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A LABORATORY STUDY OF THE BINDERLESS BRIQUETTING OF WESTERN CANADIAN COALS

by

A. R. McKENZIE, JACQUELINE L. PICARD,
AND J. VISMAN

FUELS DIVISION

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A.R. McKenzie*, Jacqueline L. Picard**, and J. Visman***

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SUMMARY

Information is scarce on the technical and economic aspects of binderless briquetting of Canadian coals. To date, no press is available that fulfills the requirements of the industry or the physical conditions of temperature and pressure for manufacturing briquets without binder.

This preliminary series of experiments, carried out on Western Canadian coals, shows that it is physically possible to make binderless briquets that are strong, and water and frost resistant. A lignite and a subbituminous coal were successfully briquetted without binder, by a process involving the preheating of the coal for several minutes at temperatures in the range of 400 to 600 degrees Centigrade, followed by agglomeration in a laboratory die press at pressures ranging from 2.5 to 39 tons per square inch for the subbituminous coal and above 12 tons per square inch for the lignite

Similar tests with a medium volatile bituminous coking coal showed that good binderless briquets can be made with it when it is mixed with inert material such as sand or non-swelling coal. Results for semianthracite by itself were negative, but the tests indicate that it can be briquetted in a mixture with coking coal.

It would appear that these preliminary results merit further investigation of the subject, with a view to developing a press suitable for briquetting at pressures up to 13 tons per square inch and capable of handling coal preheated at temperatures ranging from 450 to 550 degrees Centigrade.

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ÉTUDE EN LABORATOIRE DE L'AGGLOMÉRATION SANS LIANT DES CHARBONS DE L'OUEST DU CANADA

par

A.R. McKenzie*, Jacqueline-L. Picard**, et J. Visman***

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RÉSUMÉ

Les aspects technique et économique de l'agglomération, sans l'aide de liant, des charbons du Canada sont peu connus. Jusqu'à présent il n'y a pas eu de presse qui ait répondu aux besoins de l'industrie ou satisfait aux conditions de température et de pression requises pour fabriquer des agglomérés sans l'aide d'un liant.

La série d'expériences préliminaires de la présente étude, qui a porté sur des charbons de l'Ouest du Canada, montre qu'il est physiquement possible de fabriquer sans liant des agglomérés qui résistent à l'écrasement, à l'eau et au gel. Un lignite et un charbon sub-bitumineux ont pu être agglomérés sans liant par le pré-chauffage pendant plusieurs minutes à des températures de l'ordre de 400 à 600 degrés Centigrade, suivi de l'agglomération dans une presse à moule de laboratoire à des pressions de 2.5 à 39 tonnes par pouce carré pour le charbon sub-bitumineux et au-dessus de 12 tonnes dans le cas du lignite.

Des essais analogues sur un charbon à coke du type bitumineux à teneur moyenne en matières volatiles ont montré qu'on peut en faire de bons agglomérés sans liant s'il est mélangé avec une matière inerte telle que du sable ou un charbon qui n'est pas gonflant. Les résultats pour le semi-anthracite seul, bien que négatifs, ont indiqué qu'il peut être aggloméré en mélange avec du charbon à coke. Il semble que ces résultats préliminaires militent en faveur de recherches plus poussées dans cette voie en vue de réaliser une presse acceptable pour l'agglomération à des pressions allant jusqu'à 13 tonnes au pouce carré et capable de traiter du charbon pré-chauffé à des températures de 450 à 550 degrés Centigrade.

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INTRODUCTION

Reduction of the amount of binder used in briquetting has had the continuing interest of the coal operators of Western Canada for a number of years. Since 1952, plant investigations, followed by laboratory studies, have been carried out at the Western Regional Laboratory of the Fuels Division, at Edmonton, Alberta, with a view to developing suitable equipment and methods, primarily for the briquetting of bituminous coals with asphalt binder. However, an exhaustive literature survey(6) has indicated that, following the pioneer work by R. J. Piersol(1, 2, 3) and others, a study of the binderless briquetting of Western Canadian coals might have potential value. A request for such a program, with special reference to subbituminous coal, was received from the coal operators in the Drumheller area of Alberta.

Following the 1957 Biennial Conference of the International Briquetting Association, held at Glenwood Springs, Colorado, a contact, initiated by Mr. E. Swartzman, senior technologist, Fuels Division of the Canadian Department of Mines and Technical Surveys, Ottawa, was made with Mr. W.S. Landers, Chief, Denver Coal Research Laboratory, Region III, of the U. S. Bureau of Mines, Denver, Colorado, to discuss the possibility of a test with Canadian subbituminous coals at the Denver Station, where considerable work had been done on American coals and where lignites from East India had been tested in a "Glomera" press(4) imported from Switzerland.

Some preliminary tests without binder were then conducted on Alberta subbituminous coals using the Glomera press at Denver. The results were negative, since apparently the press did not meet the required conditions for the Canadian subbituminous coals. It was then decided to investigate more fully the conditions of temperature, pressure and time required to make good briquets, and to extend the tests to coals of different rank, such as lignite, coking coal, and semianthracite.

These laboratory tests were based on the premise that the tars liberated on heating the coal will, under suitable pressure, have the qualities necessary for binding the coal particles together. It was postulated that a strong briquet will result only if "fusion" of the particles occurs, and not merely from compaction.

As tests described in this paper were done in a 1-in. die used in a laboratory press, they are only of a preliminary nature and merely indicate the possibilities--largely judged by qualitative examination.

EQUIPMENT AND TESTING PROCEDURES

Equipment

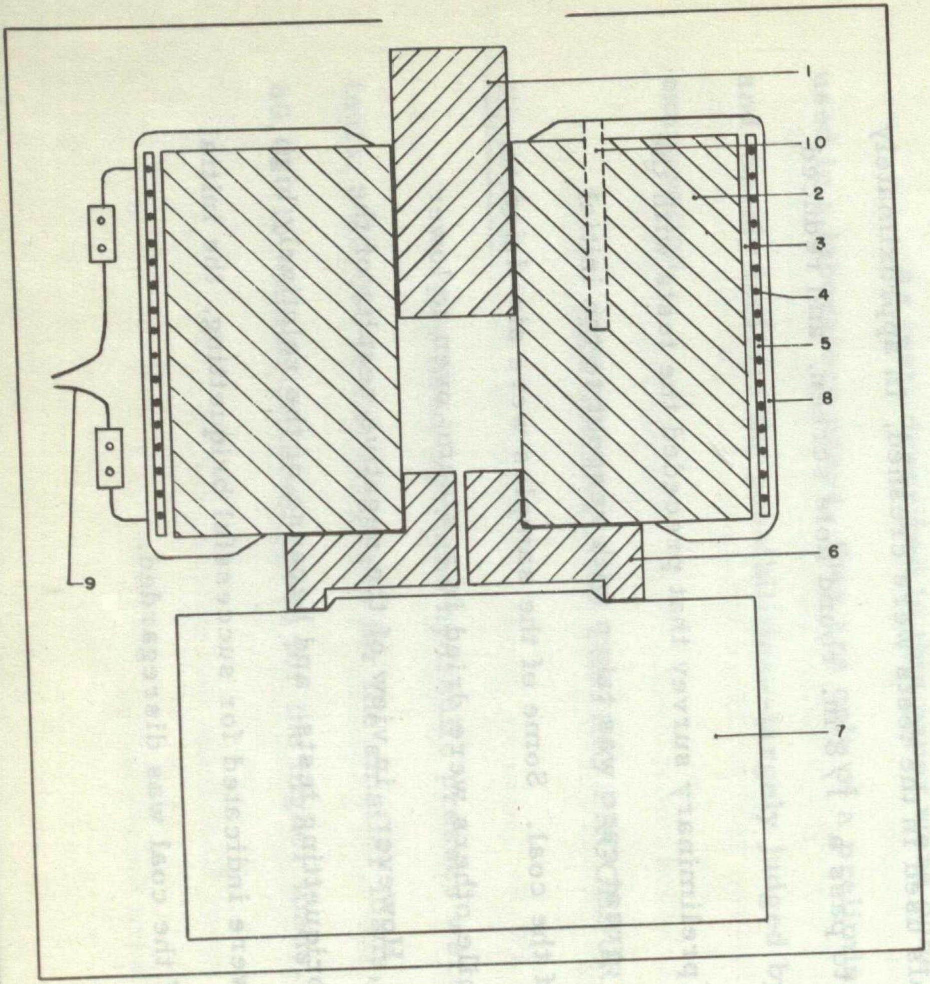
Two hand-operated hydraulic presses were used in the tests: a 20,000 lb Carver press for the smaller loads, and a 60,000 lb Watson-Stillman press for the higher loads.

The die (1 in. diameter) and briquetting assemblies are shown in Figures 1 and 2. The die assembly (see Figure 1) was of very simple construction. Provision was made to allow the gases to escape, by machining down the plunger (1) slightly and by drilling a 1/16 in. hole through the base insert (6) as indicated. The die was externally wound with 24 ft. of No. 18 resistance wire (4), embedded in ceramic cement and further insulated with asbestos. The temperature was measured with a thermocouple placed in the glass-lined well (10), and was controlled by means of a Variac. The heat capacity of the die was such that constant temperatures could be maintained, and temperatures of up to 900°C could be attained if desired.

Preparation of Samples

The coals used in the tests were crushed, in approximately 300 lb quantities, to pass a 1/8 in. round hole screen, and reduced to 5 lb lots.

For the preliminary survey that preceded the tests with the "Glomera" press, great care was taken with respect to the initial moisture content of the coal. Some of the samples were air-dried to room moisture, while others were dried in a steam oven to lower moisture contents. However, in view of the negative results of the "Glomera" press briquetting tests, and because of the relatively high temperatures that were indicated for successful briquetting, the initial moisture content of the coal was disregarded.



1. Steel plunger.
2. Steel die.
3. Two layers asbestos.
4. 24 ft. No. 18 resistance wire.
5. Ceramic insulation.
6. Base insert.
7. Base block
8. Asbestos jacket.
9. Lead wires.
10. Glass-lined thermocouple well.

Figure 1. - Die assembly

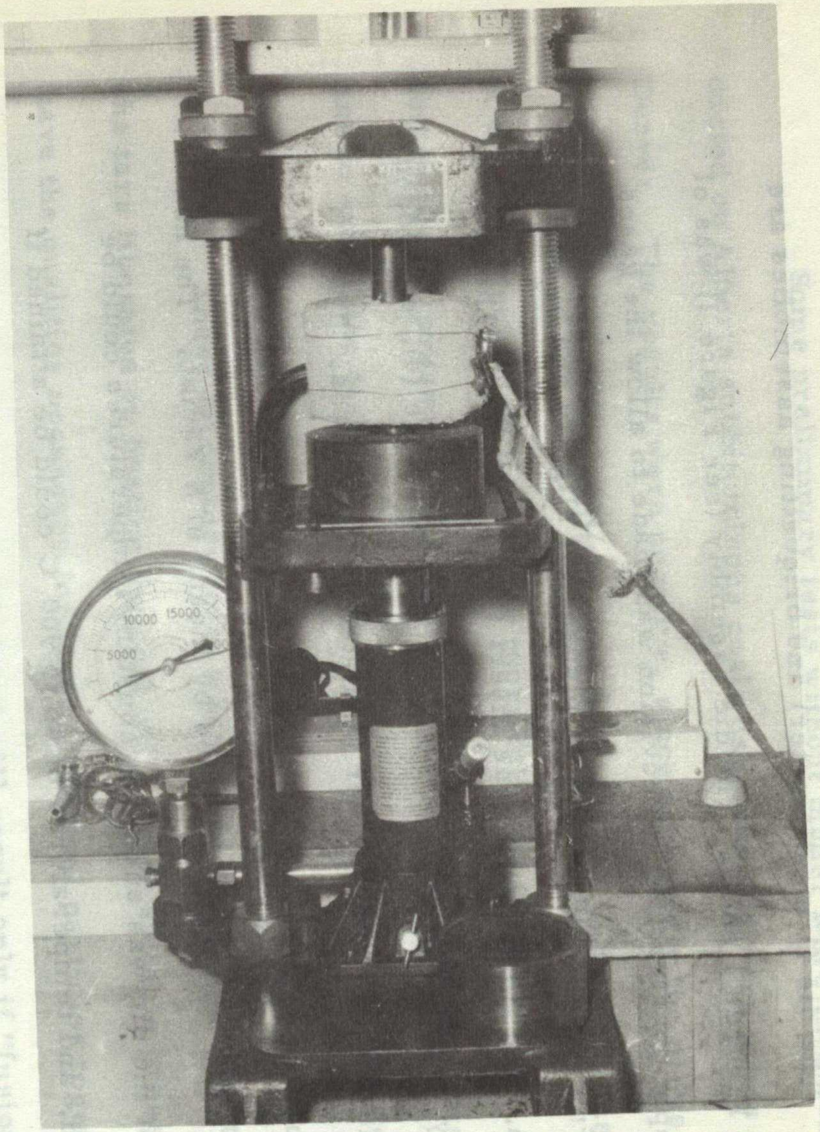


Figure 2. - Carver press and die.

in which d_o = apparent density of coal, and

d_i = apparent density of briquet,

Weathering Characteristics

This factor was determined from the degree of deterioration of the briquet that was observed as a result of the "water test" and "freezing test". The "water test" consisted of immersing the briquet in water for at least 24 hours. The freezing test consisted of freezing the briquet after it had been subjected to the water test, and then allowing it to thaw out. Generally, for all the above tests, single specimens were used.

General Briquetting Procedure

Fifteen grams of coal was placed in the die, which had been pre-heated to the desired temperature. The steel plunger, which was also up to temperature, was inserted and the pressure applied immediately. The retention, or briquetting, time was 3 minutes. This consisted of 2 minutes at full load and 1 minute during which the pressure was slowly released. This period of slow pressure release was found necessary in order to prevent shattering or severe cracking of the briquet by the violent release of gas. The base insert was then removed and the briquet extracted by pushing it through the die.

In the initial tests on subbituminous coal, pressures at four different levels were applied, namely: 2.5 t/sq. in., 12.7 t/sq. in., 18 t/sq. in., and 39.3 t/sq. in. In later tests, only the second level, 12.7 t/sq. in., was used.

TEST RESULTS

Briquetting tests were conducted with a lignite, a subbituminous B coal, a medium volatile bituminous (coking) coal, and a semianthracite. The results of these tests are discussed below, in chronological order.

Subbituminous B Coal

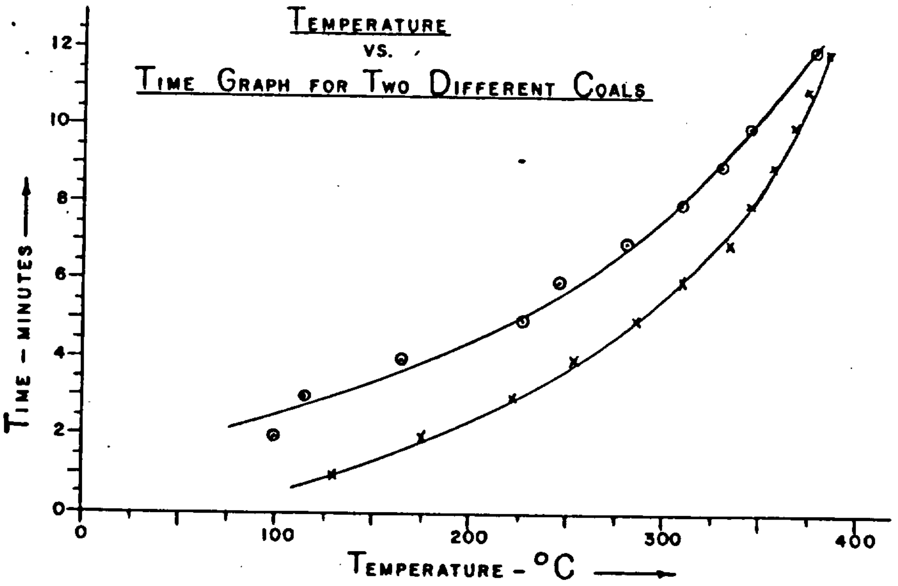
The diagram in Figure 4 illustrates the various "phases" that resulted from different combinations of temperatures and pressure in the binderless briquetting of this subbituminous coal. It should be emphasized here that these "phases" are less sharply defined than the lines of Figure 4 and the other schematic diagrams might suggest. The diagram only represents the broad distinction that is made between briquets that are compacted and those that show fusion on the interfaces between adjoining particles. It is of interest to note that, generally, the phase boundaries are at a slope, indicating that plasticity occurs at lower temperatures as the pressure is increased. The word 'plasticity' is used here in the broad sense of a material's susceptibility to being permanently deformed. The effect can be seen in Figures 6 and 7, where photographs are shown of two series of briquets made at 2.5 and 12.7 t/sq. in. respectively.

It was found that some degree of plasticizing must occur in order that fusion of particles can take place to give strength to the briquet. The fusion observed in the tests is illustrated by a micrograph, shown in Figure 11 (on page 12).

Temperature Control

An estimate of the temperature gradient of the coal within the die was obtained as follows. The die was heated and maintained at a constant temperature of 400°C. Fifteen grams, the same amount of coal as was used in making a briquet, was then placed in the die and the rate of temperature rise was measured by means of a mercury thermometer inserted in the centre of the coal. Figure 3 shows two time-temperature curves obtained in this way.

Figure 3



The rate of heat penetration into the coal can be expected to vary not only with the die temperature and compactness of the coal but also, as indicated in the graph, with the type of coal used. Generally speaking, it will take approximately 12 minutes for an equilibrium temperature to be reached. According to Piersol,$^{(1)}$ the temperature of the coal will rise to a point somewhat above the die temperature and then remain constant. Piersol also found that the sudden application of pressure at temperatures above 300°C resulted in a slight increase in the temperature. However, since the tests discussed in this report were of a preliminary nature, it was felt that exact temperature of the coal relative to the die was not of too great importance. For this reason, and the fact that the die could be more easily controlled, the temperature of the die was taken as the basis for comparison. In the majority of the cases, the temperature of the coal over the 3-minute briquetting period reached only 1/2 to 3/4 that of the indicated die temperature.

Tests for Briquet Quality

Compressive Strength

The strength of the briquets(5) was measured with a hand-operated Komarek-Greaves tester. The "side load" was taken as the means of comparison, because in the end-on position a number of the specimens could not be broken. Generally, the "side strength" was found to be about 1/4 of the "end strength".

Porosity

The degree to which the coal particles of the briquet were agglomerated was determined from the density of the briquet. Estimates of the interstitial volume (I) of the briquets were based on the following formula:

$$I\% = 100(d_o - d_i)/d_o,$$

Figure 4

SCHEMATIC VIEW OF RESULTS FOR SUBBITUMINOUS COAL

(NO DEGASSING)

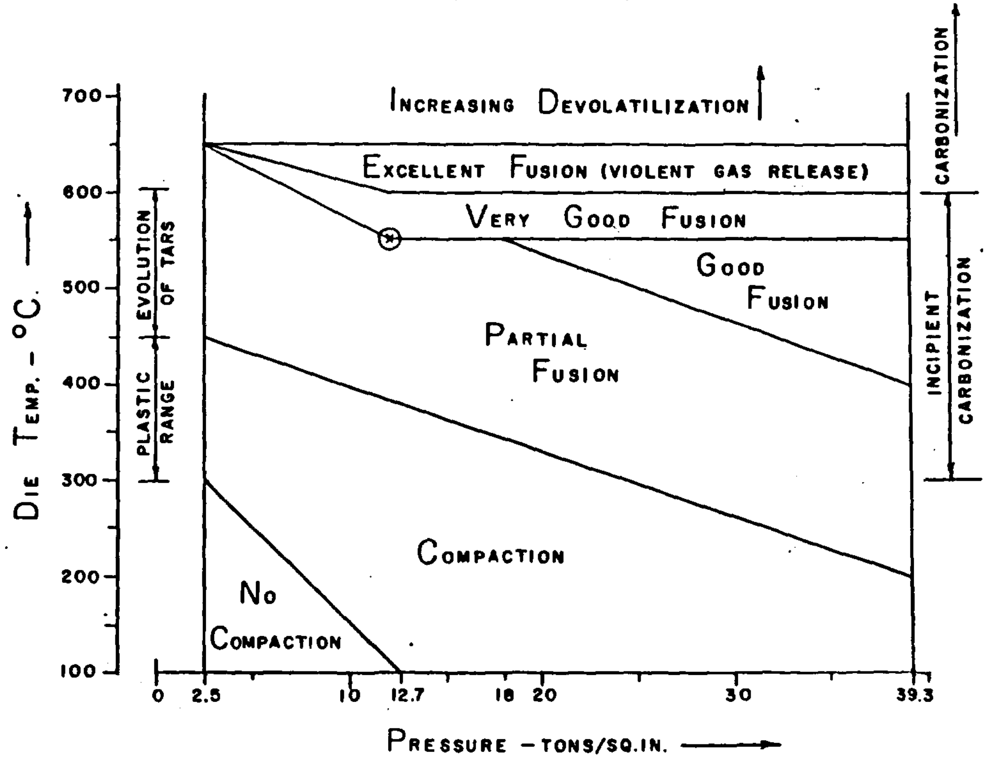
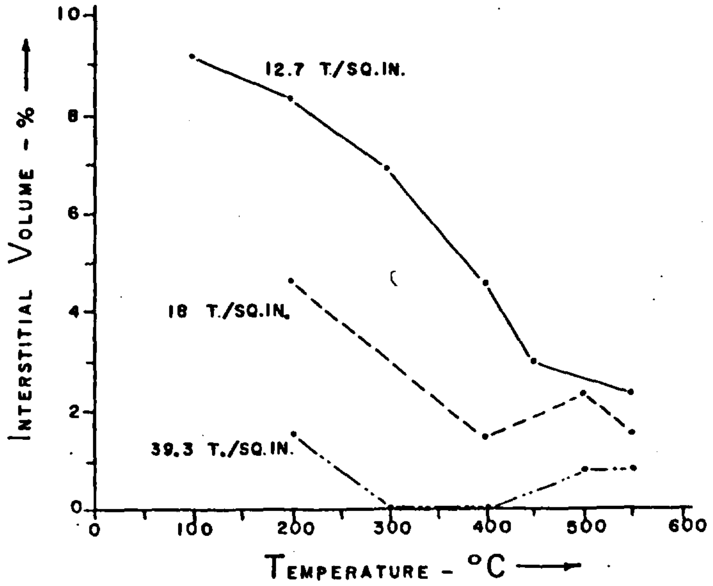


Figure 5

POROSITY OF SUBBITUMINOUS BRIQUETS



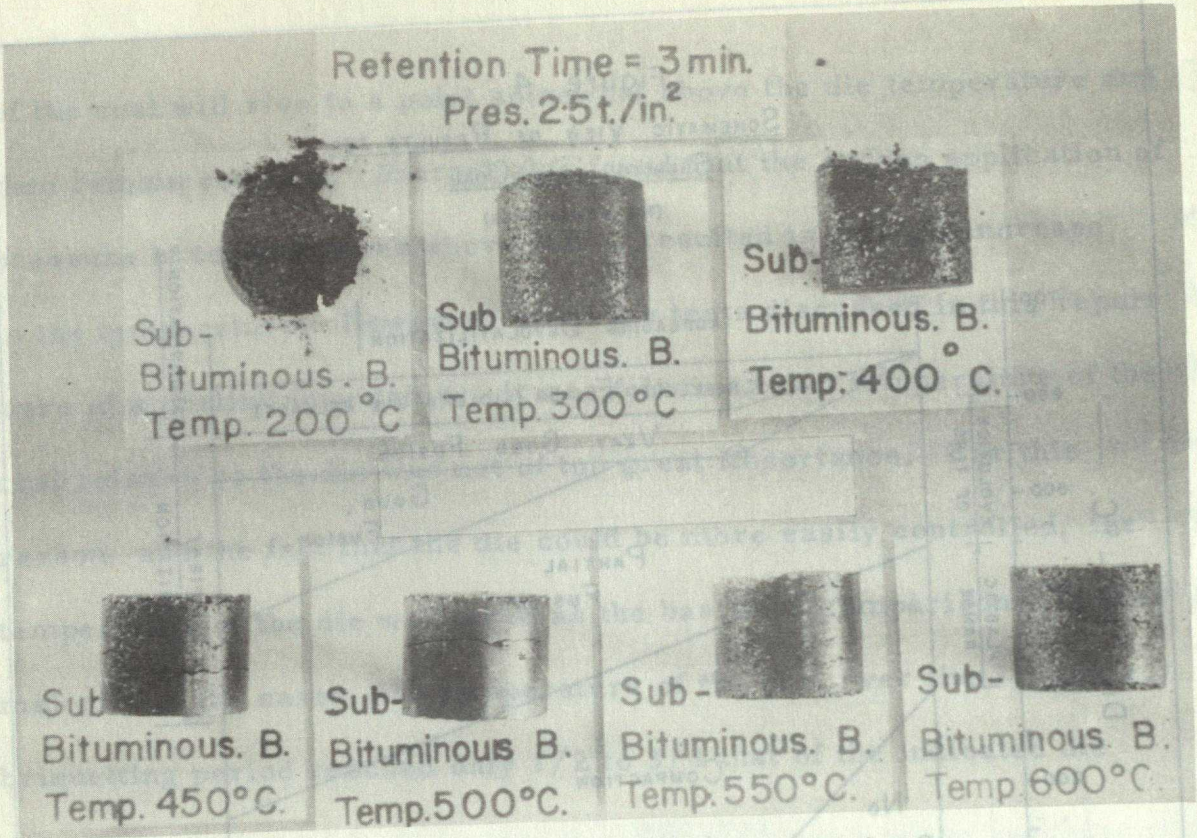


Figure 6. - Subbituminous briquets made at 2.5 t/sq in.

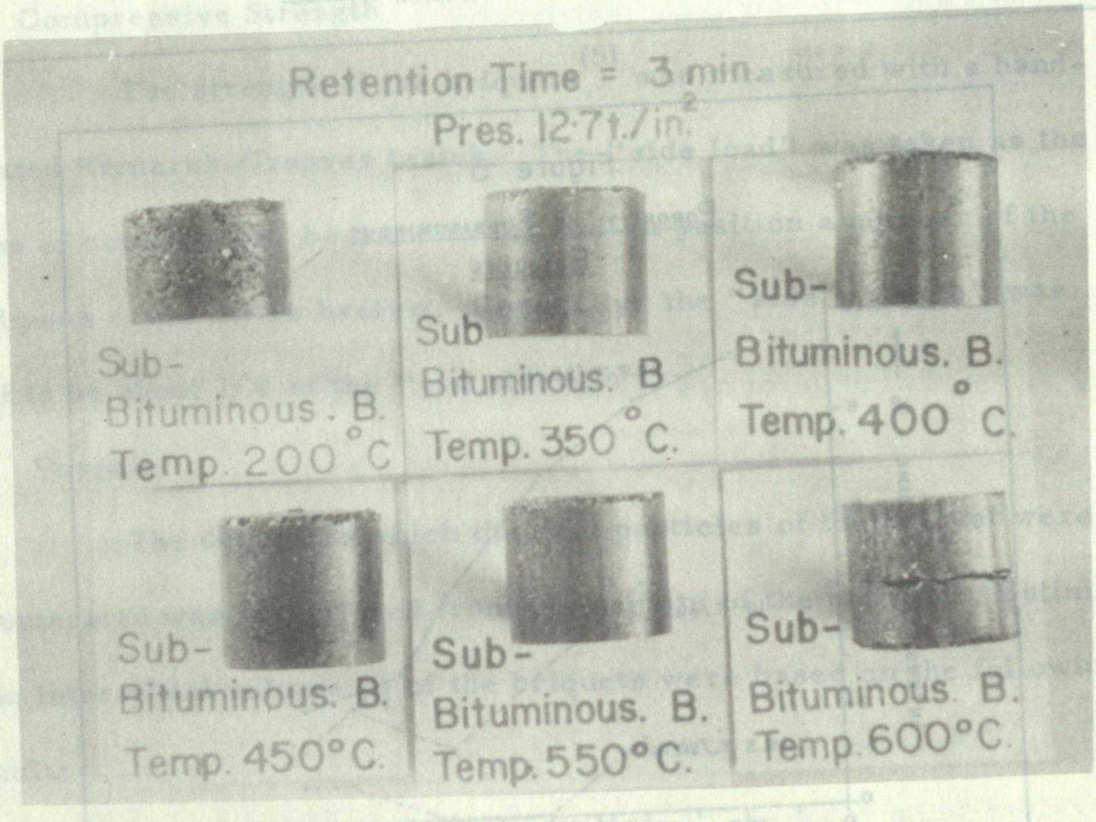


Figure 7. - Subbituminous briquets made at 12.7 t/sq in.

The main effect of heating the coal would appear to be to produce the tars which will partly dissolve the coal particles at the interfaces and thus prepare the particle mixture for briquetting. The best results were obtained within a fairly high and narrow temperature range (550-600°C). The analyses in Table 1 show that a drop of approximately 15% in the volatile matter content occurred in the course of briquetting under the optimum conditions at 550°C and 12.7 t/sq. in.

TABLE 1

Proximate Analyses of Subbituminous B Coal and Briquets

(Dry Basis)

	Raw Coal*	Briquet
Ash............. %	8.5	9.3
Volatile matter .. %	35.9	20.9
Fixed carbon .... %	55.6	69.8
Calorific value gross .....Btu/lb	12,150	12,820

*Values from "Analyses of Canadian Coals and Peat Fuels", by J.H.H. Nicolls. Publication No. 831, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada, 1952.

Figure 8 typifies a briquet showing compaction only, whereas Figure 9 shows the type of fused briquet produced under optimum conditions. As indicated in Figure 4, increasing the

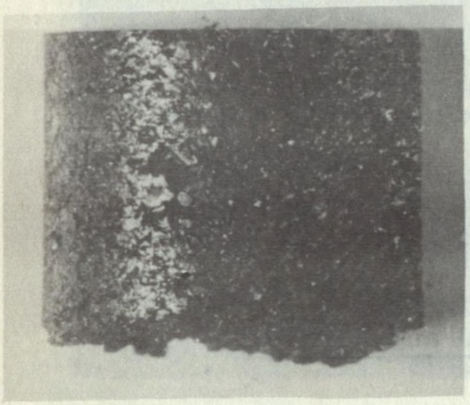


Figure 8. - Subbituminous briquet showing compaction only. 2.5 t/sq. in.,; 400°C.

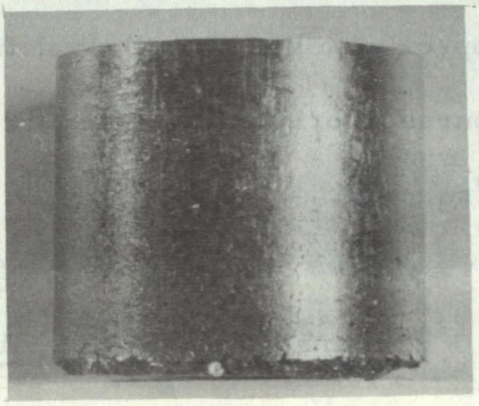


Figure 9. - Subbituminous briquet showing fusion, under optimum conditions. 12.7 t/sq. in.; 550°C.

Figure 10. - Subbituminous briquet cracked as a result of high internal gas pressures. 39.3 t/sq. in.; 600°C.

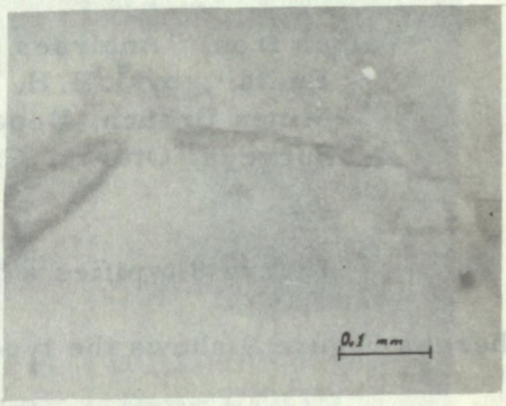


Figure 11. - Photomicrograph (X 116) of subbituminous briquet. 12.7 t/sq. in.; 550°C.

pressure beyond 12.7 t/sq. in. at a temperature of 550°C is of no apparent advantage. Its only effect is to reduce the pore volume of the briquet, as shown in Figure 5 (on page 9).

From 600 to 650°C, the fusion was judged excellent. However, owing to the explosive nature of the compacted coal, due probably to the high internal pressures of the gases at those temperatures, the resulting briquets were usually split or very badly cracked, as shown in Figures 7 and 10.

The resistance of the briquets to disintegration on water immersion increased with increasing briquetting temperature. The optimum quality briquet was only slightly swollen after being immersed 24 hours in water.

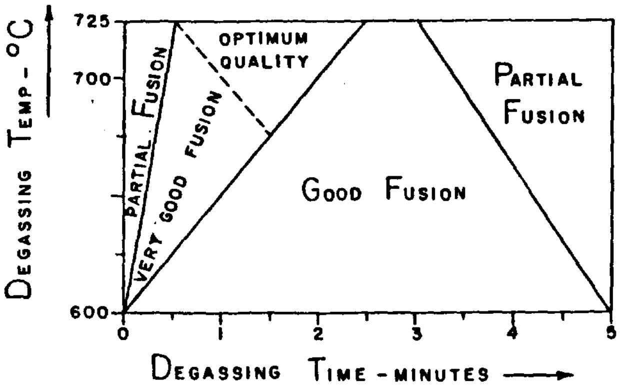
As strength varies with the porosity of the briquet, the apparent density was determined as a function of the pressure and temperature. The average apparent density of the pre-dried coal used in the tests was found to be 1.31 ± 0.025 g/cm^3 at about 5 percent moisture. It is noted that the coal itself might have a slightly different density after briquetting. However, although the estimates may not be accurate, Figure 5 indicates a general decrease in porosity with increasing temperatures and pressures.

Previous studies by Piersol on the subject of binderless briquetting indicated that partial devolatilization of the coal prior to briquetting was necessary in order to produce a good quality of briquet. In order to determine whether this applies to subbituminous coal, samples were degassed in covered porcelain crucibles at various temperatures prior to briquetting.

Figure 12 shows the effects of degassing the coal, outside the die, for various periods at different temperatures, and then cooling before briquetting at 500° C and 12.7 t/sq. in.

Figure 12

SCHEMATIC VIEW OF BRIQUET QUALITY FOR SUBBITUMINOUS COAL, DEGASSED AND COOLED PRIOR TO BRIQUETTING. (12.7 T./SQ.IN., 500°C)



Comparison of Figures 4 and 12 shows that degassing improved the quality of the briquet over that made without degassing. For example, Figure 4 shows that, without degassing, only partial fusion occurred in briquets made at 500C° and 12.7 t/sq. in. In Figure 12, on the other hand, very good fusion was obtained under the same briquetting conditions when the coal had been degassed beforehand. In other words, coal that is degassed prior to briquetting is in the same condition that prevails when non-degassed coal is briquetted at higher temperatures and pressures. This would suggest that by degassing in advance, good briquets could be produced at lower briquetting temperatures and pressures.

Under optimum conditions (500°C and 12.7 t/sq. in.), the compressive strength (end load) of briquets made of degassed coal was 450 units on the Komarek-Greaves tester. This figure marks the end of the scale on the tester, indicating considerable strength. The comparable strength under side load conditions appeared to be approximately 75 units K-G.

Lignite

In testing lignites and the coals higher in rank than subbituminous, the briquetting pressure used was 12.7 t/sq. in. The results for lignite that was not degassed in advance are shown in Figures 13 and 17. As indicated in Figure 13, the degree of "fusion" increased with the temperature from 100 to 500°C, with the optimum fusion being attained between 400 and 500°C. At 600°C, as might have been expected, the briquet exploded.

Figure 14 shows the effects of degassing in the die between 400 and 500°C for specified times and briquetting immediately afterwards. A decrease in the compressive strength was observed as the degassing temperature was increased (see Figure 15). The

Figure 13

RESULTS FOR LIGNITE COAL

(12.7 T./SQ.IN., NO DEGASSING)

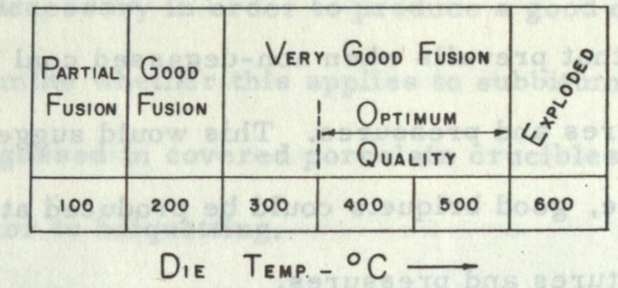


Figure 14

EFFECT OF DEGASSING LIGNITE COAL

IN DIE BEFORE BRIQUETTING (12.7 T./SQ.IN.)

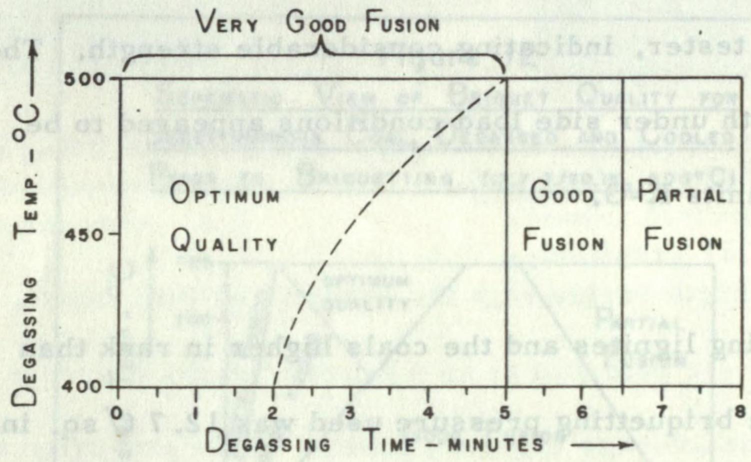
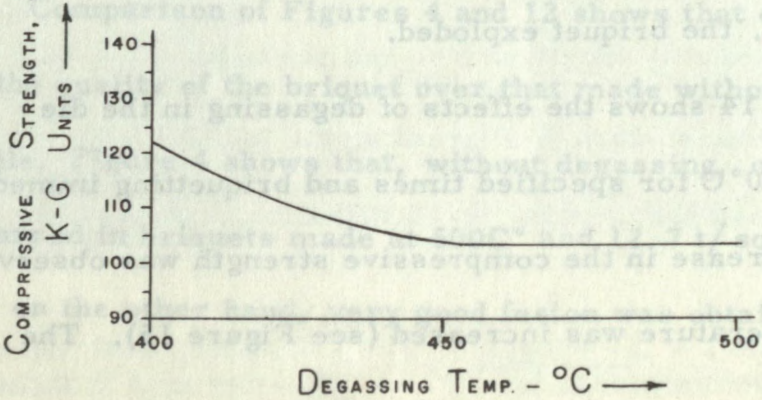


Figure 15

AVERAGE STRENGTH OF LIGNITE BRIQUETS

VS.

DEGASSING TEMPERATURE



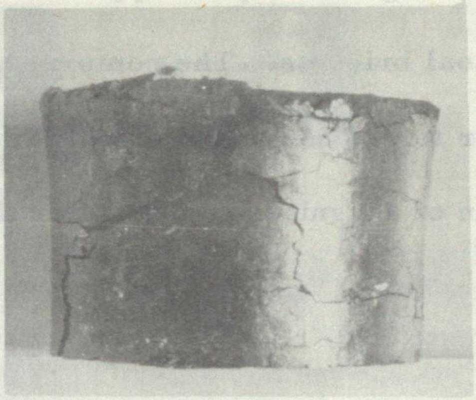


Figure 16. - Lignite briquet after water treatment for 24 hours. (Briquet made at 12. 7 t/ sq. in. and 450°C.)

Figure 17. - Lignite briquets without prior degassing.

resistance to water of the lignite briquets appeared to be lower than for the subbituminous coal briquets. The compressive strength of briquets soaked in water for 24 hours and dried was 20-30 units K-G (side load). A specimen of a lignite briquet after the water treatment is shown in Figure 16.

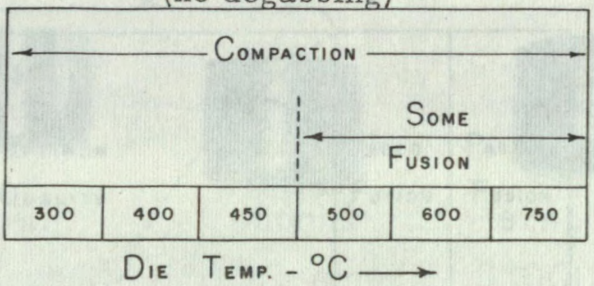
Semianthracite

Figure 18

RESULTS FOR SEMIANTHRACITE.

(12.7 T./SQ.IN.)

(no degassing)



As expected, the results for semianthracite were negative. Figure 18 shows that, essentially, only compaction occurred throughout the temperature range, although from 500 to 750°C there appeared to be a slight amount of "fusion". The coal was compacted into layers as is shown in Figures 19 and 20. In most cases the briquets were split in two at the middle.

Figure 19. - Semianthracite briquets made at various temperatures. (Pressure, 12.7 t/sq. in.; no degassing).

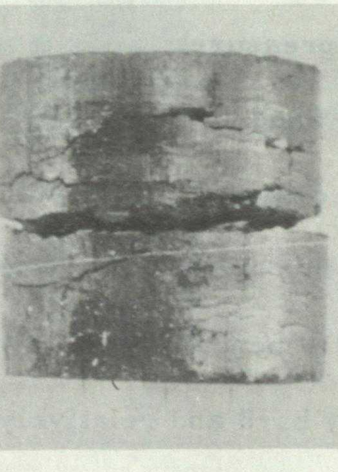


Figure 20. - Semianthracite briquet made at 12.7 t/sq. in. pressure and 450°C.

Medium Volatile Bituminous Coking Coal

Experiments were conducted to determine whether good briquets could be produced from a medium volatile bituminous coking coal, or mixtures containing it, at temperatures from 300 to 500°C, the region where a coking coal becomes plastic and fuses readily.

The coal used for the tests bordered on the high volatile bituminous class. Three series of tests, using this type of coal, were carried out: 1) medium volatile bituminous coking coal, alone; 2) medium volatile bituminous coking coal + sand; and 3) medium volatile bituminous coking coal + medium volatile bituminous non-coking coal. The retention time RT was 3 min, in all tests.

1) Coking Coal Alone

This series of tests gave a negative result. Within the range of briquetting temperatures (300-500°C), the coal was very difficult to handle because of swelling and the briquets had a tendency to explode while under pressure.

2) Coking Coal + Sand

The coking coal was mixed with varying percentages of sand, and briquetted. In Figure 21 are shown briquets, made at 600°C, containing 2.5, 5, and 10 percent coal, respectively. The latter two mixtures produced very hard and relatively strong briquets (side load 40 and 80 units K-G respectively). Results for the 20 and 30 percent mixtures are shown in Figures 22 and 23. Optimum temperature for these and the 40 percent coal mixtures (not shown) was between 400 and 450°C in spite of the better outside appearance of briquettes made between 300 and 400°C. These results suggest that use could be made of the agglomerating powers of this type of coal in the smelting of ores.

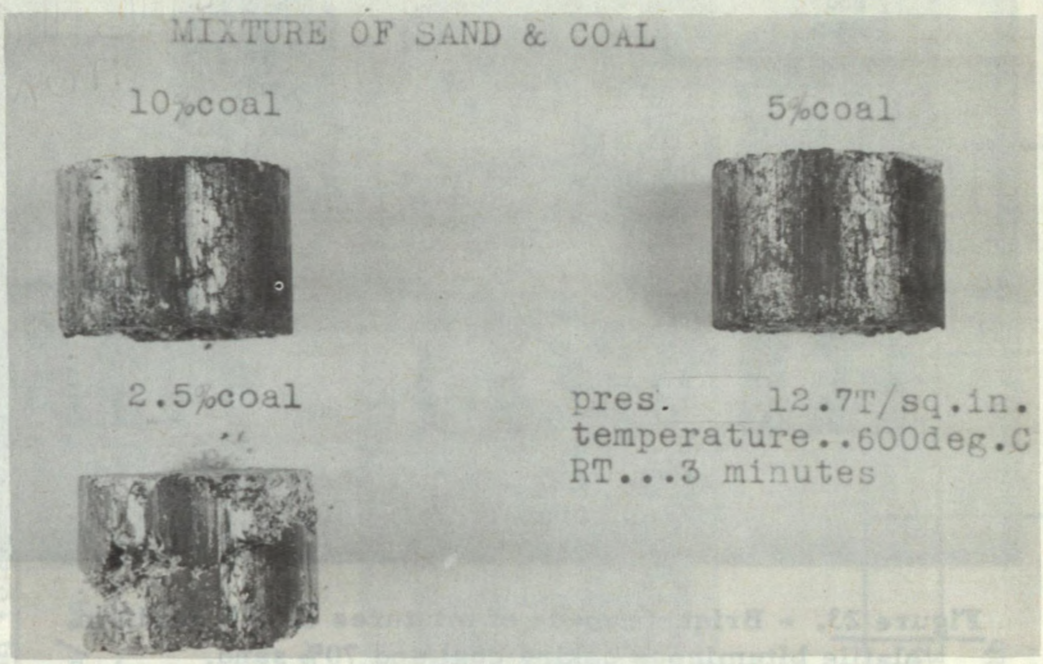


Figure 21. - Briquets made of medium volatile bituminous coking coal mixed with sand.

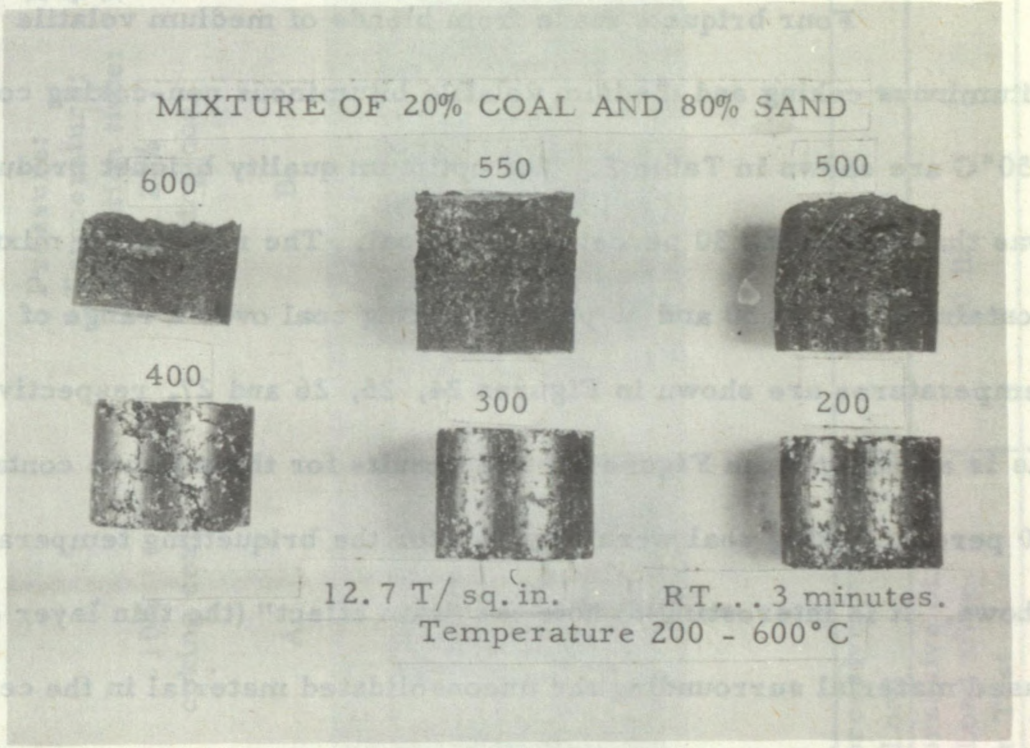


Figure 22. - Briquets made of mixtures of 20% medium volatile bituminous coking coal and 80% sand.

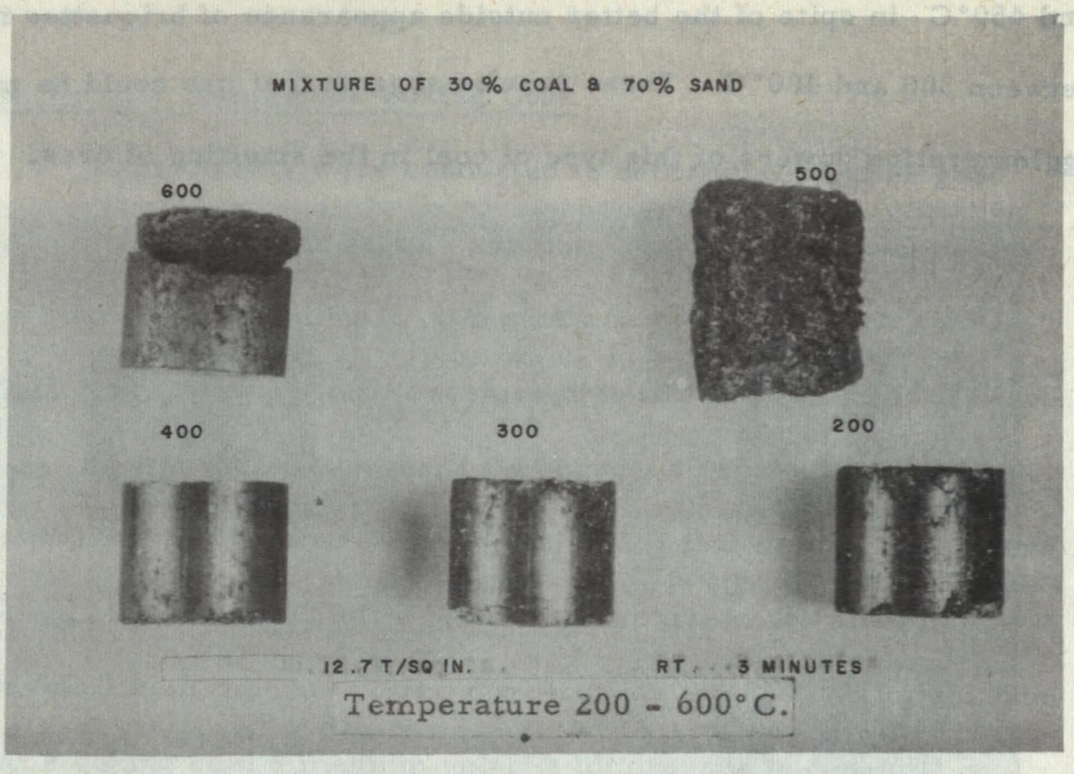


Figure 23. - Briquets made of mixtures of 30% medium volatile bituminous coking coal and 70% sand.

3) Coking Coal + Non-coking Coal

Four briquets made from blends of medium volatile bituminous coking and medium volatile bituminous non-coking coal at 450°C are shown in Table 2. The optimum quality briquet produced was that containing 30 percent coking coal. The results for mixtures containing 10, 20, 30 and 40 percent coking coal over a range of temperatures are shown in Figures 24, 25, 26 and 27, respectively. As is apparent from Figure 24, the results for the mixture containing 10 percent coking coal were negative for the briquetting temperatures shown. It is interesting to note the "skin effect" (the thin layer of fused material surrounding the unconsolidated material in the centre of the briquet) that occurred at the lower briquetting temperatures (200 and 300°C). The optimum die temperature in all cases was found to lie between 400 and 450°C.

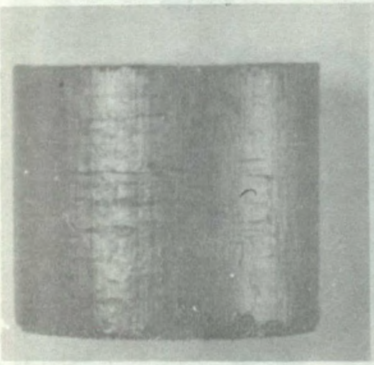
TABLE 2

Mixtures of Coking and Non-coking Medium Volatile Bituminous Coals

Pressure: 12.7 ton/sq. in.
Temperature: 450 deg. C
Retention time: 3 min.

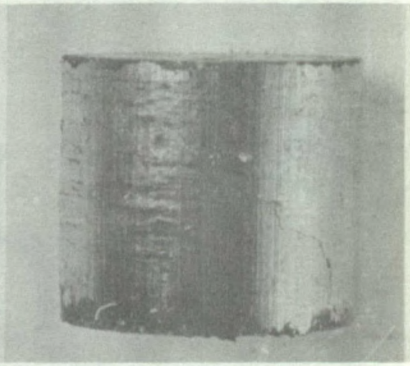
10%
coking coal

A



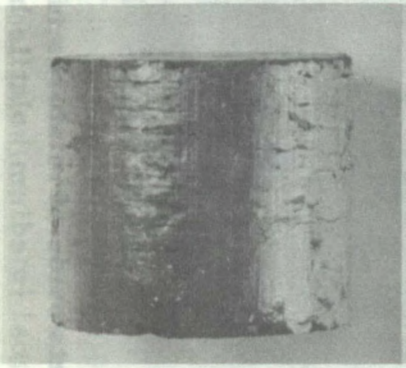
20%
coking coal

B



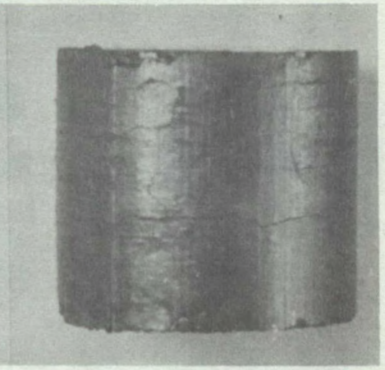
30%
coking coal

C



40%
coking coal

D



	A	B	C	D
Compressive Strength, Side Load	75 lb	75 lb	75 lb	60 lb
Compressive Strength, Side Load after Water Test	40 lb	25 lb	60 lb	20 lb
Remarks	No effect from water on briquet appearance			

Note: The briquets bonded into horizontal layers, and along these layers the briquets broke easily.

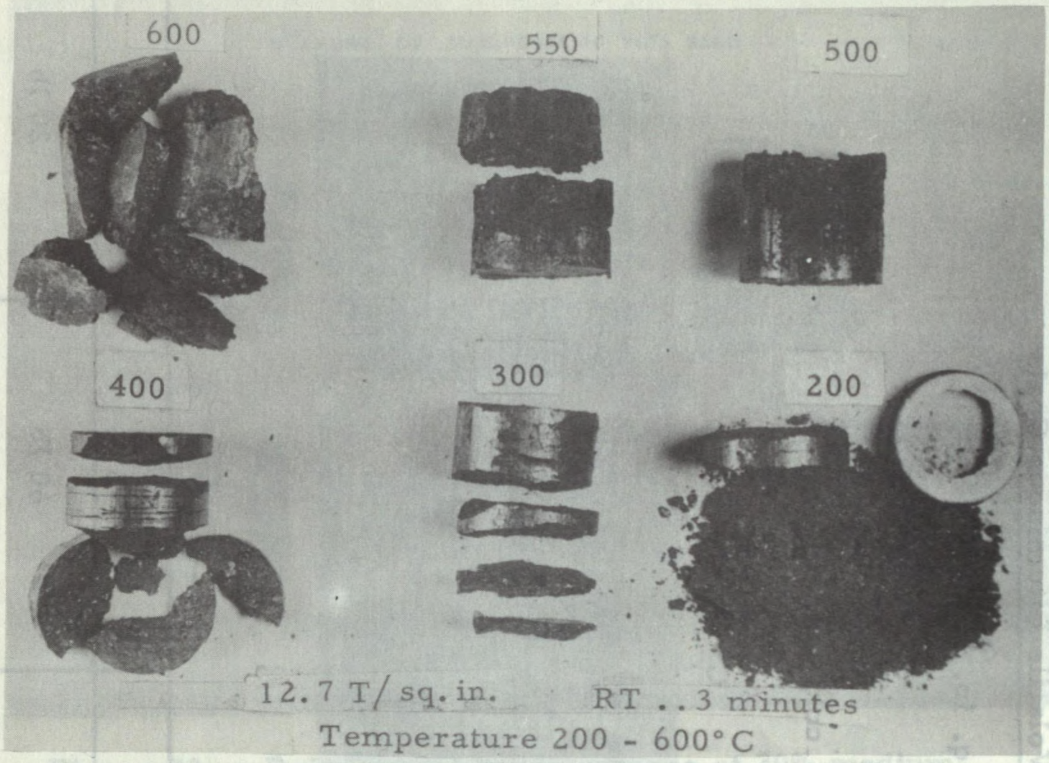


Figure 24. - Briquets made of mixtures of 10% coking and 90% non-coking coal (medium volatile bituminous).

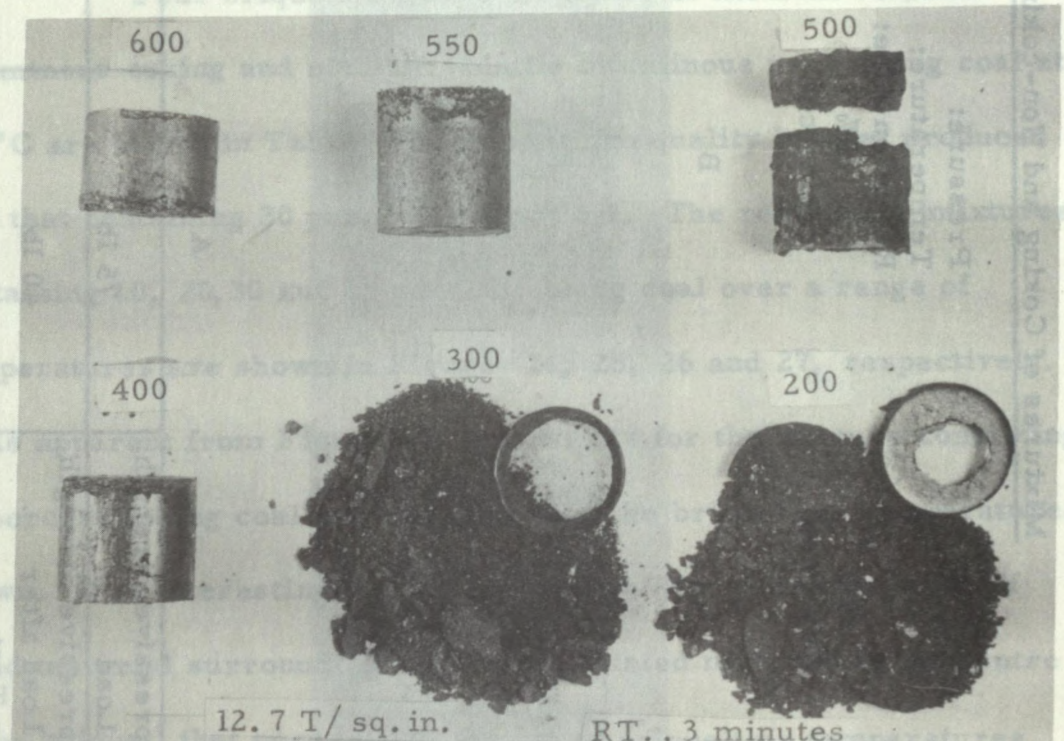
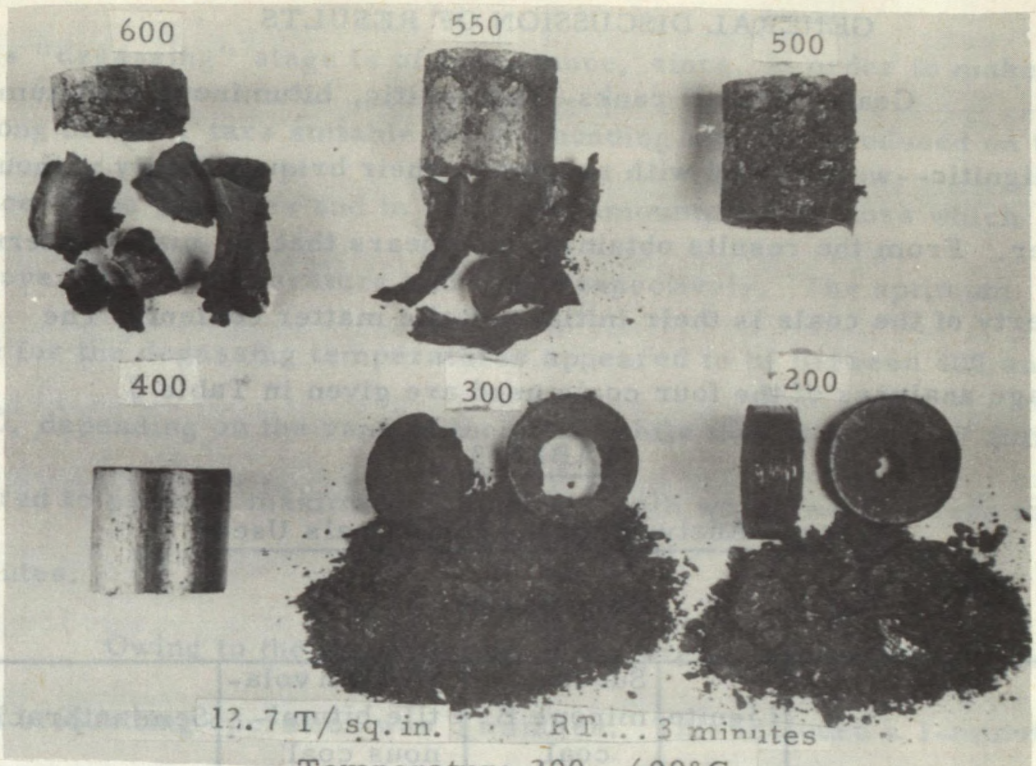
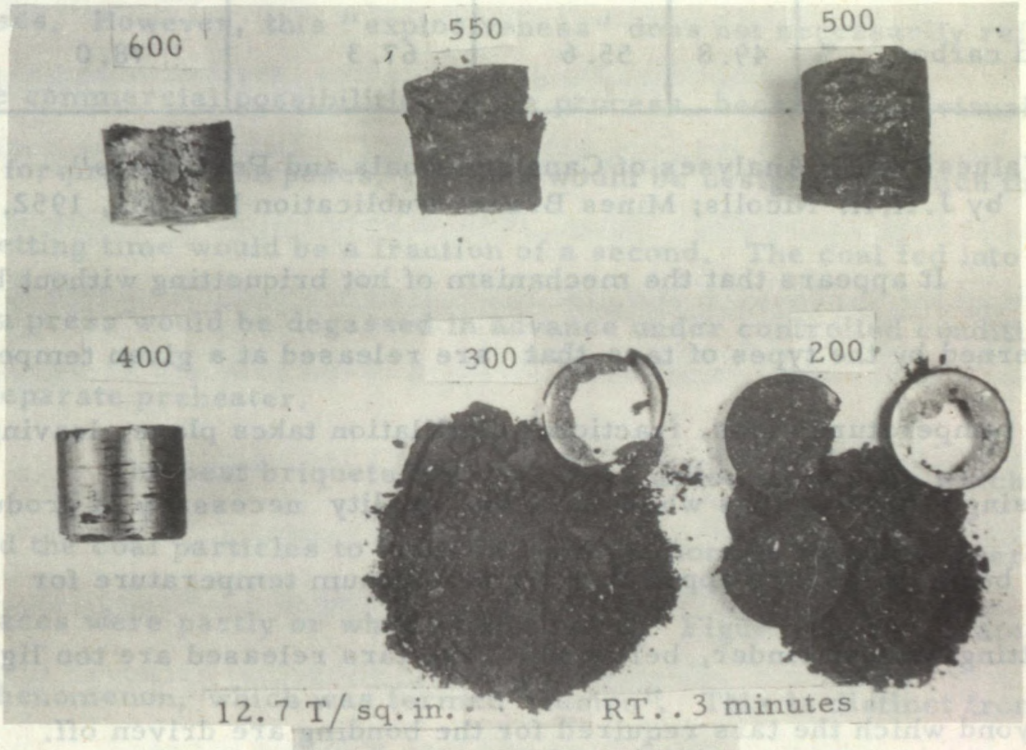


Figure 25. - Briquets made of mixtures of 20% coking and 80% non-coking coal (medium volatile bituminous).



Temperature 200 - 600°C

Figure 26. - Briquets made of mixtures of 30% coking and 70% non-coking coal (medium volatile bituminous).



Temperature 200 - 600°C

Figure 27. - Briquets made of mixtures of 40% coking and 60% non-coking coal (medium volatile bituminous).

GENERAL DISCUSSION OF RESULTS

Coals from all ranks--anthracitic, bituminous, subbituminous, and lignitic--were tested with respect to their briquettability without binder. From the results obtained, it appears that a major determining property of the coals is their initial volatile matter content. The average analyses of the four coals used are given in Table 3.

TABLE 3

Average Analyses of the Four Coals Used*

(Dry Basis)

	Lignite	Subbituminous B coal	Medium volatile bituminous coal	Semianthracite
Ash .... %	10.2	8.5	8.9	8.6
Volatile matter %	40.0	35.9	23.8	13.4
Fixed carbon.. %	49.8	55.6	67.3	78.0

*Values from "Analyses of Canadian Coals and Peat Fuels", by J.H.H. Nicolls; Mines Branch Publication No. 831, 1952.

It appears that the mechanism of hot briquetting without binder is governed by the types of tars that are released at a given temperature. As the temperature rises, fractional distillation takes place, leaving increasingly heavier tars which have the quality necessary to produce proper bonding. There appears to be an optimum temperature for briquetting without binder, below which the tars released are too light, and beyond which the tars required for the bonding are driven off.

The required tars can be produced, prior to briquetting, by the heating of the coal, with resultant release of gas. The duration of this "degassing" stage is of importance, since, in order to make a strong briquet, tars suitable for the bonding must be produced on the surface of the particles and in sufficient amount, two factors which are governed by temperature and time respectively. The optimum range for the degassing temperatures appeared to be between 400 and 600°C, depending on the rank of the coal, while the "degassing" time required to produce maximum briquet strength was generally less than 2 minutes.

Owing to the construction of the press, the duration of the actual briquetting operation was 3 minutes. This included a 1-minute period of slow pressure release, which was found necessary to prevent severe cracking or shattering of the briquet by the sudden release of gases. However, this "explosiveness" does not necessarily reflect on the commercial possibilities of the process, because it is visualized that, for practical purposes, presses would be designed in which the briquetting time would be a fraction of a second. The coal fed into such a press would be degassed in advance under controlled conditions in a separate preheater.

The best briquets were obtained under conditions which caused the coal particles to form an intimate bond to the point where interfaces were partly or wholly obliterated. Figure 11 illustrates this phenomenon, which was termed "fusion". This is distinct from briquets where particles were merely compacted by interlocking.

The "fused" briquets were the only ones that withstood the "water" and "freezing" tests, i.e. submersion of the briquet in water for at least 24 hours, followed by freezing.

Subbituminous B Coal

From the various temperature-pressure combinations used, it was found that increasing the pressure usually had the effect of lowering the temperature at which fusion of the coal particles took place. With a briquetting time of 3 minutes and no prior degassing, optimum conditions were 550°C and 12.7 t/sq. in. A loss of about 15 percent volatile matter occurred during briquetting at this temperature and pressure. Degassing the coal prior to briquetting resulted in a better quality of briquet. Resistance of the briquets to the "water" test increased with briquetting temperature.

Lignite

With a briquetting time of 3 minutes, the optimum temperature at 12.7 t/sq. in. was between 400° and 500°C. Degassing the coal in the die in this temperature range, immediately followed by briquetting, improved the appearance and also the resistance of the briquets to the "water" test. The compressive strength of the briquets decreased with increasing degassing temperature.

Semianthracite

With a briquetting time of 3 minutes at 12.7 t/sq. in., results were negative. Essentially, only compaction occurred from 300 to 750°C, although some "fusion" was obtained between 500 and 750°C. However, coking coal mixed with semianthracite could be expected to produce the same results as those reported for mixtures of medium volatile bituminous coking coal with inert materials or bituminous non-coking coal, since the coking coal acts as a binder under the elevated temperature and pressure conditions.

Medium Volatile Bituminous Coking Coal

1) Coking Coal Alone: Results were negative, owing to excessive swelling and to the tendency of the coal to explode when pressure was applied.

2) Coking Coal + Sand: The coking coal used was successfully briquetted without binder when mixed with an inert material such as sand. Mixtures of this type could possibly be used in special ore-smelting operations, such as the one described by H. Kenworthy and A.G. Starliper (7). With a briquetting time of 3 minutes at 12.7 t/sq. in., the optimum quality briquets were obtained with mixtures containing 30 to 40 percent coking coal, at temperatures between 400 and 450°C. Fairly strong briquets (side strength, 40-80 units K-G) were obtained, at 600°C, from the mixtures containing 5 and 10 percent coking coal.

3) Coking Coal + Non-coking Coal: With a briquetting time of 3 minutes at 12.7 t/sq. in., optimum quality briquets were obtained from the mixture containing 30 percent coking coal. The optimum temperature for all proportions of coking coal (10, 20, 30 and 40 percent) was between 400 and 450°C.

CONCLUSIONS

The results of the tests indicate that Western Canadian coals of widely varying rank can be briquetted without binder. However, strongly coking, highly swelling bituminous coals require the addition of inert materials, whereas non-coking bituminous and semianthracitic coals must be mixed with coking bituminous coal. Preheating of the coal to incipient carbonizing temperatures removes the lighter oils and retains tar fractions at the particle surface that are suitable for making a strong briquet.

The laboratory tests reported in this paper indicate that further study of the subject is warranted. From the results so far obtained it appears that there is merit in considering the development of a press for briquetting coals without a binder.

ACKNOWLEDGMENT

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