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HOT BRIQUETTING STUDY USING WESTERN CANADIAN COAL SAMPLES

W.R. Leeder and M.J. Malette

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W.R. Leeder* and M.J. Malette**

ABSTRACT

Preliminary hot briquetting studies were done by the Canadian Metallurgical Fuel Research Laboratory (CMFRL) with one Fording Coal Limited coking, and three CanPac Minerals Limited (Lethbridge, Brooks and Ardley) non-coking exploration coal samples. The CanPac coal samples, even when cleaned, had ash and alkali metal contents that would be considered too high by steel companies. The "cleaned" Fording exploration sample was moderately caking and can be classified as a high volatile bituminous (hvAb) coal, unlike the low caking medium volatile product presently mined for export. Based on laboratory studies, it was concluded that the hvAb Fording sample would probably be unsatisfactory as the only binder component in hot briquetting as it generally gave hot briquettes of lower strength than those made with a highly caking hvAb binder coal (Devco-26). As well, when the hvAb Fording binder coal was used, the strength of heat-treated hot briquettes did not increase as it did with Devco-26. These results are in agreement with previous work that suggested western Canadian coking coals, because of their poor caking properties, would probably make a poor hot briquette binder if used alone.

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UNE ETUDE DU BRIQUETTAGE A CHAUD DES ECHANTILLONS DE CHARBON DE L'OUEST DU CANADA

par

W.R. Leeder* et M.J. Malette**

RESUME

Le Laboratoire canadien de recherches sur les combustibles métallurgiques (CMFRL) a entrepris des études préliminaires sur le briquettage à chaud d'un échantillon de charbon cokéfiant de Fording Coal Limited et de trois échantillons de charbon non-cokéfiant de CanPac Minerals Limited (Lethbridge, Brooks et Ardley). Même nettoyés, les échantillons prélevés de CanPac avaient une teneur en cendres et alcali trop élevée pour être acceptés par les compagnies d'acier. L'échantillon d'exploration Fording "nettoyé" était légèrement agglutinant et peut donc être classé parmi les charbons (hvAb) bitumineux très volatiles contrairement au produit à faible agglutination et à moyenne volatilité exploité en ce moment pour être exporté. A la suite des études effectuées en laboratoire, on a pu conclure que l'échantillon hvAb Fording s'avérerait insatisfaisant comme seul liant dans le briquettage à chaud car il produit habituellement des briquettes chaudes à plus basse résistance que celles qui sont fabriquées à partir d'un charbon liant hvAb de haute agglutination (Devco-26). De plus, lorsque le charbon liant hvAb Fording était employé, la résistance des briquettes chaudes traitées thermiquement n'avait pas augmenté comme cela était le cas avec Devco-26. Ces résultats confirment les résultats d'études précédentes indiquant que les charbons cokéfiants provenant de l'ouest du Canada seraient un mauvais agent liant pour les briquettes chaudes si employés seuls à cause de leurs faibles propriétés d'agglutination.

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1. INTRODUCTION

Formed coke is a preformed and thermally treated carbonaceous agglomerate* that can be used as a substitute in the iron blast-furnace for conventional metallurgical coke produced in slot-type coke-oven batteries (1,2,3,4,5,6). Interest in formed-coke processes exists because, unlike conventional slot-type coke-oven battery operations, they can utilize non-coking and finely sized coal in a continuous, cleaner and possibly less expensive process (7,8,9,10). Consequently, more than twenty formed-coke processes that use several processing methods have been developed, and at least one commercial-scale plant is in operation (7,11). These processes can be classified into two groups: cold forming with a pitch binder and hot forming with a coking-coal binder. Formed agglomerates are often heat-treated at 400-600°C or carbonized at 900-1000°C to improve their mechanical strength and to reduce volatile matter content.

At present, approximately 90 per cent of the coking coals used to make metallurgical coke in Canada are imported from the United States because they are generally of higher quality and are lower in delivered price than their Canadian counterparts. Formed-coke processes would allow Canadian coke-makers to utilize domestic coals that otherwise could not be used or would cause severe operating problems in conventional coke-making. Such an objective is also consistent with the present policy of achieving Canadian energy self-reliance (12,13).

The Canada Centre for Mineral and Energy Technology (CANMET), formerly the Mines Branch, Department of Energy, Mines and Resources, has been interested in such processes for some time. Early studies involving pitch-bound briquettes culminated in the development of a commercial process in collaboration with Canmore Mines Limited. Current CANMET studies have focused on hot briquetting (14,15,16) but recent worldwide advances in pitch-binder processes (17) and the desire to achieve Canadian energy self-sufficiency have again made pitch-binder formed-coke processes of interest to CANMET.

This report presents the results of a short study made by the Canadian Metallurgical Fuel Research Laboratory (CMFRL) to investigate the possibility of using several western Canadian coals in hot briquetting.

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*pellet (spherical agglomerate), extrusion, briquette, etc.

One exploration coal sample from Fording Coal Limited and three from CanPac Minerals Limited, identified as Lethbridge, Brooks and Ardley, were used. The samples were analyzed chemically and found to be high in ash. They were cleaned using a sink-float method and the float portion or "clean" coal was re-analyzed before being used in the hot briquette tests. The cleaned Fording sample that floated at a specific gravity of 1.30 could be classified as a coking high volatile A bituminous (hvAb) coal, unlike the standard mvb coking coal presently produced. The cleaned CanPac coals that were floated at a specific gravity of 1.40 were non-coking and could be classified as high volatile B or C bituminous (hvBb or hvCb) coals.

The hot briquetting tests consisted of three short laboratory studies because only limited quantities of cleaned coals were available. The studies were as follows:

1. The cleaned Fording exploration sample, a moderately caking hvAb coking coal, was hot briquetted with chars made from the CanPac non-coking coals. The chars were produced by heating the coal to 750°C in the absence of air.
2. A sample of Cape Breton Development Corporation Devco-26 coal, a highly caking hvAb coking coal that had previously been shown to be an excellent hot briquetting binder coal (18,19,20,21), was hot briquetted with the CanPac coal chars. The results provided a reference with which the Fording tests were compared.
3. The cleaned Fording exploration coal sample was also hot briquetted with the cleaned Brooks CanPac coal (hvCb). This short test series represented a departure from the usual hot briquetting method using char.

Heat-treating of the hot briquettes to try to improve their mechanical strength was carried out when sufficient coal and char were available.

A discussion of the results of these tests follows. Although the tests were not comprehensive because of the shortage of cleaned coal, they reflect the relative performance of the Fording as compared with the Devco coal.

2. EXPERIMENTAL

2.1 Materials and Preparation

2.1.1 Coals

The ash contents of the "as-received" coal samples, as listed in Table 1, were too high to be acceptable for metallurgical purposes. Therefore the coal samples were cleaned by sink-float beneficiation: in this process the coal is well mixed in a washing medium that consists of a Varsol/Perlux solution, the composition of which has been adjusted to the desired specific gravity. It is left for about 10 minutes to allow the coal to separate, then the coal float-fraction is removed with a scoop having a fine mesh bottom to allow the solvent to drain off. The coal sink-fraction is filtered from the remaining solvent. Both fractions are then spread thinly in trays and are air-dried. Chemical and rheological analyses were made on samples of the Fording and CanPac coals after they had been cleaned by this method. The results of these analyses and the specific gravity yields of the coal-cleaning procedure appear in Table 2.

2.1.2 Char Preparation

Char was prepared from the three CanPac samples, all of which were found to be non-coking. This was done by placing a coal sample in a steel box and heating to 750°C in the electrically treated CMFRL slot-type coke oven designed to be charged with about 30 lb of coal. The char yields and the ash and sulphur contents appear in Table 3.

2.1.3 Sizing

The coal and char samples were crushed to minus 30 mesh (Canadian) with a laboratory hammer mill. The size analysis of about 10 grams of each sample was determined with an Allen-Bradley Sonic Sifter, the results of which appear in Figure 1.

2.2 Hot Briquetting Procedure

CANMET is developing laboratory and pilot development unit facilities with the objective of providing means to assess the formed-coking potential of Canadian coals by either hot briquetting or pitch-binding processes. The principal efforts at CANMET to date have gone into developing laboratory-scale manual batch-operated and automatic continuously-operating hot briquetting facilities, although only the manual method was available when this study was carried out.

The manual facility consists of a muffle furnace to dry and pre-heat a blend of the char and binder coal, a fluidized bed unit to heat the blend into the plastic range of the binder coal and a heated die in which the briquette is formed. Typically, 13 g of char and 7 g of binder coal are mixed in a beaker and placed in a muffle furnace at 250°C for about 30 minutes. Tests have shown that oxidation of the binder coal during drying in air is minimal because briquette strength decreased only slightly compared with drying in nitrogen (20). The dried, preheated blend is poured into an electrically heated fluidization unit (5 in. diam) which has been pre-heated to 450-515°C, using nitrogen as the fluidizing gas. After being heated for a predetermined length of time in the fluidizing unit, the mixture is transferred manually to a heated (350-410°C) tool-steel cylindrical die (1 in.^{2}) and compacted to 3000 psi using a manually-operated press. The die has been constructed so that the briquette is pushed out of the bottom and removed from a slot by hand.

2.3 Hot Briquette Curing

The hot briquettes were heat-treated for 4 to 5 hours at 550°C in a specially constructed 36-in. high by 8-in. diameter fluidized sand bed. The bed is heated by external electrical heaters and fluidized with nitrogen. Consistent and satisfactory heat-treatment results are obtained by lowering a cubic (5 in. on a side) wire mesh cage having 0.5-in. holes containing 5 to 8 briquettes into the hot fluidized sand and then only fluidizing the sand for 15 seconds every 3 minutes. Intermittent fluidization prevents unnecessary agitation of the briquettes but maintains the temperature of the sand bed.

2.4 Hot Briquette Evaluation

Blast-furnace coke must satisfy both chemical (sulphur, ash, etc.) and mechanical specifications. While chemical constraints can normally be satisfied by selecting and blending the coals to be coked, the most important mechanical parameter, referred to in North America as "coke stability", generally cannot be reliably predicted from coal-blend properties. Normally at least 500 lb of the coal is carbonized and 22 lb of the resulting coke evaluated using the ASTM Coke Tumble Test (22).

A coke stability of 55 is accepted by at least one steel company as the desirable strength for conventional blast-furnace coke (9). Formed coke must meet similar quality standards if it is to be used as a conventional coke substitute. However, laboratory formed-coke studies normally do not produce enough briquettes to carry out the ASTM Coke Tumble Test and an alternative method must be used, such as finding the average crushing strength of several briquettes. In this paper, crushing strengths and an index derived by tumbling samples in a small laboratory tumbler will be used to evaluate the mechanical quality of the hot and/or heat-treated hot briquettes.

2.4.1 Crushing Strength

CANMET hot briquette crushing strengths were determined between parallel plates closing at a rate of approximately 0.05 in./min. Usually two or three hot briquettes were crushed and the average value was calculated. Normally, if the determined values were more than ± 10 per cent from the average, additional hot briquettes would be prepared and crushed. However, because of the limited quantity of char for this study, no further hot briquettes could be made even if outlier crushing strengths were obtained.

2.4.2 Tumble Test

The small tumble test consisted of tumbling five briquettes at 80 rpm in a 4-in. diameter steel drum equipped with three equispaced 3/4-in. lifters (90° to shell). The breakdown of the briquettes was measured every 5 minutes during 30 minutes of tumbling. The percentages by weight passing 10-mesh (Canadian) and 1/2-in. sieves were determined. The 1/2-in. sieve was used to indicate whether a weaker briquette might have broken and thereby biased the results. The percentage by weight that passed through the 10-mesh sieve after 20 minutes of tumbling was used as the abradability index.

2.5 Experimental Design

Owing to the limited quantities of char available, it was decided to make only hot and not pitch-bound briquettes. After preliminary hot-briquetting tests were made to determine the influence of several experimental variables, the following variable ranges were investigated to try to optimize the quality of the manually-produced Fording hot-briquettes:

(a) three concentrations of Fording binder coal - 25, 35 and 45 per cent;

(b) three pre-set fluid-bed-unit temperatures - 450, 470 and 515°C;

(c) three coal/char retention times in the fluid bed unit- 1, 2 and 5 minutes.

The experimental variables (b) and (c) can significantly change the plastic properties of the binder coal that holds the hot briquette together; the Brooks char was chosen to optimize these variables since there was much more cleaned Brooks coal available (3450 g) than either Lethbridge (1384 g) or Ardley (1230 g). The cleaned Brooks coal was hot briquetted with the Fording binder coal.

Devco-26 coal, the analysis of which appears in Table 4, was also used as a binder coal in limited tests to provide a reference against which the Fording results could be compared. Devco-26 had been shown to be an acceptable hot briquetting binder in several CMFRL studies and by Bergbau-Forschung (BBF) who have developed a hot briquetting process to semi-commercial scale (16,18,19,20,21).

3. RESULTS AND DISCUSSION

Results of Fording/CanPac laboratory hot briquetting tests cannot be directly compared with literature results that have been obtained from pilot-scale processes. For example, BBF laboratory hot briquettes are generally only half as strong as those produced in their semi-commercial plants. However, differences between the results of test series carried out in the same laboratory or pilot facilities are considered significant (21). Consequently, in this study the absolute crushing strengths of the Fording hot briquettes will be considered to be less significant than comparing such strengths with briquettes produced from Devco-26.

3.1 Coal/Char Hot Briquettes

Initial tests were carried out to find the experimental conditions that gave hot briquettes and their heat-treated counterparts with the highest crushing strength. The influence of the temperature of the coal/Brooks-char blends in the preheating fluid-bed unit and the blend retention times in the unit were studied with the results shown in Table 5.

The fluid-bed-unit experimental conditions that appeared to yield the best Brooks-char briquettes were used to prepare hot and heat-treated briquettes with the Ardley and Lethbridge chars. These conditions were a 1-minute retention time in a fluid-bed unit at 515^{o}C with 45 per cent Fording coal, and 5 minutes at 470^{o}C for the Devco-26 coal. Sufficient hot briquettes were prepared to heat-treat several to assess the results of crushing and tumbler tests of the heat-treated hot briquettes. The results for the coal/char combinations appear in Table 6.

The results in Table 6 indicate that the Devco-26/char briquettes generally had much higher crushing strengths than the Fording/char briquettes. Heat-treating did not improve the Fording/char briquettes but improved the Devco-26/char hot briquettes in two of the three cases. The tumble-test abradability-index results are unclear, partly because of the missing Devco-26/Brooks-char results. In the case of the Ardley char, the Devco-26 heat-treated hot briquettes had clearly superior abradability characteristics compared with the Fording briquettes, but with the Lethbridge char both binder-coal combinations had similar indices. The Devco-26/Lethbridge-char results were felt to be amomalous particularly since heat-treated hot briquettes made with Devco-26 had increased strengths in all previous studies (16,19). It was concluded that this Fording coal sample would probably be unacceptable as the sole binder coal in a hot-briquetting process, although tar or pitch additions might be used to help such poor binder coals (21).

Recent CMFRL studies suggested that hot-briquetting binder coals should have a total dilatation (includes contraction) of 100 to 150 per cent to yield acceptable hot briquettes that have no other binders (16,21). The total dilatation of the hvAb Fording coal sample of 73 per cent (Table 2), indicates that this coal is not suitable as the sole binder in hot briquettes, and this conclusion is in agreement with this study. The Devco-26 coal, which had previously been shown to be an excellent hot briquetting binder coal (16,18,19), had a total dilatation of 268 per cent (Table 4).

3.2 Coal/Coal Hot Briquettes

Normal hot briquetting processes utilize coal char as the major component of the briquette. This prevents excessive shrinkage during heat-treating that would fissure and weaken the briquettes. However, tests to make hot briquettes from 100 per cent coal have been attempted with the objectives of removing the charring step from the process and/or using non-caking coals (23). Hot-briquetting tests were carried out with the Fording and Brooks coals to determine if such a combination would yield acceptable hot or heat-treated briquettes.

To obtain the best briquettes, the influence of Fording coal concentration, the fluid-bed-unit temperature, and the retention time of the Fording/Brooks blends in the unit on the resulting hot-briquette crushing strengths were studied with the results which appear in Table 7. After heat-treatment, the crushing strengths did not improve but in fact dropped dramatically in most cases. Many heat-treated briquettes fell apart or were disintegrating when they were removed from the fluidized sand-bed heat-treating unit. Consequently, this Fording-coal/Brooks-coal combination may be considered unacceptable.

3.3 CanPac Coal Char Use in Formed Coke

Chars are used in both coal and pitch-binder types of formed-coke processes. Although no pitch-bound briquettes were made in this study, several conclusions regarding formed-coke processes requiring char are suggested from the chemical analyses of CanPac coals and the behaviour of their chars in hot briquetting methods.

Chars must meet both chemical (ash, sulphur, etc.) and mechanical specifications to be acceptable for formed coke destined for the iron blast furnace. Since the crushing strengths of hot briquettes made in this study were comparable with those found in previous work using metallurgical-coke fines, and since similar coal chars did produce acceptable hot briquettes in the BBF study, it was concluded that the chars have adequate mechanical properties to be used in those formed-coke processes requiring char.

Chemically the coals were less acceptable. The ash contents of "as received" CanPac coals (Table 1) were too high at 11 to 33 per cent for blast-furnace use. Cleaning brought the ash levels of the coal down to about 8 per cent or less (Table 2). Even so, the ash levels of the cleaned coal chars were undesirably high at about 10 to 12 per cent (Table 3), because maximum permissible coke ash levels of about 8 per cent have been suggested (24)

The alkali (sodium oxide plus potassium oxide) and phosphorus levels in the cleaned coal require careful consideration as well, as they can cause severe operating problems in the blast furnace (9). The Steel Company of Canada has recommended maximum values of 0.20 per cent for the alkali level and 0.12 per cent for the phosphorus level in blast-furnace coke (9). The projected alkali and phosphorus levels that would be found if the CanPac cleaned coals were carbonized, were calculated and appear in Table 8. The results indicate that while the projected phosphorus contents of all samples and the alkali content of Fording coke are acceptable, the alkali contents of cokes from the CanPac coal samples are too high and would require further beneficiation. Coke from the Ardley sample containing 0.28 per cent alkali was fairly close to the maximum set by Stelco (0.20). Although the use of charred CanPac coals in formed-coke processes could present both an ash and alkali problem to iron blast-furnace operators, even if the coals were cleaned to the 8 per cent level used in this report, a recently suggested selective coal-cleaning scheme might rectify the problem (24).

CONCLUSIONS

The following conclusions were drawn from the test results:

1. The cleaned Fording exploration coal sample, a moderately caking hvAb coking coal unlike the currently mined low caking mvb export coal, would not be recommended as the only hot briquette binder with either chars or the CanPac Brooks non-coking coal because of the following test observations:

   (a) the Fording hot briquettes generally had lower crushing strengths than Devco-26 hot briquettes;

   (b) heat-treatment did not improve hot briquette crushing strengths with the Fording briquettes as it did with Devco-26 briquettes.

   The Fording coal was an exploration sample and may therefore not be representative of other western hvAb coking coals. However, this result is in agreement with previous laboratory-scale work that found coking coals with poor caking properties - a characteristic common for western Canadian coking coals - would probably be unsatisfactory as the only binder component in hot briquettes.

2. The use of Ardley, Brooks or Lethbridge non-coking coal chars in commercial formed coke destined for the blast furnace may require special attention. For example, although the samples used in this study were cleaned to 8 per cent ash (Table 2), as coke they would have ash and alkali-metal contents that are considered undesirably high for iron blast-furnaces. However, in such cases a recent selective coal-cleaning scheme could help rectify this problem.

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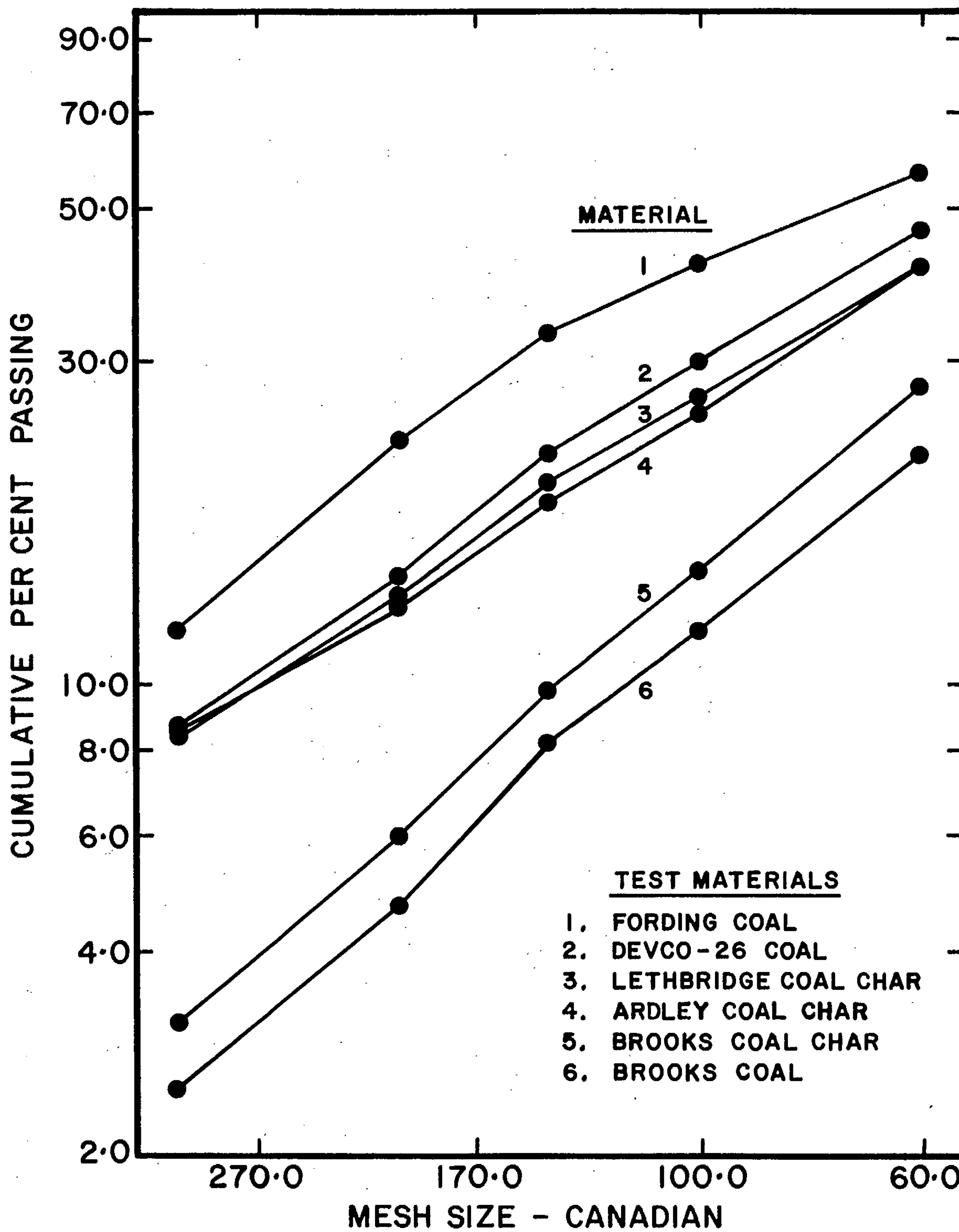

FIGURE 1. Size Analyses of the Hot Briquette Test Materials

TABLE I

Analyses of the "As-Received" Exploration Coal Samples

		Fording	CanPac Lethbridge	CanPac Brooks	CanPac Ardley
Proximate analysis (dry basis)[a]					
Ash	%	15.6	29.0	11.5	32.8
Volatile matter	%	27.6	31.4	38.1	27.5
Fixed carbon	%	56.8	39.6	50.4	39.7
Free Swelling Index[b]					
F.S.I.		6½	-	-	-
Grindability[c]					
Hardgrove index		-	58	32	-
Fusibility of ash[d]					
Initial deformation temp	°F	2490	1980	2060	2370
Softening temp, spherical	°F	2700+	2500	2280	2580
Softening temp, hemispherical	°F	2700+	2610	2430	2700+
Fluid temp	°F	2700+	2700+	2700+	2700+

(a) ASTM Standards - Part 26 (1974), D3172-73

(b) Ibid, D 720-67 (1972)

(c) Ibid, D 409-71

(d) Ibid, D 1857-68 (1974)

TABLE 2

Cleaned Coal Yields and Analyses

		Fording	CanPac		
			Lethbridge	Brooks	Ardley
Cleaner Coal					
Floated at specific gravity of		1.30	1.40	1.40	1.40
Recovery (overall)	%	55.5	55.4	79.9	21.7
Float weight recovered	g	2014	1384	3450	1230
Proximate analysis (dry basis)					
Ash	%	2.8	7.7	8.1	7.9
Volatile matter	%	34.1	37.2	38.7	36.8
Fixed carbon	%	63.1	55.1	53.2	55.3
Gross calorific value (dry basis)[(a)]	Btu/lb	14,910	12,400	11,740	11,650
Ultimate analysis (dry basis) [(b)]					
Carbon	%	84.4	71.0	68.5	68.7
Hydrogen	%	5.3	5.0	4.9	4.5
Sulphur	%	0.34	0.56	0.91	0.75
Nitrogen	%	1.6	1.8	1.6	1.0
Ash	%	2.8	7.7	8.1	7.9
Oxygen (by difference)	%	5.6	13.9	16.0	17.1
Ash analysis (dry basis) [(c)]					
SiO_2	%	60.9	51.8	39.1	43.0
Al_2O_3	%	29.5	27.1	25.1	15.0
Fe_2O_3	%	2.5	6.0	5.2	2.6
TiO_2	%	1.9	0.7	0.7	1.3
P_2O_5	%	0.8	1.3	2.3	0.3
CaO	%	1.6	7.3	12.5	22.4
MgO	%	0.5	1.8	2.1	2.2
SO_3	%	8.4	3.4	8.5	9.9
Na_2O	%	0.3	2.1	6.1	2.0
K_2O	%	1.3	0.8	0.4	0.3

TABLE 2 (continued)

		Fording	CanPac		
			Lethbridge	Brooks	Ardley
Free Swelling Index					
F.S.I.		7½	-	-	-
Fusibility of ash					
Initial deformation temp	°F	2680	1950	1950	2060
Softening temp, spherical	°F	2700	2300	2050	2150
Softening temp, hemispherical	°F	2700	2400	2140	2210
Fluid temp		2700	2700	2380	2230
Gieseler plasticity (d)					
Start	°C	409	-	-	-
Fusion temp	°C	424	-	-	-
Max fluidity temp	°C	445	-	-	-
Final fluid temp	°C	469	-	-	-
Solidation temp	°C	475	-	-	-
Melting range	°C	60	-	-	-
Max fluidity	dd/min*	155	-	-	-
Torque	g in.	40	-	-	-
Ruhr dilatation (e)		370	-	-	-
T_i - softening temp	°C	370	-	-	-
T_{ii} - max contraction temp	°C	436	-	-	-
T_{iii} - max dilatation temp	°C	469	-	-	-
Contraction	%	32	-	-	-
Dilatation	%	41	-	-	-

(a) ASTM Standards - Part 26 (1974), D3286-73
(b) Ibid, D3176-74
(c) Ibid, D2795-69
(d) Ibid, D2639-74
(e) German Industrial Specification No. DIN 51739/March 1951

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*dd/min - dial divisions per minute

TABLE 3

Yields and Analyses of the CANPAC Cleaned Coal Chars

		Coal Used to Produce Char		
		Lethbridge	Brooks	Ardley
Proximate analysis (dry basis)				
Ash	%	10.5	12.6	11.6
Volatile matter	%	5.0	7.8	4.4
Fixed carbon	%	84.6	79.6	84.0
Ultimate analysis (dry basis)				
Sulphur	%	0.48	0.48	0.46
Char yield				
% by wt of coal		67.7	-	67.5
wt of char	g	937	-	840

TABLE 4

Analyses of Devco-26 Coal

Test		Devco-26
Proximate analysis (dry basis)		
Ash	%	6.1
Volatile matter	%	35.6
Fixed carbon	%	58.3
Gross calorific value (dry basis)		
	Btu/lb	14,470
Ultimate analysis (dry basis)		
Carbon	%	80.6
Hydrogen	%	5.4
Sulphur	%	1.65
Nitrogen	%	1.8
Ash	%	6.1
Oxygen (by difference)	%	4.4
Grindability		
Hardgrove index		62
Free Swelling Index		
F.S.I.		7½
Gieseler plasticity		
Start	°C	390
Fusion temp	°C	401
Max fluid temp	°C	435
Final fluid temp	°C	472
Solidification temp	°C	478
Melting range	°C	82
Max fluidity	dd/min	25,100
Torque	g in.	40
Dilatation		
T_i - softening temp	°C	343
T_{ii} - max contraction temp	°C	407
T_{iii} - max dilatation temp	°C	463
Contraction		28
Dilatation		240

TABLE 5

Influence of Fluid Bed Unit Temperature and Retention Time in the Unit on Hot and Heat-treated Hot Briquette Crushing Strengths for Various Coal/Brooks-Char Combinations

Coal in hot briquette	Fluid bed unit temp (°C)	Retention time in fluid bed unit (min)					
		1		2		5	
		Crushing strength of hot and heat-treated hot briquettes (psi)					
		Hot	Hot-treated	Hot	Hot-treated	Hot	Hot-treated
45% Fording	515	483	575	168	350	-	-
	470	200	470	455	457	458	465
	450	171	60	138	70	306	407
35% Fording	515	508	368	146	312		
30% Devco-26	470	341	677	318	562	478	1057

TABLE 6

Crushing Strengths and Abradability Indices of Hot and Heat-Treated Hot Briquettes made from Various Coal/Char Combinations

Combination used in hot briquettes		Crushing strength of hot and heat-treated hot briquettes (psi)		Abradability index for heat-treated hot briquettes (%)
Char	Coal*	Hot	Hot-treated	
Ardley	(a) Fording	242	196	26.7
	(b) Devco-26	455	1066	13
Brooks	(a) Fording	483	575	49.5
	(b) Devoc-26	478	1057	-
Lethbridge	(a) Fording	207	140	27.0
	(b) Devco-26	912	763	34

*Experimental conditions:

(a) 45 per cent Fording Coal with char - retained in 515°C fluid bed unit for 1 minute.

(b) 30 per cent Devco-26 coal with char - retained in 470°C fluid bed unit for 5 mintues.

TABLE 7

Influence of Fording Binder-coal Concentration, Fluid Bed Unit Temperature and Retention Time in the Unit on Hot and Heat-treated Hot Briquette Crushing Strengths for Various Fording-Coal/Brooks-Char Combinations

Coal in hot briquette	Fluid bed unit temp (°C)	Retention time in fluid bed unit (min)					
		1		2		5	
		Crushing strength of hot and heat-treated hot briquettes (psi)					
		Hot	Hot-treated	Hot	Hot-treated	Hot	Hot-treated
45% Fording	515	353	212	400	140	197	-
	470	630	357	525	172	430	322
	450	-	-	270	246	-	-
35% Fording	470	200	-	670	40	250	-
	450	-	-	100	-	-	-
25% Fording	470	65	-	325	-	215	-

TABLE 8

Calculated Alkali and Phosphorus Contents of Coke if CanPac Cleaned Coals were Carbonized

Coal Source	Calculated content of coke (%)	
	Alkali [a]	Phosphorus [b]
Conventional blast furnace coke oven blend [c]	max 0.20	max 0.12
Fording [d]	0.06(0.18)	0.015(0.04)
Ardley	0.28	0.02
Brooks	0.86	0.13
Lethbridge	0.35	0.06

(a) Sodium oxide plus potassium oxide.
(b) Elemental phosphorus.
(c) See Reference 9.
(d) Cleaned to unreasonably low levels. The normal levels, that would be expected to be about 3 times as high, are shown in brackets.

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