SAMPLING AND COKING STUDIES OF COAL FROM CASTLE MOUNTAIN MINE, MATANUSKA COALFIELD, ALASKA

by Robert S. Warfield and W. S. Landers
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CONTENTS

Page

Abstract...

Introduction...

Location and accessibility...

Geology..

Castle Mountain coal deposit and sampling............................

Cleaning and coking studies..

ILLUSTRATION

Fig. — Follows page

1. Gas-heated 50-pound carbonizing unit, with a 10-inch circular retort..

TABLES

Page

1. Chemical and size analysis of drill cuttings from Castle Mountain mine, Alaska...
2. Float and sink data on drill cuttings from Castle Mountain mine, Alaska...
3. Analysis of reduced ash Castle Mountain sample....................
4. Precision laboratory carbonization assays and analyses: Alaskan coals..
5. Coking properties of samples carbonized at 925 °C in 10-inch circular, 50-pound retort...
6. Physical properties of 925° C coke.................................
7. Summary of selected measures of quality of coke produced from Castle Mountain coal and blends and from Fontana blend in 50-pound retort...

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R. S. Warfield[1] and W. S. Landers[2] and Staff

ABSTRACT

A sample of high-volatile A bituminous coal consisting of cuttings from multiple auger holes was taken from a stripped segment of a 5.3-foot coalbed at the now idle Castle Mountain mine, Matanuska coalfield, Alaska. The sample was shipped to the Bureau of Mines Denver Coal Research Laboratory where studies of its coking properties were made. The ash content of the sample was reduced by float and sink methods from 16.5 percent to 10.4 percent. After bench scale tests indicated good coking qualities for the "cleaned" coal, three 50-pound coking tests were conducted. Coke from the unblended coal was strong and seemed of foundry quality. Using 30 percent of Castle Mountain as a blending coal with a Utah base coal produced a coke with reasonably good characteristics.

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INTRODUCTION

In June 1964, a sample for coking studies was cut from a single coal-bed of the now inactive Castle Mountain coal mine. The mine is in the geologically complex Chickaloon area of the Matanuska coalfield about 65 miles northeast of Anchorage and formerly produced coal by opencut mining methods for military power plants in Anchorage.

The remaining strip minable reserves at the Castle Mountain mine are small, but the area that may be underlain by coal of a quality equal to that mined is fairly large. Thus, favorable results of coking studies on these coals, it is hoped, may add incentive to a search for new minable reserves.

The coking studies were made at the Bureau of Mines Denver Coal Research Laboratory, Denver, Colorado. Laboratory work included "cleaning" of the sample to reduce ash content, appropriate bench scale studies and analyses, actual coke production tests, and testing of the coke produced.

LOCATION AND ACCESSIBILITY

Castle Mountain mine is about 83 miles (65 miles straight-line distance) by road northeast of Anchorage and about 1.5 miles south of Castle Mountain in the NE 1/4, NE 1/4, Section 21, T 20 N, R 5 E, Seward meridian. About 78.5 miles of this distance is over the Glenn Highway, a hard surfaced all-weather highway. The remaining 4.5 miles from the Glenn Highway to the mine is a gravel road, of which the last 3 miles were built and maintained by the mine operators. Very little maintenance has been performed on the last 3 miles of privately built road since cessation of mining operations in 1960, but access was still possible with a 4-wheel-drive vehicle in the spring of 1964.

GEOLOGY

The general geology of the Castle Mountain area, which is a part of the Matanuska coalfield, is described or mentioned in several U.S. Geological Survey publications (Bulletins 712, 791, and 861); and the geology of the Wishbone Hill district, the southwestern part of the Matanuska coalfield that currently (1965) supports the only mining activity within the field, is described in detail in relatively recent publications of both the Bureau of Mines and U.S. Geological Survey (R.I. 5950 and Bulletin 1016). The following geologic description is a very brief summary from these reports.

The coalbeds of the Matanuska coalfield occur in the Chickaloon formation of Tertiary age. The Chickaloon formation is comprised of 3,000 to 5,000 feet of interbedded sandstone, siltstone, claystone, and many coalbeds. The thickness of individual coalbeds may vary within relatively short distances, or the beds may be comparatively clean at one locality and extremely dirty at another. The thinning out or intergrading of a coalbed within relatively short distances is believed to be due primarily to the deltaic origin of the deposits, but also may be due in part to distortion incident to folding and faulting. Variations in the physical characteristics of the coalbeds, together with the complex structure, lack of markers, and scarcity of outcrops, make correlation of individual coalbeds very difficult.

The Matanuska Valley and thus the coalfield is bounded on the north and south by zones of major faulting which separate the sedimentary rocks of the valley from the older intrusive and metamorphic rocks of the mountains on either side. The sedimentary rocks of the valley have been subjected to folding and faulting, the intensity of which apparently increases up the valley from west to east becoming especially complex in the Chickaloon area. In addition, the sedimentary rocks, in a few places, have been invaded by intrusive rocks, usually in the form of either dikes or sills.

Much of the Matanuska Valley is mantled by a variable thickness of glacial debris, terrace gravel, landslide debris, and alluvial deposits on the present flood plains. This surface in turn, except on bedrock cliffs and the steeper valley sides, supports a dense growth of grasses, underbrush, and timber. Such a surface makes prospecting for coal outcrops or detailed geologic mapping difficult.

CASTLE MOUNTAIN COAL DEPOSIT AND SAMPLING

The Castle Mountain mine consists principally of two open pits that are offset from each other by faulting. In the southern pit, two coalbeds, separated by about 7 feet of clay and bone, were mined along a strike length of about 250 feet and a downdip distance of 75 to 100 feet. The upper coalbed was mined out to the highwall but in the north end of the pit a small unmined segment about 75 feet along strike by about 75 feet downdip remains of the lower bed.

The coalbed of the northern open pit was mined along an approximately parallel strike length of about 400 feet and downdip a distance of about 100 feet to the pit bottom; a few thousand tons remain that could be recovered from between the present toe of the dip slope and the highwall on final retreat. A single coalbed was mined in this opencut. Either the coalbeds of the two pits are noncorrelative or one bed in the northern pit thins within a very short strike length to nonexistence.

The two opencuts are offset 75 to 100 feet by the S 70° W-striking transverse fault, the northern pit offset to the east relative to the southern pit. Apparently the coalbeds at each end of the opencuts thinned to uneconomic mining thicknesses, thus a total of only about 650 feet along strike was mined. The mine operated on a production basis during the years 1958 and 1960. Production of "cleaned" coal was 10,491 tons in 1958 and 10,243 tons in 1960.

The former operators and lessees of the Castle Mountain mine estimate approximately 5,000 additional tons could be recovered from the existing opencuts without another lift on the highwall.

The sample was cut from near the base of the unmined segment in the southern pit by collecting cuttings from multiple 1-5/8-inch auger holes. The coalbed at the sample site was 5.3 feet thick; strike was measured at N 20° E and dip at 40° to 45° E. Observation of auger cuttings indicated the coalbed contains lenslike high ash material; the cuttings from one drill hole appeared relatively clean whereas cuttings from a nearby hole obviously contained bony material.

As will be discussed later, in detail, this sample was judged to be strongly coking, whereas a sample taken by the Bureau of Mines in 1957 from near the outcrop level, as stripping of overburden was taking place in preparation for mining, was non caking. The present sample cut from the same bed about 75 feet downdip from the outcrop had a free swelling index of 9.

CLEANING AND COKING STUDIES

The sample consisted of approximately 175 pounds of auger cuttings that, except for a few slightly larger pieces (up to about 1/2 inch), were mainly less than 10 mesh in size. Proximate and ultimate analyses, heating value, ash fusibility, and size analyses are given in table 1.

As the high ash content of the sample was considered likely to mask a useful evaluation of carbonization characteristics, a 20-pound split of the sample was taken (after minimal air-drying) for a preliminary examination of ash-reduction possibilities. Minus 100-mesh material (22.5 percent, containing 12.3 percent ash, dry basis) was removed; organic liquids were used to separate the plus 100-mesh material into six float-and-sink fractions. Moisture and ash determinations were made on each float-and-sink fraction. Dry weights and dry ash contents of the plus 100-mesh float-and-sink fractions are reported in table 2, together with the effects of recombining minus 100-mesh material.

Free-swelling tests were conducted on the original head sample, on the 100 mesh x 0 fines, on the plus 100-mesh material, and on each float-and-sink fraction. The free-swelling indexes are as follows:

Fraction	FSI	Fraction of plus 100m	FSI
Head sample	9	1.40 float	9
100 m x 0	9	1.40F - 1.45S	5
Plus 100 m	9	1.45F - 1.50S	3
		1.50F - 1.55S	2
		1.55F - 1.59S	1-1/2
		1.59 sink	1

On the basis of the float-and-sink data and the free-swelling indexes, it was decided to process the bulk of the Castle Mountain sample by:

TABLE 1. - Chemical and size analysis of drill cuttings from Castle Mountain mine, Alaska

Denver laboratory No.	2136	
Basis	As-received[1/]	Maf
Proximate analysis, percent:		
Moisture	3.4	
Volatile matter	28.0	34.8
Fixed carbon	52.6	65.2
Ash	16.0	
Ultimate analysis, percent:		
Hydrogen	5.0	5.7
Carbon	69.2	85.9
Nitrogen	1.6	1.9
Oxygen	7.7	5.9
Sulfur	.5	.6
Ash	16.0	
Heating value, Btu/lb	12,320	15,280
Fusibility of ash, °F:		
Initial deformation	2860	
Softening	2910+	
Size consist, cumulative retained on, percent:		
No. 4	2.1	
8	10.2	
16	27.6	
30	46.9	
50	64.7	
100	71.2	
200	87.2	
Pan	100.0	
Average size, inch	.0395	

1/ After preliminary air drying to remove surface moisture, resulting in 1.3 percent weight loss.

TABLE 2. - Float and sink data on drill cuttings from Castle Mountain mine, Alaska

Plus 100 mesh fraction only1/

	Dry weight, percent	Dry ash, percent	Cumulative Dry weight, percent	Cumulative Dry ash, percent
1.40 float	69.5	4.5	69.5	4.5
1.40 sink - 1.45 float	5.8	19.8	75.3	5.7
1.45 sink - 1.50 float	3.3	25.7	78.6	6.5
1.50 sink - 1.55 float	3.9	28.8	82.5	7.6
1.55 sink - 1.59 float	2.1	32.7	84.6	8.2
1.59 sink	15.4	54.1	100.0	15.3

Plus 100 mesh fraction, cleaned as indicated, with all 100 mesh x 0 material1/ recombined

	Dry weight, percent	Dry ash, percent
1.40 float	76.3	6.8
1.45 float	80.9	7.5
1.50 float	83.4	8.1
1.55 float	86.5	8.8
1.59 float	88.1	9.3
Head	100.0	14.6

1/ Of head sample, 77.5 percent was plus 100 mesh and 22.5 percent was minus 100 mesh. The minus 100 mesh material contained 12.3 percent dry ash.

1. Separating at 100 mesh,

2. Floating the plus 100 mesh fraction at 1.48 specific gravity, and

3. Recombining the 100 mesh x 0 fines with the 1.48 float portion of the plus 100 mesh fraction.

It was estimated that this procedure would result in an 83 percent yield of 8-percent-ash coal.

Accordingly, the bulk of the remaining sample was screened by hand at 100 mesh, and the oversize was separated by organic solution at 1.48 specific gravity. The float portion so obtained was then combined with all 100 mesh undersize. The net result was the removal of the 1.48-sink portion of the 100 mesh oversize, which had an ash content of 46.8 percent, moisture-free. By this procedure, the weight of a 149-pound sample of as-received coal having a moisture-free ash content of 16.5 percent was reduced to 121 pounds having a moisture-free ash content of 10.4 percent (see table 3 for a complete analysis of the reduced-ash coal). This was a slightly lower yield and a somewhat higher ash content than was projected on the basis of the preliminary split; however, the major objective of a substantial ash reduction was achieved.

The maf oxygen content of this coal (6.4 percent) indicated that the coal was likely to be strongly coking. The free swelling index was 9, even when the coal was tested before its ash content was reduced by the float-and-sink operation. The coal is of hvab rank.

To learn more about the coal, a 500° C carbonization assay and a Gieseler plastometer test were conducted. The assay data are given in table 4. The plastometer results are as follows:

TABLE 3. - Analysis of reduced ash Castle Mountain sample

Denver laboratory No.	2136-C	
Description	Castle Mountain blend: 73.7 percent float plus 26.3 percent fines	
Basis	As-received	Maf
Proximate analysis, percent:		
Moisture (XYlol)	1.0	
Volatile matter	28.8	32.5
Fixed carbon	59.9	67.5
Ash	10.3	
Ultimate analysis, percent:		
Hydrogen	5.0	5.5
Carbon	76.0	85.6
Nitrogen	1.7	1.9
Oxygen	6.4	6.4
Sulfur	.6	.6
Ash	10.3	
Heating value, Btu/lb	13,600	15,330
Fusibility of ash, °F:		
Initial deformation temperature	2910+	
Softening temperature	-	
Fluid temperature	-	

TABLE 4. - Precision laboratory carbonization assays and analyses: Alaskan coals

Assay number	1234
Material	Coal
Mine	Castle Mountain
State	Alaska
Denver laboratory number	2136-C
Temperature of carbonization, °C	500
Carbonization yields, maf, percent:	
Char	81.3
Water formed	2.5
Tar, dry	10.1
Light oil	1.6
Gas	4.5
Hydrogen sulfide	.1
Total	100.1
Gas composition (O_2- N_2-free), percent:	
CO_2	6.1
Illuminants	2.1
CO	5.1
H_2	22.5
CH_4	56.3
C_2H_6	7.9
Net gas yield, maf, cu ft/lb	1.024
Heat in gas, maf, Btu/lb	869
Heating value, calculated, Btu/cu ft	849
Specific gravity, calculated (air = 1)	0.581
Analysis of coal, maf:	
Proximate analysis, percent:	
Volatile matter	32.5
Fixed carbon	67.5
Ultimate analysis, percent:	
Hydrogen	5.5
Carbon	85.6
Nitrogen	1.9
Oxygen	6.4
Sulfur	.6
Heating value, Btu/lb	15,330

Maximum fluidity......................................225 ddpm

Temperature at:
  Initial softening....................................372° C
  Maximum fluidity.....................................457° C
  Solidification.......................................489° C

In view of the foregoing bench-scale evidence of good coking qualities for this coal, the following program of three 50-pound coking tests was conducted:

Coking Test No.	Blend
CP-147	Washed Castle Mountain (10.4 percent ash).
CP-151	30 percent washed Castle Mountain plus 70 percent Sunnyside.
CP-152	80 percent washed Castle Mountain plus 20 percent East Allen char (13.9 percent volatile matter).

The tests were conducted in a modified BM-AGA (Bureau of Mines-American Gas Association) 50-pound, 10-inch circular gas-fired retort. Byproducts were not collected but were burned in a combustion chamber during tests. The furnace and auxiliary equipment are illustrated in figure 1.

In each test, a 50-pound charge of coal was carbonized with the temperature of the outer surface of the charge maintained at 925° C. Carbonization was considered complete when the temperature of center of charge reached 925° C. Normally this operation requires 3 to 4 hours.

After the charge was coked, the retort was withdrawn from the furnace, cooled, and opened. Coke yields were determined by weighing all coke produced. The coke was then "stabilized" by one 6-foot drop in the ASTM drop-shatter apparatus, and screen analyses were made.

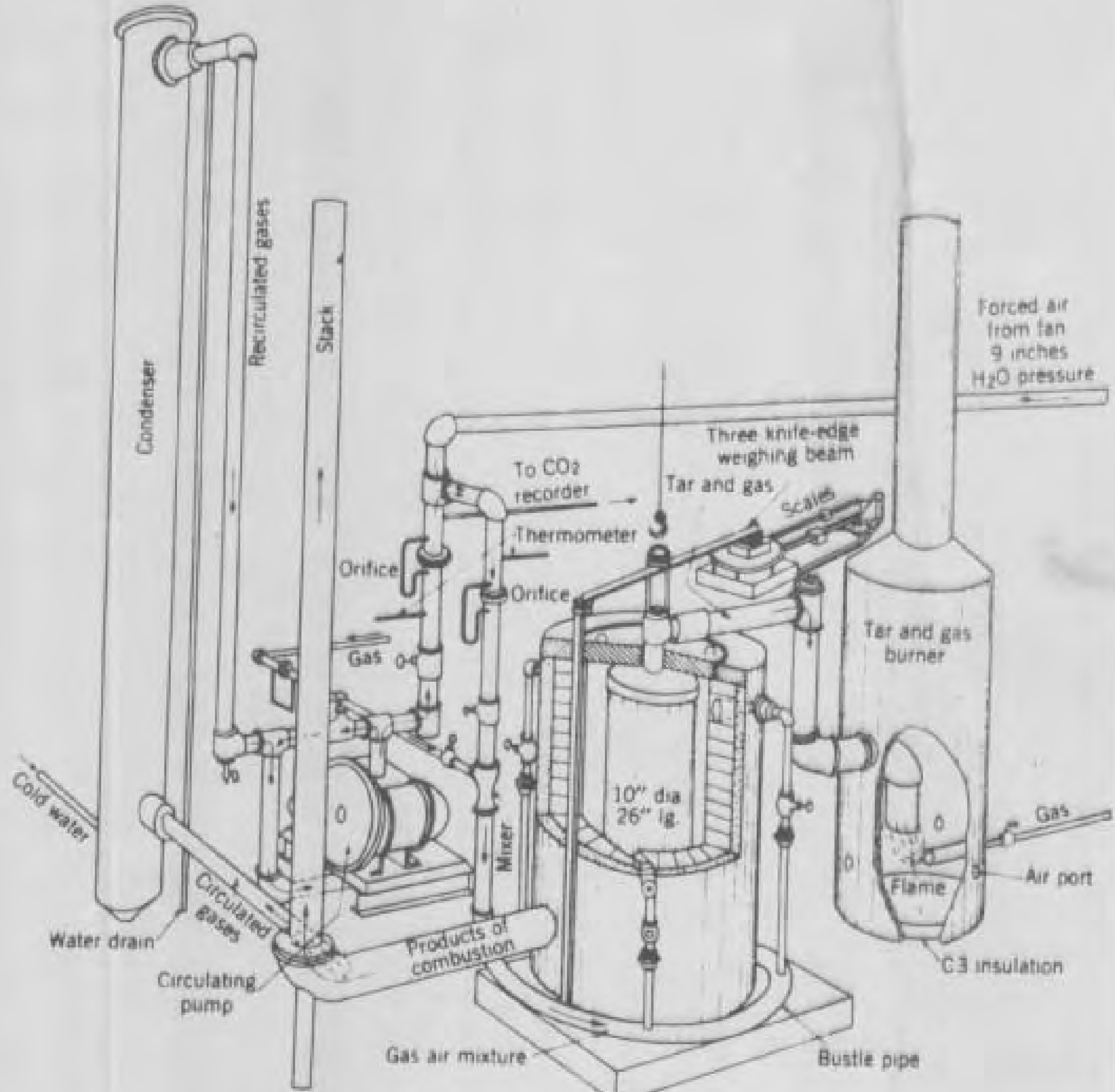

FIGURE - Gas-heated 50-pound Carbonizing Unit, with a 10-inch Circular Retort.

GO-552

Coke strength was evaluated by use of the "Columbia tumbler," a tumbler that produces less degradation than the standard ASTM tumbler and is better suited to studies of the less strongly coking coals typical of Western United States. The tumbler is 18 inches in diameter, with four internal lifters. For each test, 10 pounds of plus 1-inch pieces, selected to match the observed size analysis, was tumbled 720 revolutions at 24 rpm, and the resultant was screened for size. Average resultant particle size was computed and expressed as a percentage of average particle size of the 10-pound charge to the tumbler. This percentage is defined as "size stability." Size stability as determined by the Columbia tumbler tests is not to be confused with the ASTM "stability factor."

Through a minor error in pyrometry, these three 50-pound coking tests were conducted at 925° C rather than the customary 900° C. The results of the tests are given in full in tables 5 and 6; they are summarized in table 7. For comparison, a summary of the physical properties of Fontana blend coke (CP-136) as produced in the same retort and by the same carbonization procedures is also presented in table 7. The Fontana blend is a blend of coals that has been used by the Kaiser Steel Corporation in making metallurgical coke at Fontana, California. This commercial coking blend is composed of 85 percent Sunnyside No. 1 coal (hvbb rank, Sunnyside No. 1 mine, Dragerton, Carbon County, Utah), 7-1/2 percent Coal Basin coal (mvb rank, Pitkin County, Colorado), and 7-1/2 percent Red Indian coal (mvb rank, Wyoming County, West Virginia). Although the Fontana blend coke has been produced at 900° C, it is not believed that the slightly higher temperature used in the Castle Mountain tests will prevent making useful comparisons.

TABLE 5. - Coking properties of samples carbonized at 925 °C in 10-inch circular, 50-pound retort

Mine	Castle Mtn.	Castle Mtn.	Castle Mtn.	Fontana blend
Laboratory sample number (chg.)	2136-C	3136-E	3136-G	
Coke test number	CP-147	CP-151	CP-152	CP-136
Charge:				
Square hole	3/16"x0"	1/2"x0"	3/16"x0"	
Size charged, average...inches	0.0336	0.0891	0.0330	
Bulk density...pcf	55.0	53.7	53.7	
Blend	1/	2/	3/	
Plastic properties of coal:				
Free swelling index	9+	6	8-1/2	
Giesler plastometer:				
0.1 ddpm...°C	372	370	376	
Maximum fluidity...°C	457	442	460	
Maximum fluidity...ddpm	225	45	350	
Solidification point...°C	489	475	489	
Calculated coking index4/	1.58	1.30	1.60	
Coke data:				
Yield, as carb...percent	78.0	66.0	76.6	
Coke yield, mf...do..	73.7	68.8	77.7	68.0
Coke yield, maf...do..	70.9	66.1	72.9	
Value of "R"	2.8	4.7	5.1	
Average size:				
Entire sample	1.834	1.513	1.884	1.64
Plus 1.00 inch fraction	1.952	1.662	2.051	
Tumbler size stability5/...percent	80.4	55.2	46.8	56.8
Apparent specific gravity	0.762	0.776	0.833	0.656
True specific gravity	1.954	1.921	1.976	
Cell space...percent	61.0	59.6	57.8	
Volatile matter, mf...do..	1.3	1.1	1.1	
Ash, mf...do..	13.9	10.7	17.8	
Sulfur...do..	.5	.6	.5	
Heating value, mf...Btu/lb	12,420	12,820	11,810	
Coke strength index6/	153.4	108.5	121.1	122.4
Net resultant coke factor7/	1.035	0.528	0.632	
Coal analysis, as carbonized:				
Moisture...percent	1.0	4.0	1.4	
Volatile matter...do..	28.8	34.7	27.1	
Fixed carbon...do..	59.9	54.5	59.3	
Ash...do..	10.3	6.8	12.2	
Heating value...Btu/lb	13,600	13,400	13,050	
Sulfur...percent	.6	.7	.6	
Oxygen-free volatile matter	23.3	27.8	21.8	
Coal analysis, maf:				
FC/VM	2.08	1.58	2.18	
H_2 to O_2 ratio	0.86	0.71	0.84	
Oxygen...percent	6.4	7.9	6.2	
Coal, moist, ash-free...Btu	15,330	15,030	14,860	

See footnotes following table 6.

TABLE 6. - Physical properties of 925° C coke

Mine	Castle Mtn.	Castle Mtn.	Castle Mtn.	Fontana blend
Laboratory sample number (coke)	2136-D	2136-F	2136-H	
Coke test number	CP-147	CP-151	CP-152	CP-136
Charge:				
Square hole	3/16"x0"	1/2"x0"	3/16"x0"	
Size charged, average ... inches	0.0336	0.0891	0.0330	
Bulk density ... pcf	55.0	53.7	53.7	
Blend	1/	2/	3/	
Coke yield, mf ... percent	73.0	66.0	76.6	
Coke yield, maf ... do.	70.9	66.1	72.9	
Screen analysis, cumulative percent retained on:				
4.000 inch	-	-	-	
3.000 inch	1.5	-	6.7	
2.000 inch	34.2	15.2	39.2	
1.500 inch	74.0	46.9	68.8	
1.000 inch	91.2	84.6	88.9	
0.750 inch	95.1	94.5	94.4	
0.500 inch	97.0	97.0	96.6	
0.375 inch	97.4	97.4	97.1	
0.250 inch	97.7	97.7	97.5	88.7
0.187 inch	97.9	98.0	97.9	
0.132 inch	98.2	98.1	98.2	
0.093 inch	98.5	98.3	98.5	
Pan	100.0	100.0	100.0	
Average size:				
Entire sample	1.834	1.513	1.884	
Plus 1.00 inch fraction	1.952	1.662	2.051	
Plus 0.50 inch fraction	1.885	1.554	1.949	
Small tumbler, resultant, cumulative percent retained on:				
2.000 inch	24.6			
1.500 inch	69.6	1.1	8.9	
1.000 inch	78.4	44.8	54.9	
0.500 inch	82.5	85.9	79.3	
0.250 inch	83.2	88.3	83.1	88.7
0.132 inch	83.7	89.0	84.9	
Pan	100.0	100.0	100.0	
Charge, average size ... inches	1.9370	1.663	2.034	
Resultant, average size ... do.	1.5576	0.918	0.953	
Degradation ... percent	19.5	44.8	53.2	
Size stability5/ ... do.	80.4	55.2	46.8	
Specific gravity:				
Apparent	0.762	0.776	0.833	
True	1.954	1.921	1.976	
Cell space ... percent	61.0	59.6	57.8	

See footnotes on following page.

Footnotes to tables 5 and 6

1/ Washed Castle Mountain (Alaska) (DL 2136-C).

2/ 30 percent washed Castle Mountain (DL 2136-C) plus 70 percent Sunnyside (DL 2146-B).

3/ 80 percent washed Castle Mountain (DL 2136-C) plus 20 percent East Allen char (DL 1784-30).

4/ Calculated coking index of coal is defined as: $[(22/O_2$, maf basis) + $(2H_2/O_2$, maf basis) + (0.769 FC/VM) + heating value, Btu/lb on moist, ash-free basis)/13,600], all divided by 5.

5/ Tumbler size stability is calculated from tumbler data and is defined as:

$$\frac{100 \times (\text{Average size of tumbler resultant})}{(\text{Average size of tumbler charge})}$$

6/ Modified coke strength index is calculated as follows:

0.284 x (cumulative coke percentage retained on 1.50-in. screen)

+ 0.202 x (cumulative coke percentage retained on 1.00-in. screen)

+ 0.902 x (cumulative tumbler resultant percentage on 1.00-in. screen)

+ 0.259 x (cumulative tumbler resultant percentage on 0.25-in. screen)

+ 0.269 x (tumbler size stability).

7/ Net resultant coke factor is defined as: (Percent coke yield, ash-free) times (average size of coke, inches) times (tumbler size stability, percent) times 10^{-4}.

TABLE 7. - Summary of selected measures of quality of coke produced from Castle Mountain coal and blends and from Fontana blend in 50-pound retort

50-pound test No.......	CP-147	CP-151	CP-152	CP-136
Coking temperature...°C	925	925	925	900
		Blends		
	Castle Mt., unblended	30 pct Castle Mt. plus 70 pct Sunnyside	80 pct Castle Mt. plus 20 pct Allen char	Fontana blend
Coke yield, mf......pct	73.7	68.8	77.7	68.0
Coke size, average ....inches	1.83	1.51	1.88	1.64
Tumbler size stability ....pct	80.4	55.2	46.8	56.8
Apparent specific gravity...............	0.762	0.776	0.833	0.656
Tumbler resultant retained on 0.25-in. screen.............pct	83.2	88.3	83.1	88.7
Modified coke strength index.................	153.4	108.5	121.1	122.4

The data indicate that the Castle Mountain coal would produce a large and extremely strong coke, probably of foundry quality. The coke produced in 50-pound coking test CP-147 was considerably stronger, blockier, and heavier than the Fontana blend coke. When the Castle Mountain coal was blended with 20 percent of char (CP-152), a large, heavy coke was produced in high yield and with a strength approximating the Fontana blend coke. Even using Castle Mountain coal as a blending coal in a 30 percent concentration with Sunnyside coal (CP-151) produced a coke of good characteristics. The char used in the Castle Mountain blend was made from East Allen hvab coal (Las Animas County, Colorado), a base coal in a blend used industrially by the Colorado Fuel & Iron Corporation to produce metallurgical coke. The use or substitution of char as a blending material is a part of research experimentation being conducted by the Bureau of Mines Denver Coal Research Laboratory. The research is aimed, in particular, toward economically producing by entrained bed carbonization, a char of suitable characteristics to be used as a blending material with its own parent coal in the production of metallurgical coke.