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REPORT ON
THE BENEFICIATION OF DRUMHELLER SUBBITUMINOUS COALS
BY BRIQUETTING
USING VARIOUS KINDS OF BINDERS

by

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PREFACE

This report comprises the results of an investigation conducted during the last two and one half years on the amenability to briquetting of slack sizes of subbituminous coal from the Drumheller coal field in Alberta. It is a revision of a report issued in April of this year, designated as F.R.L. No. 66, advance copies of which were supplied to colliery operators and officials of the Drumheller Coal Operators Association.

It may well be considered a supplement to a former Bureau of Mines publication, viz., No. 775 entitled "Fuel Briquetting" by R.A. Strong, E. Swartzman and E.J. Burrough. This publication, in addition to containing a summary of the results of briquetting tests conducted at the Fuel Research Laboratories up to 1937, was largely a review of the literature on the subject and included a comprehensive patent review as well as an extensive reference list. This former report included tests on both caking and non-caking bituminous and subbituminous coals and concluded that the amenability to briquetting of such coal varying somewhat in rank, had a direct relationship to the caking (or coking) properties, and that the blending of a caking coal with non-caking coals was essential for the production of good briquettes from the latter.

Since the lower rank coals, including the non-caking bituminous (and lignites), as mined and marketed slack readily on exposure to the atmosphere with the resultant production of an excessive proportion of fines, they present a problem in regard to finding some method of beneficiation. Briquetting as a means of increasing the form value of the slack back to that of stabilized lump sizes has been considered worthy of continued study.

The investigation here reported was confined to determining the briquetting properties of the raw coal, alone and in blends with caking coal in a standard roll press operating at normal low pressure. The Drumheller non-caking coals tested were not pretreated in any way except for the reduction in moisture content taking place on air drying. Tests were conducted to determine the comparative value of several binders, viz., petroleum asphalt, starch, concentrated sulphite liquor, and different mixtures of asphalt and starch.

The results indicate that, although a strong briquette can be produced from Drumheller coal alone by using a dual starch and petroleum asphalt binder, that will weather well and not produce excessive smoke, a minimum of 20% of a good caking coal must be added in order to obtain a product that will stand up in the fire. Such a briquette will be lower in moisture and higher in calorific value than the original Drumheller coal, will stand up far better to weathering than lump sizes of the coal, and should find a ready market in competition with other briquettes and also with higher rank Alberta coals for domestic use.

R.E. Gilmore,
Chief, Division of Fuels.

INTRODUCTION

During the war years 1940-1945, due to abnormally increased industrial activity, no difficulty was apparently experienced by Canadian collieries in disposing of all their coal, whatever it's rank, grade or size. However prior to the war, under more or less normal industrial conditions, the marketing of slack coals, especially those of lower rank, became a problem of major importance, and one that seriously affected the economics of coal mining in view of the lower sale price of the finer sizes in comparison to the sized lump coals. It is anticipated that in the not too distant post-war period when industrial activity generally becomes stabilized to peace time economic conditions the disposition of slack from the lower rank coals will again become a major problem and may in fact be aggravated by the possibility of increased production of fine sizes, because of both economic and competitive factors.

As the cost of production has risen during the war, and may well continue to rise to some degree in the post-war period, the necessity to reduce costs will lead to more extensive mechanical mining and preparation, which unavoidably will result in increased production of fines. In addition, competition with other fuels such as oil and gas, especially in the domestic field, where the increased demand for new types of semi or fully-automatic equipment is anticipated, will in all probability necessitate the supply of larger quantities of closely sized products of the smaller sizes, a condition in preparation which will also result in an increased production of fines because of the necessity to crush the larger sizes. The above conditions can quite conceivably result in such an excessive over production of fines that slack coal will again have to be stored indefinitely at the pithead or discarded.

This anticipated increased production of slack coal will, as long as there is maintained a substantial differential in the price of various sizes in favour of the larger sizes, necessitate it's upgrading in form, and thus in price value, or place an ever increasing load on the larger sizes. Among the various methods usually considered for processing fine coal in order to produce a lump fuel with an increased value, coking and briquetting are still the most popular. However, in so far as the sub-bituminous coals from the Drumheller field are concerned, coking of the coal is out of the question because the coals do not even agglomerate. Thus briquetting appears, at least for the present, to offer the most likely solution to the problem. This report presents the results of an extensive investigation, undertaken by the Division of Fuels during 1945-46, on the briquetting of Drumheller coals, conducted with a view to determining whether a briquette with suitable handling, storing and burning properties could be produced from these coals alone or blended with others of required quality without any preliminary treatment, with exception of partial drying.

I

COALS TESTED

The coals from the Drumheller Alberta coalfield, used in this investigation, came from various mines in the field, the locations of which are listed below:-

1. Coal A:-Sec. 9, Twp. 29, Range 20, West of the 4th Meridian, near Drumheller.

2. Coal B:-Sec. 11, Twp. 29, Range 20, West of the 4th Meridian, near Drumheller.

3. Coal C:-Sec. 15, Twp. 29, Range 20, West of the 4th Meridian, near Drumheller.

4. Coal D:-Sec. 27, Twp. 29, Range 19, West of the 4th Meridian, near Rosedale.

All the above coals, although mined in different parts of the field, come from the same seam, namely No. 1 seam, and do not vary to any appreciable degree either in their physical or chemical characteristics. Table I presents the data relavent to the chemical and physico-chemical properties of the four coals used in this study.

TABLE I.

CHEMICAL AND PHYSICO-CHEMICAL PROPERTIES
OF THE DRUMHELLER COALS
(As received basis)

	A	B	C	D
Proximate Analysis-				
Moisture--------%	13.8	15.1	14.5	15.5
Ash-------------%	8.2	8.0	9.8	8.6
Volatile Matter-%	31.9	31.0	31.6	30.4
Fixed Carbon----%	46.1	45.9	44.1	45.5
Sulphur---------%	0.3	0.6	0.4	0.6
Calorific Value- B.T.U./lb.	10,205	10,245	9,885	10,030
Soft.Temp. of Ash-°F	2,150	2,220	2,300	2,260
Caking properties-	N.A.*	N.A.*	N.A.*	N.A.*
Rank--------------	Subbituminous B.			

*N.A.=Non-Agglomerate.

Although further east, in the East Coulee district of the Drumheller field, the coals are somewhat higher in moisture and lower in calorific value, their physical characteristics differ little from those in the Drumheller and Rosedale districts, and in so far as their briquetting properties are concerned, may be, for all practical purposes, considered similar, and thus what applies to the above listed coals in this regard, will apply equally to all the Drumheller coals whether from the No. 1, No. 5, or No. 2 (East Coulee) seams.

For blending purposes, in order to improve certain of the characteristics of the briquettes, two medium volatile coking coals, one from Alberta and the other from British Columbia, and having widely different coking properties, were used. These coals came from the following areas:-

1. Coal E:-Michel District, Crowsnest, B. C. area:-This was a mixture of coals from two seams, namely, No. 3, and B.

2. Coal F:-Mountain Park Area, Luscar Basin; Twp. 47, Range 24, West of the 5th Meridian, near Luscar, Alberta.

The analyses of the above coals used in this investigation are shwon in Table II below:-

TABLE II.

CHEMICAL AND PHYSICO-CHEMICAL PROPERTIES OF THE BITUMINOUS BLENDING COALS (As received basis)

	E	F
Proximate Analysis-		
Moisture---------------%	1.1	1.8
Ash--------------------%	11.0	15.0
Volatile Matter-------%	23.2	23.7
Fixed Carbon----------%	64.7	59.5
Sulphur-----------------%	0.7	0.3
Calorific Value-B.T.U./lb.	13,675	12,690
Caking Properties-		
(a) By 950°C. button---	Good	Good
(b) Swelling Index-----	1,100	121
(c) Caking Index-------	48	35

Commercially, in either case, a lower ash product could be produced, but for these tests, samples were prepared from the run-of-mine coal obtained for the Physical and Chemical Study of the coals as mined. So long as the ash content was not excessive, it was not considered to be a critical factor in studying the briquetting properties of the coals.

The chemical analyses of the various Drumheller and bituminous coal blends used for the briquetting tests are shown in Tables IIA and IIB.

TABLE IIA.

CHEMICAL ANALYSES OF BLENDED COALS
(As received basis)

	80% Drum-D 20% M.V.-E*	75% Drum-D 25% M.V.-E*	70% Drum-D 30% M.V.-E*
Proximate Analysis-			
Moisture--------%	12.6	11.9	11.2
Ash-------------%	9.1	9.2	9.3
Volatile Matter-%	29.0	28.6	28.2
Fixed Carbon----%	49.3	50.3	51.3
Sulphur------------%	0.6	0.6	0.6
Calorific Value- B.T.U./lb.	10,760	10,940	11,430

*M.V.=Medium volatile bituminous.

TABLE IIB.

CHEMICAL ANALYSES OF BLENDED COALS
(As received basis)

	80% Drum-B 20% M.V.-E*	90% Drum-B 10% M.V.-E*	80% Drum-C 20% M.V.-F*
Proximate Analysis-			
Moisture--------%	12.3	13.7	12.0
Ash-------------%	8.6	8.3	10.8
Volatile Matter-%	29.4	30.2	30.0
Fixed Carbon----%	49.7	47.8	47.2
Sulphur------------%	0.6	0.6	0.4
Calorific Value- B.T.U./lb.	10,930	10,590	10,445

*M.V.=Medium volatile bituminous.

II

SIZE OF COAL BRIQUETTED

All the coal used in the briquetting tests was crushed in a Ring Mill, which was a fairly high capacity, high speed, laboratory ring mill, fitted with round-hole plate screens.

In the first series of tests, one of the Drumheller coals was ground to different fineness to determine the most suitable screen sizing for the preparation of a briquette with optimum handling properties. The screen analyses of these crushed samples are shown in Table III.

TABLE III.

SCREEN ANALYSES OF DRUMHELLER COAL CRUSHED TO DIFFERENT FINENESS

Coal	Drumheller-(A)		
Crushed to Pass	¼ in.	1/8 in.	1/16 in.
Screen Analysis*			
Plus 4 mesh------%	0.0	0.0	0.0
10-4 mesh--------%	6.4	0.1	0.0
20-10 mesh-------%	41.2	15.4	0.8
35-20 mesh-------%	26.4	34.0	14.5
48-35 mesh-------%	8.3	15.1	18.3
100-48 mesh-------%	10.0	20.1	38.0
0-100 mesh------%	7.7	15.3	28.4
	100.0	100.0	100.0
Bulk Density-lb./cu.ft.	47.0	46.0	47.0

* Tyler standard sieves.

In Table IV are shown the comparative screen analyses of the four Drumheller coals when crushed to pass a 1/8 in. screen, and as used in all subsequent tests.

TABLE IV.

COMPARATIVE SCREEN ANALYSES OF THE VARIOUS DRUMHELLER COALS CRUSHED TO PASS A 1/8 IN. SCREEN

Coal	Drumheller A	D	B	C
Crushed to Pass	1/8 in.	1/8 in.	1/8 in.	1/8 in.
Screen Analysis*				
Plus 4 mesh--%	0.0	0.0	0.0	0.0
10-4 mesh----%	0.1	0.1	1.7	1.3
20-10 mesh---%	15.4	15.4	24.9	17.6
35-20 mesh---%	34.0	33.1	31.6	32.8
48-35 mesh---%	15.1	15.2	13.6	14.4
100-48 mesh---%	20.1	20.4	15.2	19.3
0-100 mesh--%	15.3	15.8	13.0	14.6
	100.0	100.0	100.0	100.0
Bulk Density-lb./cu.ft.	46.0	48.0	47.5	46.5

* Tyler standard screens.

Table V presents the comparative screen analyses of the two bituminous coals used for blending purposes, and crushed, as the above, to pass a 1/8 in. screen.

TABLE V.

COMPARATIVE SCREEN ANALYSES OF THE BITUMINOUS BLENDING COALS CRUSHED TO PASS A 1/8 IN. SCREEN

Coal	Bituminous E	F
Crushed to pass	1/8 in.	1/8 in.
Screen Analysis*		
Plus 4 mesh-------%	0.0	0.0
10-4 mesh---------%	0.3	0.8
20-10 mesh--------%	10.4	13.6
35-20 mesh--------%	28.4	31.9
48-35 mesh--------%	17.9	16.8
100-48 mesh--------%	22.7	18.2
0-100 mesh-------%	20.3	18.7
	100.0	100.0
Bulk Density-lb./cu.ft.	48.0	49.0

* Tyler standard screens.

III

BINDERS EMPLOYED

Three commonly used binding materials were employed in this investigation, namely, petroleum asphalt, starch (wheat flour), and a sulphite liquor concentrate trade named "Glutrin".

Petroleum Asphalt-The asphalt used was a standard product produced by the Imperial Oil Co., Ltd., for the briquetting of coal, and had a softening point of 145°F by the Ball-and-Ring method. The analysis of a sample of this material was as follows:-

Moisture-------------------%	0.01
Ash------------------------%	0.17
Volatile Matter-----------%	73.22
Fixed Carbon--------------%	26.60
Sulphur-------------------%	1.16
Calorific Value-B.T.U./lb.	17,685
Caking properties--------	Good

In comparison to the vegetable binders used, this material yields fairly large volumes of dense smoke on burning.

Starch-A second grade wheat flour was employed as the starch binder. This type of flour, on the average, has the following analysis:-

Moisture-------------------%	12.0
Ash------------------------%	0.4
Organic residue-----------%	87.6
Calorific Value-B.T.U./lb.	6,370

"Glutrin"-This is a neutralized concentrate of sulphite liquor used extensively in foundries for core work. The organic materials responsible for the binding characteristics of the liquor consist mainly of lignin, carbohydrates (various sugars), proteins, resin and fats, the dry residue containing from 10-15% ash. The material used in this investigation had the following approximate analysis:-

Moisture-------------------%	50.0
Ash------------------------%	6.0
Organic residue-----------%	44.0
Calorific Value-B.T.U./lb.	3,500

Starch-Asphalt Binder

For many of the tests petroleum asphalt and flour were used as a dual binder. In some of the tests they were added separately whereas in others a so-called emulsion was prepared.

The starch-asphalt emulsion was prepared by first making a thick boiled paste of flour and water and then mixing with this, while stirring, the hot molten asphalt. A recommended binder of this type containing 1¼% starch, 3½% asphalt and 11% water, as a percentage of the coal, has been found to be a satisfactory binder for many coals, resulting in the production of a strong briquette, easily handled when fresh from the press, and not requiring special drying. As this particular formula was not found to be entirely satisfactory for the coals tested, variations of it were investigated.

Where flour and petroleum asphalt were added separately, the preheated coal was first moistened with water, then the flour added, and the coal and flour mixed and heated until the whole mass became pasty. Then, and not until then, the asphalt was added.

IV

THE BRIQUETTING TESTS

The briquetting tests were conducted with the aid of more or less standard laboratory equipment used for such processing. The press consisted of a standard type, electrically operated, low capacity Komarek-Greaves roll press, fitted with rolls, two pockets in width, 20½ inches in diameter, and 4-5/8 inches wide, making 1-3/4 ounce, 2-inch square, pillow-shaped briquettes. The coal, usually in 50-pound batches, was heated, mixed and treated with binders in a 75-pound capacity double-paddled, steam jacketed, bread mixer, and the hot mix was cooled to a suitable briquetting temperature by spreading it out on the floor.

In order to obtain the information required, a total of forty-two tests in duplicate were conducted as follows, to determine:-

(I) MOST SUITABLE COAL SIZE FOR BRIQUETTING AND VALUE OF PETROLEUM ASPHALT AS BINDER WITH DRUMHELLER ALONE

				Test No.
1.	100% Drum-(A):	-¼ in.--6%	pet. asphalt	13
2.	" :	-¼ in.--8%	" "	12
3.	" :	-¼ in.-10%	" "	14
4.	" :	-1/8 in.--6%	" "	7 & 11
5.	" :	-1/8 in.--8%	" "	8
6.	" :	-1/8 in.-10%	" "	9 & 23
7.	" :	-1/8 in.-12%	" "	10
8.	" :	-1/16 in.--8%	" "	15
9.	" :	-1/16 in.-10%	" "	17
10.	" :	-1/16 in.-12%	" "	21

(II) VALUE OF FLOUR AS BINDER WITH DRUMHELLER COAL ALONE

11.	100% Drum-(D):	-1/8 in.--5%	flour	35
12.	" :	-1/8 in.--6%	"	34
13.	" :	-1/8 in.--7%	"	33
14.	100% Drum-(C):	-1/8 in.--7%	"	63

(III) VALUE OF FLOUR AS BINDER USING BLEND OF DRUMHELLER WITH BITUMINOUS COAL

15.	80% Drum-(D), 20% M.V.-E:	-1/8 in.-5%	flour	29
16.	" , " :	-1/8 in.-6%	"	28
17.	" , " :	-1/8 in.-7%	"	27

(IV)
VALUE OF GLUTRIN AS BINDER USING BLEND OF DRUMHELLER WITH BITUMINOUS COAL

		Test No.
18.	80% Drum-(B), 20% M.V.-E:-1/8 in.--12% Glutrin (6% Solids)	36
19	" , " :-1/8 in.--16% Glutrin (8% Solids)	37
20.	" , " :-1/8 in.--20% Glutrin (10% Solids)	38

(V)
EFFECT OF VARYING QUANTITY OF BITUMINOUS COAL IN BLEND

21.	80% Drum-(D), 20% M.V.-E:-1/8 in.-8% pet.asphalt	30
22.	75% " , 25% M.V.-E:-1/8 in.-8% " "	31
23.	70% " , 30% " :-1/8 in.-8% " "	32

(VI)
VALUE OF FLOUR-ASPHALT BINDER, UNMIXED AND AS EMULSION, WITH DRUMHELLER COAL ALONE

24.	100% Drum-(B):-1/8 in.--4% flour, 2% asphalt (unmixed)	43
25.	" :-1/8 in.--3% flour, 3% asphalt (emulsion)	57

(VII)
VALUE OF FLOUR-ASPHALT BINDER, UNMIXED, WITH A BLEND OF DRUMHELLER AND BITUMINOUS COAL

26.	80% Drum-(B), 20% M.V.-E:-1/8 in.-3% flour, 2% asphalt	40
27.	" , " :-1/8 in.-3% " , 4% "	50
28.	" , " :-1/8 in.-4% " , 1% "	39
29.	" , " :-1/8 in.-5% " , 1% "	41
30.	" , " :-1/8 in.-5% " , 2% "	42
31.	" , " :-1/8 in.-2% " , 6% "	56
32.	80% Drum-(B), 20% M.V.-F:-1/8 in.-2% " , 6% "	58

(VIII)

EFFECT OF VARYING QUANTITY OF BITUMINOUS COAL IN BLEND WHEN USING THE FLOUR-ASPHALT BINDER, UNMIXED

33.	80% Drum-(B), 20% M.V.-E:-1/8 in.-4% flour, 2% asphalt	59A
34.	85% " , 15% " :-1/8 in.-4% " , 2% "	46
35.	90% " , 10% " :-1/8 in.-4% " , 2% "	45
36.	95% " , 5% " :-1/8 in.-4% " , 2% "	44

(IX)

VALUE OF FLOUR-ASPHALT BINDER, AS EMULSION, WITH A BLEND OF DRUMHELLER AND BITUMINOUS COAL

						Test No.
37.	80% Drum-(B),	20% M.V.-E:	-1/8 in.-	$1\frac{1}{4}$% flour,	$3\frac{1}{2}$% asphalt	52
38.	" ,	" :	-1/8 in.-	2% " ,	$3\frac{1}{2}$% asphalt	53
39.	" ,	" :	-1/8 in.-	$2\frac{1}{2}$% " ,	3% "	54
40.	" ,	" :	-1/8 in.-	3% " ,	3% "	55
41.	" ,	20% M.V.-F:	-1/8 in.-	3% " ,	3% "	59
42.	90% " ,	10% M.V.-E:	-1/8 in.-	4% " ,	1% "	51

The results of these tests giving such details as the condition of the mix prior to briquetting, and performance during briquetting, are presented in Tables VI to XII inclusive.

V

TESTING OF THE QUALITY OF THE BRIQUETTES

After thorough cooling and seasoning, the briquettes from each test were subjected to various physical and chemical tests for comparative purposes.

Physical Tests

(a) Bulk Density:-The density in bulk or weight per cubic foot was determined.

(b) Compressive Strength:-Resistance to compression was determined by means of the Komarek-Greaves tester. This instrument consists of a calibrated spring attached to a threaded plunger by means of which the briquette is compressed between two flat surfaces. The compression of the spring is indicated on a pointer gauge marked in pounds, and experience has shown that commercial briquettes which break at less than 130 pounds are not sufficiently strong to withstand normal handling.

(c) Resistance to Handling:-This is determined on small quantities of briquettes by means of the F. R. L. Tumbler Test(1). This test, designed to determine the relative stability to shattering, as well as the abradability, of briquettes, consists of tumbling, in a laboratory ball mill jar fitted with iron frames upon which are $1\frac{1}{4}$ in. projecting strips, 1000 grams of briquettes for one-half hour at 40 r. p. m. The shattered and abraded briquettes are then screened, the material retained on a 1-inch screen, calculated as a percentage, indicating the

(1) This is a modification of the A. S. T. M. tentative standard test Designation D441-37T-"Method of Tumbler Test for Coal".

stability or resistance to shatter, and the material passing a 10 mesh screen, calculated as a percentage, indicating the degree to which the briquettes abrade. Previous experience has indicated that the results of this test appear to agree quite well with the results of larger standard tests, inasmuch as the material over 1-inch in size from this test compares favourably with the $1\frac{1}{2}$ inch shatter index determined by the method used for testing coke,(2) and the quantity of material passing the 10 mesh screen approximates to the sum of the breakage in the shatter test (i.e. material through $\frac{1}{2}$ inch), and the dust due to abrasion as determined by the Sheffield Abrasion Test.(3)

(d) Resistance to Water Immersion:-The waterproof characteristics of briquettes may be indicated by their resistance to wetting on immersion in water. For these tests, 1000 grams of briquettes were immersed in ordinary tap water at room temperature for one hour, and then weighed to determine absorption.

Chemical Tests

The briquettes were tested for their proximate composition, that is, for their moisture, ash, volatile matter and fixed carbon contents. The sulphur contents and calorific values were calculated from the analyses of the coals and binders in the mixtures.

All the above data with regard to the physical and chemical properties of the briquettes are given in Tables VI to XII inclusive.

(2) "Drop Shatter Test for Coke"-A.S.T.M. Standard Designation D141-23.

(3) Sheffield Abrasion Test-Developed for coke testing by the Midland Coke Research Committee and described in the publication "The Quality of Coke", the Second Report of the Committee-1939- by R. A. Mott & R. V. Wheeler.

Caking Properties

Because briquettes are prepared from fine particles of coal, it is important that they be of such a nature that they do not fall apart readily, and collapse on burning, otherwise burning conditions will be poor, and loss of combustible in the refuse will be excessive. Retention of the strength and form of a briquette during burning is dependent, either on the binding together of the particles as a result of the inherent caking properties of the coal itself, or of the binder.

To determine the comparative caking properties of the briquettes, single briquettes were burned in an electric muffle at about 1740°F. in a stream of air until the volatile matter was completely driven off. The carbonized residues of the briquettes were then visually examined for their retention of form, shrinkage, and development of fractures. In addition, in order to obtain a numerical value for comparative purposes, the compressive strength of each of the caked residues was determined by compressing the carbonized product between two flat, one square inch surfaces, the apparatus operating on the lever principle with the fulcrum between the weight and the resisting briquette. All these tests were conducted in duplicate, and the results are presented in Table XVI. Plates III and IV show photographically the various residues in comparison to the raw briquette.

Storage Properties

A briquette to be commercially successful, and compete with high grade fuels, must be of such a quality that it can be stored in the open under varying weather conditions without deteriorating to any great degree in physical quality. With subbituminous coals, such as those dealt with in this study this attribute of good storage quality, is of added importance, because the coal itself, expecially in the smaller sizes, weathers readily, breaking down to a pulp of fine material.

Small scale outdoor storage tests were thus conducted on eleven different samples of briquettes. Twenty-pound quantities of each type of briquette were placed in small conical piles on a ½-inch square mesh screen supported on tubs. They were allowed to be exposed to the weather, on the roof of a one story building, for a period of from 95 to 102 days between June 11 and September 20, 1946. The weather record during this period is shown in Table XIII.

During the storage period observations, at various intervals, were made as to the condition of the briquettes, thus giving a progressive history of the storage of each of the briquette samples. This record is shown in Table XIV. Plates I & II are photographs of the storage test samples, taken at the beginning and at the conclusion of the test period, and serve to indicate the degree of deterioration of the various samples.

In order to determine numerically the effect of the storage on the physical quality of the briquettes, they were tested, at the end of the storage period, for their resistance to handling by the F. R. L. Tumbler Test, and compared to the quality of the same briquettes before storage. The results of these tests are given in Table XV.

TABLE VI

Details of Briquetting Tests

Test No.	13	12	14	7&11	8	9&23	10
Coal or Blend	100% Drumheller						
Size of Coal	-1/4"	-1/4"	-1/4"	-1/8"	-1/8"	-1/8"	-1/8"
Binder	6% pet. asphalt	8% pet. asphalt	10% pet. asphalt	6% pet. asphalt	8% pet. asphalt	10% pet. asphalt	12% pet. asphalt
Condition of Mix							
(a) Water added..............................%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(b) Temp. of preheated coal.........Deg. C.	112	115	110	115	118	112	115
(c) Temp. of mixture................Deg. C.	122	125	120	125	130	127	130
(d) Temp. of mix to press...........Deg. C.	92	90	87	92	88	85	88
Performance during Briquetting							
(a) Sticking in rolls...................:	Nil	Nil	Nil	Nil	Nil	Nil	Serious[a]
(b) Compression.........................:	Fair	Fair	Fair	Fair	Fairly good	Good	Fair
(c) Condition leaving press.............:	Weak	Fair	Fairly Good	Fair	Fairly good	Good	Weak
Quality of Briquettes							
Physical properties							
(a) Bulk density.................lb./cu.ft.	34.8	34.8	34.5	33.8	36.8	41.0	36.8
(b) Resistance to handling (Tumbler Test)							
1. Stability (plus 1 in.).........%	16.8	39.8	65.7	25.1	81.5	91.1	82.9
2. Abradability (-10 mesh)........%	67.6	54.6	32.1	67.3	18.5	8.9	16.8
(c) Resistance to water immersion........:	Good	Good	Good	Good	Good	Good	Good
1. Water absorbed.......................%	1.8	1.6	1.5	1.9	1.7	1.8	1.5
(d) Compressive strength (b)............:	25	50	80	25	60	100	70
Chemical properties							
Proximate analysis							
Moisture................................%	9.8	10.4	10.6	11.5	10.5	11.7	9.7
Ash.....................................%	8.8	9.2	8.7	8.4	9.6	9.2	10.2
Volatile matter.........................%	32.6	31.8	33.1	32.7	31.8	32.0	31.8
Fixed carbon............................%	48.8	48.6	47.6	47.4	48.1	47.1	48.3
Sulphur.................................%	0.3(#)	0.3(#)	0.3(#)	0.3(#)	0.3(#)	0.3(#)	0.3(#)
Calorific value................B.T.U./lb.:	11,100(#)	11,175(#)	11,295(#)	10,890 (#)	11,170(#)	11,130(#)	11,530(#)
Coking properties.......................:	A(c)	A(c)	A(c)	A(c)	A(c)	A(c)	A(c)

TABLE VII
Details of Briquetting Tests

Test No.	15	17	21	35	34	33	63(d)
Coal or Blend	100% Drumheller A			100% Drumheller D			Drum. C.
Size of Coal	-1/6"	-1/16"	-1/16"	-1/8"	-1/8"	-1/8"	-1/8"
Binder	8% pet. asphalt	10% pet. asphalt	12% pet. asphalt	5% flour	6% flour	7% flour	7% flour
Condition of Mix							
(a) Water added..........................%	0.0	0.0	0.0	16.0	16.0	16.0	16.0
(b) Temp. of preheated coal.........Deg. C.	112	115	115	115	118	115	118
(c) Temp. of mixture...............Deg. C.	130	125	128	110	110	100	105
(d) Temp. of mix to press..........Deg. C.	87	90	88	90	90	90	90
Performance during Briquetting							
(a) Sticking in rolls...................:	Nil	Nil	Nil	Nil	Nil	Nil	Nil
(b) Compression.........................:	Fair	Fair	Fair	Good	Good	Good	Good
(c) Condition leaving press..............:	Weak	Fair	Fair	Good	Good	Good	Good
Quality of Briquettes							
Physical properties							
(a) Bulk density...............lb/cu. ft.	32.5	33.0	33.5	38.8	37.3	39.3	42.0
(b) Resistance to handling (Tumbler Test)							
1. Stability(plus 1 in.)..........%	18.0	53.5	59.5	90.0	88.4	91.1	97.3
2. Abradability (-10 mesh)........%	68.8	43.9	37.8	8.9	11.5	8.8	2.4
(c) Resistance to water immersion.........	Good	Good	Good	Very poor(g)	Very poor(g)	Poor(g)	Poor(g)
1. Water absorbed.................%	1.6	1.8	1.4	28.8	35.0	29.1	40.1
(d) Compressive strength (b)............:	55	70	70	130	135	138	145
Chemical properties							
Proximate analysis							
Moisture..............................%	11.5	10.8	9.9	15.6	14.9	10.8	16.3
Ash...................................%	9.1	9.5	8.7	9.6	7.8	8.4	8.5
Volatile matter.......................%	31.8	32.1	32.5	32.2	33.9	32.5	34.3
Sulphur...................................%	0.3(#)	0.3(#)	0.3(#)	0.6(#)	0.6(#)	0.6(#)	0.4(#)
Calorific Value.................B.T.U./lb..	11,040(#)	11,245(#)	11,500(#)	9,745(#)	9,985(#)	10,385(#)	9,580(#)
Coking properties........................	A(c)	A(c)	A(c)	N.A.(e)	V.W.A.(f)	V.W.A.(f)	V.W.A.(f)

TABLE VIII

Details of Briquetting Tests

Test No.	29	28	27	36	37	38
Coal or Blend	80% Drumheller, 20% M.V.B.-E			80% Drumheller, 20% M.V.B.-E		
Size of Coal	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"
Binder	5% flour	6% flour	7% flour	12% glutrin (6% solids)	16% glutrin (8% solids)	20% glutrin (10% solids)
Condition of Mix						
(a) Water added.............................%	16.0	16.0	16.0	Nil	Nil	Nil
(b) Temp. of preheated coal.........Deg. C.	118	115	120		not preheated	
(c) Temp. of mixture................Deg. C.	105	110	105	90	90	90
(d) Temp. of mix to press...........Deg. C.	90	88	88	60	70	80
Performance during Briquetting						
(a) Sticking in rolls.......................:	None	None	None	None	None	Some sticking
(b) Compression.............................:	Good	Good	Good	Fair	Fair	Good
(c) Condition leaving press.................:	Good	Good	Good	Fair	Fair	Fairly good
Quality of Briquettes						
Physical properties						
(a) Bulk Density.............lb./cu. ft.	42.3	41.0	42.8	36.0	38.5	39.0
(b) Resistance to handling (Tumbler Test)						
1. Stability (plus 1 in.)........%	95.2	95.8	96.7	47.5	79.8	90.0
2. Abradability (-10 mesh).......%	4.8	4.2	3.3	47.4	19.3	9.7
(c) Resistance to water immersion.......:	Poor(g)	Poor(g)	Poor(g)	Very poor	Very poor	Very poor
1. Water absorbed................%	16.2	14.3	16.7	3/4 disintegrated	1/2 disintegrated	1/4 disintegrated
(d) Compressive strength (b)............:	267	290	330	30	112	180
Chemical properties						
Proximate Analysis						
Moisture..............................%	13.7	12.2	11.8	11.0	11.1	11.4
Ash...................................%	13.0	12.6	13.4	8.1	7.9	8.0
Volatile matter.......................%	30.1	30.2	31.1	33.6	33.1	33.1
Fixed carbon..........................%	43.2	45.0	43.7	47.3	47.9	47.5
Sulphur...............................%	0.6(#)	0.6(#)	0.6(#)	----	----	----
Calorific Value.................B.T.U./lb.	9,890(#)	10,095(#)	10,005(#)	10,930(#)	10,860(#)	10,725(#)
Coking properties.........................:	V.W.A.(f)	V.W.A.(f)	V.W.A.(f)	W.A.(h)	W.A.(h)	W.A.(h)

TABLE IX
Details of Briquetting Tests

Test No.	30	31	32	43	57
Coal or Blend	80% Drum. 20% M.V.B.-E	75% Drum. 25% M.V.B.-E	70% Drum. 30% M.V.B.-E	100% Drumheller-B	
Size of Coal	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"
Binder	8% pet. asphalt	8% pet. asphalt	8% pet. asphalt	4% flour, 2% pet. asphalt	3% flour, 3% pet. asphalt emulsion
Condition of Mix					
(a) Water added..........%	0.0	0.0	0.0	18.0	16.0
(b) Temp. of preheated coal..........Deg. C.	118	114	117	115	150
(c) Temp. of mixture..........Deg. C.	118	118	117	110	120
(d) Temp. of mix to press..........Deg. C.	85	87	90	95	120
Performance during Briquetting					
(a) Sticking in rolls..........:	None	Nil	Nil	Nil	Nil
(b) Compression..........:	Fairly good	Fairly good	Fairly good	Fairly good	Fairly good
(c) Condition leaving press..........:	" "	" "	" "	" "	" "
Qaulity of Briquettes					
Physical properties					
(a) Bulk Density..........lb/cu.ft.	38.5	39.0	39.0	37.5	39.3
(b) Resistance to Handling (Tumbler Test)					
1. Stability (plus 1 in.)..........%	72.3	69.2	72.1	81.5	87.5
2. Abradability (-10 mesh)..........%	27.0	29.0	27.8	18.2	12.5
(c) Resistance to water immersion..........:	Good	Good	Good	Good	Good
1. Water absorbed..........%	1.2	1.3	1.0	2.1	2.7
(d) Compressive strength (b)..........:	190	220	268	60	90
Chemical properties					
Proximate analysis					
Moisture..........%	7.1	7.0	7.2	12.7	13.8
Ash..........%	13.1	13.1	12.7	10.0	10.0
Volatile matter..........%	32.4	31.1	31.1	33.4	29.4
Fixed carbon..........%	47.4	48.8	49.0	43.9	46.8
Sulphur..........%	0.6(#)	0.6(#)	0.6(#)	0.6(#)	0.6(#)
Calorific value..........B.T.U./lb..	11,505(#)	11,610(#)	12,010(#)	10,304(#)	10,265(#)
Coking properties..........:	S.A.(i)	S.A.(i)	S.A.(i)	W.A.(h)	W.A.(h)

TABLE X

Details of Briquetting Tests

Test No.	40	50	39	41	42	56	58
Coal or Blend	80% Drumheller, 20% M.V.B.-E						80% Drum. 20% M.V.B.-F
Size of Coal	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"
Binder	3% flour 2% asphalt	3% flour 4% asphalt	4% flour 1% asphalt	5% flour 1% asphalt	5% flour 2% asphalt	2% flour 6% asphalt	2% flour 6% asphalt
Condition of Mix							
(a) Water added..............%	16.0	16.0	16.0	16.0	16.0	16.0	16.0
(b) Temp. of preheated coal.........Deg. C.	120	120	115	120	120	120	120
(c) Temp. of mixture...............Deg. C.	110	105	100	110	110	120	130
(d) Temp. of mix to press..........Deg. C.	90	85	80	90	90	90	110
Performance during briquetting							
(a) Sticking in rolls..............:	Nil	Nil	Nil	Nil	Nil	Nil	Nil
(b) Compression....................:	Fair	Fair	Fair	Fair	Good	Good	Good
(c) Condition leaving press........:	Weak	Fair	Fair	Fair	Good	Good	Good
Quality of Briquettes							
Physical properties							
(a) Bulk density..............lb./cu.ft.	37.3	39.5	36.3	39.3	39.0	42.0	42.0
(b) Resistance to handling(Tumbler Test)							
1. Stability (plus 1 in.)........%	40.4	86.6	72.4	85.9	95.3	90.8	94.6
2. Abradability (-10 mesh).......%	53.3	13.3	26.4	12.1	4.6	9.2	5.4
(c) Resistance to immersion.........:	Good	Good	Good	Good	Good	Good	Good
1. Water absorbed................%	2.0	1.9	2.0	2.0	1.8	1.2	1.2
(d) Compressive strength (b)..........:	20	145	55	190	362	208	220
Chemical Properties							
Proximate analysis							
Moisture..........................%	10.4	10.7	10.9	10.7	11.6	11.8	12.2
Ash...............................%	9.8	11.1	6.8	8.5	8.8	11.9	10.7
Volatile matter...................%	31.9	31.6	32.8	33.6	32.0	31.1	32.3
Fixed carbon......................%	47.9	46.6	49.5	47.2	47.6	45.2	44.8
Sulphur...........................%	0.6(#)	0.6(#)	0.6(#)	0.6(#)	0.6(#)	0.6(#)	0.4(#)
Calorific value................B.T.U./lb..	11,030(#)	10,950(#)	11,235(#)	10,990(#)	10,900(#)	10,890(#)	10,800(#)
Coking properties.....................:	W.A.(h)	A(c)	W.A.(h)	W.A.(h)	W.A.(h)	A(c)	A(c)

TABLE XI

Details of Briquetting Tests

Test No.	57A	46	45	44
Coal or Blend	80% Drum. 20% M.V.B.-E	85% Drum. 15% M.V.B.-E	90% Drum. 10% M.V.B.-E	95% Drum. 5% M.V.B.-E
Size of Coal	-1/8"	-1/8"	-1/8"	-1/8"
Binder	4% flour 2% asphalt	4% flour 2% asphalt	4% flour 2% asphalt	4% flour 2% asphalt
Condition of Mix				
(a) Water added............................%	16.0	16.0	16.0	16.0
(b) Temp. of preheated coal..........Deg. C.	120	120	120	120
(c) Temp. of mixture................Deg. C.	110	110	110	112
(d) Temp. of mix to press...........Deg. C.	90	100	90	90
Performance during Briquetting				
(a) Sticking in rolls....................:	Nil	Nil	Nil	Nil
(b) Compression..........................:	Good	Fair	Fair	Fair
(c) Condition leaving press..............:	Good	Good	Fair	Fair to poor
Quality of Briquettes				
Physical properties				
(a) Bulk density.............lb./cu.ft..	39.5	39.0	38.3	37.0
(b) Resistance to handling (Tumbler Test)				
1. Stability (plus 1 in.)..........%	91.0	87.8	71.1	59.7
2. Abradability (-10 mesh).........%	9.0	12.2	22.6	40.0
(c) Resistance to immersion............:	Good	Good	Good	Good
1. Water absorbed..................%	2.3	2.5	2.3	2.9
(d) Compressive strength (b)............:	150	120	90	27
Chemical properties				
Proximate analysis				
Moisture...............................%	11.0	11.8	11.8	12.8
Ash....................................%	8.9	8.8	8.8	11.7
Volatile matter........................%	32.4	32.5	33.4	32.7
Fixed carbon...........................%	47.7	46.9	46.0	42.8
Sulphur...................................%	0.6(#)	0.6(#)	0.6(#)	0.6(#)
Calorific value...............B.T.U./lb..	11,075(#)		10,740(#)	
Coking properties.........................:	W.A.(h)	W.A.(h)	W.A.(h)	W.A.(h)

TABLE XII

Details of Briquetting Tests

Test No.	52	53	54	55	59	51
Coal or Blend	80% Drumheller, 20% M.V.B.-E				80% Drum. 20% M.V.B.-F	90% Drum. 10% M.V.B.-E
Size of Coal	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"	-1/8"
Binder	$1\frac{1}{4}$% flour $3\frac{1}{2}$% asphalt emulsion	2% flour $3\frac{1}{2}$% asphalt emulsion	$2\frac{1}{2}$% flour 3% asphalt emulsion	3% flour 3% asphalt emulsion	3% flour 3% asphalt emulsion	4% flour 1% asphalt emulsion
Condition of Mix						
(a) Water added..........................%	11.3(j)	18.0(j)	18.0(j)	16.0(j)	16.0(j)	18.0(j)
(b) Temp. of preheated coal.........Deg. C.	130	140	150	150	150	140
(c) Temp. of mixture...............Deg. C.	120	130	120	130	150	130
(d) Temp. of mix to press..........Deg. C.	90	95	90	95	100	95
Performance during briquetting						
(a) Sticking in rolls....................:	Nil(k)	Nil(l)	Nil	Nil	Nil	Some
(b) Compression..........................:	Poor	Fair	Fair	Good	Good	Fair to poor
(c) Condition leaving press..............:	Poor	Fair	Good	Good	Good	Poor
Quality of Briquettes						
Physical properties						
(a) Bulk density..............lb./cu.ft..	37.0	41.0	43.0	40.3	40.3	38.0
(b) Resistance to handling (Tumbler Test)						
1. Stability (plus 1 in.)........%	4.8	76.8	84.2	91.0	95.8	54.6
2. Abradability (-10 mesh).......%	75.3	23.2	15.8	9.0	4.2	42.6
(c) Resistance to immersion.............:	Good	Good	Good	Good	Good	Good
1. Water absorbed................%	1.5	1.5	1.8	2.0	1.5	2.2
(d) Compressive strength (b)............:	20	65	77	93	205	40
Chemical properties						
Proximate analysis						
Moisture..............................%	9.2	9.1	9.7	10.3	12.0	10.0
Ash...................................%	9.7	9.7	11.8	12.5	10.1	10.3
Volatile matter.......................%	31.6	30.7	31.6	30.4	30.8	32.5
Fixed carbon..........................%	49.5	50.5	46.9	46.8	47.1	46.3
Sulphur...................................%	0.6(#)	0.6(#)	0.6(#)	0.6(#)	0.4(#)	0.6(#)
Calorific value..................B.T.U./lb.	11,360(#)	11,350(#)	10,940(#)	10,750(#)	10,630(#)	10,595(#)
Coking properties........................	W.A.(h)	W.A.(h)	W.A.(h)	W.A.(h)	W.A.(h)	W.A.(h)

Glossary of References for Tables VI to XII

(#) - Calculated

(a) - Too much binder, mix held up in hopper and very sticky

(b) - By Komarek-Greaves Tester

(c) - Agglomerate

(d) - This test is a duplicate of Test #33, using a coal from a different mine in the Drumheller area.

(e) - Non-agglomerate

(f) - Very weak agglomerate

(g) - Briquettes swelled but did not disintegrate

(h) - Weak agglomerate

(i) - Strong agglomerate

(j) - Water used for making flour paste

(k) - Mix rather dry and crumbly

(l) - Mix not as dry and crumbly as in test #52.

VI

DISCUSSION OF RESULTS

Suitable briquettes for the domestic market, irrespective of the base solid fuel from which they are prepared, should have qualities approximating the following:-

1. They should be strong enough to withstand normal handling.

2. They should have a high density.

3. They should not deteriorate in quality or form during storage.

4. They should not disintegrate and should produce very little more and preferably less smoke during burning.

5. They should, as a minimum requirement, retain all the desirable chemical and physical properties of the raw coal from which they are made, but preferably should exhibit improved quality especially when made from low rank coals.

In order to determine the conditions under which a product with the above characteristics could be produced, with non-coking Drumheller coal as a base, it was necessary to carry the investigation through several phases, in which the influence of various controlling factors, such as particle size of coal, type of binder, and effect of blending with bituminous coking coals, were studied. In all this work it was attempted to demonstrate whether, and in which way, suitable briquettes could be made from the raw coal without the necessity of drying to a low moisture content.

A. Most Suitable Coal Size for Briquetting

A sample of Drumheller coal was crushed in a ring mill to three different sizes, namely to pass a $\frac{1}{4}$ inch, a 1/8 inch, and a 1/16 inch round-hole screen. These samples, the screen analyses of which are shown in Table III and in Figure I, were employed in a series of tests using petroleum asphalt as the binder to determine the degree of crushing required to yield briquettes with the optimum characteristics in so far as resistance to handling is concerned.

The table below compares the three sizes with regard to the size of Tyler screen which would give a 50% cut in each case. (See Figure II)

Crusher Setting	Screen Thru Which 50% of Material Passes	
in.	Mesh	Screen Openings Inches
¼	20	.0328
1/8	35	.0164
1/16	65	.0082

It is of interest to note that the size of the resultant crushed coal as indicated by the screen size through which 50% of the coal passes is directly related to the crusher setting for the particular crusher used. This is a good indication of uniformity in crusher performance and allows for the crusher setting, that is the screen opening, to be used directly as an index of the size produced.

The results of the briquetting tests are shown in Tables VI and VII. Using the stability factor, that is the percentage of material retained on a 1-inch screen after the briquettes were exposed to the Tumbler Test, as an index of resistance to handling, it is quite apparent that the coal crushed to pass the 1/8-inch screen gave by far the best results, and the finer coal, crushed to pass a 1/16-inch screen, the poorest result, irrespective of the quantity of binder employed. These results are shown graphically in Figure II. Thus it

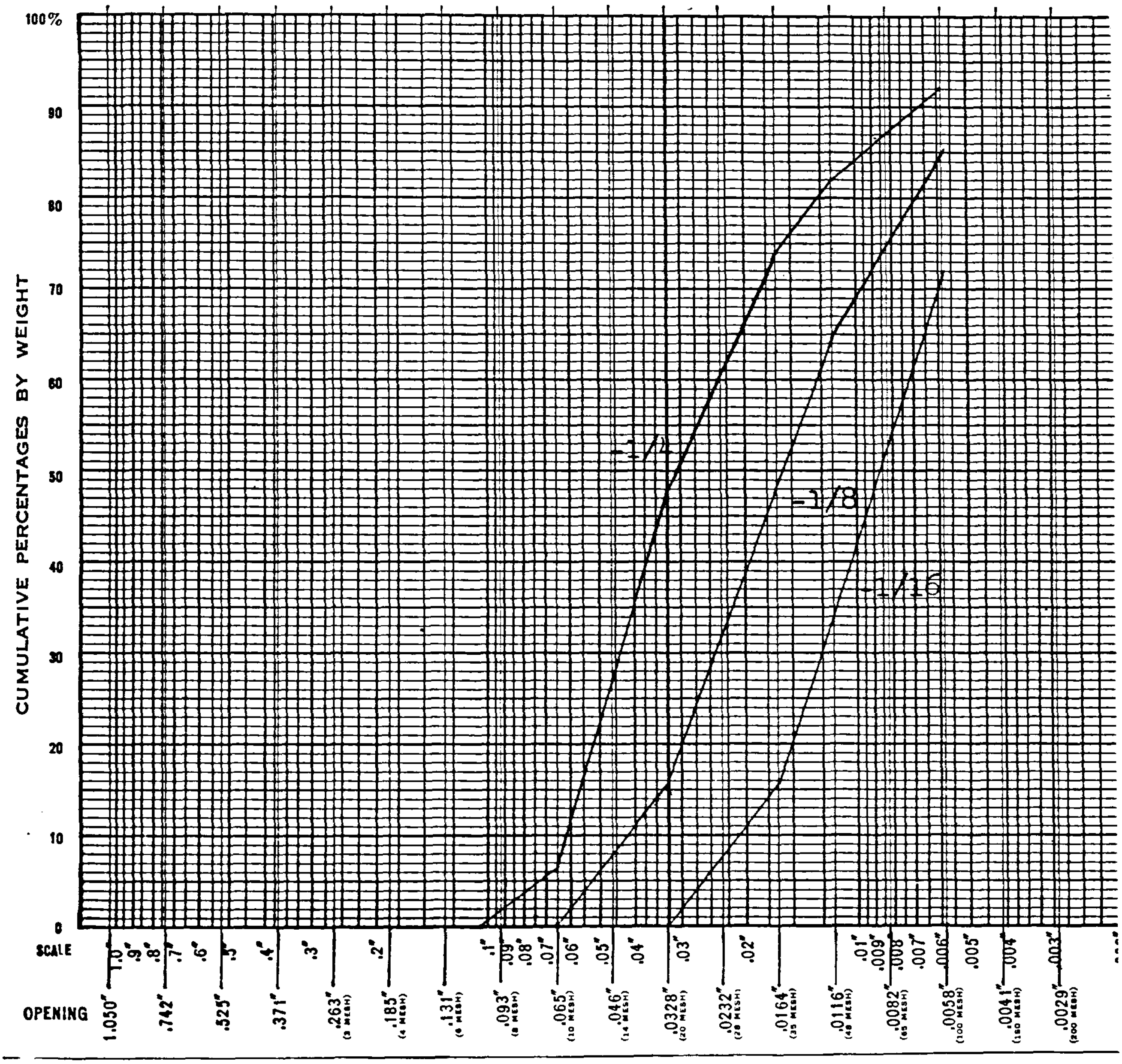
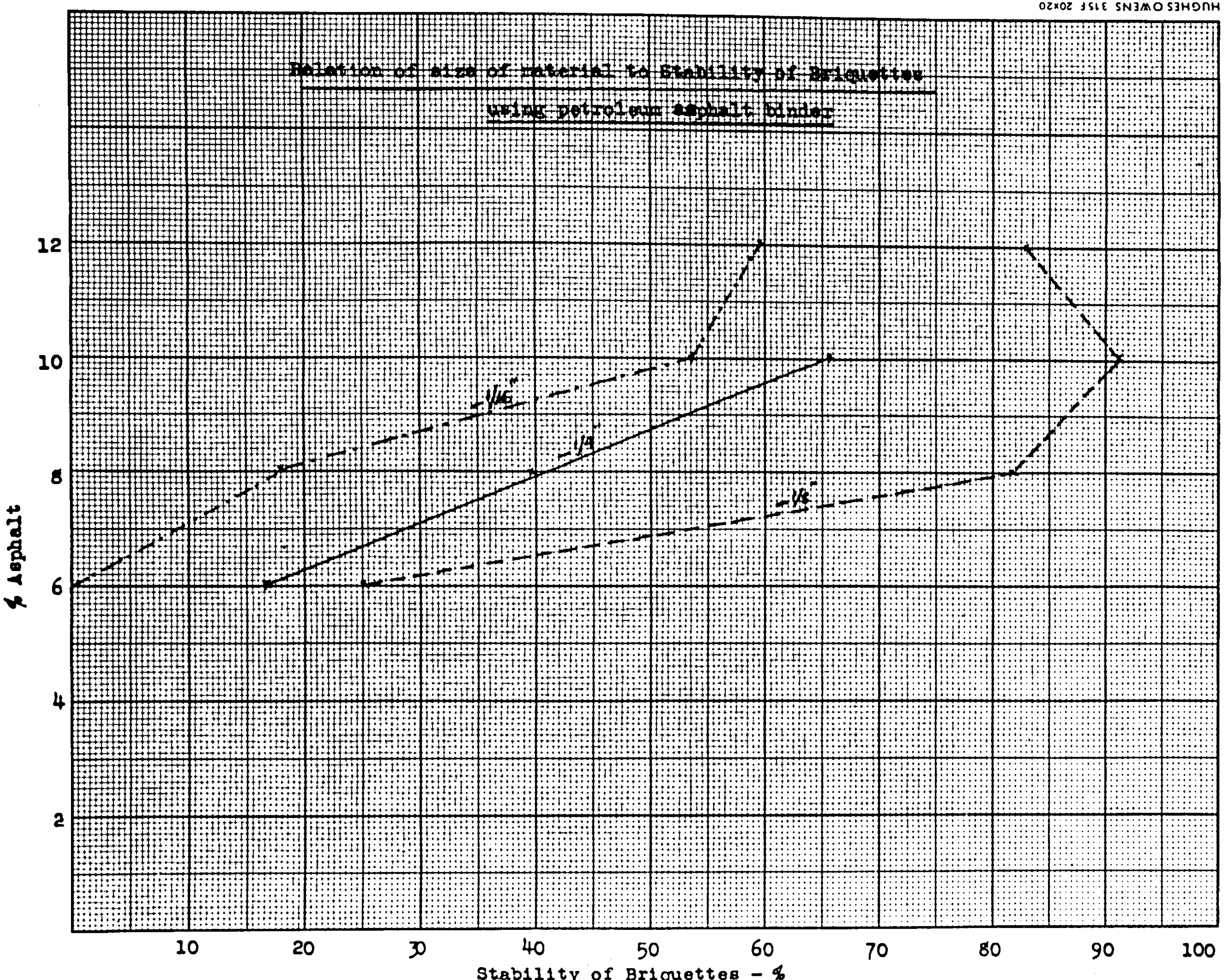


Figure I - Screen analysis of coals for briquetting

Figure II


HUGHES OWENS 315F 20x20
Relation of size of material to Stability of Briquettes
using petroleum asphalt binder
% Asphalt
2
4
6
8
10
12
1/16"
1/4"
1/8"
10
20
30
40
50
60
70
80
90
100
Stability of Briquettes - %

appears that the size of coal found most suitable was one in which there was practically no material on the 10 mesh screen, and only about 15% through the 100 mesh screen, with approximatoly 50% retained on or passing through a 35 mesh screen. There is also an apparent relationship between the strength of the resultant briquettes and the ratio of particles retained on a 35 mesh screen to those passing the 35 mesh screen of the crushed coal, as shown below, and in Figure III, the optimum conditions for briquetting being approached as this ratio approaches 1.

Crusher Setting	Ratio: % + 35 Mesh Coal / % - 35 Mesh Coal	Stability of Briquettes-% Petroleum Asphalt 6%	8%	10%	12%
¼ in.	2.85	16.8	39.8	65.7	---
1/8 in.	0.98	25.1	81.5	91.1	82.9
1/16 in.	0.18	0.0	18.0	53.5	59.5

In view of the fact that for the Drumheller coals a material crushed to pass a 1/8-inch screen with a size distribution shown in Table IV was found most suitable, all subsequent tests were conducted with coals approaching this size distribution.

B. Effectiveness of Various Binders

1. Comparison of Petroleum Asphalt and Wheat Flour as Binders for Briquetting Drumheller Coal

Although petroleum asphalt is used extensively in the briquetting of coals, ususally resulting in a strong product which is water and weatherproof, past experience has indicated that the lower rank coals do not make as good briquettes as the bituminous coals (4) with this binder. Thus a series of tests

(4) "Fuel Briquetting"-R. A. Strong, E. Swartzman, E. J. Burrough; Bureau of Mines, Dept. of Mines & Resources. Publication No 775 (See pages 51 and 52.)

was conducted to determine the comparative value of petroleum asphalt and flour as binders, in so far as resultant strength only is concerned, as briquettes made with flour alone will not store well. The results of these tests are shown in detail in Tables VI and VII, and the stability of the briquettes (resistance to shattering) in relation to the quantity and type of binder used, is shown graphically in Figure IV. Using Drumheller coal alone, without admixture of bituminous coal, it is quite obvious that wheat flour, added dry and then formed into a paste while being admixed with the coal, results in a far stronger briquette than when using petroleum asphalt. The results indicate that 5% flour (on the basis of the as received coal) yields as strong a briquette as one made with 10% petroleum asphalt. It is of interest to note that although 16.0% of water had to be added to the flour and coal in order to ensure proper gelatinization of the starch, the briquettes handled well as they left the press and air-dried readily down to a moisture content equal to or lower than the original coal.

2. Comparison of Drumheller Coal when Briquetted alone and in Blends with Bituminous Coal Using Flour as a Binder

In order to improve the burning quality of briquettes made from low rank non-caking coals, coking bituminous coal is usually added. In view of the fact that it has been found in the past that amenability to briquetting appears to improve with the rank, from the lignite to medium volatile bituminous coals, it was of interest to determine whether blending bituminous coal with the subbituminous coal would improve the resultant briquette when flour was used as the binding medium. The results of this series of tests are shown in Tables VII and VIII, where tests 33 to 35 are on the 100% Drumheller coal, and tests 27 to 29

Figure III

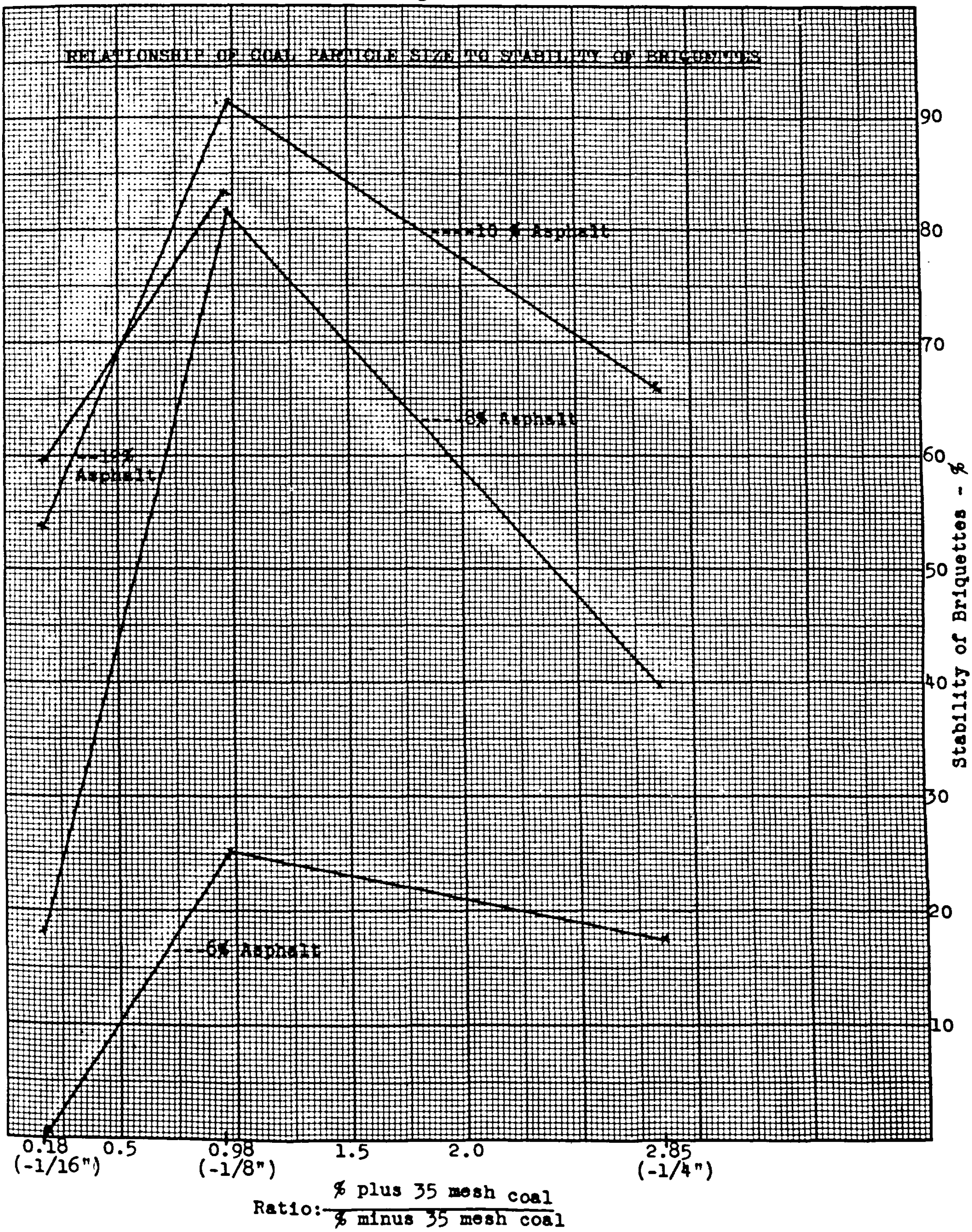
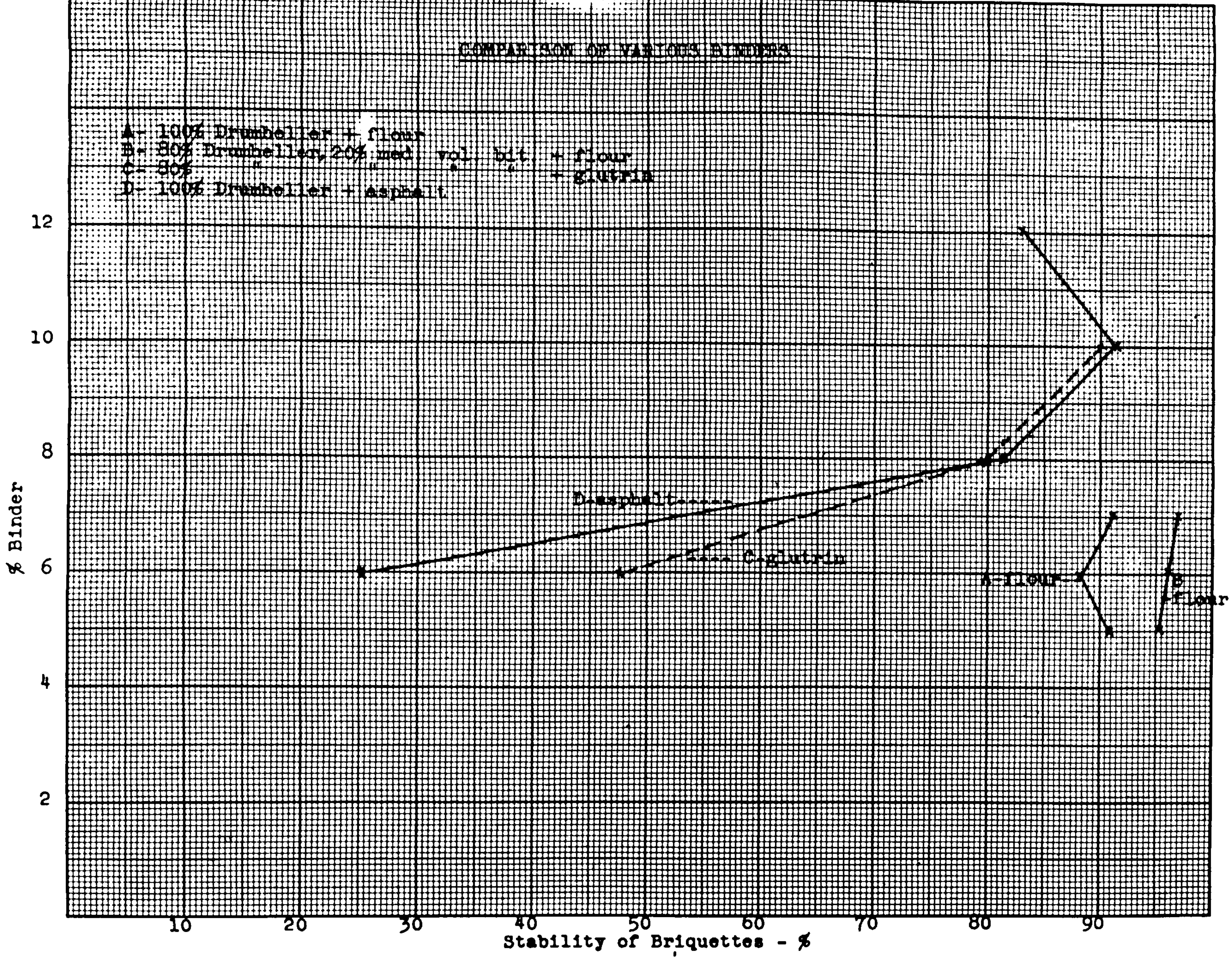

RELATIONSHIP OF COAL PARTICLE SIZE TO STABILITY OF BRIQUETTES
10 % Asphalt
8% Asphalt
10% Asphalt
6% Asphalt
90
80
70
60
50
40
30
20
10
Stability of Briquettes - %
0.18 (-1/16")
0.5
0.98 (-1/8")
1.5
2.0
2.85 (-1/4")
Ratio: % plus 35 mesh coal / % minus 35 mesh coal

Figure IV


HUGHES OWENS 315F 20x20
COMPARISON OF VARIOUS BINDERS
A- 100% Drumheller + flour
B- 80% Drumheller, 20% med. vol. bit. + flour
C- 80% " " " + glutrin
D- 100% Drumheller + asphalt
D-asphalt-----
---- C-glutrin
A-flour-
B
flour
12
10
8
6
4
2
% Binder
10
20
30
40
50
60
70
80
90
Stability of Briquettes - %

are on a blend of 80% Drumheller and 20% medium volatile bituminous coal from the B. C. Crowsnest area. The stability of the briquettes in relation to the quantity of flour binder used is indicated graphically in Figure IV. From these tests it appears that although strong briquettes were made with either Drumheller coal alone or blended, blending the bituminous with the subbituminous coal showed a definite improvement in the strength of the finished product.

3. Comparison of Drumheller Coal When Briquetted alone and in Blends with Bituminous Coal Using Asphalt as a Binder

In view of the above noted improvement in the strength of the briquettes as a result of blending bituminous coal with the Drumheller coal, using flour as a binder, a series of tests were conducted to determine whether similar results would be obtained when using petroleum asphalt, which had by previous tests been found to be inferior to flour as a binder for the subbituminous coals. The results of these tests, using 8% petroleum asphalt binder and varying the quantities of the medium volatile bituminous coal, are given in Table VI (test 8), and Table IX (tests 30 to 32). Below are shown the stability of the resultant briquettes when tested by the Tumbler Test.

Coal or Blend	Stability (% on 1" screen)
100% Drumheller (Test 8)	81.5
80% Drumheller;20% med.vol.bit.coal	72.3
75% " ;25% " " " "	69.2
70% " ;30% " " " "	72.1

These results indicate quite clearly that blending the Drumheller coal with even as much as 30% of the medium volatile bituminous coal did not improve the strength of the resultant briquettes. These tests serve to confirm the conclusion that petroleum asphalt when used alone is not as satisfactory a binder for Drumheller subbituminous coal as starch, even when employed in much larger quantities.

4. "Glutrin" as a Binder

"Glutrin", a concentrated sulphite liquor product containing approximately 50% of solids has been tried by various experimenters as a binder for coal briquettes but without much success, not only because of various technical difficulties, but because the resultant product is not weather-proof. However, in order to determine it's value in comparison to flour and asphalt, a series of tests were conducted using a blend of 80% Drumheller and 20% medium volatile bituminous coal. The results of these tests are shown in Table VIII (Tests 36, 37 & 38), and the stability of the briquettes to handling in relation to the quantity of binder used is shown graphically in Figure IV. After some experimenting it was found that in order to make briquettes with Glutrin binder that would not stick in the rolls the mix must be made and fed to the rolls at room temperatures (about 70°F). The briquettes were of the same order in strength as those made with petroleum asphalt, and much inferior to those prepared with flour. "Glutrin" binder equivalent to the addition of 10% solids was found to be equal to about 5% wheat flour.

5. Petroleum Asphalt and Starch as a Dual Binder

Although starch (wheat flour) was found to be superior to petroleum asphalt as a binder with Drumheller coal, the resultant briquettes are not weather-proof. It was thus vital to determine whether, and to what extent, petroleum asphalt, which imparts weather-proofness, could be used together with flour, each added separately, to produce a briquette which would be sufficiently strong for handling and at the same time weather-proof. The results of these tests both on a sample of Drumheller coal alone, and in blends with 20% of a medium volatile bituminous coal are shown in Table IX (test 43), Table X (tests 39, 40, 41, 42, 50, 56, and 58), as well as in Table XI (tests 44, 45, 46, and 59A). In the table below is shown the stability of the briquettes as determined by the Tumbler Test.

Test No.	Coal or Blend	Binder	Stability of Briquettes (% + 1 in. screen)
43	100% Drumheller	4% flour, 2% asphalt	81.5
40	80% Drum.20% bit.*	3% " , 2% "	40.4
50	" . " .	3% " , 4% "	86.6
39	" . " .	4% " , 1% "	72.4
59A	" . " .	4% " , 2% "	91.0
41	" . " .	5% " , 1% "	85.9
42	" . " .	5% " , 2% "	95.3
56	" . " .	2% " , 6% "	90.8
58	" . " ,**	2% " , 6% "	94.6

* bit.=med. volatile bituminous coal from Crowsnest Area, B.C.
** bit.=med. volatile bituminous coal from Luscar Basin, Mountain Park Area, Alta.

From the above it is quite clear that strong briquettes could be made with quite a variation in the proportions of the flour and asphalt binder, and that where flour is used as the base binder a lower total quantity of binder is required than when petroleum asphalt is used. Thus 6% asphalt and 2% flour makes no stronger briquette than one made with 4% flour and 2% asphalt.

In the subsequent discussion it will be indicated what appears to be the minimum amount of the two binders rquired in order to result in a briquette that will be sufficiently strong for handling and at the same time store well. However, in so far as strength alone is concerned, and keeping in mind the production of a briquette with a minimum of increased tendency to smoke formation, (petroleum asphalt increasing the tendency to production of objectionable smoke), it would appear that a binder consisting of 4% or 5% flour and 2% asphalt is the most suitable.

6. Petroleum Asphalt and Starch as an Emulsion Binder

Although the advantage of using a dual binder is obvious from the results discussed above, it necessitates the addition of two binders separately. The use of these binders admixed as one in the form of a so-called emulsion has certain advantages from an operational viewpoint, and it has been claimed that with the use of such a binder, stronger briquettes with less total binder may be made. The binder is prepared by making a hot paste of flour and water and then adding the molten asphalt. For these tests the ratio of flour, asphalt and water was varied in order to determine the composition of the most suitable emulsion binder for the coals being investigated. The result of this series of tests is shown in Table XII; (tests 51 to 55 inclusive and test 59) and in Table IX (test 57). This latter test was conducted to determine whether the starch-asphalt emulsion binder is as suitable for Drumheller coal alone as when blended with coking bituminous coal.

In tests 52 to 55 inclusive, using 80% Drumheller with 20% bituminous coal, the quantity of asphalt in relation to the coal was left more or less constant at 3% to 3½% and the flour was increased to determine the maximum quantity of this latter binder required to give briquettes of optimum strength. The stability to handling of these briquettes produced are shown below.

Test No.	Binder-%	Stability-%
52	1¼% flour, 3½% asphalt	4.8
53	2% " , 3½% "	76.8
54	2½% " , 3% "	84.2
55 (a)	3% " , 3% "	91.0
59 (b)	3% " , 3% "	95.8

(a) blend with strongly coking bituminous coal from B.C.
(b) blend with weakly coking bituminous coal from Alta.

Test 52 was conducted with an asphalt-starch emulsion as recommended by some commercial experimenters for bituminous coals and anthracites, but it was found to be entirely unsatisfactory for the Drumheller-bituminous coal blend. The subsequent tests indicated rather conclusively that the quantity of flour would have to be at least doubled before a briquette of good strength would result.

A comparison of tests 55 and 59 indicates that changing the medium volatile bituminous coal in the blend from a strongly to a weakly coking one does not appear to adversely affect the stability to handling of the resultant briquette providing no change is made in the binder.

Test 57, conducted on Drumheller coal alone with an emulsion consisting of 3% flour and 3% asphalt indicates that addition of the bituminous coal when such a binder is used only improves the stability to handling of the resultant briquette to a limited extent.

Altering the ratio of flour to asphalt, (see Test 51) by reducing the asphalt even though increasing the amount of flour, appears to result in a weaker briquette as judged by it's stability to handling. It would thus seem that the correct balance between the two binders when used as an emulsion for the Drumheller coal is reached when there are equal quantities of the two materials and when they are used combined to the extent of 6% of the coal. Thus from all the above it may be concluded that the starch-asphalt binder is quite suitable when used as an emulsion, and the indications are that some reduction in total binder could be expected when they are used in this manner, in comparison to their use together but unmixed.

C. The Weathering and Waterproof Characteristics of the Briquettes

1. Waterproof Properties

The waterproof properties of the various briquettes produced, as indicated by their resistance to immersion in water, are shown in Tables VI to XII inclusive. The water absorbed in one hour by each type of briquette is shown in resume below:-

Test No's.	Coal or Blend	Binder	% Water Absorbed in 1 hour
7-23	100% Drumheller	6-12% Petroleum	1.4 to 1.9
33-35, 63	100% Drumheller	5-7% Flour	28.8 to 40.1
27-29	80% Drumheller 20% M.V.B.*	5-7% Flour	14.3 to 16.7
36-38	80% Drumheller 20% M.V.B.*	6-10% Glutrin Solids	Disintegrate
30-32	80-70% Drum., 20%-30% M.V.B.*	8% Asphalt	1.0-1.3
39-41, 50, 56, 58	80% Drumheller 20% M.V.B.*	Flour & Asphalt (unmixed) (varying ratios)	1.2-2.0
43	100% Drumheller	4% Flour, 2% Asphalt (unmixed)	2.1
44-46, 59A	80-95% Drum., 20-5% M.V.B.*	4% Flour 2% Asphalt (unmixed)	2.3-2.9
52-55, 59	80% Drumheller 20% M.V.B.*	Flour-Asphalt Emulsions (varying ratios)	1.5-2.2
51	90% Drumheller 10% M.V.B.*	4% Flour 1% Asphalt Emulsion	2.2
57	100% Drumheller	3% Flour, 3% Asphalt Emulsion	2.7

*M.V.B.=Medium Volatile Bituminous Coal.

The above data indicates that, although the briquettes did not disintegrate during the hour test, flour alone as a binder does not result in a waterproof briquette, irrespective of the quantity of binder used. However even though neither Drumheller coal alone nor when blended with up to 20% of a medium volatile bituminous coal gave a waterproof briquette there does appear to be an indication that the addition of the bituminous coal to the Drumheller results in some improvement. However, it should be noted, that even bituminous coal by itself does not result in a waterproof briquette when flour alone is used as a binder.

"Glutrin" (concentrated sulphite liquor) when used as a binder results in a briquette with absolutely no waterproof characteristics. Due to the hygroscopic nature of the "Glutrin" solids, water is absorbed very rapidly and the briquettes disintegrate in a very short time, the rate of disintegration being roughly inversely propertional to the quantity of binder emloyed.

Petroleum asphalt by itself, irrespective of the quantity used (6%-10%), and irrespective of the coal or blend employed, resulted in the production of briquettes which were completely waterproof as judged by the water immersion test.

Petroleum asphalt and flour when used as a dual binder, but unmixed, in various proportions, resulted in the production of good waterproofed briquettes. Even quantities of asphalt as low as 1%, providing sufficient flour had been added to give a reasonably strong briquette, resulted in waterproof briquettes. Good waterproof products resulted, irrespective of whether the Drumheller coal was used alone or in blends with increasing amounts of medium volatile bituminous coal.

Petroleum asphalt-starch emulsion when used as binders, irrespective of the ratio of asphalt to starch, and even though the briquettes were weak, resulted in briquettes which exhibited waterproof properties equal to those made with asphalt alone.

It is obvious from these tests that petroleum asphalt is an exceptionally good waterproofing agent for briquettes, and when used in conjunction with flour binder, imparts good waterproof characteristics to the resultant product even when used in quantities as low as 1% of the coal.

2. Weathering or Storage Properties of the Briquettes

A series consisting of eleven different types of the experimental briquettes were stored in 20 pounds lots in the open air exposed to all conditions of weather from June 11th. to September 20th., 1946. The weather record during this period is presented in Table XIII, and it should be noted that the briquettes were exposed to a greater than normal rainfall. The condition of the briquettes as the storage period progressed is shown in Table XIV. From this it is apparent that the briquettes prepared with Glutrin as a binder disintegrated in a very short time into a pulp which was readily washed away by the rain. The briquettes made with flour as a binder stored much better than those made with Glutrin. At the end of the test period the surface briquettes were broken to a pulp, and although those underneath remained whole they were badly fractured and weak. Addition of 20% medium volatile bituminous coking to the Drumheller coal did not improve the storage properties.

The briquettes made with asphalt alone appeared to store very well although they seemed to have weakened as a result of the weathering.

Asphalt and flour used together as a binder, but not in the form of an emulsion, appeared to weather quite well although at the end of the test period the surface briquettes were partially broken down and the protected briquettes seemed weaker.

Briquettes made with the asphalt-starch emulsion also weathered quite well appearing much the same as those made with the two binders unmixed.

Table XV presents the comparative data with respect to the resistance to shatter of the briquettes before and after the storage period.

TABLE XIII - WEATHER RECORD DURING STORAGE PERIOD* A
1946

Day of Month	June Temperature Max. °F	June Temperature Min. °F	June Rain in.	July Temperature Max. °F	July Temperature Min. °F	July Rain in.	August Temperature Max. °F	August Temperature Min. °F	August Rain in.	September Temperature Max. °F	September Temperature Min. °F	September Rain in.
1				88	66	.37	79	60		78	50	.36
2				73	59		76	54	.18	61	44	
3				74	58		71	57	.26	63	38	
4				80	55		80	55	.33	68	40	
5				82	55		80	56		73	39	
6				88	58		86	52		77	49	.10
7				78	60	.25	86	53		74	64	
8				70	55	.33	88	55	.02	65	51	
9				76	59		89	65	1.68	63	50	.37
10				79	53		78	65	.22	76	55	.12
11	70	53	.56	89	57	.30	69	58		59	58	
12	77	53	.02	78	70		69	43	.02	55	38	
13	63	48		76	57		69	54	.02	64	31	
14	64	38		80	56	.04	76	50		69	33	
15	73	40		68	43		80	49	.02	73	35	
16	78	45		75	40		76	56	.05	79	45	
17	83	65	3.05	85	47		74	65		85	55	
18	63	52		89	50		73	49	.02	86	58	
19	70	42		93	62		74	58	.62	85	54	
20	71	48	.40	82	63		67	53		86	49	
21	66	59	.04	80	62	.02	77	53	.46			
22	70	55		78	62	1.24	59	55				
23	84	54		79	66	.26	68	52				
24	81	63		78	59	.05	63	51				
25	86	63		70	56		72	48	.05			
26	88	64		72	50		71	52	.02			
27	85	63		79	46		73	50				
28	90	60		83	52		71	47	.37			
29	89	68		86	58		60	49				
30	91	68		79	60		66	37				
31				79	60		70	43				
Av.	77.1	55.0		79.5	56.6		74.3	53.0		72.0	46.8	
Total			4.07			2.86			4.34			.95

*Taken from records of Meteorological Observations supplied by the Field Husbandry Division, Central Experimental Farm, Ottawa, Ontario.

A - Briquettes at Beginning of Storage Test - June 11/46

B - Briquettes at end of Storage Test - Sept. 20/46

C - Briquettes at end of Storage Test - Sept. 20/46

PLATE I

TABLE XIV - PROGRESS REPORT ON STORAGE OF BRIQUETTES

TEST NO.	34	63	27	31	32	38
COAL OR BLEND	100% Drumheller	100% Drumheller	80% Drumheller 20% M.V.B.(#)	75% Drumheller 25% M.V.B.(#)	70% Drumheller 30% M.V.B.(#)	80% Drumheller 20% M.V.B.(#)
BINDER	6% flour	7% flour	7% flour	8% pet. asphalt	8% pet.asphalt	20% Glutrin (10% Solids)
1946						
June 11	-----	-----	Storage begun	-----	Storage begun	Storage begun
June 13	-----	-----	Surface cracking	-----	No change	Surface eroding
June 14	-----	-----	" "	-----	" "	" "
June 17	-----	-----	" "	Storage begun	" "	" " and cracking
June 18	Storage begun	Storage begun	Softened, surface cracking	No change	" "	Erosion extensive
June 20	No change	Surface cracking	Surface fractures increased	" "	" "	" "
June 21	Surface cracking	" "	Surface fractures serious	" "	" "	" "
June 24	No change	No change	No change	" "	" "	No change
July 2	More serious surface fractures	More serious surface fractures	More serious surface fractures	" "	" "	Partially washed away
July 9	Surface briquettes breaking up	Surface briquettes breaking up	Surface briquettes breaking up	" "	" "	Over $\frac{1}{4}$ washed away
July 23	" " "	" " "	Surface briquettes almost broken to pulp	Some surface fracturing	Some surface fractures	Almost completely broken down, $\frac{1}{2}$ washed away
Aug. 6	" " "	" " "	" " " " "	No change	No change	Completely broken down
Aug. 24	Surface briquettes almost broken to pulp	Surface briquettes almost broken to pulp	Surface briquettes completely broken to pulp	" "	" "	$\frac{3}{4}$ washed away
Sept. 20 (End of Test)	Surface briquettes broken to pulp. Subsurface ones weak	Surface briquettes broken to pulp. Subsurface ones weak	Surface briquettes broken to pulp. Subsurface ones weak	Somewhat cracked on surface. All briquettes slightly weakened	Somewhat cracked on surface. All briquettes slightly weakened	No whole briquettes, $\frac{3}{4}$ washed away

TABLE XIV - (CONT.) PROGRESS REPORT ON STORAGE OF BRIQUETTES

TEST NO.	43	46	54	55	57
COAL OR BLEND	100% Drumheller	85% Drumheller 15% M.V.B.(#)	80% Drumheller 20% M.V.B.(#)	80% Drumheller 20% M.V.B.(#)	100% Drumheller
BINDER	4% flour 2% asphalt	4% flour 2% asphalt	2½% flour 3% asphalt-emulsion	3% flour 3% asphalt-emulsion	3% flour 3% asphalt-emulsion
1946					
June 11	Storage begun	----	Storage begun	Storage begun	Storage begun
June 13	No change	----	No change	No change	No change
June 14	" "	----	" "	" "	" "
June 17	" "	Storage begun	" "	" "	" "
June 18	" "	No change	" "	" "	" "
June 20	" "	Surface cracking	" "	" "	" "
June 21	" "	No change	" "	" "	" "
June 24	Some surface erosion	" "	" "	" "	" "
July 2	No change	Briquettes weakening	Briquettes weakening	Briquettes weakening	Briquettes weakening
July 9	" "	No change	No change	No change	No change
July 23	Some surface cracking	Some surface cracking	" "	Some surface cracking	Some surface cracking
Aug. 6	Some surface erosion	Briquettes weakening	Briquettes weakening	Some surface erosion	" " "
Aug. 24	Briquettes weakening	" "	" "	Briquettes weakening	Briquettes weakening
Sept.20 (End of Test)	Surface briquettes partially broken down. Subsurface ones weakened	Surface briquettes partially broken down. Subsurface ones weakened	Surface briquettes cracked. Subsurface ones weakened	Surface briquettes cracked. Subsurface ones weakened	Surface briquettes cracked. Subsurface ones weakened

(#) Medium volatile bituminous coal.

TABLE XV

Effect of Storage on Physical Quality of Briquettes

Test No.	34	63	27	38	31	32
Coal or Blend	100% Drum.	100% Drum.	80% Drum. 20% M.V.B.©	80% Drum. 20% M.V.B.©	75% Drum. 25% M.V.B.©	70% Drum. 30% M.V.B.©
Binder	6% flour	7% flour	7% flour	20% Glutrin (10% Solids)	8% pet. asphalt	8% pet. asphalt
Duration of Storage............days	95	95	102	102	96	102
Wt. of briquettes stored.........lb.	20.0	20.0	20.0	20.0	20.0	20.0
Wt. of briquettes at end of test.lb.	16.5	16.25	16.5	5.0	19.75	19.75
Loss in weight...................%	17.5	17.75	17.5	75.0	1.25	1.25
Stability of Briquettes						
Before test....................%	88.4	97.3	96.7	90.0	69.2	72.1
After test(1)...................%	17.2	2.4	42.1	0.0	64.0(54.2)	66.0
Stability of Stored briquettes in relation to fresh ones(1)....%	19.5	2.5	43.5	0.0	92.4(78.3)	91.5
Abradability of Briquettes						
Before test....................%	11.5	2.4	3.3	9.7	29.0	27.8
After test (1)..................%	54.4	17.5	35.8	100.0	34.0(41.3)	29.0
Abradability of stored briquettes in relation to fresh ones.......%	473.0	729.0	1085.0	1030.0	117.2	104.3
Waterproof properties						
Water absorbed in 1 hr..........%	35.0	40.1	16.7	¼ Disintegrated	1.3	1.0
Resistance to immersion.........:	Very poor	Very poor	Poor	Very poor	Good	Good

(1) Values in brackets are for briquettes from the surface of the stored briquettes. The unbracketed values are for subsurface ones, that is, those protected from the direct impact of the weather.

© - Medium volatile bituminous coal.

TABLE XV (Cont.)

Effect of Storage on Physical Quality of Briquettes

Test No.	43	46	57	55	54
Coal or Blend	100% Drum.	85% Drum. 15% M.V.B.(2)	100% Drum.	80% Drum.	20% M.V.B.(2)
Binder	4% flour 2% pet. asphalt	4% flour 2% pet. asphalt	3% flour 3% asphalt emulsion	3% flour 3% asphalt emulsion	2½% flour 3% asphalt emulsion
Duration of Storage............days	102	96	102	102	102
Wt. of briquettes stored.........lb.	20.0	20.0	20.0	20.0	20.0
Wt. of briquettes at end of test.lb.	19.75	18.75	19.75	19.75	19.75
Loss in weight.....................%	1.25	6.25	1.25	1.25	1.25
Stability of Briquettes					
(a) Before Test.................%	81.5	87.8	87.5	91.0	84.2
(b) After Test (1)...............%	61.6(21.2)	44.2(25.2)	75.6(38.8)	64.4(37.2)	72.1(44.2)
Stability of stored briquettes in relation to fresh ones(1).%	75.5(26.0)	50.4(28.7)	86.4(44.3)	70.8(40.9)	85.6(52.5)
Abradability of Briquettes					
(a) Before test.................%	18.2	12.2	12.5	9.0	15.8
(b) After test (1)...............%	30.0(43.2)	32.8(38.8)	18.1(31.6)	34.0(47.6)	26.9(39.3)
Abradability of stored briquettes in relation to fresh ones....%	164.7	268.3	144.7	377.8	170.2
Waterproof properties					
Water absorbed in 1 hr.......%	2.1	2.5	2.7	2.0	1.8
Resistance to immersion.......	Good	Good	Good	Good	Good

The stability of the stored briquettes as determined by the Tumbler Test in relation to the fresh briquettes is shown below.

Test No.	Coal	Binder	Stability of Stored Briquettes as % of Stability of Fresh Briquettes
34	Drumheller	6% flour	19.5
63	Drumheller	7% flour	2.4
27	80% Drumheller 20% Bituminous	7% flour	42.1
38	" "	10% Glutrin solids	0.0
31	75% Drumheller 25% Bituminous	8% asphalt	92.4
43	Drumheller	(4% flour (2% asphalt	75.5
32	70% Drumheller 30% Bituminous	8% asphalt	91.5
46	85% Drumheller, 15% Bituminous	(4% flour (2% asphalt	50.4
57	Drumheller	(3% flour (3% asphalt (emulsion)	86.4
55	80% Drumheller 20% Bituminous	(3% flour (3% asphalt (emulsion)	70.8
54	80% Drumheller 20% Bituminous	(2½% flour (3% asphalt (emulsion)	85.6

The above results indicate very clearly that petroleum asphalt by itself results in a briquette that weathers very well but Glutrin is absolutely useless as binder in this regard. Flour although appreciably better than Glutrin does not result in a product which can be expected to stand up for very long and must also be considered as unsatisfactory. However, mixtures of asphalt and starch whether added separately or as an emulsion appear to result in briquettes with fairly good resistance to weathering as indicated by the strength of the briquettes after storage. In view of the fact that the briquettes were exposed in small quantities the test was quite severe and thus in commercial storage piles where the ratio of the surface area to the total volume is very much smaller than in the case of these very small test piles the storage of the briquettes containing the flour and asphalt could be expected to be better than indicated.

D. Caking Properties of the Briquettes

The degree to which briquettes will hold together or fall apart during burning is a characteristic of prime importance in adjudicating the value of the product, as a competitive fuel, it being a requirement that the fuel ratain it's form throughout burning with as little degradation as possible. Where a non-coking coal , reduced to a fine size, is briquetted the retention of form will be due either to the cementing power of the binder on heating or the agglutinating power of an added coking coal or both. As it was not feasible to conduct full scale burning tests the caking properties of the briquettes were tested empirically by burning them singly in air in an electric muffle preheated to about 1740°F. until they were devolatilized. The resultant carbonized briquettes were then tested for their compressive strength. The results are shown in Table XVI.

Where Drumheller coal was used by itself, employing either flour or petroleum asphalt as binders, the latter even up to 10%, the resultant carbonized briquettes had a very low compressive strength (560 to 575 gms. per sq. in.) crumbling readily with very mild handling.

Blending the Drumheller coal with 20% of a good coking medium volatile coal, and using flour as a binder resulted in carbonized residues which retained their form, handled fairly well and exhibited fairly high compressive strengths varying between 4350 and 6711 gms. per sq. inch.

Using "Glutrin" with a blend of 80% Drumheller and 20% good coking medium volatile bituminous coal, it is of interest to note, yielded briquettes whose carbonized residues were stronger than those made with flour, the compressive strength being proportional to the quantity of binder used and varying from 7961 to 11540 gms. per sq. in. The results of these tests appear to indicate that the solids of the "Glutrin" binder, on carbonization, have a superior binding action to the flour.

The tests using asphalt and flour as a dual binder without mixing them prior to addition to a blend of 80% Drumheller and 20% medium volatile bituminous coking coal or in the form of an emulsion appeared to indicate that the asphalt had a greater influence on the resulting caking properties of the briquettes than did the flour. This is demonstrated by comparing the compressive strengths of the carbonized briquettes, shown below in the exerpt from Table XVI.

Test No.	Binder	Compressive Strength of Carbonized Briquette gms./sq.in.
39	1% Asphalt, 4% Flour	1911
40	2% " , 3% "	2416
42	2% " , 5% "	4770
54	3% " , 2½% " *	4825
55	3% " , 3% " *	4848
59**	3% " , 3% " *	4605
53	3½% " , 2% " *	4713
50	4% " , 3% "	6392
56	6% " , 2% "	6694

* Asphalt-starch emulsion binder.

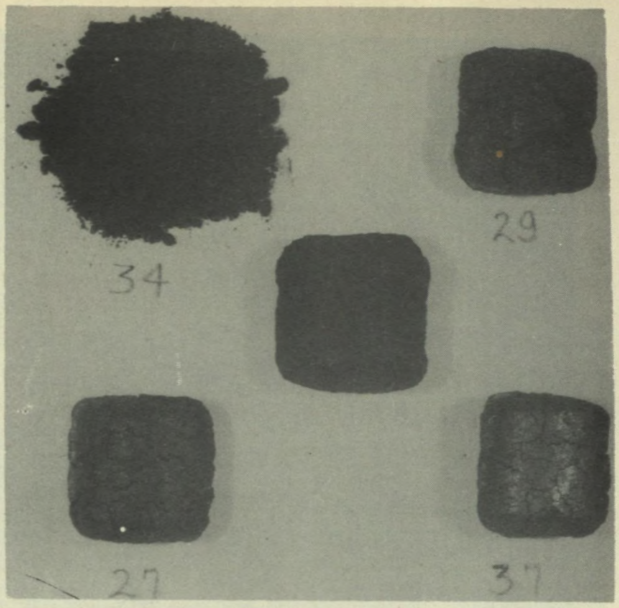
** The Alberta medium volatile bituminous coal used in this blend was not as strongly swelling as the B. C. coal of similar rank used in the other blends.

It is of interest to note in comparing the results of tests 55 and 59, that although the briquettes of test 55 were

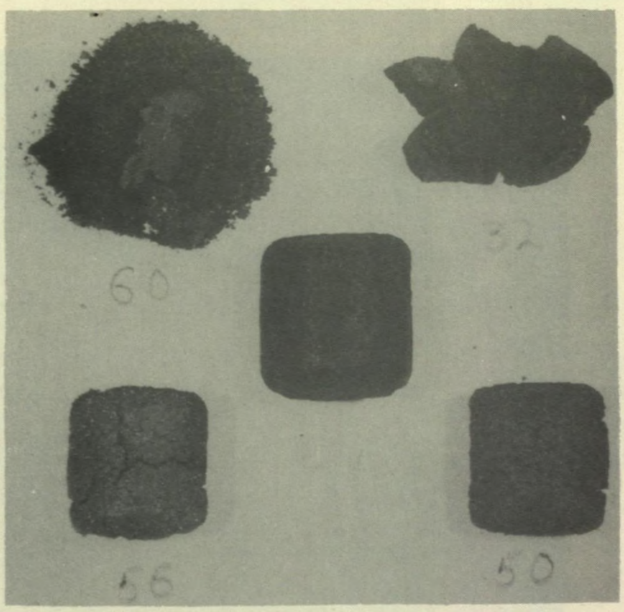
TABLE XVI - CAKING PROPERTIES OF BRIQUETTES (1)

Test No.	Coal or Blend	Binder	Degree of Agglomeration	Degree of Fracture	Retention of Form	Compressive Strength (2) gms./sq.in.
35	100% Drumheller	5% flour	Very weak	Very high amt.	Crumbles readily	540
34	100% "	7% flour	" "	" " "	" "	575
29	80% Drum., 20% M.V.B.@	5% flour	Fair to good	Medium amt.	Good, shrinks	6711
28	" " ., " "	6% flour	" " "	" "	" , "	4350
27	" " ., " "	7% flour	" " "	" "	" , "	5468
36	" " ., " "	12% Glutrin (6% Solids)	" " "	" "	" , "	7961
37	" " ., " "	16% " (8% ")	" " "	" "	" , "	10870
38	" " ., " "	20% " (10% ")	Good	Small "	" , "	11540
60	100% Drumheller	10% pet. asphalt	Very weak	Very high amt.	Crumbles readily	560
32	70% Drum., 30% M.V.B.@	8% " "	Very good	Small amt.	Good, some swelling	9566
56	80% " ., 20% "	2% flour, 6% asphalt	Good	" "	" , shrinks	6694
50	" " ., " "	3% " , 4% asphalt	"	" "	" , "	6392
39	" " ., " "	4% " , 1% "	Fair	Medium to high amt.	Broke readily	1911
44	90% " ., 10% "	4% " , 2% "	Weak	High amt.	Crumbles readily	568
45	95% " ., 5% "	4% " , 2% "	"	" "	" "	589
40	80% " ., 20% "	3% " , 2% "	Fair	Medium amt.	Fair to good	2416
42	" " ., " "	5% " , 2% "	"	" "	" " "	4770
53	" " ., " "	2% " , 3½% " -em.@@	Fair to good	" "	Good	4713
54	" " ., " "	2½% " , 3% " -em.@@	" " "	Small "	"	4825
55	" " ., " "	3% " , 3% " -em.@@	" " "	" "	"	4848
59	" " ., " " @@@	3% " , 3% " -em.@@	" " "	" "	"	4605

(1) Determined by burning of single briquettes in an electric muffle at about 1740 Degrees F. in a stream of air.
(2) Compressive strength of carbonized briquettes.
@ - Medium volatile bituminous coal from B.C.-strongly swelling
@@em.- emulsion.
@@@ - Medium volatile bituminous coal from Alberta-poorly swelling.



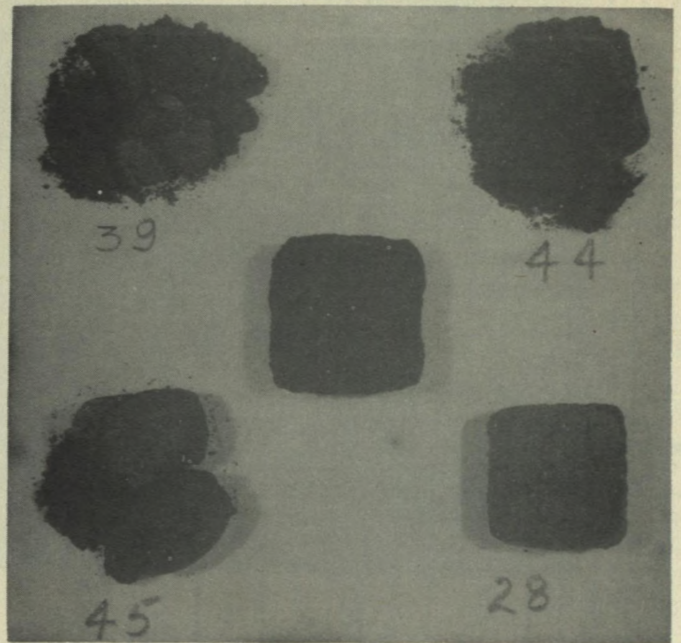
34 - 100% Drumheller-----------------7% flour
29 - 80% Drumheller, 20% M.V.B.-E*--5% flour
27 - 80% Drumheller, 20% M.V.B.-E*--7% flour
37 - 80% Drumheller, 20% M.V.B.-E*-16% Glutrin (8% Solids)



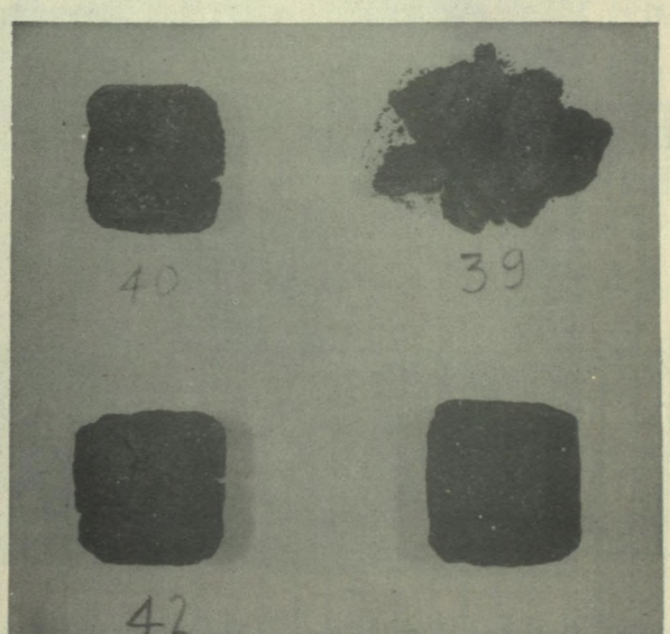
60 - 100% Drumheller---------------10% pet. asphalt
32 - 70% Drumheller, 30% M.V.B.-E*-8% pet. asphalt
56 - 80% Drumheller, 20% M.V.B.-E*-2% flour, 6% asphalt
50 - 80% Drumheller, 20% M.V.B.-E*-3% flour, 4% asphalt

* Medium volatile bituminous--B.C.

PLATE II



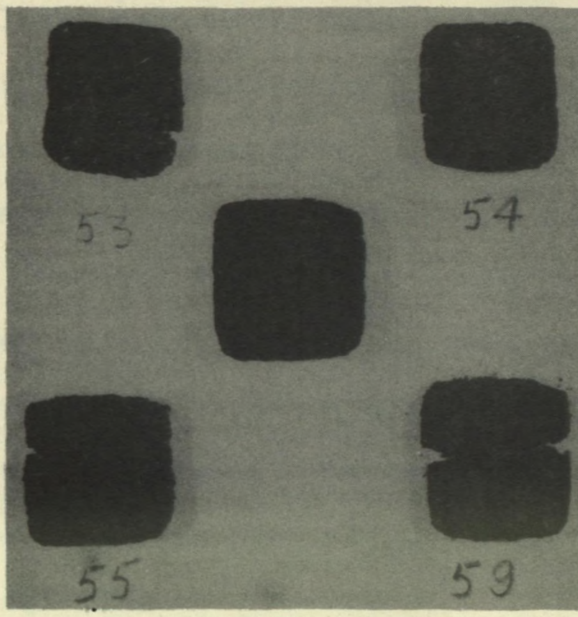
39 - 80% Drumheller, 20% M.V.B.-E*-4% flour, 1% asphalt
44 - 90% Drumheller, 10% M.V.B.-E*-4% flour, 2% asphalt
45 - 95% Drumheller, 5% M.V.B.-E*-4% flour, 2% asphalt
28 - 80% Drumheller, 20% M.V.B.-E*-6% flour



40 - 80% Drumheller, 20% M.V.B.-E*-3% flour, 2% asphalt
39 - 80% Drumheller, 20% M.V.B.-E*-4% flour, 1% asphalt
42 - 80% Drumheller, 20% M.V.B.-E*-5% flour, 2% asphalt

*Medium volatile bituminous--B.C.

PLATE III



53 - 80% Drumheller, 20% M.V.B.-E*- 2% flour, 3½% asphalt
54 - 80% Drumheller, 20% M.V.B.-E* 2½% flour, 3% asphalt
55 - 80% Drumheller, 20% M.V.B.-E* 3% flour, 3% asphalt
59 - 80% Drumheller, 20% M.V.B.-F** 3% flour, 3% asphalt

* Medium volatile bituminous--B.C.
** Medium volatile bituminous--Alta.
N.B. The binders are so-called emulsions.

PLATE IV

made with a blend containing 20% of a strongly coking medium volatile bituminous coal, (swelling index about 1000, and caking index about 48) and those of test 59 with 20% of a bituminous coal of similar rank but with much reduced coking tendency, (swelling index about 200, and caking index about 35) the strength of the resultant carbonized briquettes was practically the same. Thus, contrary to expectations, the results appear to indicate that the non-caking Drumheller coal may be blended with bituminous coking coals having quite a range in coking quality to produce resultant products which stand up equally well in the fire. This contention is confirmed by the results of tests 44 and 45 in which 10% and 5% respectively of the strongly coking coal were blended with Drumheller. The carbonized residues of these briquettes were very weak exhibiting a compressive strength of 568-589 gms. per sq. inch.

In general it may be conluded that, irrespective of the binder employed, it is necessary to blend a minimum of 20% of a reasonably good coking bituminous coal with the non-caking Drumheller coal before a briquette is produced which can be expected not to deteriorate in the fire.

E. Chemical and Physico-Chemical Quality of the Briquettes

The chemical and physico-chemical (calorific value and ash fusibility) quality of the briquettes shown in Tables VI to XII is of course entirely dependent upon the quality of the coal and binder constituents used. Employing asphalt as a binder would increase the calorific value of the product over and above the coal because this material has a higher calorific value than the coal, whereas using flour would somewhat decrease the heating value below that of the coal, both changes being proportional to the quantity of binder used. Blending bituminous coking coals with the Drumheller coal will increase the heating value of the resultant briquette in proportion to the amount of higher rank coal added.

In so far as ash and sulphur content are concerned the briquettes will be of practically the same quality as the coal, if not possibly somewhat better due to the addition of low ash and sulphur binders. Due to the method of processing the briquettes can be expected to have a substantially lower moisture content than the raw Drumheller coal. From the results of the tests it is anticipated that due to heating required during mixing, and subsequent air-drying, a briquette containing about 11% moisture could be produced from the raw coal containing originally about 18% moisture. A product with this lower moisture content has an advantage over the raw product in that it has reached a point of stability in so far as gain or loss in moisture is concerned under normal weather conditions.

F. Smoke Producing Characteristics of the Briquettes

Although no special tests were conducted to determine this undesireable characteristic, it may be assumed that due to the smoke producing properties of asphalt, the briquettes, even when made with Drumheller coal alone, will give off varying quantities of sooty smoke dependent on the quantity of asphalt added. In addition blending bituminous coal with the Drumheller coal will also increase the tendency towards smoke production in proportion to the amount of these coals added. However, using flour as a binder will have a tendency to somewhat reduce the production of smoke as this material is less smoky in burning than the Drumheller coal.

In any case, however, it is not felt that the increased smoke producing characteristics of the briquettes will be of such a degree as to result in the production of an obnoxious product.