART 2

by

J.T. Price* and W.R. Leeder**

ABSTRACT

The Canada Centre for Mineral and Energy Technology (CANMET) operates several pilot-scale coke ovens. Testing in ovens of this size is considered to be the best laboratory method for assessing coking characteristics of coal. Each oven differs in construction and operates under different conditions. At the time of investigation, ovens were operated which had coking chambers of 310- and 460-mm widths in Ottawa, and 310 mm in Edmonton. The objectives of this report are to describe an investigation conducted between 1972 and 1977 and to compare coking results. Comparisons were made by plotting and linearly regressing the coke ASTM stability and hardness strength indices, coke mean size, apparent specific gravity, and coking pressure. Regression analyses in Part 1 of this investigation showed the ASTM stability factor - the prime North American coke quality parameter - was equal for any of the ovens when a single coal or blend was carbonized. Coke ASTM hardness factor, apparent specific gravity, mean size, and coking pressure, were similar for the Ottawa and Edmonton 310-mm ovens, but differed systematically from the 460-mm oven. Coke yield was similar for the Edmonton 310-mm and the Ottawa 460-mm ovens, but was slightly higher in the Ottawa 310-mm oven.

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*Research scientist, Coal Processing Research Section, Coal Resource and Processing Laboratory; **Manager, Western Research Laboratory (Edmonton); Energy Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

COMPARAISON DES COKES PRODUITS AU CANMET DANS DES FOURS A COKE DIFFERENTS - PARTIE 2

par

J.T. Price* and W.R. Leeder**

RESUME

Le Centre canadien de la technologie des minéraux et de l'énergie (CANMET) opère plusieurs fours à coke à l'échelle pilote. Les essais effectués dans des fours de cette dimension sont considérés comme la meilleure méthode pour évaluer les caractéristiques de cokéfaction du charbon. Chacun de ces fours a été construit différemment et leurs conditions de fonctionnement diffèrent. Au moment de l'étude, les fours utilisés avaient des chambres de cokéfaction de 310 et de 460 mm de largeur à Ottawa et 310 mm à Edmonton. Le but de ce rapport est de décrire une analyse effectuée entre 1972 et 1977 et d'en comparer les résultats. Les comparaisons ont été basées sur les tracés graphiques et les régressions linéaires des indices de dureté et de stabilité ASTM du coke, sur la granulométrie du coke, sur la densité apparente spécifique et sur la pression de cokéfaction. Les analyses de régression dans la première partie de cette étude démontrent que le facteur de stabilité ASTM - le principal indice de la qualité du coke en Amérique du Nord - est le même pour chacun des fours utilisés lorsque un seul charbon ou mélange était carbonisé. Le facteur de dureté ASTM du coke, la gravité apparente spécifique, la granulométrie et la pression de cokéfaction sont semblables pour les fours de 310 mm d'Ottawa et d'Edmonton mais diffèrent systématiquement des mêmes données pour le four de 460 mm. Le rendement du coke était semblable pour le four à coke de 310 mm d'Edmonton et celui de 460 mm d'Ottawa, mais était un peu plus élevé pour le four de 310 mm d'Ottawa.

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*Chercheur scientifique, Section de recherche sur le traitement du charbon, Laboratoire sur les ressources et le traitement du charbon, **gérant, Laboratoire de recherche de l'Ouest (Edmonton); Laboratoires de recherche énergétique, CANMET, Energie, Mines et Ressources Canada, Ottawa.

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INTRODUCTION

The purpose of this report is to compare the coking test results from three CANMET pilot-scale coke ovens of 200 to 350-kg capacity. The ovens, referred to in previous reports as 12- and 18-in. ovens, have slot-type coking chambers of 310- and 460-mm nominal widths. It is generally recognized that testing with such ovens is required for the manufacture of metallurgical coke. These ovens are used to carry out carbonization research and are used in Canada by mining companies, commercial coke-makers and government departments in evaluating coking coals and blends.

This is the second in a series of reports to consider differences in the coking characteristics and properties of cokes produced in different test ovens. The conclusions from these reports should be useful in interpreting results from coking tests.

Of the several sizes of experimental ovens at CANMET, the selection is usually made on the basis of availability, amount of coal supplied, and number of tests required. As the size and mode of operation can influence coke quality it is assumed that the more closely the size and operation of the technical-scale oven approaches that of industrial units, the greater the confidence in the test results (1,2,3,4,5).

Each oven has a different construction and is used under different conditions as suggested by the manufacturer or as determined at CANMET. Oven construction and operation were described in detail in the first report (6) and are summarized in Table 1. Preliminary tests suggested that the ovens produced coke with similar American Society for Testing and Materials (ASTM) stability factors, the prime North American coke quality parameter; however, other characteristics varied from oven to oven. To clarify these differences, coking studies were undertaken between 1972 and early 1977 comparing several different coking coals and coal blends in two or more of the three ovens. The first report of this study described differences in oven operation but was concerned mainly with the ASTM stability factor and the Japanese Industrial Standard (JIS) DI^{30}_{15} index; as these are the prime quality parameters of interest to North American and Japanese ironmakers (3,6). Results showed that under early 1977 standard CANMET operating practices, the 460- and 310-mm ovens did produce cokes of very similar ASTM stability factors and JIS DI^{30}_{15} strength indices, even though the ovens had coking chambers of different widths and were operated differently. The ASTM hardness of cokes made in the two smaller ovens were nearly the same, but were greater than the ASTM hardnesses of cokes made from the same coals in the larger oven. In this report consolidated stability and hardness factors, mean coke size, coke yield, oven pressure and apparent specific gravity obtained from the 1972-1977 study, are compared and linearly regressed.

EXPERIMENTAL

MEAN COKE SIZE

A half hour after the centre temperature of an oven charge has reached 1000 to 1010°C, the coke is pushed, quenched with water, dropped 3.0 m to a concrete floor to simulate coke handling in a commercial plant, dried overnight at 105°C and then weighed. The dried coke is manually sized on screens with openings of 100 mm (4 in.), 75 mm (3 in.), 50 mm (2 in.), 37.5 mm (1.5 in.), 25 mm (1 in.), 19 mm (0.75 in.), and 12.5 mm (0.5 in.). The cumulative per cent weights retained on these screens and the per cent of total passing the 12.5-mm screen are recorded. The mean coke size is then calculated using the following Organization of International Standards (ISO) standard formula based on cumulative per cent (7):

$$\text{Mean coke size (MCS)} = \frac{B(a-c) + \ldots + J(j-k) + 100j}{200}$$

where a b c d ... h j k are sieve sizes and 0 B C D ... H J K were the corresponding cumulative percentage weights of coke retained on each screen

Table 1 - CANMET pilot-scale coke ovens - construction and operating conditions, early 1977

Oven designation:	310-mm (12-in.)		460-mm (18-in.)
Design basis	Eastern Coal Assoc.	Koppers	Bethlehem
Location	Ottawa	Edmonton	Ottawa
Date installed	1971	1972	1970
Oven construction:			
Movable wall	Yes	Yes	Yes
Nominal coking chamber width, mm	310	305	460
Coking chamber refractories	Silicon carbide	Alcor	Silicon carbide
Heating method	Glow bars	Natural gas	Glow bars
Standard oven test conditions			
Approximate charge weight, kg	230	200	350
Charge pulverization, % - 3.36 mm	80 ± 5	80 ± 5	80 ± 5
Target charge moisture, %	2.0	2.0	6.0
Resulting estimated charge dry Bulk density in oven, kg/m^3	817 ± 15	817 ± 15	745 ± 15
Flue temperature control	900 to 1070°C @ 19.44°C/h	Constant 1077°C	900 to 1070°C @ 12.22°C/h
Charge push method*	0.5 h after C_T = 1010°C	0.5 h after C_T = 1010°C	0.5 h after C_T = 1010°C
Normal push time, h	9	9	18

*C_t = Charge centre temperature

COKE YIELD

Coke yield is calculated by dividing the weight of dry coke removed from the coke ovens by the weight of dry coal charged to the coke ovens. The result is reported as a percentage. The weight of dry coal charged to the oven is obtained by subtracting the weight of moisture in the charge from the total weight of the moist coal charged. The moisture level in the coal is obtained using a Harry W. Dietert Co. Moisture Teller.

APPARENT SPECIFIC GRAVITY

The method used for obtaining the apparent specific gravity, ASG, of coke is a modification of the ISO method based on measuring the weight of coke in air and in water (8). Coke, 50 by 75-mm (2 by 3-in.) is placed in a basket, weighed, immersed in water for 10 min, weighed in the water, then weighed again in air after allowing 1 min of drainage time. The ASG is calculated according to the formula

$$\text{ASG} = \frac{\text{wt of dry coke}}{\text{wt of coke wet in air} - \text{wt of coke in water}}$$

OVEN PRESSURE

The coke oven pressures are calculated by dividing the force exerted on the movable oven wall during cabonization by the area of the oven wall inside the oven against the coke. The wall force for the Ottawa 310-mm oven is simply measured by a load cell attached to a fixed beam and contacting the movable wall oven at its centre. The wall force on the 460-mm oven is obtained by summing the forces exerted on four load cells. The load cells are attached to four tie rods, each joining a corner of the movable wall to the adjacent corner of the fixed wall. The wall force on the 310-mm Edmonton oven is measured by a balance using counterweights attached to a series of levers making contact at the centre of the movable wall.

DATA AND STATISTICAL METHODS

The data used in this publication were tabulated in Appendix B of Part 1 (6). In comparing data, the Visman and Picard least squares linear regression model was used and the method of analyzing the data was described (9,6). Data for coal No. 18 in the 460-mm oven were not used because the coal had burned during testing. Data used in regressions are summarized in the Appendix of this report.

RESULTS AND DISCUSSION

Coke mean size, stability factor, hardness factor, yield apparent specific gravity, and coking pressures - the bases for comparing similarities of cokes from the three ovens - were plotted in pairs as seen in Fig. 1 through 11. A summary of the data and regressions appears in the Appendix.

COKE TUMBLER STRENGTH

The most important criteria of coke quality are its tumbler test strength indices, such as the ASTM stability and hardness factors that are considered to represent coke shatter and abrasion resistance respectively. Part 1 of this report concluded that cokes of similar stability but of different hardness, were produced from the 460- and 310-mm ovens (6). All the results from that report were combined to demonstrate this point in Fig. 1 and 2, with details of the regression analyses appearing in Table 2. Coke stabilities were equivalent statistically for all ovens (Fig. 1). The hardnesses of cokes were equivalent statistically for the two smaller ovens charged with coal to a bulk density of 817 ± 15 kg/m^3, but were 5 to 7 units greater than for the 460-mm oven charged to 745 ± 15 kg/m^3 (Fig. 2). Such differences in hardness may be expected as charge oven bulk density is one of the most important oven variables affecting hardness (1,4). This increased oven bulk density should yield more compact, harder and less abradable cokes with greater apparent specific gravities. Charge oven bulk density, coke apparent specific gravity and coke hardness are interrelated (1,5).

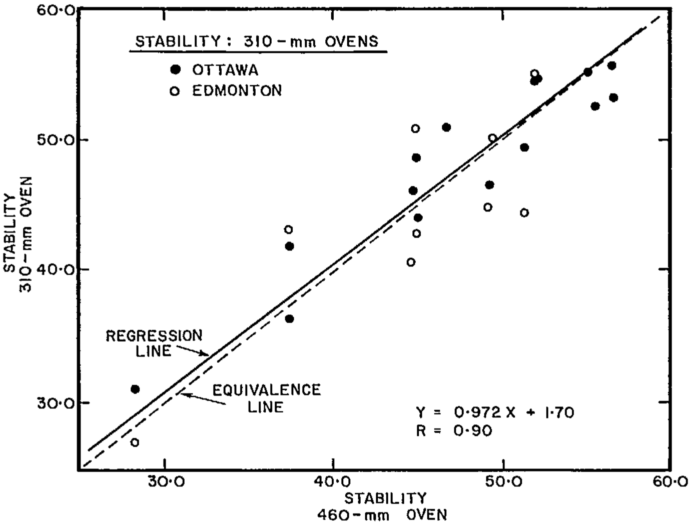

Fig. 1 - Coke stability from the two 310-mm ovens vs 460-mm oven

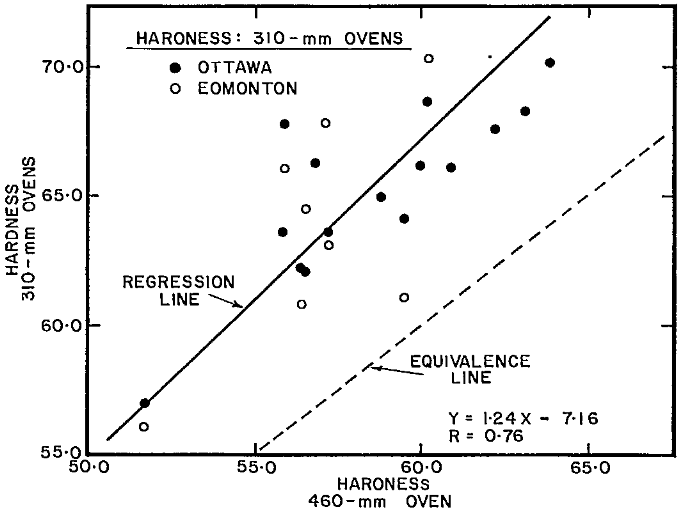

Fig. 2 - Hardness of coke from the two 310-mm ovens

Table 2 - Summaries of linear regression results for comparing coke stability factor, hardness factor, mean size, yield, apparent specific gravity and coking pressures of different CANMET coke ovens which may be expressed by the equation $Y = A + BX$.

Oven results for* X	Y	N	A	B	R**	
1	Stability					
18	OT & K	24	1.70	0.972	0.900	(0.404)
2	Hardness					
18	OT & K	23	-7.16	1.24	0.760	(0.413)
3	Mean coke size					
K	OT	10	-24.3	1.458	0.6236	(0.632)
18	OT	16	1.27	0.8317	0.859	(0.497)
18	K	6	20.5	0.5415	0.568	(0.811)
18	OT & K	22	7.13	0.7425	0.773	(0.423)
4	Coke Yield					
18	K	9	-10.41	+1.145	0.696	(0.666)
18	OT	19	10.36	0.890	0.705	(0.456)
K	OT	13	-12.56	1.196	0.912	(0.553)
5	Apparent specific gravity					
K	OT	7	-0.271	1.301	0.813	(0.754)
18	OT	10	-0.140	1.220	0.877	(0.632)
18	K	4	+0.371	0.6098	0.921	(0.950)
18	OT & K	14	-0.011	1.07	0.919	(0.532)
6	Coking pressure					
K	OT	11	-2.36	1.384	0.940	(0.602)
18	OT	10	-1.19	2.784	0.827	(0.632)
18	K	5	-2.76	3.432	0.634	(0.878)
18	OT & K	15	-1.61	+2.980	0.880	(0.514)

* K = Edmonton 310-mm OT = Ottawa 310-mm, 18 = Ottawa 460-mm oven.

**R = Correlation coefficient. The values in brackets are the minimum values for significance at the 0.05 confidence level.

N = Number of data points.

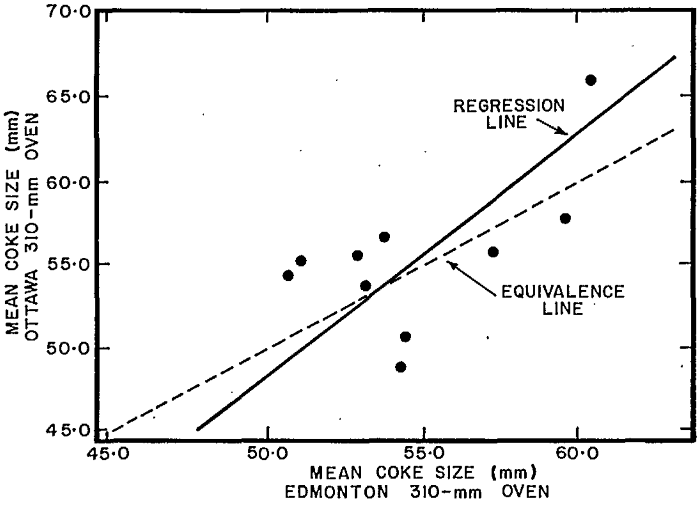

Fig. 3 - Mean size of coke (MCS) from the Ottawa 310-mm oven vs Edmonton 310-mm oven

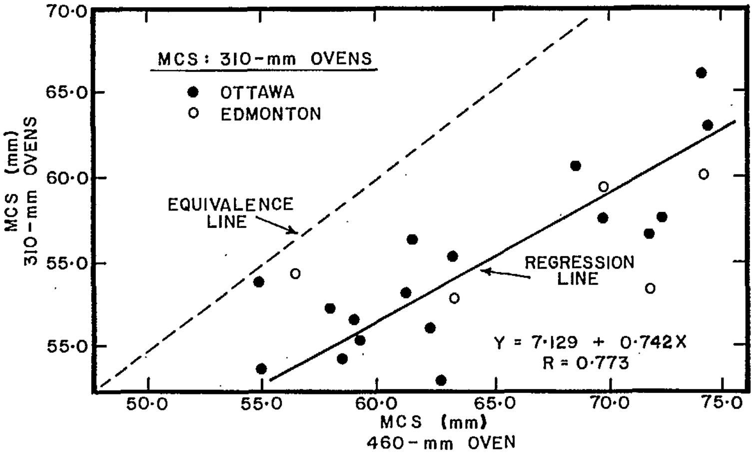

Fig. 4 - Mean size of coke (MCS) from the two 310-mm ovens vs 460-mm oven

MEAN COKE SIZE

Linear regression analysis results in Table 2 indicate that acceptable linear models can be used with 95% confidence to relate the mean size of cokes obtained from the Ottawa 310-mm oven to that obtained from the 460-mm and the Edmonton 310-mm ovens. Mean coke size from the Edmonton oven and the 460-mm oven does not relate at the 95% confidence level, probably because of insufficient data. However, the distribution of data points about the equivalence line of Fig. 3 indicates that both 310-mm ovens produce cokes of similar size. When the data for the small ovens were plotted against those for the 460-mm oven, all data points were found to lie off the equivalence line (Fig. 4). The mean size of coke from either of the small ovens is 5 to 10 mm (0.2 to 0.4 in.) smaller than that from the 460-mm oven, or about 74% that of the 460-mm oven coke using the regression slope. This could be the result of differences in fissure formation influenced by the bulk density of the charge in the oven or by the rate of change of charge temperature, both which appear to influence coke size (2,10). The CANMET results suggest that differences in test bulk densities did not appear related to changes in size of coke produced in either the large oven or the Edmonton oven. Thus it appears that changes in coke size are primarily a function of the heating rate, a condition governed by a number of factors such as mode of controlling flue temperature, refractory materials used in oven construction, and coking chamber width (11). Higher heating rates in the charge generally lead to smaller coke. Interestingly, cokes from the two small ovens appear to be equal in size although the ovens used different methods of supplying heat to the coking chamber, one being programmed and the other having a constant temperature flue mode of control.

Mean coke size is an important parameter, not only because of the importance of burden size distribution in blast furnace operation but because, in some cases, it can alter the coke strength indices if slightly different sized coke is used for the tumbler tests (12). It has been observed that the mean size of oven coke can be related to the coke stability factor where an increased mean coke size tends to increase the stability factor (13,14). According to Cudmore, the 5 to 10-mm (0.2 to 0.4-in.) larger mean size of 460-mm oven coke, compared with coke from the 310-mm ovens, could result in a potential increase in the stability factor of the larger oven coke by as much as 13 stability units (3). This could explain in part why the two sizes of ovens produce cokes of very different hardnesses and apparent specific gravities yet have similar stabilities.

COKE YIELD

Coke yield is dependent mainly on the volatile content of the parent coal. As a result all data were used in the regression analysis except for coal No. 18 in Reference 6 which had burned when tested and gave a particularly low yield. The linear regression results, Table 2, show that all ovens can be linearly related to each other with 95% confidence. Figure 5 has a regression line near the eqivalence line indicating that the Edmonton and the 460-mm ovens probably have equal yields. However, Fig. 6 and 7 indicate that the Ottawa 310-mm oven had about 2% higher coke yield than either the Edmonton oven or the 460-mm oven which have similar coke yields although charge bulk densities were 800-835 kg/m^3 (50-52 lb/ft^3) and 720-752 kg/m^3 (45-47 lb/ft^3) respectively. Thus the observed differences in the coke yield were not because of differences in charge oven bulk densities.

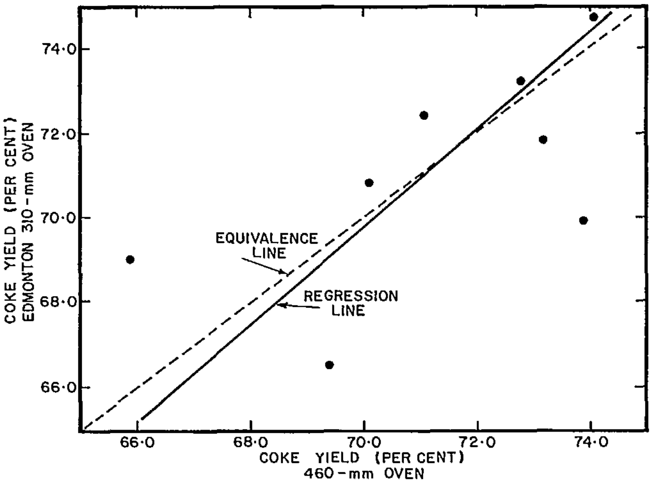

Fig. 5 - Yield from Edmonton 310-mm oven vs 460-mm oven

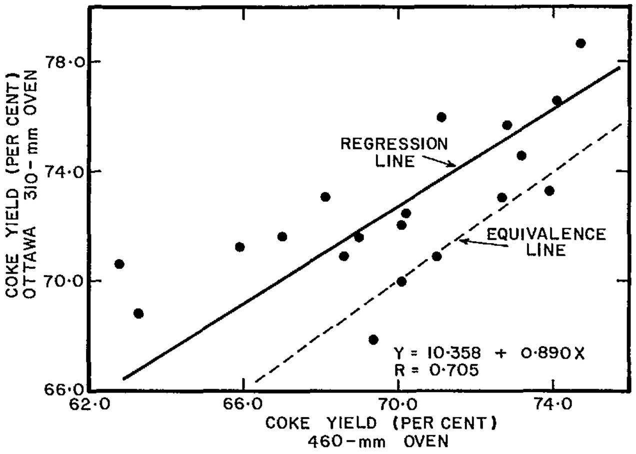

Fig. 6 - Yield from Ottawa 310-mm oven vs 460-mm oven

Recent rebuilding of the 460-mm oven has reduced its difference in coke yield compared with the smaller Ottawa unit from about 3% as evidenced in this report, to about 1% (15). One of the reasons for rebuilding the oven was to make it more air-tight. It is possible that the slightly lower yield from the 460-mm oven observed in this report was due to some burning of the charge.

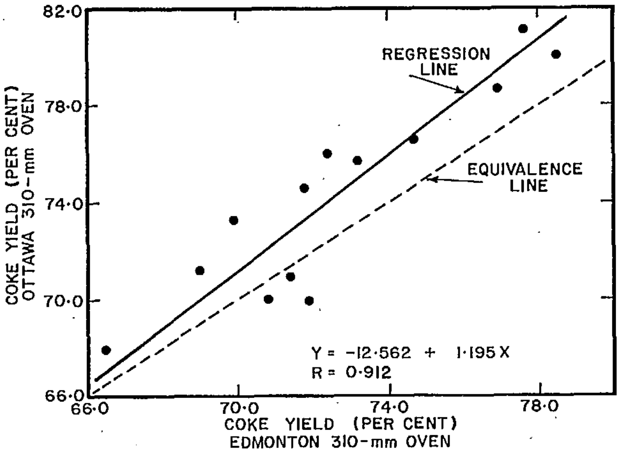

Fig. 7 - Yield from Ottawa 310-mm oven vs Edmonton oven

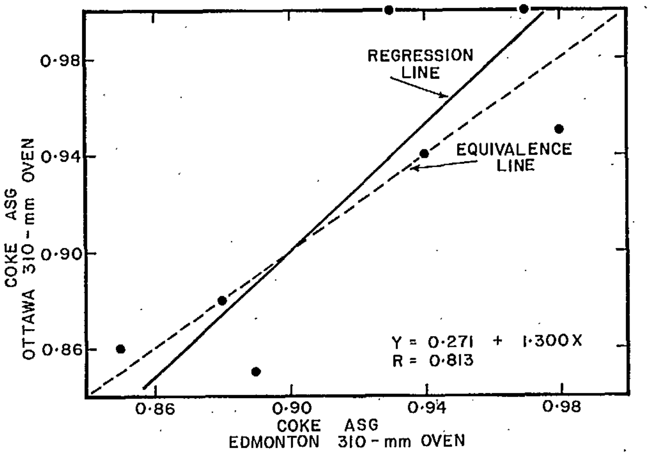

Fig. 8 - Apparent specific gravity (ASG) of coke from Ottawa 310-mm oven vs Edmonton oven

APPARENT SPECIFIC GRAVITY

The apparent specific gravity of a coke is primarily dependent on the volatile and mineral content of the coal and on oven bulk density (5). As a result only data obtained by using standard densities have been used in the linear regression analyses summarized in Table 2. The apparent specific gravity of coal No. 8 was previously incorrectly reported and should have been 0.781. The linear relationship in Table 2 for the regression of the apparent specific gravities of coke from the 460-mm and Edmonton ovens can not be accepted with 95% confidence because of limited data. Figure 8 shows that the regression line from the two small ovens is near the equivalence line although the data points are scattered. Assuming the coke apparent specific gravities are equal for the 310-mm ovens, Fig. 9 indicates them to be about 0.04 units greater than from the larger oven. This is to be expected because of the higher charge bulk density used in them. The higher apparent specific gravities from these ovens might be expected to yield coke with a higher hardness than from the large oven, and this was in fact observed, as discussed in the previous section.

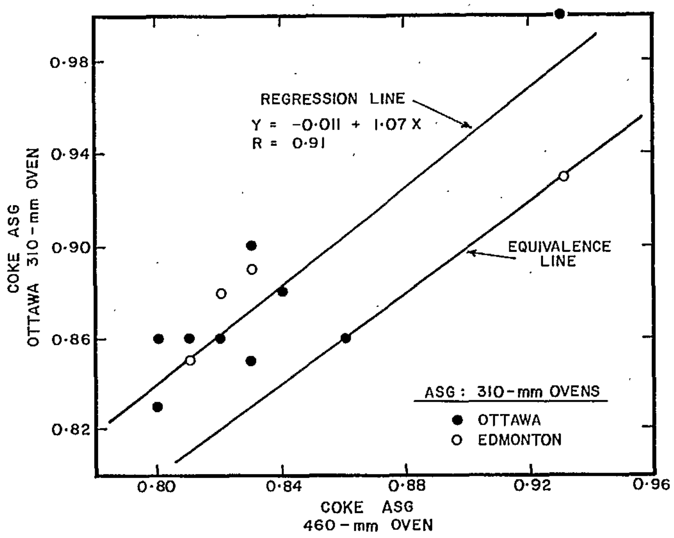

Fig. 9 - Apparent specific gravity (ASG) of coke from two 310-mm ovens vs 460-mm oven

COKE OVEN PRESSURE

The magnitude of the pressures developed on coke oven walls during carbonization can be strongly influenced by the coal caking and volatile properties, the bulk density of the coal in the oven, and to a lesser extent by the coking rate (4,13,16). Because the difference in coking rate of the ovens should lead to small differences in coking pressure (13), and all data were obtained from the same coals or blends, only charge oven bulk densities need be taken into account. Only data obtained from tests using standard charge oven bulk densities have been used in the regression analyses. Table 2 shows that linear relationships can be used with 95% confidence to relate the coking pressures observed in the two

Ottawa ovens and between the two 310-mm ovens. The relationship between the Edmonton oven and the 460-mm oven is less satisfactory, probably because there were only 5 data points.

Figure 10 shows that the coking pressure data for the two 310-mm ovens are similar and that the regression is not significantly different from the equivalence line.

Figure 11 shows that the two 310-mm ovens have higher coking pressures than the 460-mm oven. According to Jackman et al. the coking pressure from ovens having a charge bulk density of 745 kg/m^3 (46.5 lb/ft^3) should be 0.4 times the coking pressure of ovens charged at 817 kg/m^3 (51 lb/ft^3) (4). This is the case for the 460-mm oven compared with either of the two 310-mm ovens. Such a line is shown in Fig. 11 and agrees very well with the results observed in this study. It might therefore be concluded that at standard operating conditions the pressure differences observed in the ovens were primarily a result of the charge bulk density differences and not to oven design, width or heating rates.

CONCLUSIONS

Operation of the two 310-mm ovens at heating rates and charge oven bulk densities higher than for the 460-mm oven, produced cokes having very similar strengths as measured by standard ASTM stability of JIS DI^{30}_{15} indices, but other coking results could be quite different. In most cases these differences could be related through linear regression.

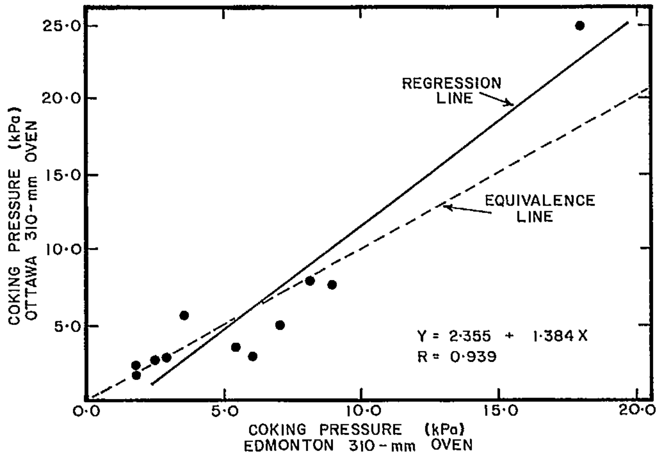

Fig. 10 - Coking pressures from Ottawa 310-mm oven vs Edmonton 310-mm oven

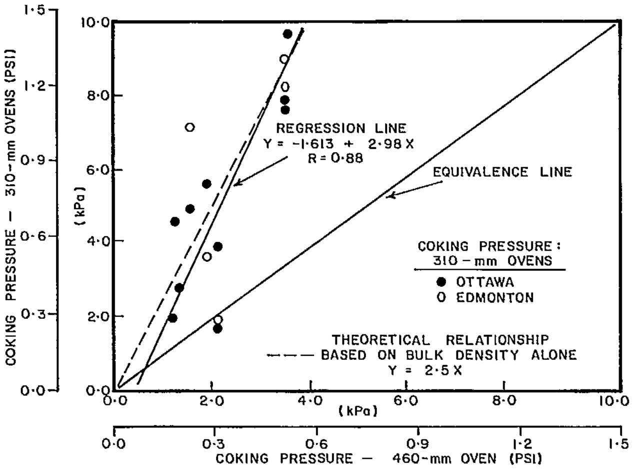

Fig. 11 - Coking pressures from the two 310-mm ovens vs 460-mm oven

The study of the quality of coke from the different movable wall coke ovens operated in early 1977 demonstrated the following:

1. The stabilities of cokes produced in the 460-mm and 310-mm ovens are statistically equal.
2. The hardnesses of cokes produced in the two 310-mm ovens are statistically equal but about 5 - 7 points higher than for the 460-mm oven coke.
3. The apparent specific gravity of cokes produced in the two 310-mm ovens are statistically equal but about 0.04 units greater than for the 460-mm oven coke.
4. The mean sizes of coke produced in the 310-mm ovens appear to be statistically equal but about 5 to 10 mm smaller than that produced in the 460-mm oven.
5. The coke yields from the Edmonton 310-mm oven and the Ottawa 460-mm oven are similar but about 2% lower than from the Ottawa 310-mm oven.

6. Coking pressures found in either of the 310-mm ovens are statistically equal but about 2.5 times greater than from the 460-mm oven.

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APPENDIX A

REGRESSION ANALYSES

Table A1 - Linear regression results for mean coke size (Y = A + BX)

Y oven vs X oven	Ottawa 310-mm (Y) vs Edmonton 310-mm (X)		Edmonton 310-mm (Y) vs 460-mm (X)		460-mm (Y) vs 310-mm (X)			
	(mm)		(mm)		(mm)			
	Y	X	Y	X	Y	X	Y	X
Data	55.4	52.8	52.8	63.2	52.8	57.9	57.7	69.8
	56.4	53.6	53.6	71.9	51.3	62.2	48.7	54.9
	66.0	60.2	60.2	74.2	49.3	58.4	62.9	74.4
	55.6	57.2	54.4	56.4	50.5	59.2	48.0	62.7
	50.5	54.4	59.4	69.9	53.1	61.2	60.7	68.6
	57.7	59.4	53.8	54.9	51.6	58.9	56.4	61.4
	48.7	53.8			55.4	63.2		
	53.6	53.1			56.6	71.8		
	55.1	51.1			57.7	72.4		
	54.1	50.8			66.0	74.2		
$\bar{X}$	54.6		65.1		64.4			
$\bar{Y}$	55.3		55.8		54.9			
N	10		6		16			
A	-24.3		20.5		1.27			
B	1.458		0.5415		0.0832			
R	0.624		0.568		0.859			

Table A2 - Linear regression results for coke yields (Y = A + BX)

Y oven vs X oven	Edmonton 310-mm (Y) vs 460-mm (X)		Ottawa 310-mm (Y) vs Edmonton 310-mm (X)		Ottawa 310-mm (Y) vs 460-mm (X)			
	(%)		(%)		(%)			
	Y	X	Y	X	Y	X	Y	X
Data	66.5	69.4	67.9	66.5	68.8	63.3	72.5	70.2
	69.0	65.9	71.2	69.0	70.6	62.8	70.9	71.9
	69.9	73.9	73.3	69.9	71.6	67.0	71.6	69.0
	71.8	73.2	74.6	71.8	73.0	68.1	73.0	72.7
	72.4	71.1	76.0	72.4	67.9	69.4	70.9	68.6
	74.7	74.1	81.1	77.6	71.2	65.9	72.1	70.1
	76.9	74.7	80.1	78.5	73.3	73.9		
	73.2	72.8	76.6	74.7	74.6	73.2		
	70.8	70.1	78.7	76.9	76.0	71.1		
			75.7	73.2	76.6	74.1		
			70.0	70.8	78.7	74.7		
			70.9	71.4	75.7	72.8		
			69.9	71.9	70.0	70.1		
$\bar{X}$	71.689		72.662		69.85			
$\bar{Y}$	71.689		74.308		72.96			
N	9		13		19			
A	-10.41		-12.56		+10.36			
B	+1.145		1.196		0.890			
R	0.696		0.912		0.705			

Table A3 - Linear regression results for apparent specific gravity of coke (Y = A + BX)

Y oven vs X oven	Ottawa 310-mm (X) vs Edmonton 310-mm (Y)		Ottawa 310-mm (Y) vs 460-mm (X)		Edmonton 310-mm (Y) vs 460-mm (X)	
	Y	X	Y	X	Y	X
	0.86	0.85	0.83	0.80	0.85	0.81
	0.88	0.88	0.86	0.80	0.88	0.82
	0.85	0.89	0.90	0.83	0.89	0.83
	1.00	0.97	0.86	0.82	0.93	0.93
	0.94	0.94	0.86	0.81		
	0.95	0.98	0.88	0.82		
Data	1.00	0.93	0.86	0.86		
			0.85	0.83		
			1.00	0.92		
			0.88	0.84		
$\bar{X}$	0.920		0.8340		0.8475	
$\bar{Y}$	0.926		0.878		0.8875	
N	7		10			
A	-0.2712		-0.140		+0.3707	
B	1.301		1.220		0.610	
R	0.8134		0.877		0.9211	

Table A4 - Linear regression results for coking pressures (Y = A + BX)

Y oven vs X oven	Ottawa 310-mm (Y) vs Edmonton 310-mm (X)		Ottawa 310-mm (Y) vs 460-mm (X)		Edmonton 310-mm (Y) vs 460-mm (X)	
	(kPa)		(kPa)		(kPa)	
	Y	X	Y	X	Y	X
	1.65	1.86	2.76	1.38	1.86	2.14
	4.90	7.10	1.93	1.24	7.10	1.59
	7.58	8.96	4.55	1.31	8.96	3.52
	7.86	8.20	9.65	3.59	8.20	3.52
	3.45	5.52	1.65	2.14	3.59	1.93
Coking	24.8	18.00	4.90	1.59		
pressures	2.90	6.14	7.58	3.52		
	5.58	3.59	7.86	3.52		
	2.83	2.96	5.58	1.93		
	2.69	2.55	3.86	2.14		
	2.28	1.86				
$\bar{X}$	6.07		2.23		2.54	
$\bar{Y}$	6.04		5.03		5.94	
N	11		10		5	
A	-2.36		-1.19		-2.76	
B	1.384		2.784		3.432	
R	0.940		0.827		0.634	

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