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CARBONIZATION OF CANMORE (ALTA.) COAL BRIQUETTES IN A VERTICAL SHAFT FURNACE

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SUMMARY

A vertical shaft furnace was constructed at the Mines Branch to carbonize, on a continuous basis, briquettes pressed from several blends of coal fines submitted by The Canmore Mines Limited, Canmore, Alberta. The results of the experimental program indicate that this method is feasible to prepare carbonized briquettes for use as a reductant in the phosphorus industry. The volatile matter contents and the compressive strengths of the briquettes carbonized were satisfactory, but stability and abradibility results were somewhat low. These latter properties could likely be improved by modifying the coal blends used.

A larger vertical shaft furnace, capable of producing two tons of carbonized briquettes per hour, has been constructed by The Canmore Mines Limited at the mine at Canmore.

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INTRODUCTION

This report describes an experimental program carried out to convert briquetted coal fines from The Canmore Mines Limited, Canmore, Alberta, into carbonized briquettes suitable for use as a reductant in the phosphorus industry. Coke in small sizes is usually used for this purpose in electric furnaces of industry. The plants operating in the northwestern states of the United States are supplied with coke mostly from the eastern United States--at considerable cost, due to the long rail haul. Two plants in the southern part of Idaho alone consume 150,000 tons of coke annually, so this large potential market is attractive to the management of Canmore Mines Limited. The Victor Chemical Company, near Butte, Montana, has expressed interest in the carbonized briquette, and, since the freight rate to this plant is $1.20 per ton less than to the other phosphorus producers, The Canmore Mines Limited is endeavouring to supply this company with a 500-ton sample of carbonized briquettes for a large-scale test in the near future.

Engineers of The Canmore Mines Limited have been working for more than a year on the problem of producing this suitable briquette. Experimental work was first carried out in a beehive-type oven, and later in a sole-heated oven, each having a capacity of about 100 pounds.

The experimental work in this field is hampered by rather ill-defined specifications. Apparently, only a full-scale test can determine the suitability of the Canmore briquettes for this purpose.

The size of the briquettes should be about plus one quarter inch and minus one inch, with a low volatile matter content. On different occasions, two and four percent volatile matter contents were quoted as satisfactory.

There is reason to believe that the National Research Institute of Laramie, Wyoming, is also conducting research with a view to producing, from subbituminous Wyoming coal, a low volatile reductant for the phosphorus industry.(1)

PRELIMINARY WORK CARRIED OUT AT CANMORE MINES LIMITED

The original work in the beehive and sole-heated ovens indicated that mixtures of coking and non-coking coals might be carbonized to give a suitable product but the proportion of coking coal in the blend would be excessive. As a next step, coking and non-coking coals were briquetted together before carbonizing. Table 1 gives the mixes that were prepared.

TABLE 1

Coal Blends Briquetted and Carbonized at Canmore Mines Limited

Mix 1	Mix 2	Mix 3	Mix 4
100% Canmore #4 Slack	90% Canmore #4 Slack 10% Coleman Slack	80% Canmore #4 Slack 20% Coleman Slack	100% Canmore #4 Slack

Note: 4% asphalt binder was used as binder in Mixes 1, 2 and 3 and coal tar pitch in Mix 4.

Carbonization treatment: 1560°F for 2 to 4 hr.

Mix 1 briquettes tended to split into four pieces unless the temperature was raised gradually. Mix 2 briquettes were somewhat better, and the coal tar binder (Mix 4) seemed to give better results than did asphalt. Mix 3 briquettes seemed to give the best results. The yields obtained were about 75%, although theoretically 80% or better could be expected. Yields below 75% are considered to be uneconomic.

Samples of the carbonized briquettes were sent to the phosphorus plant of the Wesvaco Chemical Corporation, in Idaho, which reported the following assessment:

TABLE 2

Wesvaco Comparison of Canmore Briquettes with Coke

	Normal Coke Used	Canmore Carbonized Briquettes
Volatile matter, %	2	3 to 7
Ash, %	17	7 to 10
Strength Index*	86 to 91	70 to 84

* The strength index was obtained from a tumbler test similar to the ASTM Standard Tumbler Test for Coal (D441-45).

The Wesvaco Chemical Corporation also indicated that it was interested in other properties of the briquettes, such as porosity, reactivity, electrical resistivity, and resistance to thermal shock, although the minimum requirements for these properties were not specified. This company also stated that a large-scale test was necessary to assess the suitability of the briquettes.

PRELIMINARY WORK CARRIED OUT AT THE MINES BRANCH, OTTAWA

The first series of experiments were devolatilization tests carried out on buckwheat size coal in a rotary kiln. Repeated tests showed that it was possible to reduce the volatile matter of Cairnes Creek coal from 11 to 3 percent at a kiln temperature of 800°C and a retention time of 30 minutes. Additional tests were carried out, blending "Marker" (Coking) and No. 4 Seam (Non-coking) fines, on the assumption that agglomeration would take place. In this work, the proportion of "Marker" coal was limited to 25% of the blend, because of its high swelling properties. Although there was a limited amount of agglomeration on kiln processing this blend, the char was very friable and was not considered an acceptable product. This work was reported by W.J. Montgomery of the Fuels Division (2).

To better assess the potential application of the rotary kiln to this carbonization, five blends of Canmore-made briquettes were carbonized in the Salem-T-Grid rotating furnace of the Extraction Metallurgy Division of the Mines Branch. Other briquettes were carbonized in the Bethlehem test oven of the Fuels Division. Considerable degradation was found. This work was described by J.C. Botham,(3). Two other studies completed the Fuels Division's preliminary work on the carbonization program, one by J.G. Jorgensen (4) dealing with the relative stability of small size coal from two seams, and the other by J.C. Botham (5) dealing with possible metallurgical applications of Canmore coals.

SUMMARY OF PREVIOUS WORK

This work was summarized on April 17, 1959, at a meeting attended by Mr. W. Wilson, General Manager of The Canmore Mines Limited, and officers of the Mines Branch. Since there was excess production of fines at the mine, and the market for buckwheat coal was adequate, no further studies of simple devolatilization were to be undertaken. It was considered urgent to supply a large size sample of about 500 tons to the phosphorus industry for test purposes, and various methods for producing it were considered. Briquetting seemed to be essential if the expense of constructing a coke oven were to be avoided. At this and previous meeting with officials of the company, three carbonization techniques were discussed: rotary kiln, travelling grate, and vertical shaft. Previous work had indicated that rotary kilns caused too much break-down of the briquettes. While some American companies were using travelling-grate methods, that technique would entail a heavy capital investment. One of the authors (J.H. Walsh) had discussed the problem with some French coke-making authorities, including M.P. Foch, technical director of the Cherchar-Marienau experimental station, and M.C. Jully, chief engineer of the Houlieres de Lorrain, and most agreed that a shaft type process might work. A furnace designed by Brennstoff-Technique and operated at Marienau during World War II had been inspected, and the engineers of the plant had indicated that a vertical shaft briquette carbonization had operated satisfactorily. It was decided, after much discussion, that a shaft-type process had the best promise, both from the point of view of making the 500-ton sample and as a production tool. Accordingly, the erection of a small test unit had been begun at the Fuels Division in March, 1959.

DESCRIPTION OF THE VERTICAL SHAFT TEST UNIT

Construction of the test unit was completed on April 21, 1959. This unit consists of a vertical shaft 10 in. square and 11 ft long, the lower portion of the shaft being 1/8-in.-thick stainless steel plate and the remainder being 1/8-in.-thick mild steel plate. This shaft was suspended over a water-filled drum which rotated with a clearance between the lower end of the shaft and the drum face. The discharge clearance was adjusted to allow approximately 100 lb of briquettes to be discharged from the column per hour when the drum was rotated at 1 rpm. This drive speed was obtained from an electric motor through a reduction gear and a ratchet-and-pawl on a large gear attached to the same shaft as the water-filled drum.

Heat for the process was supplied by four Globar resistance heating elements located in the corners of a square chamber built around the lower stainless section of the column. The brickwork which forms the outer wall of this square chamber was tapered in at the top so that it made contact with the mild steel section of the column to the top of the unit. In this way, heat was applied only to the lower stainless steel section of the column. The temperature in the heating chamber was registered on an indicating potentiometer and was manually controlled to within 50°F of the desired

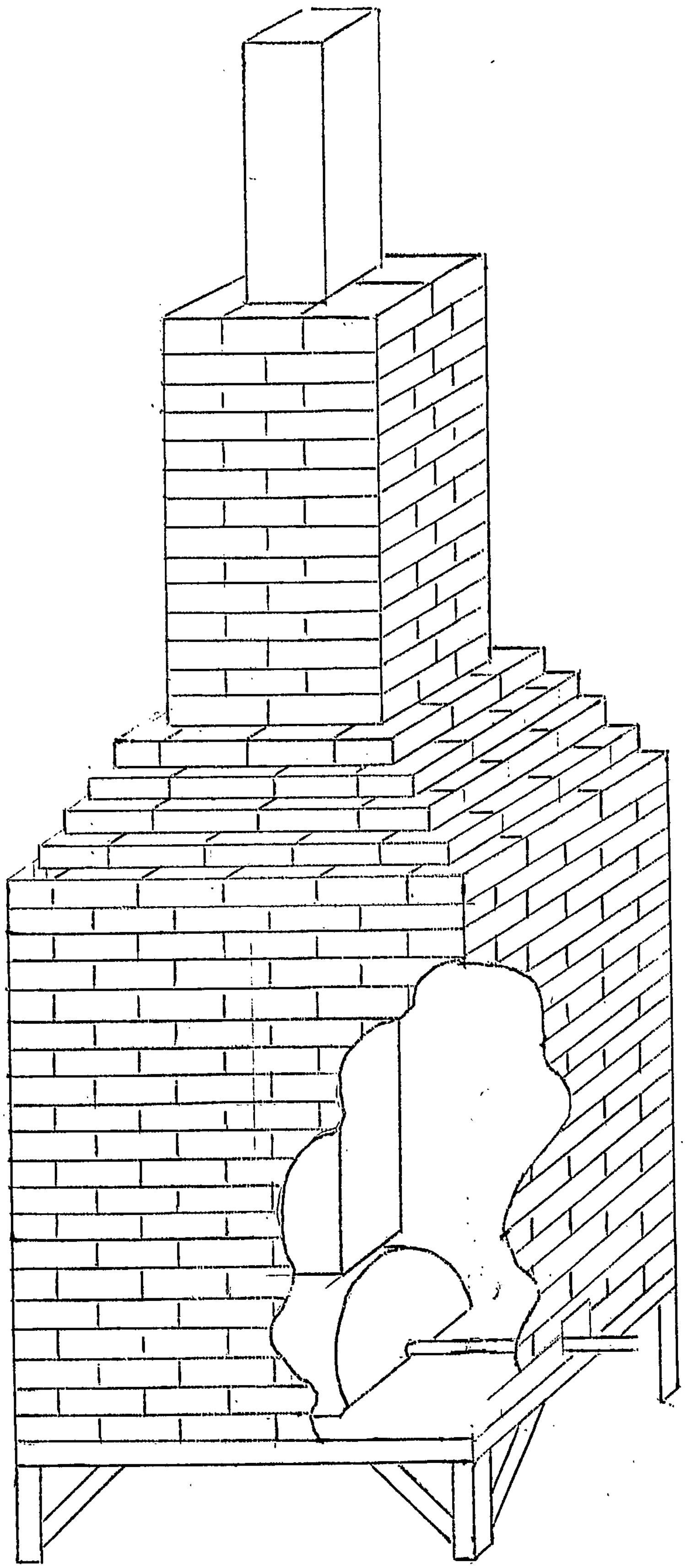

Figure 1 - Sketch of vertical shaft furnace

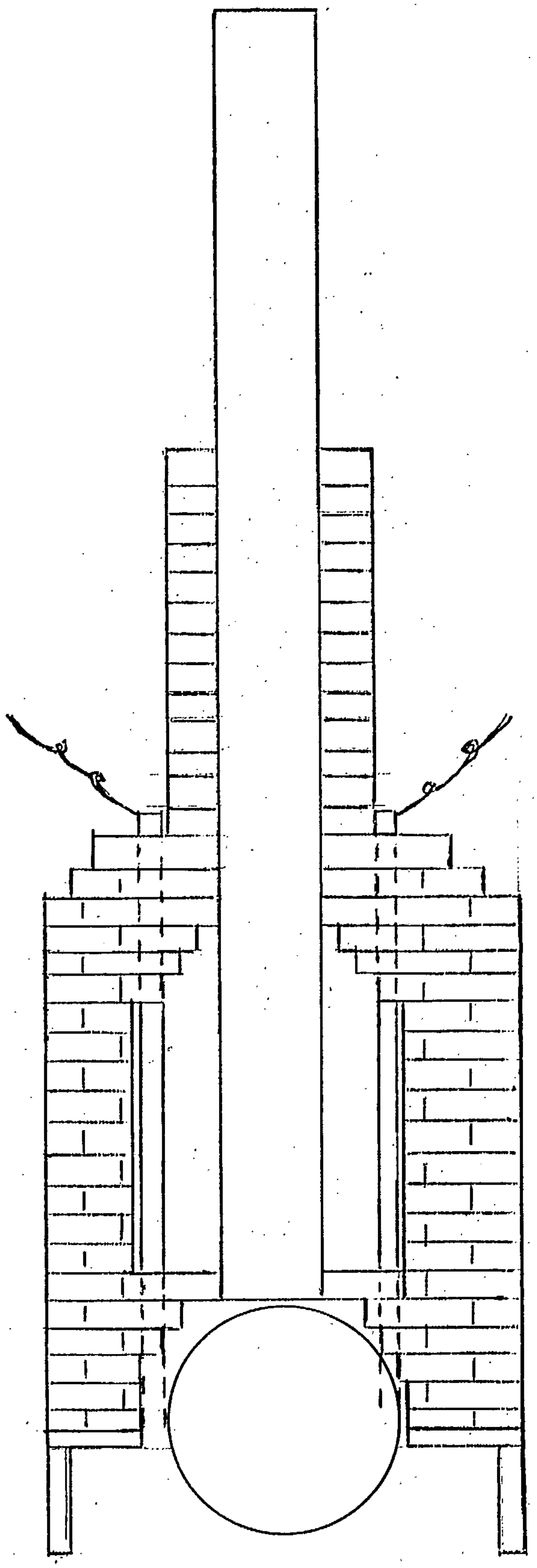

Figure 2 - Side view of vertical shaft furnace

temperature. Means were provided for feeding raw briquettes in the top of the column and for quenching as they were discharged. The gases escaped through the top of the column, preheating the briquettes as they rose (see Figures 1 and 2).

OPERATING PROCEDURE

Preliminary test runs, using briquettes rolled at the Mines Branch, indicated that an operating temperature of 1500°F was not high enough to produce a strong product. There was a marked tendency for the briquettes to fuse together and hang up in the column at this temperature. Further test runs at 1800°F produced a much more satisfactory product and eliminated the tendency for the charge to fuse together and hang up in the column. This higher temperature was therefore used throughout subsequent test runs.

Preliminary test runs also indicated the need for a starting plug of coke in the hot zone in the bottom of the shaft. The use of this initial plug allowed the remainder of the charge in the column to be subjected to a normal preheat period before it entered the hot zone.

The operating procedure adopted after the preliminary runs was therefore to fill the hot zone of the shaft with coke and heat the unit up to operating temperature, i.e. 1800°F. The remaining space in the shaft was then filled with the briquettes under test and the unit was kept at operating temperature for one hour before starting the discharge mechanism. Operation under these test conditions was continued until at least 500 lb of the briquettes were processed. The carbonized briquettes were quenched with water when discharged from the column.

DISCUSSION OF RESULTS

The results from this series of tests are listed in Tables 3, 4, and 5. Table 3 lists the general results observed during the test period. The item "Loss %-3/4 Rd. Screen" was obtained by screening the product from the discharge end of the retort after it had been quenched; this figure can only be approximate, because of the moisture content. The item "Coke Quality (Observed)" is only an estimate of the quality of the product, based on its appearance. A more accurate measure of the quality of the carbonized briquettes can be obtained from the tumbler and compression tests given in Table 5. Any difficulties experienced in passing the charge through the retort are listed under "Handling Characteristics", which is the last column in Table 3.

Table 4 lists the proximate analyses of the test samples before and after they were processed through the retort. It is of interest to note the uniformity of the volatile matter content of the different briquettes after carbonization. Sample E is an exception, but in this case the individual briquette was only one-sixth the weight of the briquettes used in the other tests.

The results of the physical tests, tabulated in Table 5, show that although good compressive strengths were obtained, the stability and abradibility of the carbonized briquettes were lower than those of the uncarbonized briquettes as measured in the tumbler

TABLE 3

<u>Test Runs in the Vertical Column Carbonizing Unit</u>

Run No.	Charge	Operating temp., °F	Residence time (estimated), hr	Loss % -3/4 Rd Screen	Coke quality (observed)	Handling characteristics
1	Mixed briquettes	1500	2 to 3 hrs	-	Fair to good	Irregular discharge and some hang-ups
2	Local 50% Marker 50% #4	1500	4 to 16 hrs	-	Good	Coked into solid mass
3	Mixed Canmore	1500-1800	4 to 16 hrs	-	Fair to good	Irregular at 1500 good at 1800
4	Canmore A	1800	2 to 3 hrs	approx 15%	Good	Slight indication of hang-up
5	" B	1800	2 to 3 hrs	" 20%	"	Regular discharge, no hang-up
6	" C	1800	3 hrs plus	" 20-25%	"	Irregular discharge and some hang-up
7	" D	1800	2 to 3 hrs	" 15%	"	Regular discharge
8	" E (small)	1800	2 hrs	" 15%	"	" "
9	Mines Branch 50% Marker 50% #4	1800	4 to 5 hrs	" 25%	"	Coked into solid mass with irregular discharge

TABLE 4

Proximate Analyses of Canmore Briquettes Carbonized in a Vertical Shaft Furnace

Briquette		Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)
Sample A	Raw	2.27	9.49	17.63	70.61
	Carbonized	2.04	10.70	2.06	84.40
Sample B	Raw	2.08	9.25	16.21	72.46
	Carbonized	1.85	9.13	2.58	86.94
Sample C	Raw	0.74	12.12	18.41	68.73
	Carbonized	1.44	18.46	2.40	77.70
Sample D	Raw	1.25	9.94	16.07	72.74
	Carbonized	1.30	12.22	2.04	84.44
Sample E	Raw	0.99	8.58	20.39	70.04
	Carbonized	0.64	11.18	1.25	86.93
Mines Branch	Raw	-	-	-	-
	Carbonized	1.79	9.67	2.59	85.95

TABLE 5

Results of Tests on Canmore Briquettes Carbonized in Vertical Shaft Furnace

	TUMBLER TEST			COMPRESSION TEST		
	Stability		Abradibility	Briquettes Crushed At (grams)	Wt. Each (grams)	Approx. Spec. Grav.
	On 1 -1/2	On 3/4	- 10 Mesh			
Canmore A						
Raw	81.25	81.25	18.13	10,899	64.79	1.14
Carbonized	38.49	54.63	37.12	27,774	52.46	1.08
Canmore B						
Raw	71.55	72.92	26.61	9,482	63.41	1.14
Carbonized	18.47	32.25	50.46	13,996	52.34	1.12
Canmore C						
Raw	52.53	58.13	39.25	12,214	63.66	1.17
Carbonized	29.28	51.56	20.82	31,416	52.70	1.07
Canmore D						
Raw	85.07	85.07	14.77	8,788	62.85	1.19
Carbonized	27.97	45.21	36.80	15,968	52.00	1.14
Canmore E						
Raw	-	72.88	26.90	-	11.20	1.17
Carbonized	-	64.91	28.53	42,226	10.25	1.15
Mines Branch 18 CP						
Raw	-	73.58	26.12	16,442	13.52	1.23
Carbonized	-	61.58	29.63	43,576	9.80	0.98

Canmore A - 50% No. 4, 50% Stewart; Canmore B - 80% No. 4, 20% Stewart;
C - 50% No. 4, 50% Marker; Canmore D - 80% No. 4, 20% Marker;
E - 80% No. 4, 20% Coleman; Mines Branch 18 C P - 50% No. 4, 50% Marker.

test. As a comparison, the amount retained on a 1-in. screen for the carbonized briquettes was from 18 to 38, while for metallurgical coke it would be about 65. Similarly, on a 3/4-inch screen, the carbonized briquettes gave from 32 to 65 retention while for metallurgical coke the value would be about 87. It is believed that considerable improvement can be obtained by increasing the proportion of coking coal and by adjusting the sizes used in the blends. The appearance of many of the briquettes suggested that good strength characteristics were obtainable.

CONCLUSIONS

The vertical shaft furnace appears to be a feasible method for carbonizing briquettes on a continuous production basis. While the specifications for briquettes for use as a reductant in the electric furnaces of the phosphorus industry are not known with certainty, it seems likely that an acceptable product can be made by this method. The volatile matter content was, in all cases, lower than 2.59 percent, and good compressive strength values were obtained. Stability and abradibility results were somewhat low, but doubtless these properties could be improved by modifying the coal blends used.

Since this work was completed, The Canmore Mines Limited has constructed a larger vertical shaft furnace, capable of producing two tons of carbonized briquettes per hour. Initial results indicate that the method will be successful.

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