CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA

MINES BRANCH TECHNICAL BULLETIN

TB 6

PRICE 25 CENTS

RELATIONSHIP OF VARIOUS FACTORS TO THE QUALITY OF COKED BRIQUETS MADE FROM MIXTURES OF COKING COALS AND INERT MATERIAL

by

E. SWARTZMAN

FUELS DIVISION

SEPTEMBER 1959

CANADA

DEPARTMENT OF MINES AND
TECHNICAL SURVEYS, OTTAWA

MINES BRANCH
TECHNICAL BULLETIN

TB 6

Price 25 Cents

RELATIONSHIP OF VARIOUS FACTORS TO THE QUALITY OF COKED BRIQUETS MADE FROM MIXTURES OF COKING COALS AND INERT MATERIAL

by

E. Swartzman

Fuels Division

Presented at the 6th Biennial Conference of the International Briquetting Association, East Glacier Park, Montana, August 24-26, 1959.
(ex TM 73/59-PREP)

September, 1959

Mines Branch Technical Bulletin TB 6

RELATIONSHIP OF VARIOUS FACTORS TO THE QUALITY OF COKED BRIQUETS MADE FROM MIXTURES OF COKING COALS AND INERT MATERIALS

by

E. Swartzman*

==

SYNOPSIS

This paper deals with a study of certain factors which influence the quality of coked briquets made from coking coal and finely divided inerts, such as minerals, for use in the metallurgical and chemical industries. The data obtained tend to show the following:

1. The strength of briquets coked at 2°C/min to 750°C tends to increase with an increase in the proportion of coal in the mix up to 50 percent, the limit used in these tests.

2. The coked briquet strength appeared to decrease with an increase in rank from high volatile A to low volatile bituminous coal.

3. Varying the type of inert did not seem to affect the quality of the coked briquet.

4. The rate of coking in a stationary bed was found to have a strong influence on the quality of the coked briquets. There was a trend towards increasing strength with increasing rate of carbonization. However, coking at faster rates resulted in a fusing together of the individual briquets.

5. Close relationship between the strengths of coked briquets and the free swelling indices of the mixtures was not found.

6. Compaction during briquetting has a strong positive influence on the quality of the coked briquets. Even mixes that showed no agglomeration in the free swelling test resulted in the production of well coked briquets with fair strength.

7. The "maximum fluidity" of a coal attained during plasticity on heating would appear to bear a relationship to the quality of the resultant coked briquets. For the coals studied, the strength of the coked briquets increased with an increase in the "maximum fluidity" of the coal. Furthermore, the higher the "maximum fluidity" the greater was the amount of inert material that could be mixed with the coal to obtain a certain quality of briquet.

---

* Senior Scientific Officer, Fuels Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

Direction des mines, Bulletin technique TB 6

INFLUENCE DE DIVERS FACTEURS SUR LA QUALITÉ DES AGGLOMÉRÉS CARBONISÉS PRÉPARÉS À PARTIR DE MÉLANGES DE CHARBONS À COKE ET DE MATIÈRES INERTES

par

E. Swartzman*

RÉSUMÉ

Le présent mémoire traite de certains facteurs qui influent sur la qualité des agglomérés cokéfiés faits de charbons à coke et de matières inertes de faibles dimensions, par example des minéraux, et destinés aux industries métallurgiques et chimiques. Cette étude semble indiquer les conclusions suivantes:

1. La résistance mécanique des agglomérés carbonisés à 2°C/minute jusqu'à 750°C tend à s'améliorer avec l'augmentation de la teneur en charbon du mélange jusqu'à la limite de 50 p. cent utilisée pour le présent travail.

2. La résistance mécanique des agglomérés carbonisés a paru diminuer à mesure qu'augmentait le rang de la houille, depuis les "charbons bitumineux à haute teneur en matières volatiles du type A" jusqu'aux "charbons bitumineux à faible teneur en matières volatiles".

3. La qualité des agglomérés carbonisés ne semble pas être affectée par le changement de matière inerte.

4. La vitesse de cokéfaction en lit stationnaire a eu une grande influence sur la qualité des agglomérés carbonisés, leur résistance mécanique ayant eu tendance à augmenter avec la vitesse de carbonisation. Cependant les divers agglomérés se fusionnaient lorsque le rythme de cokéfaction s'accélérait.

5. On ne découvrit aucune corrélation étroite entre la résistance mécanique des agglomérés carbonisés et les indices de gonflement des mélanges.

6. La qualité des agglomérés carbonisés est nettement améliorée si une pression s'exerce pendant l'agglomération. Même des mélanges qui ne s'agglutinaient pas au cours de l'essai de gonflement ont donné des agglomérés bien cokéfiés et ayant une résistance mécanique satisfaisante.

7. Il semblerait y avoir un lien entre la "fluidité maximum", atteinte par un charbon rendu plastique par chauffage, et la qualité des agglomérés carbonisés qui en sont faits. Pour les charbons utilisés dans la présente étude, la résistance des agglomérés carbonisés était améliorée lorsque la "fluidité maximum" du charbon était plus grande. En outre, la proportion de matières inertes qui pouvaient être mélangées au charbon était d'autant plus grande que la "fluidité maximum" était plus élevée.

---

* Chargé de recherches principal, Division des combustibles, Direction des Mines, ministère des Mines et des Relevés techniques, Ottawa, Canada.

CONTENTS

TABLES

FIGURES

==

INTRODUCTION

In an increasing number of processes associated with the metallurgical and chemical industries where the basic materials are finely divided, it is often necessary to agglomerate the fines to produce a lump material suitable for further treatment. In some processes, when a carbonaceous material is required as a reductant, or for chemical combination--to produce, for example, carbides--and/or for a source of energy, materials such as crushed coal or pulverized coke are added prior to agglomeration. When a substantial quantity of carbonaceous material is necessary, and when the agglomerates are required to remain as such without serious degradation throughout their treatment and handling at various temperatures, coking coal, because of its unique characteristic of "melting" and resolidifying as its temperature is increased, is used as the source of carbon as well as the bonding material.

The Fuels Division had occasion to conduct agglomeration tests in connection with research concerning the development of a method for the preparation of titanium metal from a slag containing about 72 percent TiO_2. This slag was considered not satisfactory as a base material for the production of titanium because adulterants, such as iron oxide, were too high and because its reactivity to chlorination was poor, requiring temperatures of 800° to 900°C. To make a more suitable product the slag was to be reduced in the solid state at 1450°C to produce a mixture of titanium oxides and carbides which would be more suitable for chlorination at about 300°C, while at the same time the iron oxide would be reduced to metallic iron which could be leached out with dilute sulphuric acid leaving a mixture of almost pure titanium compounds for chlorination. With a view to obtaining intimate contact between the minerals and the carbon materials for efficient solid state reduction, it was considered advisable to have the materials in a fine state of division. The slag was ground so that approximately 75 percent passed a 200 mesh screen, and the coal and coke were crushed to pass a 1/8 in. and a 1/16 in. screen respectively. As such finely pulverized materials could not be readily processed, it was necessary that the mixtures of fines be agglomerated. The agglomerates were to be strong enough to retain their individual identity throughout the whole processing. A few preliminary tests indicated that the production of suitable agglomerates by "balling", that is, without compaction, was not possible. Thus, a standard low-pressure double-roll briquetting press was employed.

Although the usual bonding materials, such as petroleum asphalt, coal tar pitch, and lignosulphonates, produce some bond on carbonization when used in economically permissible amounts, they would be completely consumed in the initial reduction and the agglomerated material would be reduced to a finely divided material. The most logical solution to this problem appeared to be to incorporate a coking coal to supply the bonding material as a result of becoming fluid and resolidifying during carbonization. At the same time the coal could be the main, if not the whole, source for carbon, any additional carbon required being provided by the addition of coke fines.

The type and quantity of coking coal to be used as the bonding medium as a result of carbonization would have to be such that the coked briquets would not only be strong enough for the whole processing but would not swell or fuse together during carbonization.

Although this work was unavoidably suspended before completion, some interesting information was obtained, and it is the objective of this paper to present an outline of these preliminary results, with a view to encouraging other experimenters to aid in unravelling the complex problem of the relationship of the coking characteristics of coals, and their compaction during briquetting, to the quality of coked briquets made from mixes of coals with materials that act as inerts during carbonization.

EXPERIMENTAL PROCEDURES

Briquetting

The briquetting was effected by means of a small low-pressure, double-roll press fitted with 20 in. diameter rolls about 4.5 in. wide and designed with machined pockets to make small almond-shape briquets about 1-1/8 in. long, 3/4 in. wide and about 3/4 in. thick.

The materials were blended and mixed with binder in a steam jacketed mixer fitted with two sigma-type paddles rotating in opposite directions.

A binder was required to hold the materials together until carbonization. The binder used in all the experiments presented in this paper was a 50 percent solution of calcium lignosulphonate (concentrated sulphite liquor). Experiments indicated that briquets of highest "green" strength were produced with mixes containing 6 parts of the binder per 100 parts of solid materials, provided the mix was briquetted at a temperature of about 160°F. The "case hardened", air-dried briquets approached the strength of those which were oven-dried at 230°F. This is illustrated in Table 1. Such briquets handled readily without breaking down.

TABLE 1

Comparison of the Compressive Strength of Air-Dried and Oven-Dried Briquets

(6 MR+ Lignosulphonate Binder)

Compressive Strength-kg*					
Air-Dried	Oven-Dried	Air-Dried	Oven-Dried	Air-Dried	Oven-Dried
3.6	3.5	7.0	6.6	10.6	12.8
3.7	4.2	7.0	8.8	10.8	12.7
4.0	5.1	7.1	8.1	11.1	10.5
5.6	6.3	8.3	13.1	11.0	15.8
5.7	5.1	8.4	11.5	12.3	14.7
5.8	5.3	9.3	15.4	12.6	16.1
6.2	6.2	9.6	9.4	13.0	14.5
6.3	7.0	10.1	6.1	13.3	15.0

* Each value is an average of five replicates.
\+ Mixing ratio.

Carbonization

The briquets were carbonized in stationary vertical cylindrical retorts inserted in an electric furnace. The retorts, with a capacity for about 80 briquets, were 11.5 in. long and 2.5 in. in diameter, and made of 1/2 in. steel plate. Each was fitted with a cap having a 1/2 in. outlet for escape of gases. After some experimentation a carbonization temperature of 750°C was judged to be suitable to produce well coked briquets with physical properties that could be compared in relation to subsequent processing. Tests were conducted to assess the effect of various heating rates on the physical qualities of the briquets.

Testing of Physical Quality of Briquets

The comparative strength of the air-dried, oven-dried, and coked briquets was determined by means of a compressive strength test. This uses a simple instrument, developed at the Fuels Division, whereby a a briquet is placed between a stationary and a movable anvil and the load for crushing or cracking is applied at the end of a lever, the fulcrum being between the briquet and the load. All briquets were brought to room temperature prior to testing.

COALS USED AND THEIR COKING PROPERTIES

As one of the major objectives of this study was to attempt to relate certain well known characteristics of coking coals, namely, free swelling and plasticity, to the physical quality of the coked briquets, coals of three different ranks were employed: high volatile A, medium volatile, and low volatile bituminous. The analyses of the coals used are shown in Table 2.

TABLE 2

Analyses of the Coals

	Rank of Coal		
	HVA*	MV*	LV*
Proximate Analysis			
Moisture..............................%	1.5	0.6	0.5
Ash...................................%	3.2	6.0	6.8
Volatile matter.......................%	39.5	31.4	18.3
Fixed carbon..........................%	55.5	62.0	74.4
Sulphur...............................%	1.8	0.9	1.1
Free Swelling Index (ASTM)	5.0	7.0	5.0
Plasticity (Gieseler)			
Maximum fluidity...................DDM+	4464	1544	1.7
Temp. of maximum fluidity...........°C	424	422	472
Temp. of solidification.............°C	464	505	505

* HVA = high volatile A bituminous; MV = medium volatile bituminous; LV = low volatile bituminous.

\+ DDM = rate of spindle movement in plastic coal, given in dial divisions per minute.

It is of importance to note that, insofar as coking characteristics are concerned, the major difference between the above coals is the "maximum fluidity" (Gieseler method) attained during the plastic stage of carbonization. The "maximum fluidities" decrease sharply with an increase in rank, a phenomenon which is well known.

However, as it was thought that the Free Swelling Index (ASTM Designation D720-57) of mixtures of coals and inert materials might be correlated with the strength of the coked briquets, this test was conducted on variously proportioned mixtures of the inerts (slag and coke) with the coals, all pulverized to pass 60 mesh as required in the standard test.

DISCUSSION OF RESULTS

Type of Inerts vs. Quality of Coked Briquets

The data in Table 3 show, in tests using a high volatile A bituminous coking coal, that varying the proportions of the finely ground slag (75% minus 200 mesh) and the coke (ground to pass 1/16 in.) in the mixes made no significant difference in the compressive strength of briquets coked at 2°C/min to 750°C in a stationary bed.

The variations in the compressive strengths of the briquets, when using similar quantities of the same coking coal, are partly due to the difficulty of making uniformly compacted briquets when experimenting with small (50 lb.) batches of mix. In addition, as a result of a statistical analysis of compression tests on a series of 70 briquets, the estimated coefficient of variation due to random experimental error was found to be 16.3 percent. The analysis also indicated that when the sample size was five (5) briquets, as was the case in this

TABLE 3

Quality of Briquets Coked at 2°C/min to 750°C
In Relation to Varying Proportions of Slag and Coke

Briquetting Mix			Compressive Strength of Coked Briquets, kg
Coal %	Slag %	Coke %	
33	61	6	5.1
32	59	9	6.1
31	57	12	4.5
30	56	14	5.8
30	54	16	6.1
29	53	18	4.2
31	47	22	3.0
30	44	26	6.0

work, one should not expect to detect true differences of less than 45 percent. These limitations on the compressive strength data must be kept in mind in relation to this work.

Quantity of Coal vs. Quality of Coked Briquets

In tests using the high volatile A bituminous coal it appears that the compressive strength of the coked briquets increases with an increase in the quantity of coal used, up to about 45 percent of the mix. This can be seen in the data in Table 4. Similar general trends were found when using either a medium volatile or a low volatile bituminous coking coal.

Influence of Rate of Coking

The rate of coking the briquets was found to have a strong influence on the compressive strength of the resultant carbonized products and on the degree of swelling and fusion. Tables 5 and 6 indicate that briquets made with high volatile A bituminous coal and coked at a slow rate of 2°C/min are much weaker than those coked at a fast rate of

TABLE 4

Relation of Quantity and Rank of Coal, as well as Free Swelling Index of Mixes, to Quality of Coked Briquets

Mix or Test No.	Coal in mix %	Free Swelling Index Test		Quality of Coked Briquet (1)	
		Description of Button (2)	Free Swelling Index	Visual Character (3)	Compressive Strength, kg
		High Volatile Bituminous			
S-1	16.5	N.A.	0	Fr	2.1
S-2	19.4	N.A.	0	Fr	2.4
S-3	22.4	N.A.	0	Fr	3.7
S-4	25.3	S.A.	0	Fr	4.2
S-5	31.0	A	1.0	Fr	4.6
S-6	36.0	C	1.0	Fr	5.4
S-7	41.7	C	1.0	TFr	6.4
S-8	44.0	C&S	1.5	Fr	7.4
S-9	47.0	C&S	1.5	SF	5.8
S-10	50.0	C&S	2.5	HSF	5.1
-	100.0	C&S	5.0	-	-
		Med. Volatile Bituminous			
SB-31	16.4	N.A.	0	Fr	2.6
S-16	38.6	C&S	1.5	TF	4.0
S-17	41.3	C&S	2.0	SF	4.6
SB-20, 26,28	44.4	C&S	3.0	SF	5.2
S-15	100.0	C&S	7.0	-	-
		Low Volatile Bituminous			
S-13	34.8	N.A.	1.0-	Fr	1.8-
S-14	37.5	N.A.	1.0-	Fr	1.8
SB-38	41.0	S.A.	1.0-	Fr	1.8
SB-21, 27,49	44.4	C&S	1.5	Fr	5.0
SB-29	50.0	C&S	2.5	Fr	5.6
2891	100.0	C&S	5.0	-	-

(1) Coked at 2°C/min to 750°C

(2) N.A. - non agglomerate
S.A. - slightly agglomerate
A - agglomerate
C - coking
C&S - coking and swelling

(3) Fr - free
TFr - tendency to be free
SF - swelling and fused
HSF - high swelling and fused

TABLE 5

Quality of Coked Briquets made with Varying Quantities of High Volatile A Bituminous Coking Coal and Carbonized to 750°C at Varying Rates

Quantity of Coal in Mix %	Rate of Coking - °C/Min				Rate of Coking - °C/Min			
	2	3.5	6	20	2	3.5	6	20
	Average Compressive Strength-kg(1)				Description of Coked Briquets*			
47	5.8	8.2	6.9	8.7	SF	HSF	HSF	WF
41	6.4	7.7	10.1	8.4	TFr	SF	HSF	WF
36	5.4	7.3	11.1	14.0	TFr	SF	HSF	WF
30	4.6	5.3	6.4	11.5	Fr	TFr	HSF	WF
21	3.7	6.3	8.5	8.5	Fr	Fr	SF	F
Average	5.2	6.9	8.6	10.2				

*Fr = free; TFr = tendency to be free; SF = swollen and fused; WF = well fused;
HSF = highly swollen and well fused; F = fused

(1) The compressive strength values represent an average of five replicate determinations.

TABLE 6

Quality of Coked Briquets made with Varying Quantities of High Volatile A Bituminous Coking Coal and Carbonized to 750° at 2°C/min and at 20°C/min

No. of Tests	Quantity of coal in mix %	Slow Coking - 2°C/min		Fast Coking - 20°C/min	
		Description*	Comp.strength-kg(1)	Description*	Comp.strength-kg(1)
4	16.3	Fr	2.6	Fr	16+
5	21.7	Fr	4.6	LF	8.2
3	25.3	Fr	3.5	F	8.5
11	30.4	TFr	4.4	WF	8.9
9	34.7	TFr	5.9	WF	10.9
11	40.6	TFr	5.7	WF	8.7
9	45.1	TFr	6.9	WF	10.9
4	49.6	F	6.8	WF	15+

* Fr = free; TFr = tendency to be free; WF = well fused; LF = lightly fused; F = fused.

(1) The compressive strength values represent an average of five replicate determinations for each test.

20°C/min. The results indicate that there is a trend toward increasing strength with increasing rate of carbonization. However, whereas the briquets that are coked at a slow rate do not swell and fuse together --irrespective of the quantity of coal used in the mix, up to about 45 percent--those that are coked at a fast rate are well fused together at their surfaces and are difficult to separate. At an intermediate coking rate of 6°C/min, the briquets were not only well fused, but also highly swollen, practically losing their identity. These results were not unexpected, as at slow rates of carbonization the coking properties have a greater tendency to be destroyed. It is well known in the carbonization industry that weakly coking coals can produce stronger cokes if they are carbonized at a faster rate than normally used in so-called standard high temperature ovens.

Laboratory Coking Test Data vs. Quality of Coked Briquets

In view of time and effort consumed in conducting briquetting tests, followed by coking tests, a study was begun to try to correlate the free swelling and plasticity properties of the coal to the quality of the carbonized briquets, with a view to discovering whether any of the established tests would give values that would permit of reasonable prognostication.

Free Swelling Index

(1) High Volatile A Bituminous Coal

Table 4 presents data on various mixtures of the high volatile bituminous coal (Free Swelling Index: 5) with titanium slag and coke as inert materials. Generally, it may be observed that when the free swelling index was under 1.5, one could expect to obtain coked briquets which were free from one another when coked in a stationary bed at 2°C/min to 750°C. Close relationships for fine differentiation between the strengths of coked briquets and the free swelling indices were not found.

However, broadly speaking, the strength of the coked briquets increased with the free swelling index up to an index of about 1.5, and then there appeared to be a decrease in strength with a further increase in coal. This was associated with swelling and fusion which resulted in loss of identity of the individual briquets.

These results with regard to the influence of inert materials on the free swelling index of coal mixes corroborate, to a large degree, the work of R.Q. Shotts[1] as interpreted by G.L. Kennedy[2].

Kennedy, in discussing Shotts' paper on the effect of various non-coking diluents on the free swelling index of coals, recalculated the results to the basis of total diluent and made the following observations:

(a) "Coals of similar free swelling indices are similarly affected by the same amount of dilution with a non-coking material."

(b) "The free swelling indices of the strongly swelling coals are only slightly affected by the presence of up to 25 percent of diluent, but the indices fall rapidly with further dilution."

(c) "The dilution required to cause a rapid decrease of the free swelling index of a coal is proportional to the free swelling index of the coal."

(d) "Diverse diluents, both organic and inorganic (fusain, ignited coal ash, ignited shale ash, and grey shale) have nearly the same effect in reducing the free swelling index of a coal."

The high volatile A bituminous coking coal used in our experiments with titanium oxide slag and high temperature coke as diluents had a free swelling index of 5, and thus might be expected to permit of a greater dilution with inert materials than the coals in the somewhat lower free swelling index range of 4, reported on by Shotts. In this latter case, with an increase of diluent from 10 to about 30 percent the free swelling index decreased rapidly to less than 1. The results shown in Table 4 indicate that the swelling indices in our experiments were down to 1.5 when the diluent had been increased to about 56 percent.

It is of interest to note that in the blends in our experiments the diluent was increased to 83.5 percent, and although from about 75 percent and up there was only very slight or no agglomeration of the loose mix as used in the free swelling index test, briquets of such mixes, coked at 2°C/min to 750°C in a stationary bed, held together well and exhibited a fair resistance to compression (compressive strength: 2-4 kg).

With a small change in free swelling index from 1 to 1.5 in the mix, there was a substantial increase in the compressive strength of the coked briquets. This would appear to indicate that compaction of the coal and inerts has a definite influence on the coking of the mix, which is more closely related to the proportion of the coal used than to the resultant free swelling index of the mix.

(2) Medium and Low Volatile Bituminous Coals

Although the amount of data obtained with these higher rank coking coals is meagre, the indications are that the general trends are the same as for the high volatile bituminous coal. However, with the medium volatile coal (free swelling index: 7) the free swelling indices of the mixes were higher for the same amount of coal, whereas with the low volatile coal (free swelling index: 5) the free swelling indices of the mixes were about the same as in the case of the high volatile coking coal mixes. This, as noted before, is in agreement with Shotts' findings, namely, that "coals of similar free swelling indices are similarly affected by the same amount of dilution with a non-coking material", and that "the dilution required to cause a rapid decrease of the free swelling index of a coal is proportional to the free swelling index of the coal".

It should be noted, nevertheless, that the coked briquets made with less than 45 percent of the low volatile coal were weaker than those made with the high volatile coal, even though the swelling indices of the coals were the same. In addition, in all the tests conducted using up to 50 percent of coal in the mixes, the coked briquets were free (not swollen and fused together) when coked at 2°C/min to 750°C in a stationary bed.

At about 59 percent coal in the mix, the low and high volatile bituminous coals gave coked briquets with similar strengths. However, whereas the coked briquets strength decreased when over 45 percent of high volatile coal was used, the coked briquets made with low volatile coal appeared to show an increase in strength up to

50 percent coal in the mix. It is thus possible that with a further limited increase in low volatile coal content there would be a further increase in strength of the coked briquets without serious danger of their sticking together in a stationary bed. If such were the case it might permit the production of sufficiently high fixed carbon content coked briquets without the necessity of adding coke fines.

The limited results with the low volatile coal tend to corroborate opinions expressed to the writer by various industrial representatives that high volatile A bituminous coals with certain, though undefined, characteristics are preferable to low volatile coals.

Plasticity of Coal

If the free swelling index does not, by itself, yield suitable data from which to predict the type of coked briquets that might result by mixing large quantities of inert materials with coking coal, then some other property of the coal might be more significant. One of such characteristics is the plasticity of coking coal. The Gieseler(3) method gives a value for the "maximum fluidity" (minimum viscosity) attained by a coal during its plastic state on heating and thermal decomposition. It seems obvious that the more fluid a coal becomes during its plastic state the more readily should it be able to wet particles of inert material and finally bind them together on "setting".

Table 7 presents a series of data giving the quality of coked briquets made from mixes using similar varying quantities of the three ranks of coals which exhibited widely varying "maximum fluidity" values (see Table 2). The compressive strengths of the coked briquets, plotted

TABLE 7

Comparative Briquetting and Coking Data Using Coals of Different Rank, namely, High Volatile A, Medium Volatile and Low Volatile Bituminous

Mix No.	Coal		Mix			Ratio Coal/Inert	Compressive Strength of coked briquets-kg		Visual Character[xx]	
	Rank[x]	Max. Fluidity DDM	Coal %	Coke %	Slag %		Coking Rate 2°C/m	Coking Rate 20°C/m	Coking Rate 2°C/m	Coking Rate 20°C/m
						I				
S-21	HVA	4464	16.4	32.8	50.8	0.20	3.2	20+	Fr	Fr
S-21	LV	1544	16.4	32.8	50.8	0.20	2.6	16.8	Fr	Fr
						II				
S-44	HVA	4464	35.5	0.0	64.5	0.55	5.8	8.0	Fr	WF
S-12	LV	1.7	34.2	0.0	65.8	0.52	1.8	-	Fr	Fr
						III				
S-29	HVA	4464	41.0	0.0	59.0	0.70	6.1	7.9	TFr	WF
S-29	MV	1544	41.0	0.0	59.0	0.70	4.6	-	SF	WF
S-29	LV	1.7	41.0	0.0	59.0	0.70	1.8	5.9	Fr	TFr
						IV				
S-26	HVA	4464	44.4	11.2	44.4	0.80	7.8	12.2	Fr	WF
S-26	MV	1544	44.4	11.2	44.4	0.80	5.2	-	HSF	WF
S-26	LV	1.7	44.4	11.2	44.4	0.80	5.0	11.5	Fr	TFr
						V				
S-28	HVA	4464	50.0	6.8	43.2	1.00	9.6	-	Fr	WF
S-28	LV	1.7	50.0	6.8	43.2	1.00	5.6	16.8	Fr	TFr

x HVA = high volatile A bituminous
MV = medium volatile bituminous
LV = low volatile bituminous

xx Fr = free
TFr = tendency to be free
WF = well fused
SF = swollen and fused
HSF = high swelling and fused

against the percentage of coal in the mixes and against the "maximum fluidity" of each coal at the different coal levels, are presented in Figures 1 and 2 respectively.

Figure 1 shows that, generally, the strength of the briquets coked at 2°C/min to 750°C increased with an increase in the proportion of the coal in the mix, up to 50 percent, the limit reached in these tests. It seems also that, for all coal proportions, the coked briquet strength decreased with an increase in rank, although the variations were not uniform. For the low volatile coal the line was extrapolated for 16.4 percent, as the few tests run yielded very poor or no coked briquets.

Figure 2 indicates that, within the range of "maximum fluidities" for the coals studied, the strength of the coked briquets increased with an increase in the "maximum fluidity" of the coal for the same amounts of coal used in the mixes. Limited in accuracy as these graphs are, it can be seen, for example, that a blend of 35 percent of the high volatile bituminous coal yields coked briquets equivalent in strength to those made with about 50 percent of the low volatile bituminous coal, even though their free swelling indices were the same.

The data allow for the following observations:

(a) The strength of the coked briquets increased with an increase in the "maximum fluidity" of the plastic coal, within the range examined.

(b) The higher the "maximum fluidity" of the coal the greater was the amount of inert material that could

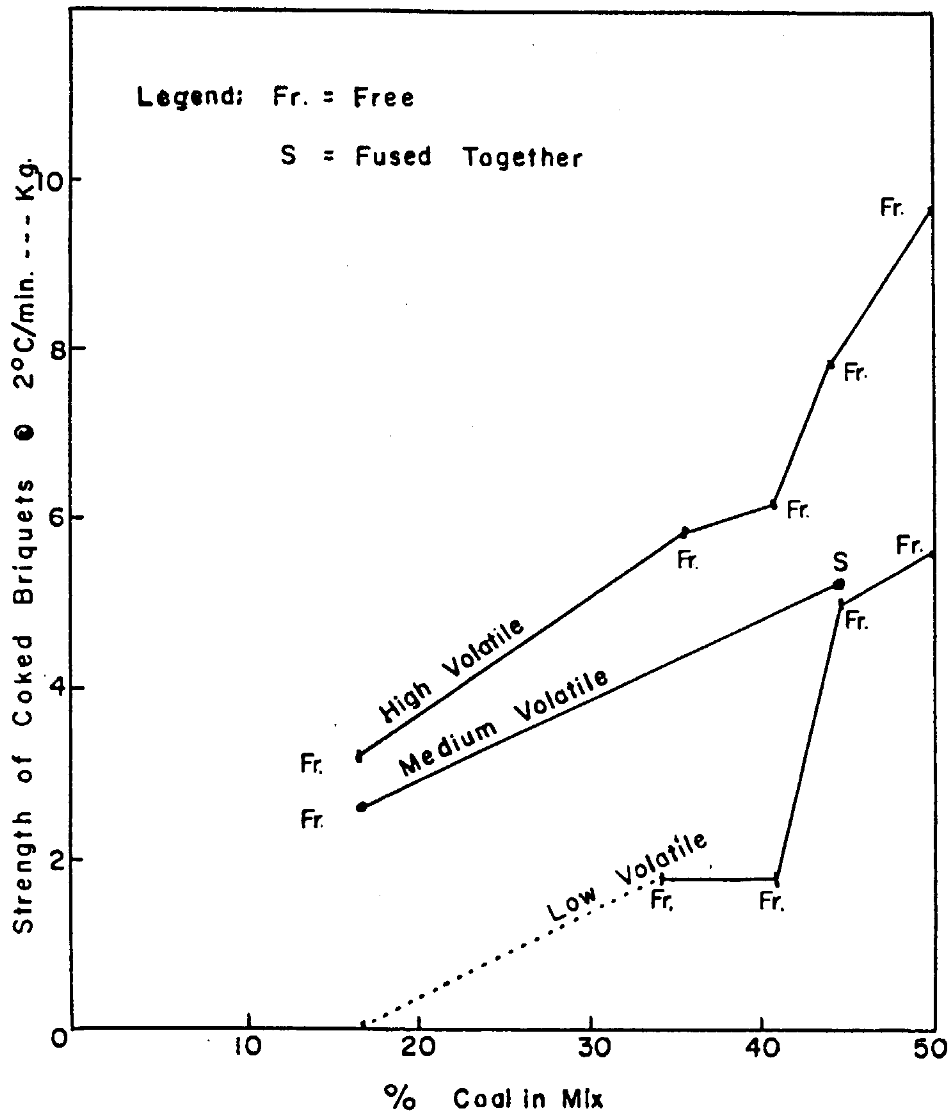

Figure 1 - Relation of quantity of coal to strength of briquets coked at 2° C./min. to 750°C.

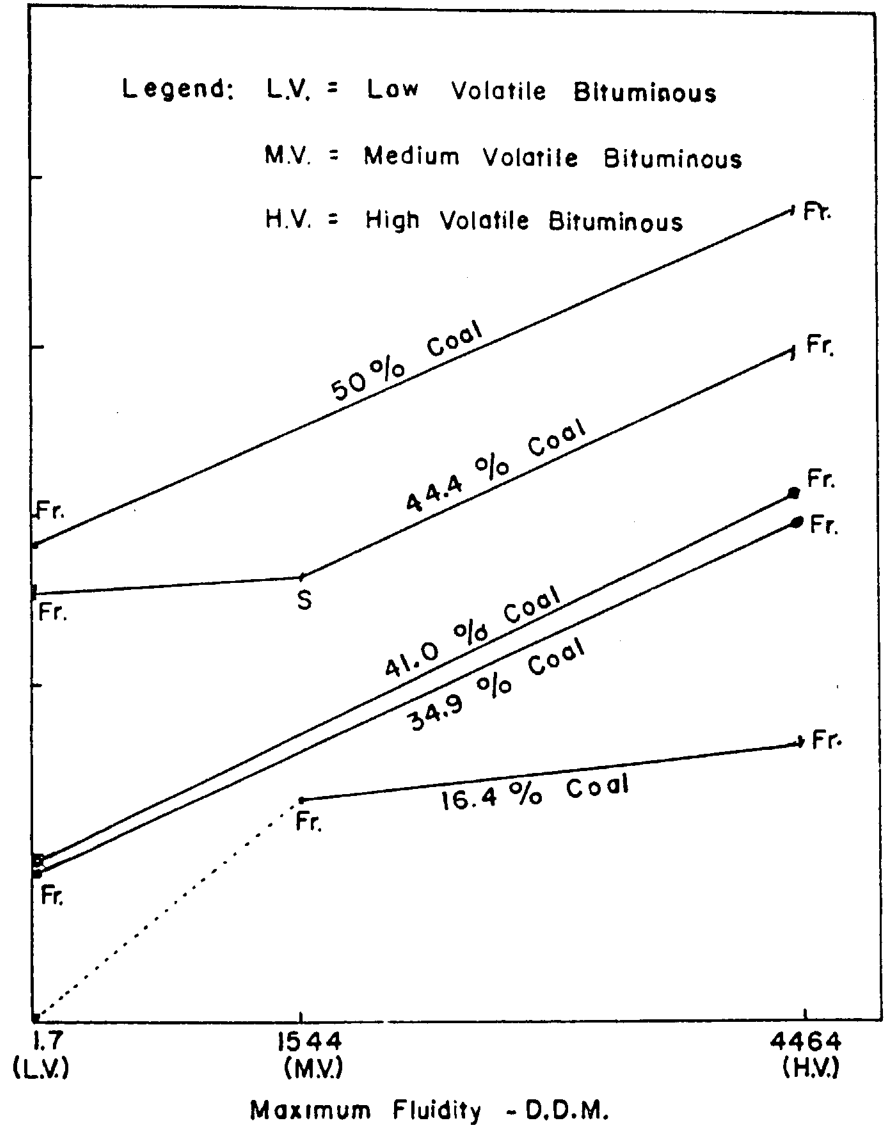

Figure 2 - Relation of "Maximum Fluidity" of coal to strength of briquets coked at 2° C./min. to 750° C.

be mixed with it to obtain a certain quality of coked briquet.

Influence of Compacting

It is apparent that compacting of coal mixed with inert material in the production of briquets influences the strength of the resultant coked briquet in a positive manner. For example, when the materials are loosely mixed, as in conducting a swelling index test, various mixes lean in coal (25 percent and lower with high volatile bituminous coal) show no agglomeration, yet the briquetted compacts held together well and showed a fair degree of resistance to compression.

It appears that it might be necessary to test the characteristics of compacts made at pressures simulating those obtained under commercial conditions. Such an investigation might result in the development of a simple test the results of which could be equated against what might be expected from briquets produced commercially.

GENERAL REMARKS

The degree to which the coked briquets remained free as separate identities or fused together, when coked at 2°C/min to 750°C, would appear to depend on various factors. In the case where the high volatile A bituminous coal was used, the briquets may be considered to have remained free for two reasons: (1) development of sufficient shrinkage due to loss of volatile matter, and (2) rather rapid destruction of coking properties as a result of thermal decomposition at the low rate of heating. Experimental evidence shows that when coking the same briquets at a higher rate, say at 6°C/min, none of the briquets remained free, irrespective of whether the blend contained 47 or 21 percent coal.

The briquets prepared with the low volatile bituminous coal remained free when coked at a slow rate, using as much as 50 percent coal, mainly because of the low fluidity of the coal during its plastic state.

The briquets made with the medium volatile bituminous coal, with medium fluidity during plasticity, fused together, it would seem, for the following reasons: (1) there was insufficient shrinkage due to loss of volatile matter; and (2) the coking properties were not as rapidly destroyed at the low rate of heating as in the case of the high volatile coal.

From the data discussed it would appear that, when used in suitable proportions in admixture with inerts, both high and low volatile bituminous coals should be suitable for making coked briquets that would remain free on coking at a low rate of heating in a stationary bed. Not enough data are available with regard to the medium volatile coal, and thus further investigation is indicated.

REFERENCES

(1) R.Q. Shotts: "Influence of Certain Inorganic Matter, Fusain and 'Dull' Coal on the Free Swelling Index of Coal" - Fuel, London, 31, pp 448-461, 1952.

(2) G.L. Kennedy: "Free Swelling Indices" - Letter to Editor; Fuel, London, 33, pp 120-124, 1954.

(3) American Society for Testing Materials: "Proposed Method of Test for Plastic Properties of Coal by the Gieseler Type Plastometer". This proposed method was published in the ASTM Standards for Coal and Coke, September 1951.

===

ES:jg