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SAMPLING AND COKING STUDIES OF COAL FROM THE KUKPOWRUK RIVER AREA, ARCTIC NORTHWESTERN ALASKA

By Robert S. Warfield, W. S. Landers, and Charles C. Boley

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UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF MINES
Walter R. Hibbard, Jr., Director

This publication has been cataloged as follows:

Warfield, Robert S

Sampling and coking studies of coal from the Kukpowruk River area, Arctic northwestern Alaska, by Robert S. Warfield, W. S. Landers, and Charles C. Boley. [Washington] U. S. Dept. of the Interior, Bureau of Mines [1966]

59 p. illus., tables. (U. S. Bureau of Mines. Report of investigations 6767)

1. Coal—Alaska. 2. Coal—Analysis. I. Landers, William Samuel, 1913- , jt. auth. II. Boley, Charles Chilton, 1911- , jt. auth. III. Title. (Series)

TN23.U7 no. 6767 622.06173

U. S. Dept. of the Int. Library

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SAMPLING AND COKING STUDIES OF COAL FROM THE KUKPOWRUK RIVER AREA, ARCTIC NORTHWESTERN ALASKA

by

Robert S. Warfield,[1] W. S. Landers,[2] and Charles C. Boley[3]

ABSTRACT

Eight samples of high-volatile bituminous coal, each large enough for a study of its coking properties by the Bureau of Mines, were obtained from a location along the Kukpowruk River, Arctic Northwestern Alaska. Bench scale and pilot plant carbonization studies with several patterns of coal blending were conducted. The data from these tests were compared to data from similar tests on a coking blend used by the Kaiser Steel Corporation at Fontana, Calif.

The majority of the samples representing the 20-foot seam was found to have significant coking properties, and produced coke approaching metallurgical quality when blended with selected coking coals. Although oxidation effects were evident in the samples representing upper portions of the seam, it appears that the whole seam could be used.

INTRODUCTION

The occurrence of coal of good quality and apparent large quantities in Arctic Northwestern Alaska has been known for many years. The earliest reported knowledge and use of these coals was during the late 1800's and early 1900's, when small-scale mining was attempted along the coast between Cape Beaufort and Cape Lisburne. Since that time, a great deal of knowledge about the general geology of Arctic Northwestern Alaska has been accumulated, principally because of the numerous geological studies and drilling programs undertaken as part of the search for oil and gas in Naval Petroleum Reserve No. 4, but detailed investigations of the numerous reported coalbeds have been practically nonexistent.

[1] Mine examination and exploration engineer, Area VIII Mineral Resource Office, Bureau of Mines, Juneau, Alaska.
[2] Former chief, Denver Coal Research Laboratory, Bureau of Mines, Denver, Colo. (Now retired.)
[3] Physical science administrator, Grand Forks Coal Research Laboratory, Bureau of Mines, Grand Forks, N. Dak.

Work on manuscript completed June 1965.

During July and early August 1962, and again during August 1963, an attempt was made to obtain strictly fresh samples for coking studies from high-volatile bituminous coalbeds that outcrop along the Kukpowruk River. The methods of sampling and the results of coking studies are the subject of this Bureau of Mines report.

The eight samples taken represent either two or three coalbeds, the determination of which is dependent on future exploration with consequent correlation of stratigraphic units on opposite sides of a fault. One coalbed is less than 5 feet thick where sampled, and has no coking properties. The other coalbed (or beds), with an average thickness of about 20 feet, possesses moderate coking properties, and might be used for the production of metallurgical coke, if blended with selected other coals. The geologic structure of the area appears fairly simple, and the dip of beds is gentle enough that the coal should be amenable to either surface or mechanized underground mining.

Both bench-scale and pilot plant carbonization studies were conducted. In the bench-scale work, free-swelling index, carbonization assay, Gieseler plastometer, and 100-gram coking tests were conducted. The pilot-plant work consisted of carbonizing 50-pound charges in a 10-inch retort, followed by appropriate coke testing. To provide data for evaluation of commercial acceptability, the data from these tests were compared to data from similar tests on a coking blend used by the Kaiser Steel Corporation at Fontana, Calif.

The majority of the samples representing the 20-foot seam, when blended with selected coking coals from West Virginia, was found to have significant coking properties. In one test pattern, Alaskan coal was substituted for the base coal, Sunnyside No. 1 seam, Utah, regularly used by Kaiser Steel, and coke was produced of nearly as good quality as the Fontana-blend coke. It appeared that the whole seam could be used for this blending, although oxidation effects were evident in samples from the upper portions of the coalbed. Exposure of one sample to normal laboratory air for extended periods did not affect the analysis of the coal, and did not reduce its coking or plastic properties more than was noted in similar treatment of the Sunnyside seam coal.

ACKNOWLEDGMENTS

Special recognition is extended to officers of Morgan Coal Co. of Indianapolis, Ind., who made available privately obtained information and data. The Kaiser Steel Corp. granted permission to present data on a coking blend used at its Fontana, Calif., works. Wien Alaska Airlines personnel stationed at Kotzebue maintained radio-telephone communications with the Bureau of Mines camps on the Kukpowruk River.

J. B. Goodman (deceased) and R. R. Allen (retired), formerly of the Bureau of Mines Denver Coal Research Laboratory, made substantial contributions during the laboratory studies and in the preparation of the manuscript.

LOCATION AND ACCESSIBILITY

The region containing the best known deposits of bituminous coal in Arctic Northwestern Alaska has been termed the Utukok-Corwin region.[4] This region lies north of the DeLong Mountains, the westernmost extension of the Brooks Range, in the extreme western part of Northern Alaska, and is bounded on the west by the Chukchi Sea. Within the region, some of the best known coal outcrops occur along the Kukpowruk River about 32 miles southeast of Point Lay; these are the deposits described in this report (fig. 1). Because the Kukpowruk River flows almost parallel to the Chukchi Sea coast over part of its course, this location is only about 15 miles inland.

The Utukok-Corwin region can be reached by air or water (during the summer months) from Kotzebue or Barrow, which are about 150 miles south and northeast, respectively. Landings with small aircraft can be made on a short airstrip at Point Lay, an Eskimo village located on the bar that forms Kasegaluk Lagoon (fig. 1). With special permission from the Air Force, landings with relatively large aircraft may be made at DEW (Distant Early Warning) sites located at Cape Lisburne, Cape Beaufort, and Point Lay; the Point Lay DEW site is located directly across Kasegaluk Lagoon on the mainland from Point Lay village. During periods of low water, some gravel bars adjacent to main rivers are sufficiently large for landings by small aircraft; in the foothills section of the region, some ridges also are smooth and level enough for this purpose. Numerous lakes on the coastal plain, a few in the foothills, and some stretches of main rivers (especially during periods of high water) will permit landings by pontoon-equipped light aircraft. Pontoon landings are also possible on Kasegaluk Lagoon wherever it can be ascertained that the water is deep enough. During winter months, landings with ski equipped aircraft are possible almost anywhere. Helicopters are an ideal method of transportation for reconnaissance work.

Water transportation to the region is possible during the ice-free months (usually about 90 days--July through September), but there is no regularly scheduled common carrier ship service further north than Kotzebue. The Bureau of Indian Affairs ship North Star visits the Eskimo coastal villages annually, and the northern DEW sites receive staple supplies, heavy equipment, and fuel by chartered tug and barges.

None of the major rivers of the region can be classed as navigable, but some river travel is possible. During periods of high water, the major rivers can be ascended considerable distances in a shallow draft boat powered by an outboard motor, and nonpowered downstream travel is possible even during low water stages.

During the 1962 field season, Bureau of Mines camp gear and supplies were transported to the Kukpowruk River project site from Kotzebue by airlifting all gear to the Cape Beaufort DEW site in a relatively large aircraft, then shuttling, with small aircraft, all the gear to a gravel bar landing along the

[4] Chapman, Robert M., and Edward G. Sable. Geology of the Utukok-Corwin Region Northwestern Alaska. Geological Survey Prof. Paper 303-C, 1960, 167 pp.

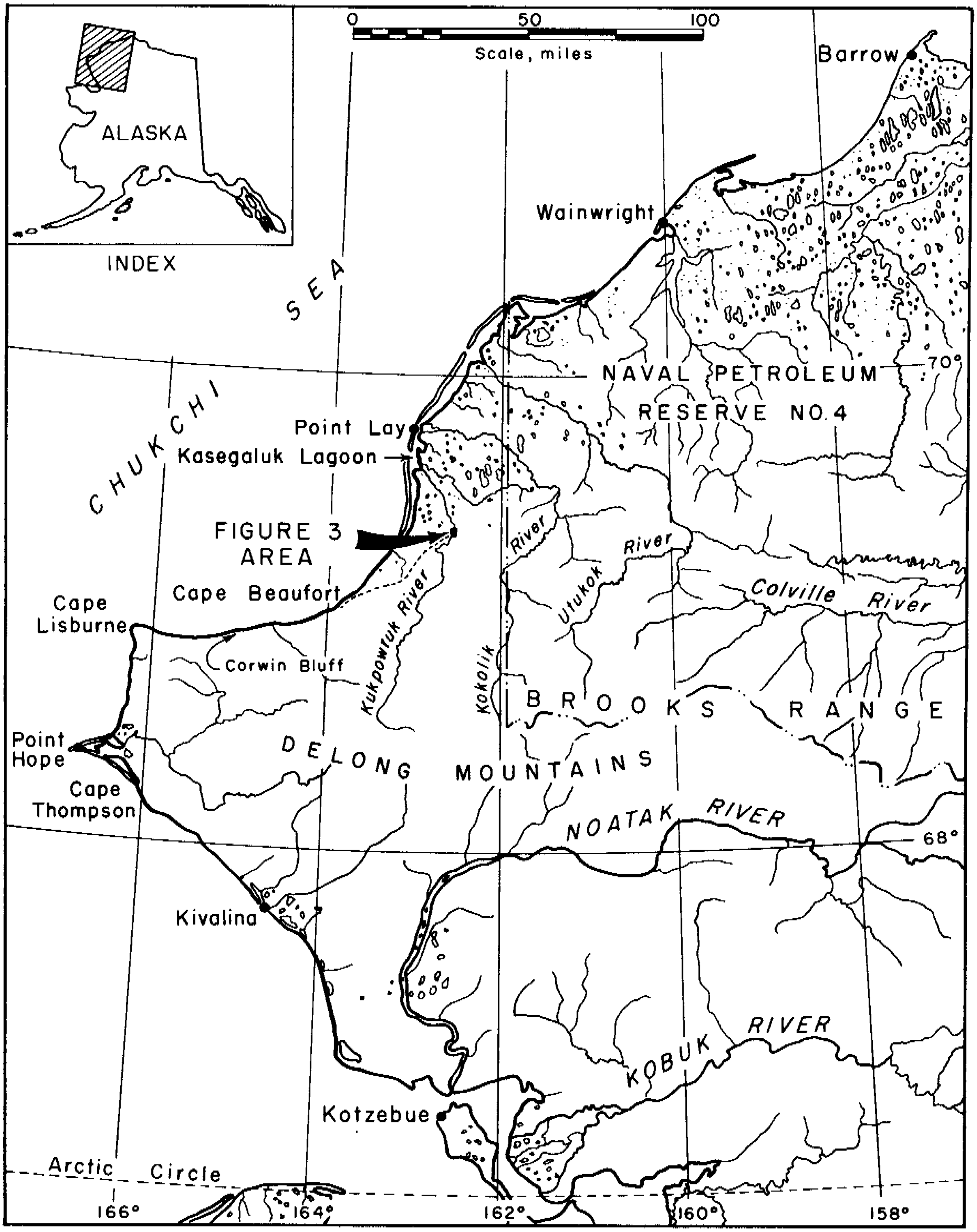

FIGURE 1. - Index and Location Map, Kukpowruk River Area, Alaska. Modified from Geological Survey Alaska Map B.

Kukpowruk River. Personnel were landed at the Kukpowruk River site directly from Kotzebue on the out-trip of the small aircraft. To exit from the area required a different system because the Kukpowruk River was in flood stage at the time of departure. In this case a pontoon-equipped aircraft was used to shuttle all gear, including coal samples, to a lake adjacent to the Point Lay DEW site, then larger aircraft were used for the return to Kotzebue.

Various types of tracked vehicles can be used for all-season transportation throughout most of the region, but successful operation on swampy parts of the coastal plain during the late summer is dependent on the depth of the seasonal thaw and the characteristics of the particular vehicle used, such as track ground pressure and ability to cross rivers.

During the 1963 field season, Bureau of Mines equipment consisting of a crawler tractor bulldozer, a wide-tracked weasel-type vehicle, dynamite, hand tools, etc. was airlifted from Anchorage and Fairbanks to the Cape Beaufort DEW site. From here, overland travel to the Kukpowruk River sample site, a distance of about 40 miles, was completed in 2½ days (fig. 1). No particular

FIGURE 2. - Typical Topography in Vicinity of Kukpowruk Coal Outcrop.

difficulties were encountered, but the routing was almost entirely in the foothills on relatively high ground compared to the coastal plain (fig. 2). Travel with the bulldozer on parts of the coastal plain during late summer, when seasonal thaw reached a maximum depth, might be very difficult, if not impossible; the weasel-type vehicle, however, could probably travel almost anywhere at any time.

OWNERSHIP

The area investigated is held under Coal Prospecting Permits issued to officers of the Morgan Coal Company of Indianapolis, Indiana.

These are Government-owned lands to which no title can be acquired. However, Coal Prospecting Permits are granted by the Department of the Interior for a period of four years to qualified applicants who meet certain reasonable requirements. Each permit covers a maximum of 2,560 acres, and no permit holder may have more than four permits (16 square miles). The recipient of a permit may remove only as much coal as is necessary to determine the commercial value of the deposit. If coal is mined commercially, a Coal Lease must be obtained. Such leases are good for 50 years and the operator must pay fees and royalties as the Secretary of the Interior may prescribe.

PHYSICAL FEATURES AND CLIMATE

The coal deposits investigated along the Kukpowruk River are almost on the border between two physiographic provinces of Arctic Northwestern Alaska. These provinces have been termed the Arctic coastal plain and the Arctic foothills;[5] the two provinces merge imperceptibly along an irregular boundary extending northwestward from Cape Beaufort.

The coastal plain is characterized by relief of less than 300 feet, many lakes and marshes, poor drainage, and poorly defined meandering streams, with the few outcrops present only in the cutbanks of major streams. The foothills section is an eastward-trending belt of rolling terrain 40 to 50 miles wide within which relief and altitude increase southward; the belt is marked by prominent cuesta ridges and mesas that reflect the underlying structural features, and which are commonly separated by wide lowland areas. Outcrops are numerous in river bluffs, along tributary streams, and on the ridges where vegetal cover is thin or absent. Relief is as much as 2,200 feet, and averages about 600 feet.

The vegetation of northern Alaska, except for willow bushes immediately adjacent to streams, is dwarfed, and consists mainly of cotton grass tussock, sedges, lichens, mosses, dwarfed berry bushes, and many wild flowers. These plants and a layer of humus and soil extending down to the perennially frozen ground, comprise the tundra of this treeless Arctic region, and cover a high percentage of the entire area. The cotton grass tussock is the most prevalent plant life, especially on the poorly drained coastal plain, and because of its closely spaced clump-like distribution and spring-like resilience, travel on foot is slow and arduous.

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[5]Work cited in footnote 4.

Permafrost[6] is believed to underlie nearly all of northern Alaska but may be at considerable depth or absent beneath large rivers and deep lakes. The permafrost, except for the shallow surface zone that is subject to summer thawing, is known to extend to depths of 1,000 feet or more.

The climate of Arctic Northwestern Alaska is semiarid with precipitation probably averaging less than 15 inches per year; in 1961, total precipitation at Kotzebue was 7.0 inches, at Cape Lisburne 15.2 inches, and at Wainwright an estimated 8.2 inches. Average yearly temperatures are well below freezing, with Kotzebue during 1961 having an average temperature of 19.8° F, Cape Lisburne 16.8° F, and Wainwright 9.4° F. During summer months, temperatures in the 60° and 70° F range are fairly common, but freezing temperatures may occur during every month of the year. Minimum temperatures during winter months in the -40° F range are common. Strong windstorms are common with many reaching gale velocities.

GENERAL GEOLOGY

The geology of the Utukok-Corwin region has been studied extensively on a regional basis by the U.S. Geological Survey; the most recent work was undertaken as a part of the program of investigation for the U.S. Navy Department in and near Naval Petroleum Reserve No. 4. The results of this and earlier work are incorporated into an excellent comprehensive report entitled "Geology of the Utukok-Corwin Region, Northwestern Alaska";[7] only that geology believed pertinent to coal deposits of the region is herein briefly summarized from the above-cited report.

Coalbeds of potential economic significance in the region are confined almost entirely to the Corwin formation. The Corwin formation is believed to be partly of middle or late early Cretaceous age and may be partly of late Cretaceous age. The formation consists of predominantly nonmarine rocks, and it intertongues with and overlies the Kukpowruk formation of late early Cretaceous age. Shale, siltstone, claystone, sandstone, coal, conglomerate, ironstone, clay, and bentonitic clay constitute most of the rock type of the Corwin formation. Sediments of the Corwin formation are believed to have been deposited everywhere in the region; only at a very few localities within the region has erosion apparently completely removed the formation.

The region has been divided into the eastern and western structural provinces. In the eastern structural province, the major folds in the northern foothills and coastal plain trend mainly west and northwest, the result of northward-directed forces from the Brooks Range. These include prominent simple synclines and basins separated by complex anticlines which may, in part,

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[6] Permafrost, or perennially frozen ground, is defined by Chapman and Sable (footnote 3) as: ". . . a thickness of soil or other superficial deposit, or even bedrock, at a variable depth beneath the surface of the earth, in which a temperature below freezing has existed continually for a long time (two to tens of thousands of years)."

[7] Work cited in footnote 4.

be the expression of major thrust faults. Surface rocks are folded to progressively greater depths westward and the western structural province is characterized by northwest-striking thrust faults which alternate with southwestward-dipping sections or partial limbs of synclines. This structural pattern is the result of eastward-directed forces from the Tigara uplift west of the area.

The western structural province includes the numerous coal outcrops of the Cape Beaufort-Corwin Bluff coastal area where more than 80 coalbeds that exceed 1 foot in thickness are known, at least 17 of which are between 2.5 and 9 feet thick. The structural geology of these coalbeds, however, appears relatively more complex than beds of the eastern structural province. Some coalbeds outcropping along the Corwin-Cape Beaufort coastal bluffs have measured dips of as much as 45°, whereas beds of the eastern structural province, at least in the synclines, are generally more gently folded. The major rivers of the region, the Kukpowruk, the Kokolik, and the Utukok, are within the eastern structural province. Each of these rivers exposes considerable thicknesses of the Corwin formation along its cutbanks, and thus many coalbeds have been exposed. The thickest mapped coalbed of the entire region is exposed along the Kukpowruk River; this is the principal bed sampled for coking studies.

DESCRIPTION OF SAMPLES

The site from which samples were taken coincides with the most eastern meander of the Kukpowruk River (fig. 3). Here the strata strike almost east-west, dip 8° to 17° northerly, and represent the south limb of a shallow syncline. This structure has been named the Howard syncline and extends at least from the Kukpowruk River to the Utukok River, a distance of 65 miles.[8]

Six samples from four locations were taken during the 1962 field season, and two samples, Nos. 7 and 8, from a single location during the 1963 field season. All samples except one were taken from excavations into outcrops; the exception, sample No. 6, was taken underground at the face of a previously driven 70-foot adit and raise. The excavations during the 1962 season were made by blasting and hand shoveling the perennially frozen overburden and weathered coal; during 1963, the bulldozer and blasting were used for removal of broken material. Figure 3 shows the location from which each sample was taken, and figure 4 shows details in sections of each sample. Each sample part was placed in a stout polyethylene-lined cloth sample sack immediately after it was obtained to minimize drying and additional oxidation during storage and transportation. The samples are briefly described as follows:

Sample 1, representing a 4.5-foot seam, was taken from an opencut dug approximately 7 feet into the outcrop near the top of a bluff on the east bank of the river. Permafrost was present in both the roof and coal seam. The sample, weighing 129 pounds, was taken from a channel cut approximately 14 inches wide by 4 inches deep.

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[8] Work cited in footnote 4.

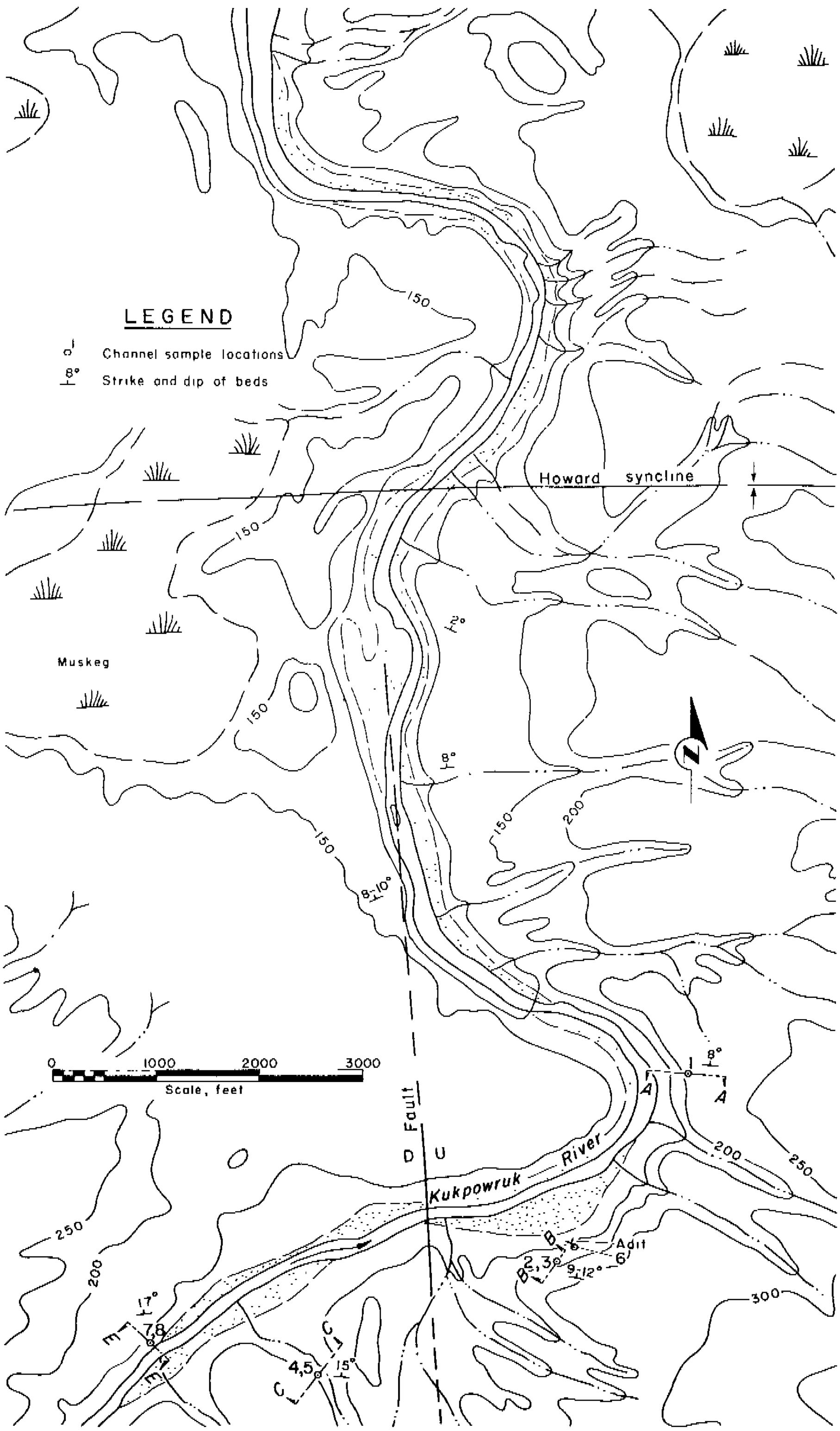

FIGURE 3. - Plan, Kukpowruk River Sample Area. Modified from preliminary map by Army Map Service and plate 9 of Geological Survey Professional Paper 303-C.

Samples 2 and 3 represent the thick coal seam that has been of principal interest to previous investigators.[9] The upper part of the seam is well exposed, almost along its dip, for a distance of about 500 feet in the east river bluff at the upstream end of the large, most eastern meander of the Kukpowruk River (fig. 5). The samples were taken from an opencut excavated into the outcrop as shown on figure 4, section B-B. Permafrost was evident throughout both samples. These samples, from a channel cut approximately 12 inches wide by 3 inches deep, were divided into sections corresponding to the following seam thickness (measured from the floor):

[9] Toenges, Albert L., and Theodore R. Jolley. Investigation of Coal Deposits for Local Use in the Arctic Regions of Alaska and Proposed Mine Development. BuMines Report of Investigations 4150, 1947, 19 pp. See work cited in footnote 4.

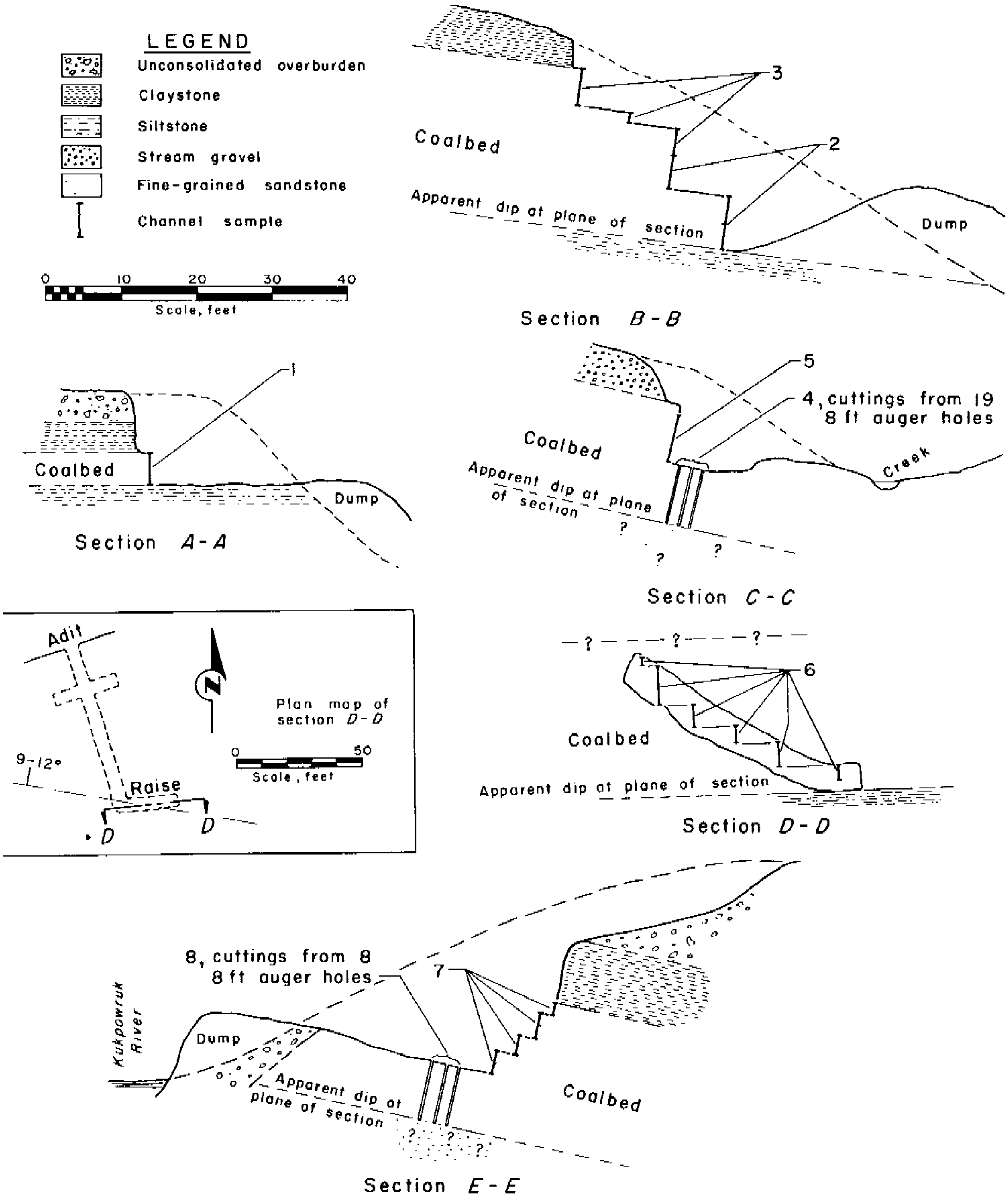

FIGURE 4. - Plan of Adit and Raise and Sections, Kukpowruk River Coal Samples.

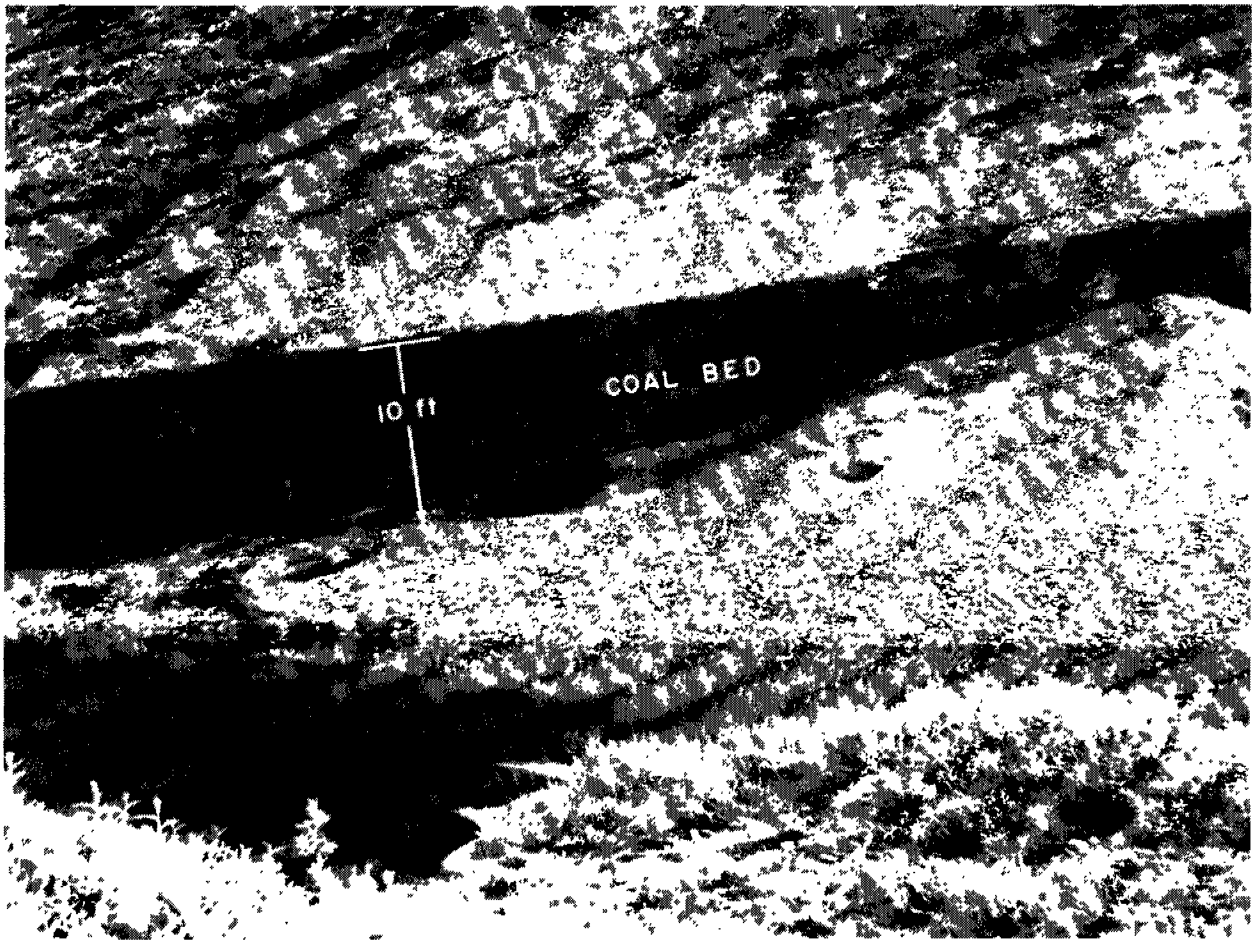

FIGURE 5. - Outcrop of 21-Foot Coalbed, Approximately 10 Feet Exposed, Kukpowruk River.

Sample No.	Weight, pounds	Interval from floor, feet	Material, as logged in the field
2 - Part 1	68.5	0.0 to 3.6	Coal.
2 - Part 2	68.5	3.6 to 7.2	Coal.
2 - Part 3	102.0	7.2 to 11.45	Coal, 2 thin (¼") silty partings upper 1 ft. - included in Part 3.
-	-	11.45 to 11.55	Silty parting - excluded from samples.
3 - Part 1	78.5	11.55 to 15.15	Coal.
3 - Part 2	20.5	15.15 to 16.55	Coal.
3 - Part 3	107.0	16.55 to 21.55	Coal.

Samples 4 and 5 were taken from a seam which outcrops along a small tributary creek of the Kukpowruk River about ½ mile southwest or upriver from the location where samples 2 and 3 were obtained. Because the floor of the seam was below creek level, sample 4 was obtained by collecting cuttings from multiple 1-5/8-inch auger holes. The position of the floor was determined by purposely drilling the first hole through the coal into the floor. The cuttings from this hole were not included in the sample, and the remainder of the holes were stopped just short of the floor. The auger holes were started from the top of a 0.05-foot silty parting; most of the parting was included in sample 4. Sample 4, weighing 164.5 pounds, represents the lower 8.0 feet of the seam. Above the coal represented by sample 4, an additional 8 feet of coal was exposed, covered by 4 feet of alluvial gravel and 1 foot of tundra. Because of the outcrop location as related to topography and dip of the seam (dip almost parallels slope of creek cutbank), there was no possibility that rock roof could occur at this site. An unknown thickness of coal had obviously been removed by erosion. About 1.5 feet of gravel on top of coal was frozen when first exposed and permafrost was noted throughout the coal exposure. Minute ice seams appeared to usually parallel the cleat faces. Because of the shallow cover and consequent probable oxidation of the upper coal, only 6.5 feet above that represented by sample 4 was sampled. Three thin partings (1/8 inch or less) were noted in the 6.5 feet sampled; these were included in the sample. The channel for sample 5 was cut approximately 12 inches wide by 3 inches deep; the sample weighed 146 pounds.

Sample 6 was taken underground in an adit and inclined raise into the seam from which samples 2 and 3 were obtained. This adit and raise were driven in 1954 by J. S. Robbins and Associates, Inc. of Seattle, Wash., for Morgan Coal Company of Indianapolis, Ind. A fairly large sample was taken at that time; results of the test work on the sample are unknown. Total overburden above the face of the raise is about 40 feet; the present sample was taken here to provide a check of coal freshness at depth versus the surface samples from opencuts. The sample, taken from a channel cut 12 inches wide, 1½ inches deep, and 17.3 feet long, was divided into two parts representing (approximately) the upper and lower halves of the sampled part of the seam. The lower 1.3 feet of the seam was not sampled because of heavy ice buildup on the floor of the adit, and the roof of the seam was not sampled because it was not exposed in the raise. If the seam thickness was the same as that at the location where samples 2 and 3 were obtained (21.55 feet), it may be inferred that about 3 feet at the roof of the seam was not sampled. The samples of the upper and lower portions of the sample section weighed 105 and 99 pounds, respectively.

Samples 7 and 8 were taken in 1963 approximately 1,600 feet west along strike and on the opposite side of the river from the 4 and 5 sample site. At the sample location, strike was measured at S 82° W, dip 17° N. Sample No. 7 represents a channel cut approximately 10 inches wide by 3 inches deep by 10.95 feet long. For sample No. 7, a cut was made into the outcrop that removed approximately 20 feet of coal between the original outcrop face and the sample face. Above the sample face, 8 feet of claystone roof was exposed, covered by 4 feet of gravel, which in turn was covered by 2 feet of tundra. This excavation was made with the bulldozer aided by blasting. Sample No. 8 is represented by drill cuttings from eight 3-inch auger holes each 8 feet deep. The drill holes were collared from a bedding plane at the base of sample No. 7. As nearly as possible, each hole was drilled normal to the bedding. Samples 7 and 8 represent a total seam thickness of 18.95 feet.

Interpretation of aerial photographs and other geologic data made available by the lessees indicates a fault aligned about as shown on figure 3. If this fault has caused a vertical displacement of about 300 feet, it is possible that all samples except No. 1 are from the same coalbed. No positive correlation has been possible between opposite sides of the fault to verify such displacement; but the similarity in thickness of the coalbed at sample sites on either side of the fault supports such a conclusion.

COKING STUDIES

Coking studies on the eight Kukpowruk River coal samples were conducted by the Denver Coal Research Laboratory. These studies were made in two series, corresponding to the two sampling campaigns (1962 and 1963) in which the samples were obtained.

Coking Studies, 1962 Series

The six samples obtained in the 1962 sampling campaign are logged graphically in figure 6. Figure 6 also illustrates the groupings of samples and sample parts as established for the laboratory coking studies and identifies the groupings by Denver Laboratory (DL) numbers.

The investigation of the coking properties of samples 1 through 6 was organized in three stages, exploratory bench-scale, detailed bench-scale, and pilot plant. Testing procedures in the second and third stages were based in part on results observed in the preceding stage.

Exploratory Bench Scale Testing

Each sample and sample part was crushed through a ¼-inch round-hole screen, grab-sampled, and immediately stored under natural gas to minimize oxidation.

Free swelling tests were conducted on each grab sample by standard ASTM procedures. Plastometer tests were conducted on samples that exhibited coking properties in the free swelling tests. For the plastometer tests a Gieseler plastometer was used, conventional in all respects except that it had been modified to give the stirring shaft a torque of 37.5 inch-grams, which is more commonly used with Western United States coals than the tentative ASTM standard of 40.0 inch-grams.

Results of the exploratory free-swelling and plastometer tests were as follows:

Alaskan sample	Part	Denver laboratory number	Free-swelling index	Gieseler maximum fluidity, dial divisions per minute[1]
1..................	-	2000-A	Noncoking	-
2..................	1	2001-A	4½	115
	2	2001-B	5	24
	3	2001-C	2½	3.30
3..................	1	2002-A	2	1.35
	2	2002-B	2½	1.70
	3	2002-C	Noncoking	-
4..................	-	2003-A	4½	-
5..................	-	2004-A	6	-
6..................	1	2005-A	4	4
	2	2005-B	4½	36

[1]Plastometer tests were conducted on grab samples that had been ground to 60 mesh x 0 and stored under a natural gas atmosphere. Results should be taken as approximations, not as true values of representative, fresh samples ground to the standard size of 35 mesh x 0.

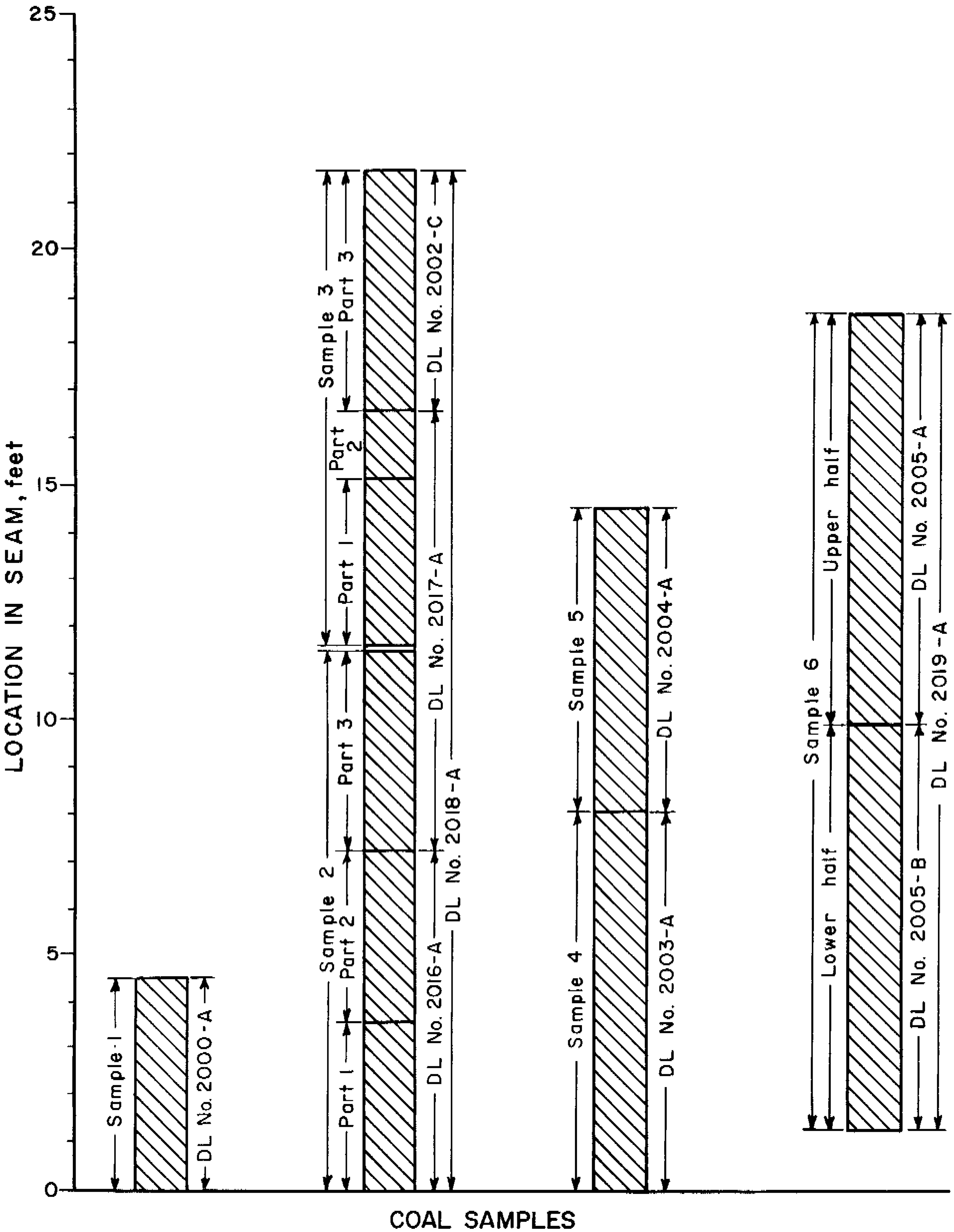

FIGURE 6. - Log and Laboratory Grouping of Coal Samples 1 Through 6 From Kukpowruk River Area, Alaska.

These results indicate that sample 1 and part 3 of sample 3 are noncoking. The coking parts of samples 2 and 3 (which represent one location) fall into two classes--one having free-swelling indices of 4½ or 5, and the other having free-swelling indices of 2 or 2½. The maximum fluidities observed in the plastometer tests also suggest the division of samples 2 and 3 into the same two classes. Both samples 4 and 5 have significant coking properties (free-swelling indices of 4½ and 6, respectively). Both parts of sample 6 have coking properties; based on the observed maximum fluidities, it appeared that the coking qualities of the two parts should be investigated separately.

Detailed Bench Scale Testing

A detailed study was conducted on selected samples and sample composites, as guided by the results of the exploratory bench scale testing, and with recognition of the desirability of full-seam rather than selective mining. In preparing composites of samples and sample selections, the components were weighted according to their thicknesses in the log of the seam. The following samples and composites were studied for coking properties (see fig. 6);

1. A composite of parts 1 and 2 of sample 2.
2. A composite of part 3 of sample 2 and parts 1 and 2 of sample 3.
3. A composite of all parts of samples 2 and 3.
4. Sample 4.
5. Sample 5.
6. Part 1 (upper half) of sample 6.
7. Part 2 (lower half) of sample 6.
8. A composite of parts 1 and 2 of sample 6.

Coking properties were studied by conducting carbonization assays, Gieseler plastometer tests, free swelling tests, and 100-gram coking tests. In addition, conventional determinations were made of proximate and ultimate composition, heating value, and ash softening temperature.

Two sets of blends were also prepared and subjected to the same tests, using two West Virginia blending coals with the indicated Alaska samples and composites. The two blending coals were Sewell (high-volatile A bituminous) from the Sterling-Sewell mine, Holcomb, Nicholas County, W. Va., and Pocahontas No. 3 (low-volatile bituminous) from the Beeson No. 2 mine, Beeson, Mercer County, W. Va. One set of blends consisted of 50 percent of Sewell coal with each of the samples and composites studied; the other set consisted of 25 percent of Sewell and 25 percent of Pocahontas with each of the samples and composites studied.

All blends were tested for coking properties by carbonization assay, Gieseler plastometer test, free swelling test, and 100-gram coking test. Proximate and ultimate analyses and heating values of the blends were calculated from data on the components of the blends.

For sample 1 and part 3 of sample 3, no coking properties had been observed in the exploratory work and hence no further study was made of their coking properties; however, the conventional determinations of proximate and ultimate composition, heating value, and ash softening temperature were made.

Table 1 lists all samples, composites, and blends and shows the Denver laboratory sample number assigned to each. The corresponding carbonization assay test numbers, 50-pound coking test numbers (as assigned in later work), and plastometer test numbers are also presented. Table 1 thus is an index to the identification and composition of all Alaskan coal samples, composites, and blends investigated in the 1962 carbonization study and to the tests made thereon.

TABLE 1. - Sample identification and composition (expressed in percentages) of Alaskan coals and blends, and tests conducted[1]

Alaskan sample No....	1	2			3			4			5	6						
Bed depth represented, feet measured from bottom of bed...	Entire	0.0 to 3.6	3.6 to 7.2	7.2 to 11.45[2]	11.55 to 15.15	15.15 to 16.55	16.55 to 21.55	0.0 to 8.0			8.0 to 14.5	Upper half	Lower half	Sewell coal	Pocahontas coal	Carbonization assay number	50-lb coking test number[5]	Gieseler plastometer test number
Denver laboratory No.	2000-A	2001-A	2001-B	2001-C	2002-A	2002-B	2002-C	2003-A	2003-A-10[3]	2003-A-20[4]	2004-A	2005-A	2005-B	2007	2006			
2000-A..............	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1016	-	-
2016-A..............	-	50	50	-	-	-	-	-	-	-	-	-	-	-	-	1017	CP-111	275, 316
2016-AA.............	-	25	25	-	-	-	-	-	-	-	-	-	-	50	-	1018	-	276
2016-AB.............	-	25	25	-	-	-	-	-	-	-	-	-	-	25	25	1019	CP-118	277
2017-A..............	-	-	-	46	39	15	-	-	-	-	-	-	-	-	-	1020	-	278
2017-AA.............	-	-	-	23	19.5	7.5	-	-	-	-	-	-	-	50	-	1021	-	279
2017-AB.............	-	-	-	23	19.5	7.5	-	-	-	-	-	-	-	25	25	1022	-	280
2002-C..............	-	-	-	-	-	-	100	-	-	-	-	-	-	-	-	1023	-	-
2003-A..............	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-	1024	CP-122	281, 319
2003-A-10...........	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	1049	-	334
2003-A-20...........	-	-	-	-	-	-	-	-	-	100	-	-	-	-	-	1079	-	340
2003-AA.............	-	-	-	-	-	-	-	50	-	-	-	-	-	50	-	1025	CP-123	282
2003-AB.............	-	-	-	-	-	-	-	50	-	-	-	-	-	25	25	1026	CP-124	283
2003-AB-10..........	-	-	-	-	-	-	-	-	50	-	-	-	-	25	25	1058	CP-140	-
2004-A..............	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-	1027	CP-125	284, 322
2004-AA.............	-	-	-	-	-	-	-	-	-	-	50	-	-	50	-	1028	CP-126	285
2004-AB.............	-	-	-	-	-	-	-	-	-	-	50	-	-	25	25	1029	CP-127	286
2005-A..............	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	1030	CP-141	287
2005-AA.............	-	-	-	-	-	-	-	-	-	-	-	50	-	50	-	1031	-	288
2005-AB.............	-	-	-	-	-	-	-	-	-	-	-	50	-	25	25	1032	-	289
2005-B..............	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-	1033	CP-128	290, 325
2005-BA.............	-	-	-	-	-	-	-	-	-	-	-	-	50	50	-	1034	-	291
2005-BB.............	-	-	-	-	-	-	-	-	-	-	-	-	50	25	25	1035	-	292
2018-A..............	-	16.8	16.8	19.8	16.8	6.5	23.3	-	-	-	-	-	-	-	-	1036	CP-119	294, 315
2018-AA.............	-	8.4	8.4	9.9	8.4	3.25	11.65	-	-	-	-	-	-	50	-	1037	CP-120	295
2018-AB.............	-	8.4	8.4	9.9	8.4	3.25	11.65	-	-	-	-	-	-	25	25	1038	CP-121	296
2019-A..............	-	-	-	-	-	-	-	-	-	-	-	50	50	-	-	1039	CP-129	297, 326
2019-AA.............	-	-	-	-	-	-	-	-	-	-	-	25	25	50	-	1040	-	298
2019-AB.............	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	1041	CP-130	299

[1] In blended samples (2016-A, 2017-A, 2018-A, and 2019-A), components were weighted according to bed thickness represented.
[2] Between 11.45 and 11.55 feet, 0.1 feet silty parting was excluded from samples.
[3] Oxidized at 70° F for 10 weeks.
[4] Oxidized at 70° F for 20 weeks.
[5] Conducted in 10-inch modified BM-AGA retort.

Table 2 presents the proximate and ultimate analyses, heating values, free swelling indices, and ash softening temperatures of the samples and composites selected for testing, and for the Sewell and Pocahontas blending coals. Calculated proximate and ultimate analyses and heating values of the blends are also presented.

All moisture determinations reported in table 2 and throughout this report were made just prior to the more specialized testing procedures. In occasional instances there are slight variations in tabulated analyses bearing the same laboratory sample number; these variations reflect minor changes in the moisture content of the sample.

Table 2 confirms the indications of the exploratory testing that sample 1 (DL No. 2000-A) and part 3 of sample 3 (DL No. 2002-C) had been oxidized. Both of these samples have high oxygen contents and low heating values. All other samples and composites have oxygen contents of 11 percent or less and heating values of over 14,400 Btu/lb, maf basis.

Using the as-received moisture contents of the samples as equivalent to the natural bed moistures, samples 2 (except part 3) through 6 are classified as high-volatile A bituminous (hvab). Sample 1 and part 3 of sample 2, having been oxidized, cannot be classified for rank.

As shown in table 2, the free-swelling indices of samples and composites were increased an average of 2½ points by the addition of 50 percent of Sewell coal, but they were unchanged by the addition of 25 percent each of Sewell and Pocahontas coals.

Comparative analytical data are given in table 3 for a commercially used Western coking coal--Sunnyside No. 1 mine, Sunnyside seam, Dragerton, Carbon County, Utah. The coal is high-volatile B bituminous in rank. In connection with oxidation studies to be discussed later, the table includes data on the Sunnyside coal after two levels of mild oxidation (exposure to laboratory air at about 70° F).

Table 3 also includes analytical data on a coking blend used by Kaiser Steel Corporation in making metallurgical coke at Fontana, Calif. This commercial coking blend, identified in this report as the Fontana blend, is composed of 85 percent Sunnyside No. 1 coal, 7½ percent Coal Basin coal (mvb rank; Pitkin County, Colo.), and 7½ percent Red Indian coal (mvb rank, Wyoming County, W. Va.). Two sets of Fontana blend analyses are presented--one made up with fresh Sunnyside coal and the other made up with Sunnyside coal that had been partially oxidized by exposure to laboratory air, as will be later discussed.

TABLE 2. - Analyses of Alaskan coals and blends, and Sewell and Pocahontas blending coals--1962 series

Denver laboratory No....	2000-A		2016-A		2016-AA		2016-AB		2017-A		2017-AA	
Basis..................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:												
Moisture..............	11.9	-	3.0	-	3.2	-	2.0	-	2.6	-	3.0	-
Volatile matter.......	30.1	37.4	39.5	41.8	34.7	37.0	31.4	33.2	36.1	38.6	33.0	35.4
Fixed carbon..........	50.3	62.6	54.9	58.2	59.1	63.0	63.1	66.8	57.3	61.4	60.3	64.6
Ash...................	7.7	-	2.6	-	3.0	-	3.5	-	4.0	-	3.7	-
Ultimate analysis, percent:												
Hydrogen..............	5.0	4.6	5.7	5.7	5.5	5.4	5.2	5.3	5.2	5.3	5.3	5.4
Carbon................	61.4	76.4	78.8	83.5	79.9	85.2	81.4	86.2	77.1	82.6	79.0	84.7
Nitrogen..............	1.2	1.4	1.4	1.5	1.6	1.7	1.4	1.5	1.4	1.4	1.6	1.7
Oxygen................	24.4	17.3	11.2	9.0	9.6	7.3	8.0	6.5	12.1	10.5	10.0	7.8
Sulfur................	.3	.3	.3	.3	.4	.4	.5	.5	.2	.2	.4	.4
Ash...................	7.7	-	2.6	-	3.0	-	3.5	-	4.0	-	3.7	-
Heating value, Btu/lb...	10,310	12,820	14,060	14,900	14,240	15,190	14,390	15,230	13,460	14,410	13,950	14,950
Ash softening temp., ° F	2290		2680		-		-		2620		-	
Free swelling index.....	-		4½		7		5½		2		6	

TABLE 2. - Analyses of Alaskan coals and blends, and Sewell and Pocahontas blending coals--1962 series--Continued

Denver laboratory No....	2017-AB		2002-C		2003-A		2003-A-10		2003-A-20		2003-AA	
Basis..................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:												
Moisture.............	2.9	-	4.9	-	1.9	-	1.3	-	1.5	-	2.3	-
Volatile matter.......	29.3	31.6	29.5	33.2	40.4	42.3	41.1	42.8	40.1	41.8	35.2	37.2
Fixed carbon..........	63.5	68.4	59.3	66.8	55.1	57.7	54.8	57.2	55.8	58.2	59.5	62.8
Ash..................	4.3	-	6.3	-	2.6	-	2.8	-	2.6	-	3.0	-
Ultimate analysis, percent:												
Hydrogen.............	5.0	5.1	4.6	4.6	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5
Carbon...............	79.5	85.6	72.4	81.5	79.5	83.3	79.8	83.2	79.6	83.0	80.6	85.1
Nitrogen.............	1.4	1.6	1.1	1.3	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.6
Oxygen...............	9.3	7.2	15.4	12.4	10.5	9.3	10.1	9.5	10.5	9.6	9.0	7.4
Sulfur...............	.5	.5	.2	.2	.3	.3	.3	.3	.3	.3	.4	.4
Ash..................	4.3	-	6.3	-	2.6	-	2.8	-	2.6	-	3.0	-
Heating value, Btu/lb...	13,910	14,990	12,280	13,830	14,250	14,940	14,260	14,860	14,180	14,790	14,390	15,200
Ash softening temp., ° F	-		2420		2250		-		-		-	
Free swelling index.....	2½		-		5½		5		5		7	

TABLE 2. - Analyses of Alaskan coals and blends, and Sewell and Pocahontas blending coals--1962 series--Continued

Denver laboratory No....	2003-AB		2003-AB-10		2004-A		2004-AA		2004-AB		2005-A	
Basis..................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:												
Moisture.............	2.0	-	1.3	-	2.2	-	2.2	-	1.9	-	2.8	-
Volatile matter.......	31.6	33.5	31.3	32.9	38.6	41.1	34.4	36.5	30.8	32.8	35.1	38.0
Fixed carbon..........	62.8	66.5	63.8	67.1	55.3	58.9	59.8	63.5	63.1	67.2	57.3	62.0
Ash..................	3.6	-	3.6	-	3.9	-	3.6	-	4.2	-	4.8	-
Ultimate analysis, percent:												
Hydrogen.............	5.3	5.4	5.2	5.3	5.3	5.4	5.3	5.3	5.1	5.2	5.1	5.2
Carbon...............	81.1	85.9	81.7	85.9	77.4	82.4	79.7	84.6	80.3	85.6	76.6	83.0
Nitrogen.............	1.4	1.5	1.4	1.5	1.3	1.4	1.5	1.6	1.4	1.5	1.3	1.4
Oxygen...............	8.1	6.7	7.6	6.7	11.8	10.5	9.4	8.0	8.5	7.2	12.0	10.2
Sulfur...............	.5	.5	.5	.6	.3	.3	.5	.5	.5	.5	.2	.2
Ash..................	3.6	-	3.6	-	3.9	-	3.6	-	4.2	-	4.8	-
Heating value, Btu/lb...	14,390	15,240	14,410	15,150	13,700	14,590	14,150	15,200	14,160	15,090	13,390	14,500
Ash softening temp., ° F	-		-		2500		-		-		2580	
Free swelling index.....	6½		5		4½		7		4		3½	

TABLE 2. - Analyses of Alaskan coals and blends, and Sewell and Pocahontas blending coals--1962 series--Continued

Denver laboratory No....	2005-AA		2005-AB		2005-B		2005-BA		2005-BB		2018-A	
Basis..................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:												
Moisture..............	3.1	-	3.0	-	1.5	-	2.9	-	2.9	-	3.2	-
Volatile matter.......	32.4	34.9	28.8	31.2	41.6	43.2	35.5	37.7	31.8	33.9	35.5	38.3
Fixed carbon..........	60.4	65.1	63.5	68.8	54.6	56.8	58.7	62.3	61.9	66.1	57.3	61.7
Ash...................	4.1	-	4.7	-	2.3	-	2.9	-	3.4	-	4.0	-
Ultimate analysis, percent:												
Hydrogen..............	5.2	5.3	5.0	5.1	5.6	5.6	5.5	5.5	5.3	5.3	5.2	5.2
Carbon................	78.8	84.9	79.2	85.8	79.8	83.1	80.0	85.0	80.5	85.9	76.3	82.2
Nitrogen..............	1.5	1.6	1.3	1.4	1.4	1.5	1.5	1.6	1.4	1.5	1.3	1.4
Oxygen................	10.0	7.8	9.3	7.2	10.7	9.6	9.7	7.5	8.9	6.8	13.0	11.0
Sulfur................	.4	.4	.5	.5	.2	.2	.4	.4	.5	.5	.2	.2
Ash...................	4.1	-	4.7	-	2.3	-	2.9	-	3.4	-	4.0	-
Heating value, Btu/lb...	13,910	14,490	13,880	15,040	14,200	14,760	14,250	15,130	14,220	15,180	13,410	14,440
Ash softening temp., ° F	-		-		2590		-		-		2260	
Free swelling index.....	7		3½		6		7		5		2	

TABLE 2. - Analyses of Alaskan coals and blends, and Sewell and Pocahontas blending coals--1962 series--Continued

Denver laboratory No..	2018-AA		2018-AB		2019-A		2019-AA		2019-AB		Sewell coal 2007		Pocahontas coal 2006	
Basis................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:														
Moisture............	3.3	-	3.2	-	1.7	-	2.9	-	2.2	-	3.4	-	3.2	-
Volatile matter.....	32.7	35.2	29.0	31.4	38.0	40.1	33.8	36.1	30.3	32.3	29.8	32.0	15.1	16.5
Fixed carbon........	60.3	64.8	63.5	68.6	56.7	59.9	59.8	63.9	63.5	67.7	63.4	68.0	76.1	83.5
Ash.................	3.7	-	4.3	-	3.6	-	3.5	-	4.0	-	3.4	-	5.6	-
Ultimate analysis, percent:														
Hydrogen............	5.2	5.2	5.0	5.0	5.2	5.4	5.3	5.3	5.0	5.2	5.3	5.3	4.5	4.5
Carbon..............	78.7	84.6	79.1	85.5	78.4	82.7	79.4	84.9	80.5	85.8	81.0	86.8	82.8	90.8
Nitrogen............	1.5	1.6	1.3	1.4	1.4	1.4	1.6	1.7	1.4	1.5	1.7	1.8	1.2	1.3
Oxygen..............	10.5	8.2	9.8	7.6	11.2	10.3	9.8	7.7	8.6	7.0	8.0	5.4	5.0	2.5
Sulfur..............	.4	.4	.5	.5	.2	.2	.4	.4	.5	.5	.6	.7	.9	.9
Ash.................	3.7	-	4.3	-	3.6	-	3.5	-	4.0	-	3.4	-	5.6	-
Heating value, Btu/lb.	13,920	14,970	13,890	15,020	13,860	14,640	14,100	15,060	14,160	15,100	14,430	15,470	14,300	15,690
Ash softening temp., ° F.................	-		-		2260		-		-		2910+		2780	
Free swelling index..	6		3		5		7½		4½		8		7½	

TABLE 3. - Analyses of Sunnyside No. 1 coal and Fontana coking blend

	Coal									
	Sunnyside		Sunnyside, oxidized 10 weeks		Sunnyside, oxidized 20 weeks		Fontana plant blend		Fontana plant blend with 10-week oxidized Sunnyside	
Lab No..................	2008-A		2008-A-10		2008-A-20		2008-3Y		2008-4H	
Basis...................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:										
Moisture..............	8.8	-	1.6	-	1.8	-	5.2	-	1.8	-
Volatile matter.......	36.8	42.8	40.0	43.0	39.1	42.2	35.8	40.1	36.7	39.6
Fixed carbon..........	49.1	57.2	52.8	57.0	53.6	57.8	53.5	59.9	56.1	60.4
Ash...................	5.3	-	5.6	-	5.5	-	5.5	-	5.4	-
Ultimate analysis, percent:										
Hydrogen..............	5.9	5.8	5.5	5.7	5.5	5.7	5.6	5.6	5.4	5.6
Carbon................	70.6	82.3	76.1	82.1	75.9	81.9	74.4	83.4	77.2	83.3
Nitrogen..............	1.6	1.8	1.7	1.8	1.2	1.3	1.6	1.8	1.7	1.8
Oxygen................	15.7	9.0	10.1	9.3	10.9	10.0	12.0	8.2	9.3	8.3
Sulfur................	.9	1.1	1.0	1.1	1.0	1.1	.9	1.0	1.0	1.0
Ash...................	5.3	-	5.6	-	5.5	-	5.5	-	5.4	-
Heating value, Btu/lb...	12,700	14,780	13,630	14,690	13,620	14,700	13,330	14,920	13,790	14,860
Ash softening temp., ° F	2780		-		-		-		-	
Free swelling index.....	5		5		4½		4½		5	

The results of the Gieseler plastometer tests on all samples, composites, and blends and on the Sewell and Pocahontas coals used for blending are presented in table 4. In connection with the blending coals, it may be noted that the Sewell coal is highly fluid, with a wide plastic range and a high solidification temperature. The Pocahontas coal has very low fluidity and a relatively narrow plastic range; however, its plastic range is displaced so high in temperature that there is only slight overlap with the plastic range of any of the Alaskan samples. Plastometric data on the Fontana blend are also listed, to assist in comparisons and evaluations.

The Gieseler plasticity data on the Alaskan coals (table 4) and composites correspond quite satisfactorily with the exploratory data (page 13) in which grab samples had been used. The data of table 4 permit several generalizations:

1. In any one seam, the upper portion has lower fluidity than the lower portion, presumably because of oxidation effects.

2. Blends containing 50 percent Sewell coal exhibited far higher fluidities and significantly higher temperatures of maximum fluidity and solidification than the unblended Alaskan samples and composites.

3. Blending with 25 percent each of Sewell and Pocahontas coals caused no consistent change in fluidity, compared with the unblended coals. In general, temperatures of maximum fluidity and solidification were increased to points intermediate between those of the unblended coals and the 50-percent-Sewell blends.

4. Samples and composites representing the lower portions of the Alaskan seams had fluidities exceeding that of the Fontana commercial blend, but somewhat lower solidification temperatures. In each case, blending raised the solidification temperature to a level as high or higher than that of the Fontana blend.

Carbonization assays, to establish yields of products under low-temperature carbonization, were conducted at 500° C by methods that have been described.[10] Results of the assays are presented in table 5. In this table the effects of oxidation are shown primarily as decreased tar plus light oil yields and lower heating values (maf). The data also reflect, in general, the higher char yields and lower tar yields expectable in blends with coals of lower volatile matter content.

Table 6 presents assay data on the Sewell and Pocahontas blending coals; for reference, assay data on the Fontana blend and on the Sunnyside component of the Fontana blend are also included.

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[10] Goodman, J. B., Manuel Gomez, V. F. Parry, and W. S. Landers. Low-Temperature Carbonization Assay of Coal in a Precision Laboratory Apparatus. BuMines Bull. 530, 1953, 24 pp.

TABLE 4. - Gieseler plastometer data on fresh Alaskan coals and blends, on Sewell and Pocahontas blending coals, and on the Fontana blend--1962 series

Test number	Denver Lab. number	° C at		Maximum fluidity		° C at		Plastic range[2]	Fusion range[3]	Coke swelled into barrel, inches
		0.1 ddpm[1]	5.0 ddpm	ddpm	° C	5.0 ddpm	Solidi-fication			
275	2016-A	360	413	84	429	449	462	102	36	0
276	2016-AA	353	413	1,010	441	467	477	124	54	2
277	2016-AB	366	417	56	438	461	477	111	44	0
278	2017-A	380	-	1.80	426 & 429	-	459	79	-	0
279	2017-AA	363	420	62	441	459	483	120	39	0
280	2017-AB	378	-	3.30	435	-	468	90	-	0
281	2003-A	356	407	275	429	452	462	106	45	1-1/4
282	2003-AA	356	409	2,210	444	468	480	124	59	2-1/2
283	2003-AB	356	413	140	435 & 438	462	477	121	49	1/8
284	2004-A	366	418	16	426	441	459	93	23	0
285	2004-AA	360	415	357	441	465	480	120	50	0
286	2004-AB	372	421	19	435	450	474	102	29	0
287	2005-A	378	-	3.40	429	-	462	84	-	0
288	2005-AA	366	420	185	444	464	480	114	44	3/8
289	2005-AB	375	-	3.80	435	-	471	96	-	0
290	2005-B	360	413	58	432	447	462	102	34	1/4
291	2005-BA	360	412	598	438	465	477	117	53	3/4
292	2005-BB	363	417	38	438	455	474	111	38	0
294	2018-A	378	-	2.80	426	-	459	81	-	0
295	2018-AA	360	416	145	438	461	477	117	45	1/4
296	2018-AB	369	-	4.30	432	-	471	102	-	0
297	2019-A	366	418	16	426	442	462	96	24	0
298	2019-AA	360	418	350	441	466	480	120	48	1/4
299	2019-AB	369	421	15	432	448	471	102	27	0
306 & 307	[4]2007	363	415	12,300	444	482	495	132	67	4-5/16
308 & 309	[5]2006	450	-	.90	477	-	507	57	-	0
302	[6]2008-T	366	416	40	435	451	468	102	35	0

[1] Continuous movement of 0.1 dial divisions per minute, or more.
[2] Plastic range is defined as the temperature range between 0.1 ddpm continuous movement and solidification.
[3] Fusion range is defined as the temperature range over which the fluidity exceeds 5.0 ddpm.
[4] Sewell coal, average of 2 tests.
[5] Pocahontas coal, average of 2 tests.
[6] Fontana blend (DL 2008-T and DL 2008-3Y) are identical in blend components and percentages.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series

Assay number	1016	1017	1018
Denver laboratory number[1]	2000-A	2016-A	2016-AA
Carbonization yields, maf, percent:			
Char	75.5	74.1	78.2
Water formed	7.2	4.4	2.7
Tar, dry	4.0	13.7	12.5
Light oil	1.3	1.5	1.4
Gas	11.6	6.4	5.0
Hydrogen sulfide	.1	.1	.2
Total	99.7	100.2	100.0
Gas composition (O_2-N_2-free) percent:			
CO_2	42.0	12.3	6.7
Illuminants	.9	3.2	2.4
CO	13.5	6.8	4.8
H_2	13.5	13.6	15.7
CH_4	24.7	49.5	57.8
C_2H_6	5.4	14.6	12.6
Net gas yield, maf, cu ft/lb	1.542	1.133	1.029
Heat in gas, maf, Btu/lb	702	1021	959
Heating value, calculated, Btu/cu ft	455	901	932
Specific gravity, calculated (air = 1)	0.983	0.735	0.643
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	37.4	41.8	37.0
Fixed carbon	62.6	58.2	63.0
Ultimate analysis, percent:			
Hydrogen	4.6	5.7	5.4
Carbon	76.4	83.5	85.2
Nitrogen	1.4	1.5	1.7
Oxygen	17.3	9.0	7.3
Sulfur	.3	.3	.4
Heating value, Btu/lb	12,820	14,900	15,190
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	14.6	15.5	12.6
Fixed carbon	74.1	80.7	82.9
Ash	11.3	3.8	4.5
Heating value, Btu/lb	12,940	14,290	14,300

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1019	1020	1021
Denver laboratory number[1]	2016-AB	2017-A	2017-AA
Carbonization yields, maf, percent:			
Char	81.0	77.9	80.4
Water formed	2.5	4.6	2.9
Tar, dry	10.1	10.2	10.2
Light oil	1.3	1.4	1.3
Gas	5.3	6.0	4.9
Hydrogen sulfide	.1	.1	.1
Total	100.3	100.2	99.8
Gas composition (O_2-N_2-free) percent:			
CO_2	6.1	13.2	8.9
Illuminants	2.6	2.4	2.3
CO	4.4	8.0	5.6
H_2	18.4	13.6	15.9
CH_4	58.8	51.3	57.0
C_2H_6	9.7	11.5	10.3
Net gas yield, maf.....cu ft/lb	1.140	1.077	1.076
Heat in gas, maf.....Btu/lb	1028	915	951
Heating value, calculated.....Btu/cu ft	902	850	884
Specific gravity, calculated (air = 1)	0.610	0.725	0.594
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	33.2	38.6	35.4
Fixed carbon	66.8	61.4	64.6
Ultimate analysis, percent:			
Hydrogen	5.3	5.3	5.4
Carbon	86.2	82.6	84.7
Nitrogen	1.5	1.4	1.7
Oxygen	6.5	10.5	7.8
Sulfur	.5	.2	.4
Heating value.....Btu/lb	15,230	14,410	14,950
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	12.3	15.7	12.9
Fixed carbon	82.8	79.0	81.9
Ash	4.9	5.3	5.3
Heating value.....Btu/lb	14,290	13,730	14,110

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1022	1023	1024
Denver laboratory number[1]	2017-AB	2002-C	2003-A
Carbonization yields, maf, percent:			
Char	82.7	82.4	73.6
Water formed	2.9	5.2	4.6
Tar, dry	8.2	4.7	13.9
Light oil	1.2	1.1	1.5
Gas	5.1	6.7	6.4
Hydrogen sulfide	.1	.1	.2
Total	100.2	100.2	100.2
Gas composition (O_2-N_2-free) percent:			
CO_2	8.1	25.6	9.6
Illuminants	2.2	1.4	3.2
CO	5.9	13.1	5.5
H_2	17.1	11.7	12.3
CH_4	58.6	43.8	53.4
C_2H_6	8.1	4.4	16.0
Net gas yield, maf ... cu ft/lb	1.052	1.047	1.164
Heat in gas, maf ... Btu/lb	908	665	1114
Heating value, calculated ... Btu/cu ft	863	635	957
Specific gravity, calculated (air = 1)	0.630	0.832	0.715
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	31.6	33.2	42.3
Fixed carbon	68.4	66.8	57.7
Ultimate analysis, percent:			
Hydrogen	5.1	4.6	5.7
Carbon	85.6	81.5	83.3
Nitrogen	1.6	1.3	1.4
Oxygen	7.2	12.4	9.3
Sulfur	.5	.2	.3
Heating value ... Btu/lb	14,990	13,830	14,940
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	12.1	14.9	12.5
Fixed carbon	82.2	77.2	83.4
Ash	5.7	7.9	4.1
Heating value ... Btu/lb	14,160	13,300	14,460

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1025	1026	1027
Denver laboratory number[1]	2003-AA	2003-AB	2004-A
Carbonization yields, maf, percent:			
Char	77.7	81.7	75.7
Water formed	3.0	2.1	4.8
Tar, dry	12.5	10.2	11.8
Light oil	1.4	1.4	1.5
Gas	5.5	4.7	6.4
Hydrogen sulfide	.1	.1	.1
Total	100.2	100.2	100.3
Gas composition (O_2-N_2-free) percent:			
CO_2	7.6	4.3	13.1
Illuminants	2.3	2.8	2.7
CO	4.5	4.3	6.8
H_2	16.2	17.5	13.2
CH_4	57.5	58.8	52.6
C_2H_6	11.9	12.3	11.6
Net gas yield, maf ... cu ft/lb.	1.125	1.001	1.155
Heat in gas, maf ... Btu/lb.	1029	951	1001
Heating value, calculated ... Btu/cu ft.	915	950	867
Specific gravity, calculated (air = 1)	0.644	0.611	0.724
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	37.2	33.4	41.1
Fixed carbon	63.8	66.6	58.9
Ultimate analysis, percent:			
Hydrogen	5.5	5.3	5.4
Carbon	85.1	86.0	82.4
Nitrogen	1.6	1.5	1.4
Oxygen	7.4	6.6	10.5
Sulfur	.4	.6	.3
Heating value ... Btu/lb.	15,200	15,250	14,590
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	14.4	11.4	15.3
Fixed carbon	81.9	84.1	79.5
Ash	3.7	4.5	5.2
Heating value ... Btu/lb.	14,350	14,440	13,930

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1028	1029	1030
Denver laboratory number[1]	2004-AA	2004-AB	2005-A
Carbonization yields, maf, percent:			
Char	78.9	81.7	79.5
Water formed	2.7	2.7	4.1
Tar, dry	11.5	9.1	10.1
Light oil	1.4	1.3	1.3
Gas	5.7	5.3	5.1
Hydrogen sulfide	.1	.1	.1
Total	100.3	100.2	100.2
Gas composition (O_2-N_2-free) percent:			
CO_2	7.6	9.7	8.8
Illuminants	2.7	2.3	2.5
CO	5.0	6.0	8.3
H_2	16.2	15.7	13.3
CH_4	60.2	57.3	57.0
C_2H_6	8.3	9.0	10.1
Net gas yield, maf, cu ft/lb	1.169	1.043	0.975
Heat in gas, maf, Btu/lb	1038	901	863
Heating value, calculated, Btu/cu ft	888	864	885
Specific gravity, calculated (air = 1)	0.634	0.661	0.677
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	36.5	32.8	38.0
Fixed carbon	63.5	67.2	62.0
Ultimate analysis, percent:			
Hydrogen	5.4	5.2	5.2
Carbon	84.6	85.6	83.0
Nitrogen	1.6	1.5	1.4
Oxygen	7.9	7.2	10.2
Sulfur	.5	.5	.2
Heating value, Btu/lb	15,020	15,090	14,500
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	12.5	11.9	16.3
Fixed carbon	82.5	82.8	77.7
Ash	5.0	5.3	6.0
Heating value, Btu/lb	14,240	14,270	13,710

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1031	1032	1033
Denver laboratory number[1]	2005-AA	2005-AB	2005-B
Carbonization yields, maf, percent:			
Char	81.0	83.3	75.0
Water formed	2.6	2.2	4.6
Tar, dry	10.0	8.3	12.7
Light oil	1.3	1.1	1.5
Gas	5.2	5.2	6.2
Hydrogen sulfide	.1	.1	.2
Total	100.2	100.2	100.2
Gas composition (O_2-N_2-free) percent:			
CO_2	9.1	7.8	10.9
Illuminants	2.4	1.8	3.2
CO	5.2	5.9	6.8
H_2	16.7	19.2	11.8
CH_4	53.5	57.7	54.6
C_2H_6	13.1	7.6	12.7
Net gas yield, maf, cu ft/lb	1.018	1.115	1.128
Heat in gas, maf, Btu/lb	918	940	1030
Heating value, calculated, Btu/cu ft	902	843	913
Specific gravity, calculated (air = 1)	0.667	0.610	0.718
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	34.9	31.2	43.2
Fixed carbon	65.1	68.8	56.8
Ultimate analysis, percent:			
Hydrogen	5.3	5.1	5.6
Carbon	84.9	85.8	83.1
Nitrogen	1.6	1.4	1.5
Oxygen	7.8	7.2	9.6
Sulfur	.4	.5	.2
Heating value, Btu/lb	14,990	15,040	14,760
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	13.2	11.6	15.1
Fixed carbon	81.3	82.3	81.8
Ash	5.5	6.1	3.1
Heating value, Btu/lb	14,050	14,100	14,380

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1034	1035	1036
Denver laboratory number[1]	2005-BA	2005-BB	2018-A
Carbonization yields, maf, percent:			
Char	78.7	81.6	78.9
Water formed	2.6	2.1	4.2
Tar, dry	11.9	10.0	9.8
Light oil	1.4	1.3	1.4
Gas	5.5	5.0	5.8
Hydrogen sulfide	.1	.2	.1
Total	100.2	100.2	100.2
Gas composition (O_2-N_2-free) percent:			
CO_2	7.7	7.4	14.2
Illuminants	2.7	2.3	2.4
CO	5.4	4.4	9.0
H_2	15.3	16.9	12.3
CH_4	57.8	59.7	54.3
C_2H_6	11.1	9.3	7.8
Net gas yield, maf, cu ft/lb	1.106	1.049	1.047
Heat in gas, maf, Btu/lb	1010	937	851
Heating value, calculated, Btu/cu ft	913	893	813
Specific gravity, calculated (air = 1)	0.654	0.623	0.724
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	37.7	33.9	38.3
Fixed carbon	62.3	66.1	61.7
Ultimate analysis, percent:			
Hydrogen	5.2	5.0	5.2
Carbon	84.9	85.9	82.2
Nitrogen	1.6	1.5	1.4
Oxygen	7.9	7.1	11.0
Sulfur	.4	.5	.2
Heating value, Btu/lb	15,130	15,180	14,440
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	12.4	11.6	15.2
Fixed carbon	84.1	84.2	79.5
Ash	3.5	4.2	5.3
Heating value, Btu/lb	14,470	14,400	13,780

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1037	1038	1039
Denver laboratory number[1]	2018-AA	2018-AB	2019-A
Carbonization yields, maf, percent:			
Char	80.4	84.1	77.2
Water formed	2.8	1.6	4.5
Tar, dry	10.1	8.2	11.2
Light oil	1.3	1.2	1.4
Gas	5.5	5.0	5.7
Hydrogen sulfide	.1	.1	.2
Total	100.2	100.2	100.2
Gas composition (O_2-N_2-free) percent:			
CO_2	9.6	10.3	11.7
Illuminants	2.3	1.9	2.8
CO	6.0	6.6	7.4
H_2	16.0	15.9	12.6
CH_4	56.9	58.1	55.0
C_2H_6	9.2	7.2	10.5
Net gas yield, maf, cu ft/lb	1.077	0.998	1.049
Heat in gas, maf, Btu/lb	932	832	916
Heating value, calculated, Btu/cu ft	865	834	873
Specific gravity, calculated (air = 1)	0.659	0.655	0.711
Analysis of coal, maf:			
Proximate analysis, percent:			
Volatile matter	35.2	31.4	40.1
Fixed carbon	64.8	68.6	59.9
Ultimate analysis, percent:			
Hydrogen	5.2	5.4	5.4
Carbon	84.6	85.5	82.7
Nitrogen	1.6	1.3	1.4
Oxygen	10.9	2.8	10.3
Sulfur	.4	.5	.2
Heating value, Btu/lb	14,970	15,020	14,640
Analysis of assay char, mf:			
Proximate analysis, percent:			
Volatile matter	12.2	12.0	15.3
Fixed carbon	82.6	82.4	80.4
Ash	5.2	5.6	4.3
Heating value, Btu/lb	14,190	14,220	13,990

[1] See table 1, page 16, for sample identification.

TABLE 5. - Precision laboratory carbonization assays and analyses Kukpowruk River, Alaska, area coals and blends at 500° C--1962 series--Continued

Assay number	1040	1041
Denver laboratory number[1]	2019-AA	2019-AB
Carbonization yields, maf, percent:		
Char	79.8	83.1
Water formed	2.7	2.1
Tar, dry	10.8	8.9
Light oil	1.4	1.3
Gas	5.1	4.7
Hydrogen sulfide	.2	.1
Total	100.0	100.2
Gas composition (O_2-N_2-free) percent:		
CO_2	7.6	8.5
Illuminants	2.2	1.9
CO	5.3	5.7
H_2	15.1	15.5
CH_4	65.3	60.2
C_2H_6	4.5	8.2
Net gas yield, maf, cu ft/lb	1.092	0.974
Heat in gas, maf, Btu/lb	937	846
Heating value, calculated, Btu/cu ft	858	869
Specific gravity, calculated (air = 1)	0.615	0.639
Analysis of coal, maf:		
Proximate analysis, percent:		
Volatile matter	36.1	32.3
Fixed carbon	63.9	67.7
Ultimate analysis, percent:		
Hydrogen	5.4	5.2
Carbon	84.8	85.8
Nitrogen	1.7	1.5
Oxygen	7.7	7.0
Sulfur	.4	.5
Heating value, Btu/lb	15,060	15,100
Analysis of assay char, mf:		
Proximate analysis, percent:		
Volatile matter	12.4	12.3
Fixed carbon	83.0	82.4
Ash	4.6	5.3
Heating value, Btu/lb	14,210	14,240

[1]See table 1, page 16, for sample identification.

TABLE 6. - Precision laboratory carbonization assays and analyses--blending coals, Sunnyside coal, and Fontana blend

Assay number	1043[1]	1044[2]	1008[3]	1047[4]
Material	Coal	Coal	Coal	Coal
Rank	Hvab	Lvb	Hvbb	Bit.
Mine	Sterling-Sewell	Beeson #2	Sunny-side	Fontana blend
State	W. Va.	W. Va.	Utah	-
County	Nicholas	Mercer	Carbon	-
Denver laboratory number	2007	2006	2008-A	2008-T
Temperature of carbonization ° C.	500	500	500	500
Carbonization yields, maf, percent:				
Char	82.2	93.8	73.9	75.4
Water formed	2.2	.9	3.5	4.7
Tar, dry	9.6	1.4	15.9	13.3
Light oil	1.5	.9	1.3	1.3
Gas	4.4	2.9	4.9	4.6
Hydrogen sulfide	.1	.0	.5	.5
Total	100.0	99.9	100.0	99.8
Gas composition (O_2-N_2-free) percent:				
CO_2	3.0	2.6	9.7	7.2
Illuminants	1.5	1.1	4.3	2.9
CO	4.0	2.1	8.1	6.3
H_2	30.1	32.2	17.3	16.4
CH_4	54.6	57.0	51.7	56.9
C_2H_6	6.8	5.0	8.9	10.3
Net gas yield, maf cu ft/lb.	1.167	0.825	0.952	0.928
Heat in gas, maf Btu/lb.	829	597	821	835
Heating value, calculated Btu/cu ft.	710	724	862	900
Specific gravity, calculated (air = 1)	0.498	0.467	0.675	0.642
Analysis of coal, maf:				
Proximate analysis, percent:				
Volatile matter	32.0	16.5	42.8	40.1
Fixed carbon	68.0	83.5	57.2	59.9
Ultimate analysis, percent:				
Hydrogen	5.3	4.5	5.8	5.7
Carbon	86.8	90.8	82.3	83.3
Nitrogen	1.8	1.3	1.8	1.8
Oxygen	5.4	2.5	9.0	8.1
Sulfur	.7	.9	1.1	1.1
Heating value Btu/lb.	15,470	15,690	14,780	14,930
Free swelling index	8	7½	5	5
Analysis of assay char, mf:				
Proximate analysis, percent:				
Volatile matter	9.6	8.4	13.3	12.8
Fixed carbon	85.7	85.6	78.9	79.4
Ash	4.7	6.0	7.8	7.8
Heating value Btu/lb.	14,450	14,570	13,470	13,580

[1] Sewell coal. As-received moisture = 3.6 percent; ash = 3.4 percent.

[2] Pocahontas No. 3 coal. As-received moisture = 3.2 percent; ash = 5.6 percent.

[3] Sunnyside No. 1 mine, Dragerton, Carbon County, Utah. As-carbonized moisture = 8.8 percent; ash = 5.3 percent.

[4] Fontana blend. As-carbonized moisture = 3.4 percent; ash = 5.5 percent.

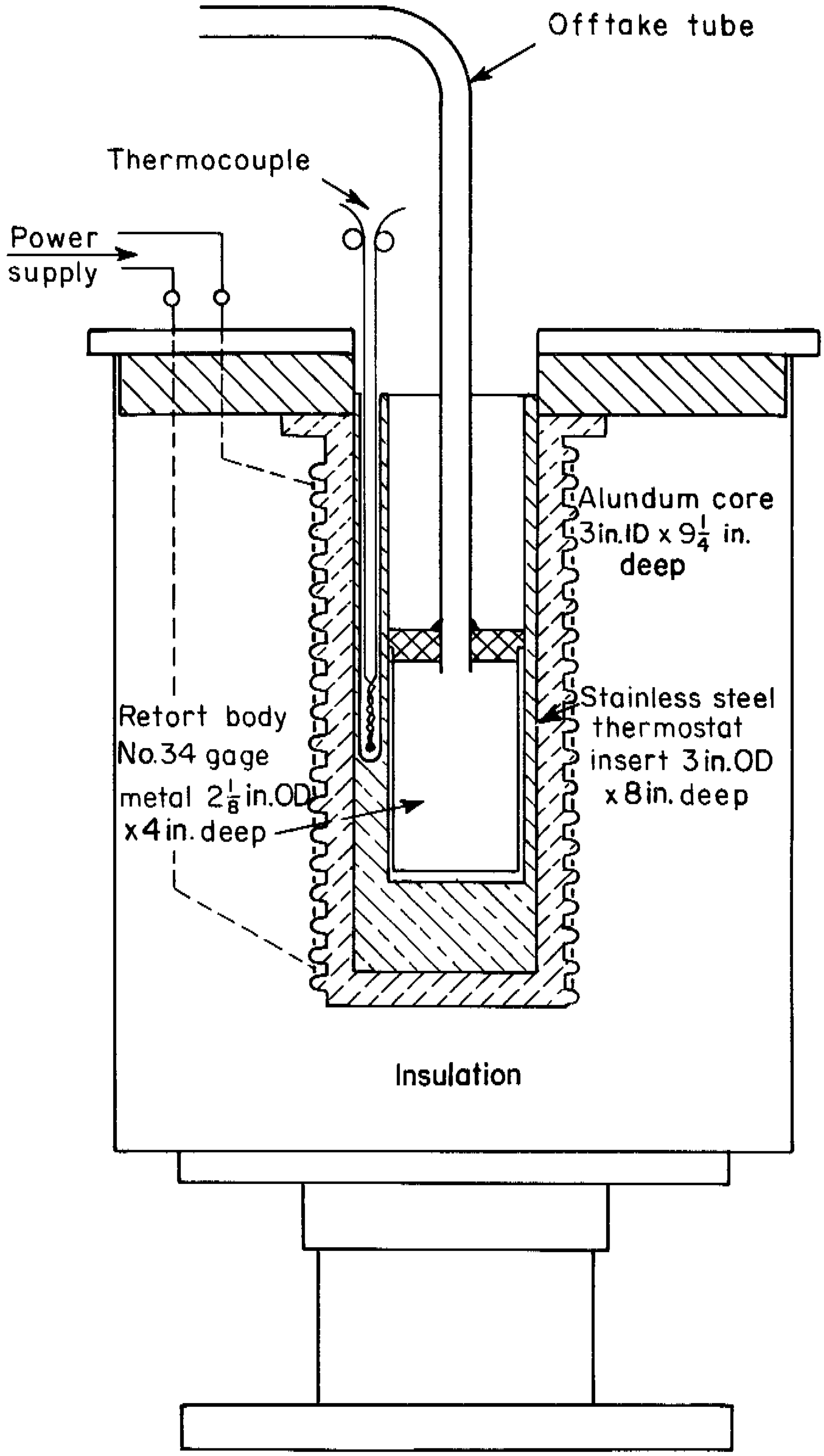

FIGURE 7. - Cross Section of Retort Heating Furnace and Thermostat Cylinder for 100-Gram Carbonization Test.

The 100-gram coking test is a useful bench-scale measure of coking quality. In this test, 100 grams of coal is carbonized at 900° C under standardized conditions in equipment illustrated in figure 7. Vapors are flared without collection of byproducts. The resultant coke weighs 60 to 75 grams, which is enough to evaluate for relative strength by a micro-drop-shatter test, consisting of repeated drops through a 6-foot length of pipe to a heavy steel plate. The average piece weight of plus ¼ inch particles after 15 drops and the percentage of the original yield retained on a ¼ inch screen are considered measures of the coke strength.

Table 7 presents a summary of results from the 100-gram coking test. The data indicate that the Alaskan coals and composites produce stronger cokes when blended with 25 percent each Sewell and Pocahontas coals than when blended with 50 percent of Sewell coal.

TABLE 7. - 100-gram coking tests on Alaskan coals and blends--1962 series

Denver laboratory No.	Coke yield, percent	Plus ¼ inch material after 15 drops		
		Number of pieces	Average weight per piece, grams	Percent retention[1]
2016-A..................	59.5	83	0.69	95.8
2016-AA.................	64.2	43	1.43	95.6
2016-AB.................	68.7	34	1.96	96.9
2017-A..................	64.2	53	1.17	96.3
2017-AA.................	66.7	38	1.69	96.3
2017-AB.................	71.0	30	2.29	96.6
2003-A..................	58.9	64	.86	93.2
2003-AA.................	64.0	43	1.42	95.5
2003-AB.................	67.7	31	2.12	96.9
2004-A..................	61.1	62	.94	94.9
2004-AA.................	65.0	42	1.49	96.3
2004-AB.................	69.0	29	2.29	96.1
2005-A..................	64.2	51	1.22	96.7
2005-AA.................	66.3	36	1.78	96.7
2005-AB.................	70.6	37	1.85	97.0
2005-B..................	59.9	75	.76	94.8
2005-BA.................	64.0	50	1.23	96.1
2005-BB.................	68.5	34	1.95	96.6
2018-A..................	63.8	47	1.30	95.9
2018-AA.................	66.5	37	1.74	96.5
2018-AB.................	70.8	36	1.90	96.8
2019-A..................	61.8	56	1.06	95.8
2019-AA.................	65.5	35	1.81	96.5
2019-AB.................	69.3	37	1.82	97.0
[2]2008-T..................	62.5	44	1.38	97.1

[1] Percentage of coke yield.
[2] Fontana blend.

Pilot Plant Testing

On the basis of data from the bench-scale tests, plus a consideration of the amount of coal available for testing, a program of 15 pilot plant carbonization tests in a 10-inch, modified BM-AGA retort was developed. In this test, 50 pounds of coal is required. The samples and blends selected for these 50-pound coking tests have been indicated in table 1. They include the lower 7.2 feet of sample 2 (parts 1 and 2); all parts of samples 2 and 3 combined; sample 4; sample 5; the upper half of sample 6; the lower half of sample 6; and a composite of both halves of sample 6. In addition, blends of certain of these samples and composites with Sewell and with Pocahontas coals were selected.

The tests were conducted with the gas-fired furnace and auxiliary equipment illustrated in figure 8. In each test, a 50-pound charge of coal was carbonized in a stainless steel retort 10 inches in diameter, with the

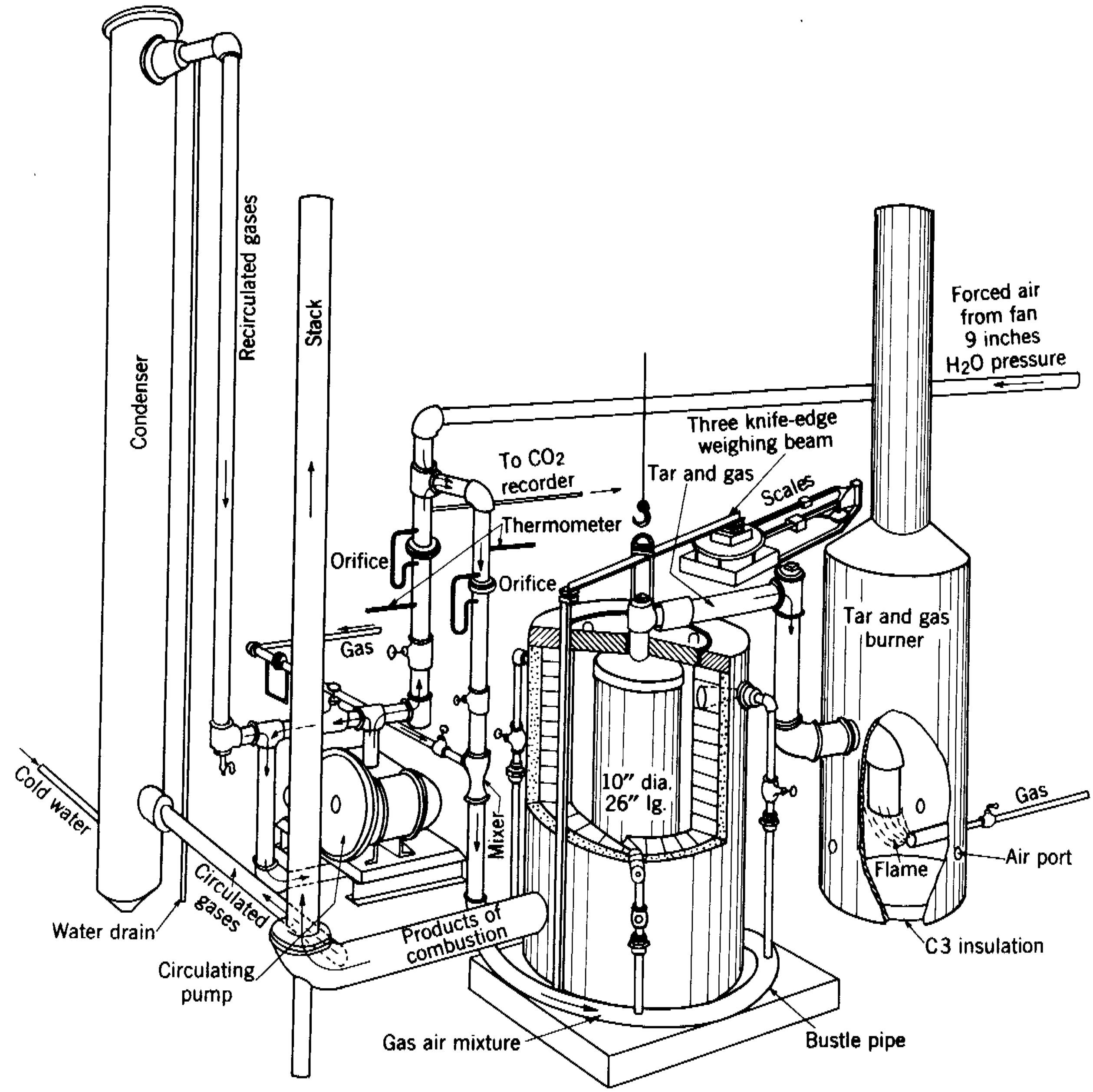

FIGURE 8. - Gas-Heated 50-Pound Carbonizing Unit, With a 10-Inch Circular Retort.

temperature of the outer surface of the retort maintained at 900° C. Carbonization was considered complete when the temperature of center of charge reached 900° C. This operation normally required 3 to 4 hours. In conducting the 50-pound tests, operating conditions were standardized at 50 pcf bulk density and ¼ inch x 0 coal size.

After the charge was coked, the retort was withdrawn from the furnace, cooled, and opened. A few inches of material was removed from the top of the coke, and the body of the coke was photographed in place. 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.

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 the West. The Columbia tumbler is 18 inches in diameter and 23½ inches long, and it is fitted with 4 internal lifters. For each test, 10 pounds of plus 1-inch coke fractions (their quantities weighted in proportion to their presence in the original screen analysis) was tumbled 720 revolutions at 24 rpm, and the screen analysis of the product was determined. 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 test, is not to be confused with the ASTM stability factor.

Table 8 presents significant information on the coking properties of the Alaskan coals, composites, and blends investigated in the 50-pound coking test, and the principal physical properties of the cokes produced therefrom. For comparison, similar data are also presented for the Fontana blend and its coke, as produced in the same retort and by the same carbonization procedures.

Gieseler plastometer tests conducted on small samples of the 50-pound charge, as reported in table 8, were in good agreement with those observed in the detailed bench-scale work, indicating that the storage procedures had prevented any perceptible oxidation.

In reviewing the data on the 50-pound coking tests reported in table 8, the properties of the Fontana blend coke were used as the criteria for probable acceptability for blast-furnace use. The most important coke properties were judged to be yield (moisture free), average size, cumulative percentage of the tumbler resultant retained on the 0.25-inch screen, and tumbler size stability. Data on these measures, compared to those produced from the Fontana blend, are summarized in table 9.

Figures 9, 10, and 11 show photographs of the cokes produced from sample 4 with its blends (fig. 9), from sample 6, both straight and blended (fig. 10), and, for comparison, from the Fontana blend (fig. 11). It should be noted that a blocky structure is preferred, with minimum "fingery" pieces and minimum sandy texture.

TABLE 8. - 50-pound coking test data for Alaskan coals and blends--1962 series

Blending coals....................percent-coal..	None	25-Sewell 25-Pocahontas #3	None	50-Sewell	25-Sewell 25-Pocahontas #3	None	50-Sewell	25-Sewell 25-Pocahontas #3
50-pound coking test number.....................	CP-111	CP-118	CP-122	CP-123	CP-124	CP-125	CP-126	CP-127
Laboratory sample number........................	2016-A	2016-AB	2003-A	2003-AA	2003-AB	2004-A	2004-AA	2004-AB
Coal data:								
Free swelling index..........................	5½	5	5	7	6	4½	7	4½
Gieseler plastometer:								
Maximum fluidity......................ddpm..	84	56	275	2210	140	16	357	19
Temperature at, ° C:								
Initial movement (0.1 ddpm)..............	360	366	356	356	356	366	360	372
Maximum fluidity..........................	429	438	429	444	436	426	441	435
Solidification............................	465	477	462	480	477	459	480	474
Oxygen, maf.........................percent..	9.0	6.5	9.3	7.3	6.6	10.5	7.9	7.2
Heating value, moist, ash-free........Btu/lb..	14,470	14,910	14,630	14,840	14,930	14,270	14,690	14,780
Calculated coking index[1].....................	1.17	1.53	1.14	1.38	1.52	1.06	1.31	1.43
Coke data:								
Yield, percent:								
As-carbonized...............................	60.8	71.7	62.9	65.8	70.8	64.8	68.5	71.9
Moisture-free...............................	62.6	73.2	64.1	69.1	72.2	66.3	70.0	73.3
Moisture- and ash-free......................	61.7	71.9	62.9	67.4	70.9	64.7	68.4	72.1
Average size.........................inches..	1.331	1.668	1.370	1.680	1.584	1.536	1.658	1.681
Apparent specific gravity.....................	0.708	0.733	0.722	0.634	0.693	0.703	0.711	0.751
True specific gravity.........................	1.862	1.900	1.912	1.900	1.908	1.917	1.913	1.913
Cell space..........................percent..	62.0	61.4	62.2	66.6	63.7	63.3	62.8	60.7
Columbia tumbler test:								
Retained on ¼ inch screen (¼ inch index).....................do.....	86.6	88.7	86.4	86.1	87.9	87.4	87.3	88.4
Size stability[2].....................do.....	37.6	56.2	44.6	54.5	58.3	43.6	51.4	55.9
Modified coke strength index[3]..............	68.7	121.2	74.5	123.9	117.8	82.0	114.0	121.0
Net resultant coke factor[4]..................	0.299	0.661	0.377	0.602	0.640	0.423	0.569	0.663

Blending coals....................percent-coal..	None	None	None	50-Sewell	25-Sewell 25-Pocahontas #3	None	50-Sewell 25-Pocahontas #3	Fontana blend
50-pound coking test number.....................	CP-141	CP-128	CP-119	CP-120	CP-121	CP-129	CP-130	CP-136
Laboratory sample number........................	2005-A	2005-B	2018-A	2018-AA	2018-AB	2019-A	2019-AB	2008-3Y
Coal data:								
Free swelling index..........................	3	6	2½	6	3	5	5	4½
Gieseler plastometer:								
Maximum fluidity......................ddpm..	3.4	58	2.8	145	4.3	16	16	[5]40
Temperature at, ° C:								
Initial movement (0.1 ddpm)..............	378	360	378	360	369	366	369	[5]366
Maximum fluidity..........................	429	432	426	438	432	426	432	[5]435
Solidification............................	462	462	459	477	471	462	471	[5]468
Oxygen, maf.........................percent..	10.2	9.6	11.0	8.1	7.3	10.3	7.1	8.2
Heating value, moist, ash-free........Btu/lb..	14,260	14,530	14,000	14,520	14,560	14,380	14,760	14,100
Calculated coking index[1].....................	1.10	1.11	1.04	1.30	1.43	1.08	1.45	1.25
Coke data:								
Yield, percent:								
As-carbonized...............................	68.0	63.9	66.6	69.4	72.3	65.8	72.6	64.5
Moisture-free...............................	69.0	64.8	68.8	71.7	74.7	67.0	74.2	68.0
Moisture- and ash-free......................	67.3	63.8	67.3	70.0	73.2	65.6	72.7	65.9
Average size.........................inches..	1.352	1.250	1.437	1.732	1.766	1.455	1.547	1.639
Apparent specific gravity.....................	0.790	0.700	0.723	0.726	0.764	0.747	0.678	0.656
True specific gravity.........................	1.930	1.911	1.906	1.893	1.906	1.925	1.915	1.924
Cell space..........................percent..	59.1	63.4	62.1	61.7	59.9	61.2	64.6	65.9
Columbia tumbler test:								
Retained on ¼ inch screen (¼ inch index).....................do.....	84.5	86.9	78.2	86.2	85.9	88.3	88.5	88.7
Size stability[2].....................do.....	53.3	44.9	41.7	52.3	51.0	49.8	59.0	56.8
Modified coke strength index[3]..............	93.2	68.7	89.4	120.1	118.9	90.7	116.9	122.4
Net resultant coke factor[4]..................	0.478	0.352	0.390	0.612	0.637	0.467	0.648	0.579

[1] 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.

[2] Tumbler size stability is calculated from tumbler data and is defined as:

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

[3] 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).

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

[5] Values given for plastic properties are for DL 2008-T, identical in blend components and percentages to DL 2008-3Y.

TABLE 9. - Summary of measures of coke acceptability: Selected Alaska samples, composites, and blends, and Fontana plant blend--1962 series

Base coal	Blending coal			Coking test number	Coke yield, mf basis	Average coke size, inches	Tumbler size stability, percent	Cumulative pct tumbler resultant retained on 0.25-inch screen	Probable acceptability
	None	50 pct Sewell	25 pct Sewell 25 pct Pocahontas						
No. 2 - lower 7.2 ft........	X	-	-	CP-111	62.7	1.33	37.6	86.6	No
No. 2 - lower 7.2 ft........	-	-	X	CP-118	73.2	1.67	56.2	88.7	Yes
No. 2 & 3 total.............	X	-	-	CP-119	68.8	1.44	41.7	78.2	No
No. 2 & 3 total.............	-	X	-	CP-120	71.7	1.73	52.3	86.2	Marginal
No. 2 & 3 total.............	-	-	X	CP-121	74.7	1.77	51.0	85.9	Do.
No. 4.......................	X	-	-	CP-122	64.1	1.37	44.6	86.4	No
No. 4.......................	-	X	-	CP-123	69.1	1.68	54.5	86.1	Marginal
No. 4.......................	-	-	X	CP-124	72.2	1.58	58.3	87.9	Yes
No. 5.......................	X	-	-	CP-125	66.3	1.54	43.6	87.4	No
No. 5.......................	-	X	-	CP-126	70.0	1.66	51.4	87.3	Marginal
No. 5.......................	-	-	X	CP-127	73.3	1.68	55.9	88.4	Yes
No. 6 - upper half..........	X	-	-	CP-141	69.0	1.35	53.3	84.5	No
No. 6 - lower half..........	X	-	-	CP-128	64.8	1.25	44.9	86.9	No
No. 6 - total...............	X	-	-	CP-129	67.0	1.46	49.8	88.3	No
No. 6 - total...............	-	-	X	CP-130	74.2	1.55	59.0	88.5	Yes
Fontana blend...............	-	-	-	CP-136	68.0	1.64	56.8	88.7	Being used

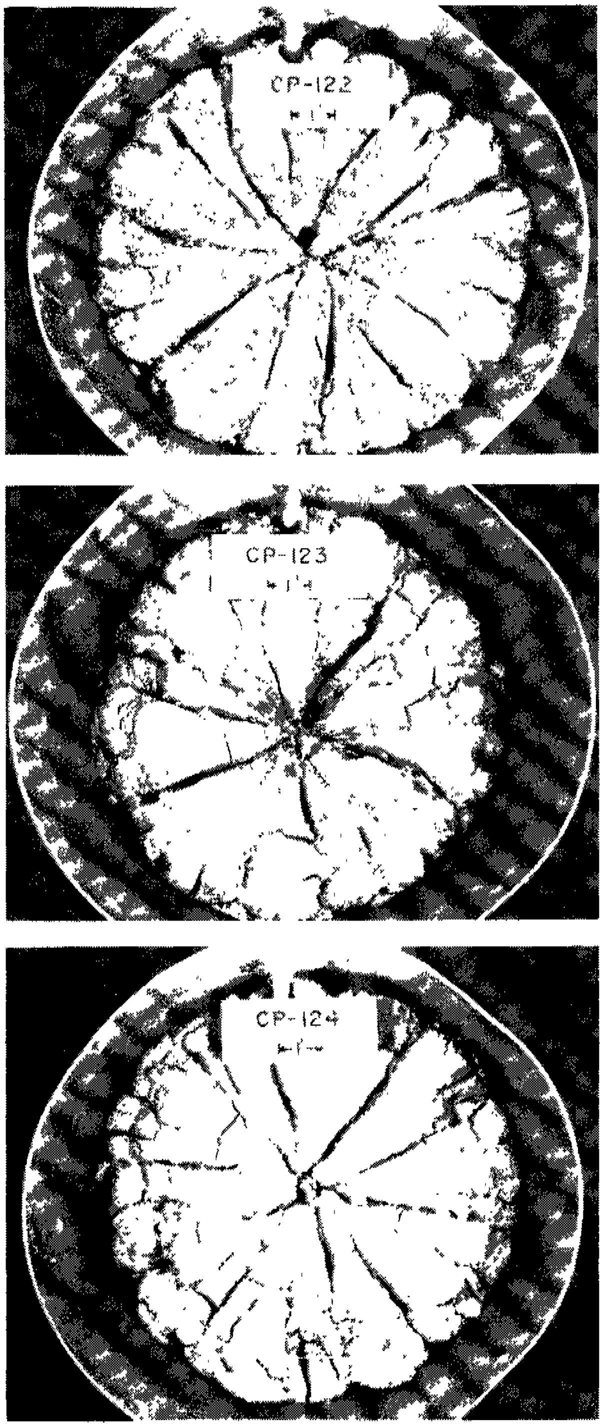

FIGURE 9. - Coke From Alaska Sample 4.

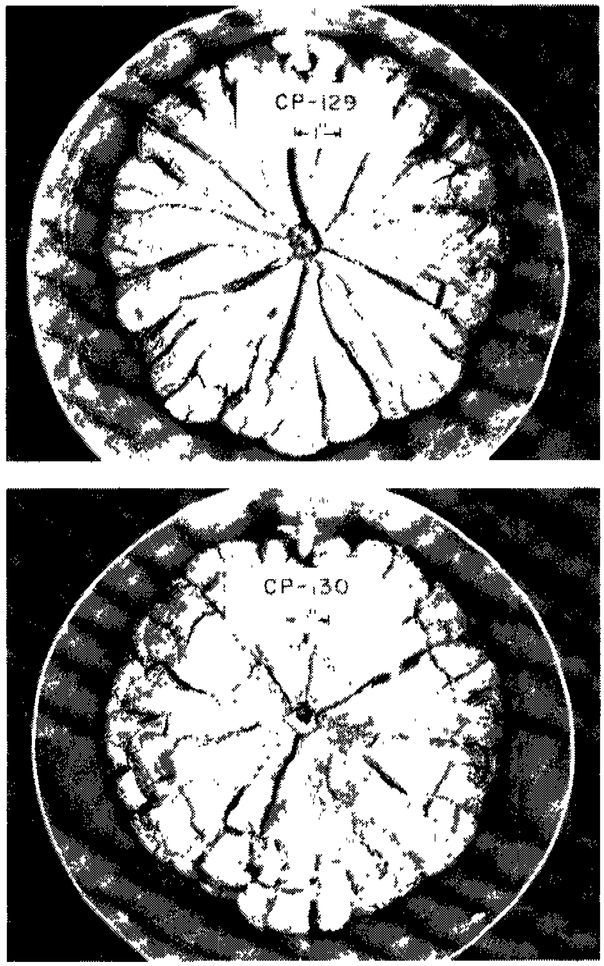

FIGURE 10. - Coke From Alaska Sample 6 (Full Seam).

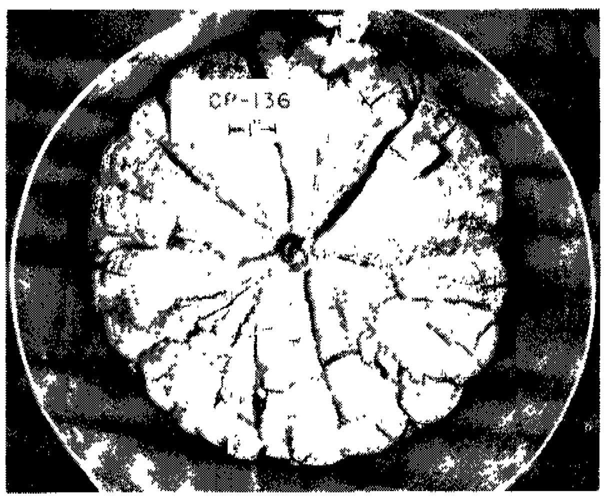

FIGURE 11. - Coke From Fontana Blend.

The data in table 9 and the examination of photographs of the cokes produced indicated that several of the Alaska coal samples obtained in 1962 would yield cokes of satisfactory strength when blended with 25 percent Sewell and 25 percent Pocahontas coals. Four of the five 50-pound tests made with this blend produced cokes rated as acceptable; the fifth was considered as marginal but worthy of further consideration. Each of the three cokes produced from 50-percent Sewell coal blends were blocky, but they were considered marginal because their size stabilities were somewhat less than that of coke made from Fontana blend. The straight Alaskan coals produced relatively weak cokes, the strongest of which was that from the upper half of sample No. 6.

Proximate and ultimate analyses and heating values of the cokes produced from the Alaska coals, together with corresponding data for coke produced from the Fontana blend, are presented in table 10.

TABLE 10. - Analyses of cokes from Alaskan samples, composites, and blends--1962 series

Denver laboratory No..	2016-A-C		2016-AB-C		2003-A-C		2003-AA-C	
Coking Test No........	CP-111		CP-118		CP-122		CP-123	
Basis.................	Mf	Maf	Mf	Maf	Mf	Maf	Mf	Maf
Proximate analysis, percent:								
Volatile matter.....	0.9	0.9	1.1	1.1	1.2	1.3	2.1	2.2
Fixed carbon........	94.9	99.1	93.7	98.9	94.3	98.7	92.4	97.8
Ash.................	4.2	-	5.2	-	4.5	-	5.5	-
Ultimate analysis, percent:								
Hydrogen............	.5	.6	.6	.6	.5	.6	.7	.7
Carbon..............	93.6	97.7	92.3	97.4	93.0	97.4	91.4	96.7
Nitrogen............	1.4	1.4	1.3	1.4	1.5	1.5	1.5	1.6
Oxygen..............	.0	.0	.1	.1	.2	.2	.4	.4
Sulfur..............	.3	.3	.5	.5	.3	.3	.5	.6
Ash.................	4.2	-	5.2	-	4.5	-	5.5	-
Heating value, Btu/lb.	13,930	14,540	13,730	14,480	13,850	14,510	13,700	14,490

Denver laboratory No..	2003-AB-C		2004-A-C		2004-AA-C		2004-AB-C	
Coking Test No........	CP-124		CP-125		CP-126		CP-127	
Basis.................	Mf	Maf	Mf	Maf	Mf	Maf	Mf	Maf
Proximate analysis, percent:								
Volatile matter.....	1.1	1.2	1.5	1.6	1.8	1.9	1.1	1.2
Fixed carbon........	93.4	98.8	92.2	98.4	92.2	98.1	93.0	98.8
Ash.................	5.5	-	6.3	-	6.0	-	5.9	-
Ultimate analysis, percent:								
Hydrogen............	.6	.6	.6	.7	.6	.6	.7	.7
Carbon..............	91.9	97.2	91.1	97.3	91.2	97.0	91.3	97.0
Nitrogen............	1.3	1.4	1.3	1.4	1.4	1.5	1.2	1.3
Oxygen..............	.2	.3	.5	.4	.4	.4	.4	.5
Sulfur..............	.5	.5	.2	.2	.4	.5	.5	.5
Ash.................	5.5	-	6.3	-	6.0	-	5.9	-
Heating value, Btu/lb.	13,700	14,490	13,590	14,510	13,630	14,500	13,620	14,470

TABLE 10. - Analyses of cokes from Alaskan samples, composites, and blends--1962 series--Continued

Denver laboratory No..	2005-A-C		2005-B-C		2018-A-C		2018-AA-C	
Coking Test No........	CP-141		CP-128		CP-119		CP-120	
Basis.................	Mf	Maf	Mf	Maf	Mf	Maf	Mf	Maf
Proximate analysis, percent:								
Volatile matter.....	1.8	1.9	1.5	1.6	1.1	1.2	1.4	1.5
Fixed carbon........	90.8	98.1	94.6	98.4	92.6	98.8	92.4	98.5
Ash.................	7.4	-	3.9	-	6.3	-	6.2	-
Ultimate analysis, percent:								
Hydrogen............	.6	.6	.6	.6	.6	.6	.5	.6
Carbon..............	90.2	97.4	93.5	97.3	91.3	97.4	91.2	97.2
Nitrogen............	1.2	1.3	1.4	1.4	1.2	1.3	1.4	1.5
Oxygen..............	.4	.5	.4	.5	.4	.5	.3	.3
Sulfur..............	.2	.2	.2	.2	.2	.2	.4	.4
Ash.................	7.4	-	3.9	-	6.3	-	6.2	-
Heating value, Btu/lb.	13,390	14,460	13,910	14,480	13,550	14,460	13,560	14,450

Denver laboratory No..	2018-AB-C		2019-A-C		2019-AB-C		2008-3Z[1]	
Coking Test No........	CP-121		CP-129		CP-130		CP-136	
Basis.................	Mf	Maf	Mf	Maf	Mf	Maf	Mf	Maf
Proximate analysis, percent:								
Volatile matter.....	1.0	1.0	1.7	1.8	1.1	1.2	0.9	1.0
Fixed carbon........	92.7	99.0	92.7	98.2	92.8	98.8	90.3	99.0
Ash.................	6.3	-	5.6	-	6.1	-	8.8	-
Ultimate analysis, percent:								
Hydrogen............	.6	.6	.6	.6	.6	.6	.5	.6
Carbon..............	91.3	97.4	91.7	97.2	91.4	97.4	88.0	96.5
Nitrogen............	1.2	1.3	1.3	1.4	1.3	1.3	1.6	1.8
Oxygen..............	.1	.2	.6	.6	.1	.2	.3	.2
Sulfur..............	.5	.5	.2	.2	.5	.5	.8	.9
Ash.................	6.3	-	5.6	-	6.1	-	8.8	-
Heating value, Btu/lb.	13,600	14,520	13,680	14,490	13,650	14,540	13,100	14,360

[1] Fontana.

Weathering Properties

In view of the extreme northern location of the Kukpowruk River deposit, it is expected that all mining activity in this area would be concentrated in a relatively short period in the summer. Utilization, on the other hand, would presumably be established on a year-round pattern. Under these circumstances much of the coal would have to be stored for months before use, which would require that the coal be reasonably nonweathering if it is to be used for coking.

To provide some information on the weathering property, a portion of one of the Alaskan samples (No. 4; Denver Laboratory No. 2003-A) was exposed in a thin layer to laboratory air at room temperature (about 70° F). As a control, a fresh sample of Sunnyside No. 1 coal was exposed under identical conditions. It is understood that Sunnyside coal can be stored for periods of approximately 90 days at Fontana without excessive loss of its coking properties.

Both of the exposed coal samples were sampled and tested for free-swelling index at weekly intervals. At the beginning of the observation period, both samples had free-swelling indices of 5; and for 10 weeks no evidence of significant change was noted in these values. At the end of this time, the more sensitive Gieseler plastometer test indicated an appreciable loss of fluidity in each coal as follows:

Exposure time, weeks	Maximum Gieseler fluidity, ddpm	
	Alaska No. 4	Sunnyside
None.....................	275	41
10.......................	76	13

In view of these indications of partial oxidation at the end of 10 weeks' exposure, portions of the test samples were prepared for 50-pound coking tests, corresponding to blends previously prepared and tested. The blends were: (1) 50 percent oxidized Alaskan No. 4, 25 percent Sewell, and 25 percent Pocahontas No. 3 (the blend identified as DL 2003-AB-10); and (2) 85 percent oxidized Sunnyside No. 1, 7½ percent Red Indian, and 7½ percent Coal Basin (the blend identified as DL 2008-4H). These two blends correspond, respectively, to DL 2003-AB and DL 2008-3Y, made with fresh Alaska and Sunnyside coals. The oxidized Alaska and Sunnyside samples and the blends were analyzed for proximate and ultimate compositions and heating value. Bench-scale tests were conducted to determine 500° C carbonization assay yields, Gieseler plasticity, and free-swelling index. The blends were carbonized in the 50-pound retort, and the resulting cokes were photographed in place and subjected to the usual physical tests.

The remainders of the samples that had been oxidized for 10 weeks were further exposed for another 10-week period, or for a total of 20 weeks. The free-swelling index for each was determined at weekly intervals. As during the first 10-week period, no change was observed. At the end of a total of 20 weeks' exposure, both samples were once more assayed at 500° C and tested for Gieseler plasticity.

Table 11 gives the results of the carbonization assays made on Alaska and Sunnyside samples as oxidized for 10 weeks, unblended; as oxidized for 10 weeks, blended; and as oxidized for 20 weeks, unblended. The table includes the proximate and ultimate analyses and heating values of the coals, blends, and resulting chars. Table 11 also gives the numbers of the corresponding assays on duplicate but unoxidized samples and blends, as reported in tables 5 and 6. A comparison of the six assays in table 11 with the corresponding assays of unoxidized material does not seem to establish any significant or consistent effects of this mild oxidation. Oxygen contents of the two coals were slightly increased (0.2 to 1.0 percentage point, maf basis) and heating values were slightly decreased (80 to 150 Btu/lb, maf basis), as would be expected; and correspondingly slight changes were observed in the blends.

TABLE 11. - Precision laboratory carbonization assays and analyses--oxidized coals and plant coking blends

Assay number	1049	1050	1058	1059	1079	1078
Material	Coal[1]	Coal[2]	Blend[3]	Blend[4]	Coal[5]	Coal[6]
Period of oxidation....weeks..	10	10	10	10	20	20
Unoxidized comparison assay	1024	1008	1026	1047	1024	1008
Mine	Prospect	Sunnyside	Prospect	Sunnyside	Prospect	Sunnyside
State	Alaska	Utah	Alaska	Utah	Alaska	Utah
County or area	Kukpowruk	Carbon	Kukpowruk	Carbon	Kukpowruk	Carbon
Denver laboratory number	2003-A-10	2008-A-10	2003-AB-10	2008-4H	2003-A-20	2008-A-20
Temperature of carbonization....° C..	500	500	500	500	500	500
Carbonization yields, maf, percent:						
Char	73.8	73.3	79.8	75.5	74.5	74.2
Water formed	4.7	4.5	3.6	3.9	4.6	4.6
Tar, dry	14.0	15.0	10.3	13.9	13.6	14.5
Light oil	1.5	1.4	1.3	1.3	1.5	1.4
Gas	5.9	5.3	4.7	5.0	5.5	4.7
Hydrogen sulfide	.2	.7	.1	.5	.1	.4
Total	100.1	100.2	99.8	100.1	99.8	99.8
Gas composition (O_2-N_2-free), percent:						
CO_2	11.0	7.5	6.4	7.2	8.5	5.3
Illuminants	3.3	3.1	2.3	2.7	3.3	3.4
CO	7.2	7.1	5.0	6.3	7.0	7.7
H_2	11.9	15.1	19.6	15.2	13.1	16.0
CH_4	51.1	56.3	55.6	56.8	56.8	55.8
C_2H_6	15.5	10.9	11.1	11.8	11.3	11.8
Net gas yield, maf....cu ft/lb..	1.039	1.051	1.009	0.984	1.067	0.944
Heat in gas, maf....Btu/lb..	968	953	902	903	978	878
Heating value, calculated....Btu/cu ft..	932	907	894	918	917	930
Specific gravity, calculated (air = 1)	0.744	0.659	0.616	0.655	0.683	0.644
Analysis of coal, maf:						
Proximate analysis, percent:						
Volatile matter	42.8	43.0	32.9	39.6	41.8	42.2
Fixed carbon	57.2	57.0	67.1	60.4	58.2	57.8
Ultimate analysis, percent:						
Hydrogen	5.6	5.7	5.3	5.6	5.6	5.7
Carbon	83.2	82.1	85.9	83.3	83.0	81.9
Nitrogen	1.4	1.8	1.5	1.8	1.5	1.3
Oxygen	9.5	9.3	6.7	8.3	9.6	10.0
Sulfur	.3	1.1	.6	1.0	.3	1.1
Heating value....Btu/lb..	14,860	14,690	15,150	14,860	14,790	14,700
Free swelling index	5	5	5	5	5	4½
Analysis of assay char, mf:						
Proximate analysis, percent:						
Volatile matter	14.1	13.5	11.4	12.9	13.2	13.2
Fixed carbon	82.4	78.9	84.3	80.0	83.1	79.3
Ash	3.5	7.6	4.3	7.1	3.7	7.5
Heating value....Btu/lb..	14,270	13,460	14,460	13,700	14,390	13,580

[1] Alaska sample No. 4, Denver Laboratory No. 2003-A, oxidized for 10 weeks in open air at room temperature before use as blending coal in modified BM/AGA and assay tests. As-carbonized moisture = 1.4 percent; ash = 2.8 percent.

[2] Sunnyside, Denver Laboratory No. 2008-A, oxidized in open air at room temperature for 10 weeks. As-carbonized moisture = 1.6 percent; ash = 5.6 percent.

[3] Blend of 10-week oxidized Alaskan coal described in footnote 1 above, 50 percent, combined with 25 percent each of unoxidized Sewell and Pocahontas No. 3 coals. Used in coking test CP-140. As-carbonized moisture = 1.6 percent; ash = 3.5 percent.

[4] Blend of 10-week oxidized Sunnyside No. 1 coal described in footnote 2 above, 85 percent, and 7½ percent each of Red Indian and Coal Basin coals. Used in coking test CP-139. As-carbonized moisture = 1.8 percent; ash = 5.4 percent.

[5] Same as footnote 1 but oxidized by exposure to laboratory air for 20 weeks.

[6] Same as footnote 2 but oxidized by exposure to laboratory air for 20 weeks.

Table 12 presents the results of the Gieseler plastometer tests on the Alaska No. 4 sample and Sunnyside coal, each as unoxidized (fresh), as oxidized 10 weeks, and as oxidized 20 weeks. For both coals, the second 10 weeks of exposure resulted in further loss in maximum fluidity; maximum fluidities in each case were only about 10 percent of those of the fresh coals. The point of particular interest is that in the mild oxidation carried out in this program, the Alaskan sample was affected no more, relatively, than the Sunnyside sample.

TABLE 12. - Gieseler plasticity data for Alaska and Sunnyside coals, in fresh and oxidized conditions

	Coal					
	Alaska No. 4			Sunnyside No. 1		
Condition.............	Fresh	Oxidized		Fresh	Oxidized	
		10 weeks	20 weeks		10 weeks	20 weeks
Denver Laboratory No...	2003-A	2003-A-10	2003-A-20	2008-A	2008-A-10	2008-A-20
Maximum fluidity ddpm..	275	76	27	41	13	5.0
Temperatures at, ° C:						
0.1 ddpm rising......	356	360	366	364	374	363
5.0 ddpm rising......	407	413	415	414	421	-
Maximum fluidity.....	429	429	432	432	432	432
5.0 ddpm falling.....	452	450	445	448	443	-
Solidification.......	462	465	459	462	462	462
Fusion range......° C..	106	105	93	98	88	99
Plastic range.....° C..	45	37	30	34	22	-
Swelling of plastic mass into retort barrel........inches..	1-1/4	1/8	1/8	0	0	0

The results of the two 50-pound coking tests on blends with base coals oxidized 10 weeks are given in table 13, paired in each case with previously reported results on corresponding blends made with fresh base coals.

TABLE 13. - 50-pound coking test data--comparison of oxidized[1] and fresh coking coal blends

Base coal	Alaska No. 4		Sunnyside No. 1	
Blending coals............percent-coal..	25-Sewell 25-Pocahontas #3		7½ Red Indian 7½ Coal Basin	
Condition of base coal	Oxidized	Fresh	Oxidized	Fresh
50-pound coking test number	CP-140	CP-124	CP-139	CP-136
Laboratory sample number	2003-AB-10	2003-AB	2008-4H	2008-3Y
Coal data:				
Free swelling index	5	6	5	4½
Gieseler plastometer:				
Maximum fluidity..............ddpm..	30	140	16	[2]40
Temperature at, ° C:				
Initial movement (0.1 ddpm)	366	356	369	[2]366
Maximum fluidity	435	435	435	[2]435
Solidification	474	477	468	[2]468
Oxygen, maf..................percent..	6.7	6.8	8.3	8.2
Heating value, moist, ash-free.....................Btu/lb..	14,920	14,930	14,590	14,100
Calculated coking index	1.51	1.52	1.25	1.25
Coke data:				
Yield, percent:				
As carbonized	71.5	70.8	67.5	64.5
Moisture free	72.4	72.2	68.7	68.0
Moisture- and ash-free	71.1	70.9	66.3	65.9
Average size....................inch..	1.756	1.584	1.513	1.639
Apparent specific gravity	0.783	0.693	0.753	0.656
True specific gravity	1.906	1.908	1.938	1.924
Cell space...................percent..	58.9	63.7	61.2	65.9
Columbia tumbler test:				
Retained on ¼ inch screen (¼ inch index)..............do.....	88.4	87.9	88.8	88.7
Size stability...............do.....	54.9	58.3	56.0	56.8
Modified coke strength index	125.7	117.8	110.0	122.4
Net resultant coke factor	0.676	0.640	0.552	0.579

[1]Base coal oxidized 10 weeks by exposure to laboratory air.
[2]Plastometric data from DL 2008T.

A summary of these results follows, together with results obtained with the two coals fresh and unblended:

Base coal	Blending coals: None	Blending coals: 25 pct Sewell 25 pct Pocahontas	Blending coals: 7½ pct Red Indian 7½ pct Coal Basin	Coke yield, mf basis	Average coke size, inches	Tumbler size stability, percent	Tumbler resultant retained on 0.25-inch screen, pct	Modified coke strength index	Net resultant coke factor
Alaska No. 4:									
Oxidized 10 weeks	-	X	-	72.4	1.76	54.9	88.4	125.7	0.676
Fresh............	-	X	-	72.2	1.58	58.3	87.9	117.8	.641
Fresh............	X	-	-	64.1	1.37	44.6	86.4	74.5	.377
Sunnyside No. 1:									
Oxidized 10 weeks	-	-	X	68.7	1.51	56.0	88.8	110.0	.552
Fresh............	-	-	X	68.0	1.64	56.8	88.7	122.4	.579
Fresh............	X	-	-	66.2	1.59	53.9	87.8	104.4	.498

Oxidation appeared to affect size stability disadvantageously for the blends of both base coals; relative to the amounts used in the blends, the effect of oxidizing the Alaskan coal was somewhat more than that of oxidizing the Sunnyside coal. Oxidation improved the average size ("blockiness") of the Alaska blend a surprising amount; the Sunnyside blend was decreased in size. The net resultant coke factor (a composite of yield, size, and tumbler strength) of the Alaska blend was improved by oxidation and the Sunnyside blend was made poorer. For the modified coke strength index, which combines certain size and tumbler strength factors, a similar pattern of oxidation effects was observed--that is, improvement for the Alaska blend and deterioration for the Sunnyside blend. The coke yield and the percentage of tumbler resultant retained on the 0.25-inch screen of neither blend was affected.

Photographs of the cokes prepared from the two mildly oxidized base coals are shown in figure 12. The appearance of the coke from the blend containing oxidized Alaskan coal was little different from that of the blend containing unoxidized coal (compare CP-124, in figure 9, and CP-140). The coke from the blend containing oxidized Sunnyside coal appears to be slightly more fingery but less sandy in texture than the basic Fontana blend coke (compare CP-136 and CP-139). Chemical analyses of the cokes are not presented, as they were practically unchanged by the oxidation of the base coals.

In summary, the mild oxidation caused by exposure to laboratory air for 10 weeks appears to have affected the Alaskan sample no more than the Sunnyside sample, as judged by the results of the 50-pound coking test. This observation reinforces a similar observation noted in connection with Gieseler plasticity data (table 12) and suggests that the Alaskan coal would be likely to store at least as well as the Sunnyside coal, with respect to coking properties. In a warm climate (Los Angeles area), Sunnyside coal can be stored without significant loss of coking properties for approximately 90 days; if a cooler area is contemplated for storage of the Alaskan coal, it is likely that storage for longer than 90 days would be practical with well-engineered placing and reclaiming techniques. In this connection, it may be noted that another Western hvab coal has been stored in a well-compacted pile for six years without significant loss of its coking properties.[11] The

[11] Purdy, J. R. Storage of high volatile coal at the Pueblo plant of C. F. & I. Corporation. Proceedings, Blast Furnace, Coke Oven, and Raw Materials Committee, Iron and Steel Division, AIME, v. 20, 1961, pp. 117-128.

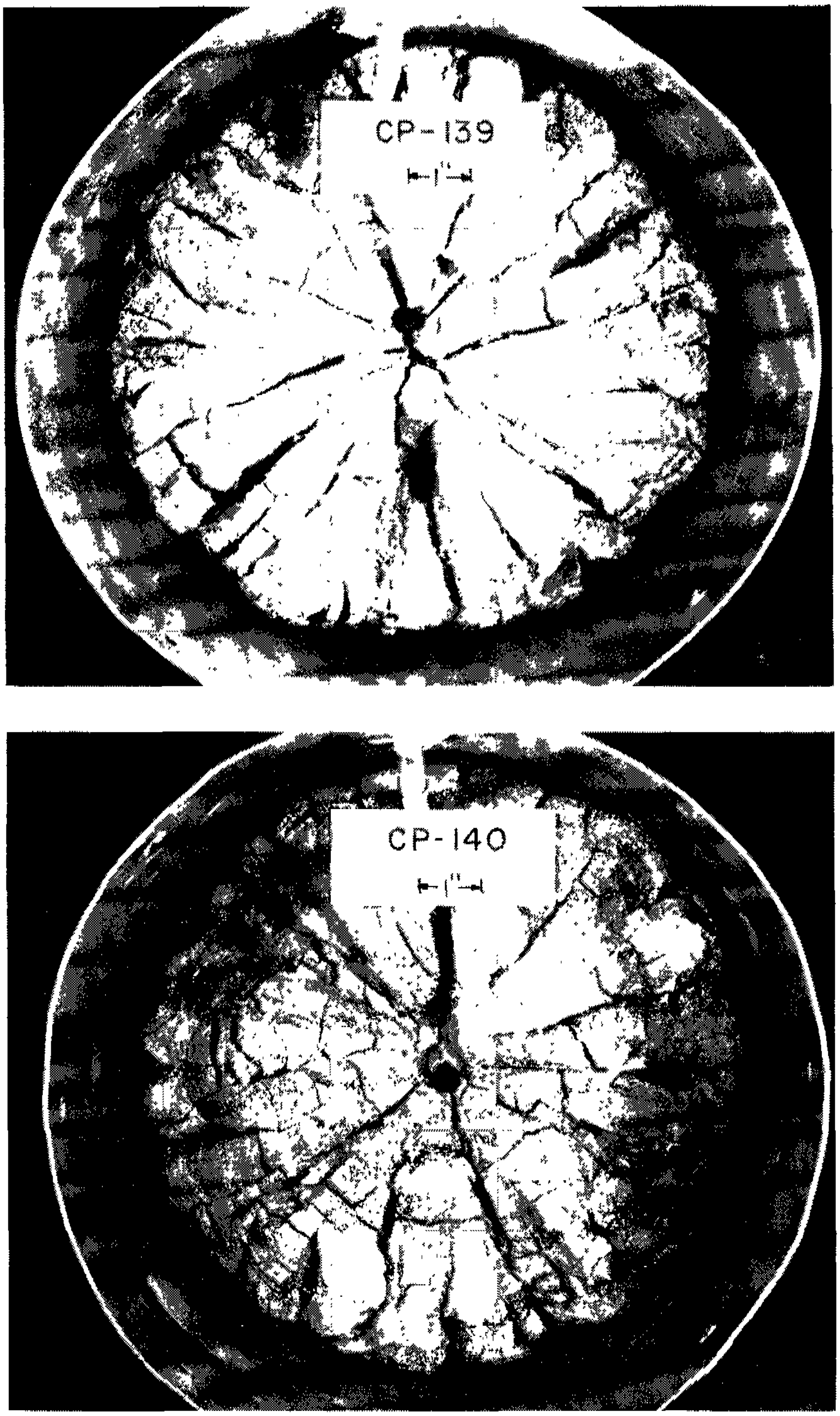

FIGURE 12. - Coke Produced From Blends With Mildly Oxidized Base Coals.

only difficulty reported in using this reclaimed coal was occasioned by the increased fines resulting from the compacting operation.

Coking Studies, 1963 Series

In 1963, the two additional samples representing one bed at a single location in the same immediate area as those represented by the 1962 samples were studied. The major objective of this study was to determine if the Kukpowruk River coal would produce acceptable metallurgical coke if it were used as the base coal in a blend similar to the Fontana blend.

Of the total seam thickness of 18.95 feet, the upper 10.95 feet were represented by sample 7, a channel sample consisting of six consecutive parts, separately identified and bagged. The lower 8 feet of the bed were represented by sample 8, consisting of cuttings from 8 drill holes, each extending from the base of sample 7 to the base of the bed. The cuttings of sample 8 were shipped in four bags, each containing the cuttings from two drill holes. A graphic log of the samples is presented in figure 13, which also indicates the laboratory numbers

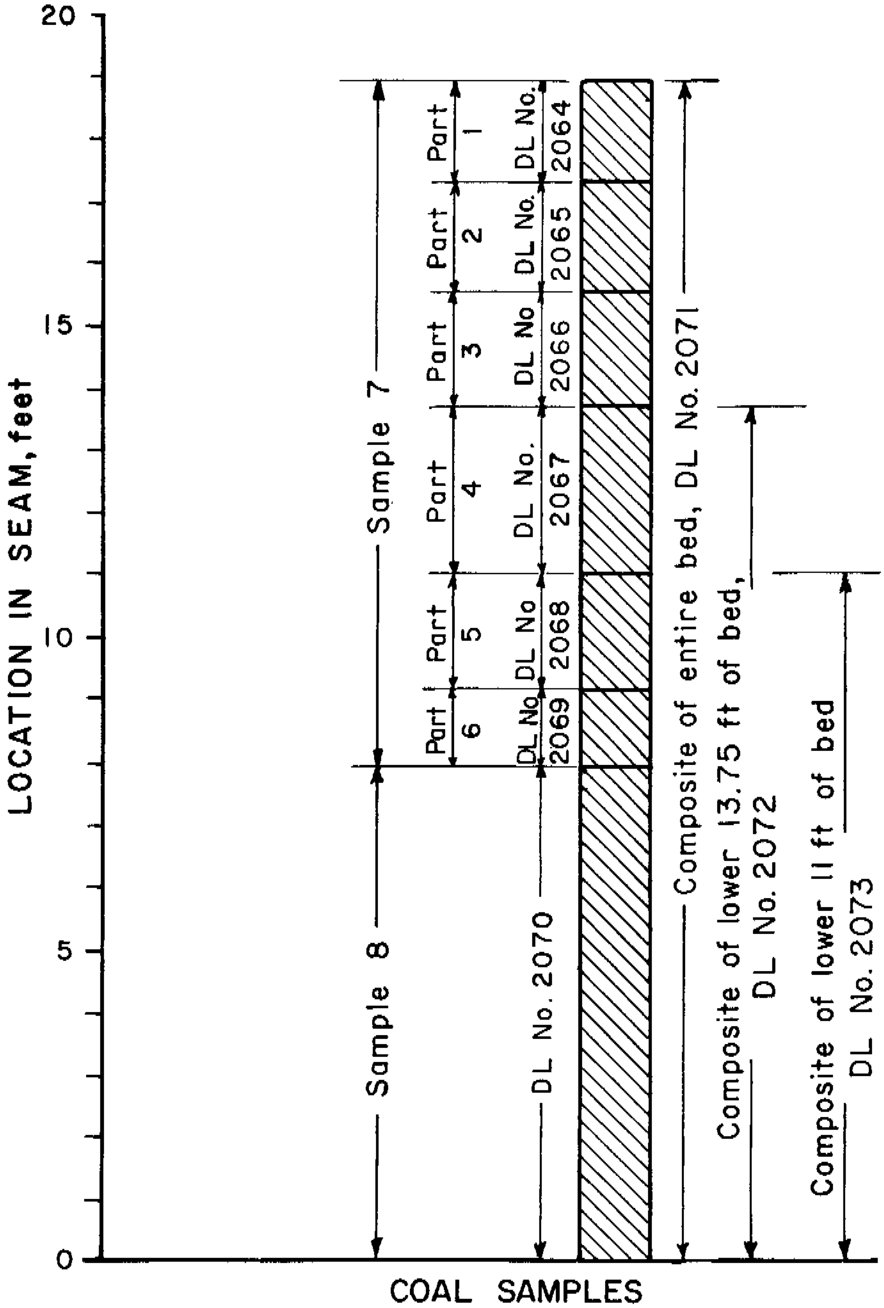

FIGURE 13. - Log and Laboratory Grouping of Coal Samples 7 and 8 From Kukpowruk River Area, Alaska.

that were assigned to the 6 parts of sample 7, to sample 8, and to selected composites of the samples.

As a first step in the laboratory work, sample 8 and each part of sample 7 were crushed to pass a ¼ inch square-hole screen and subdivided for analysis and bench-scale testing (free-swelling, Gieseler plastometer, and 100-gram coking). For this purpose, all four bags comprising sample 8 were blended into one sample before subdividing for analysis and testing. Table 14 presents analyses of the samples, composites, and blending coals, and of the blends subsequently selected for testing. Results of the physical tests on the samples, composites, and blends are presented in tables 15 and 16.

As shown in summary table 17, the upper 5.20 feet of the bed (Laboratory Nos. 2064, 2065, and 2066) was poorly coking. The portion of the bed from 11.00 to 13.75 feet above the base (Laboratory No. 2067) was questionable in its coking properties. On the basis of these results, three composite samples, each weighted in accordance with the logged thickness of the subsamples, were prepared and subjected to bench-scale tests. Laboratory No. 2071 was a composite of the entire bed; Laboratory No. 2072 was a composite of the lower 13.75 feet of the bed (including the questionable segment from 11.00 to 13.75 feet); and Laboratory No. 2073 was a composite of the lower 11 feet of the bed (excluding the questionable segment). A graphic log of the composites is included in figure 13.

TABLE 14. - Analyses of material used in coking study of Alaskan coals--1963 series

Denver laboratory No.	2064		2065		2066		2067	
Description	Part 1, Sample 7		Part 2, Sample 7		Part 3, Sample 7		Part 4, Sample 7	
Basis	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:								
Moisture	8.0	-	8.0	-	12.0	-	7.2	-
Volatile matter	28.2	32.0	31.7	37.0	28.5	33.6	33.1	37.5
Fixed carbon	60.1	68.0	53.9	63.0	56.5	66.4	55.4	62.5
Ash	3.7	-	6.4	-	3.0	-	4.3	-
Ultimate analysis, percent:								
Hydrogen	5.0	4.7	5.0	4.9	5.4	4.8	5.3	5.2
Carbon	75.3	85.4	70.9	82.8	71.8	84.4	74.0	83.5
Nitrogen	1.2	1.3	1.2	1.4	1.1	1.4	1.3	1.4
Oxygen	14.5	8.3	16.2	10.6	18.4	9.1	14.9	9.6
Sulfur	.3	.3	.3	.3	.3	.3	.2	.3
Ash	3.7	-	6.4	-	3.0	-	4.3	-
Heating value, Btu/lb	13,000	14,720	12,170	14,220	12,360	14,530	12,900	14,580
Free-swelling index	1½		2		2		3	

Denver laboratory No.	2068		2069		2070		2071	
Description	Part 5, Sample 7		Part 6, Sample 7		Sample 8		Composite, entire bed	
Basis	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:								
Moisture	6.8	-	8.8	-	7.2	-	7.9	-
Volatile matter	37.0	41.4	33.3	37.6	38.1	42.2	34.5	39.0
Fixed carbon	52.4	58.6	55.2	62.4	52.3	57.8	54.2	61.0
Ash	3.8	-	2.7	-	2.4	-	3.4	-
Ultimate analysis, percent:								
Hydrogen	5.6	5.4	5.5	5.2	5.8	5.5	5.5	5.2
Carbon	74.3	83.1	74.4	84.0	75.5	83.6	74.2	83.8
Nitrogen	.8	1.0	1.3	1.4	1.4	1.6	1.3	1.4
Oxygen	15.3	10.3	15.8	9.1	14.6	9.0	15.3	9.3
Sulfur	.2	.2	.3	.3	.3	.3	.3	.3
Ash	3.8	-	2.7	-	2.4	-	3.4	-
Heating value, Btu/lb	13,090	14,640	12,950	14,640	13,360	14,780	13,010	14,650
Free-swelling index	5		4½		5		5	

TABLE 14. - Analyses of material used in coking study of Alaskan coals--1963 series--Continued

Denver laboratory No.....	2072		2073		2074		2015	
Description.............	Composite lower 13.75 ft		Composite lower 11.00 ft		Coal Basin		Red Indian	
Basis....................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:								
Moisture...............	7.3	-	7.3	-	3.2	-	3.8	-
Volatile matter........	36.6	40.8	37.4	41.6	22.5	25.2	22.1	23.7
Fixed carbon...........	53.1	59.2	52.6	58.4	66.6	74.8	71.0	76.3
Ash....................	3.0	-	2.7	-	7.7	-	3.1	-
Ultimate analysis, percent:								
Hydrogen...............	5.7	5.4	5.7	5.5	5.0	5.2	5.4	5.0
Carbon.................	75.0	83.6	75.2	83.6	79.7	89.4	83.7	89.8
Nitrogen...............	1.3	1.4	1.3	1.4	1.8	2.1	1.4	1.6
Oxygen.................	14.8	9.3	14.8	9.2	5.2	2.7	6.3	3.1
Sulfur.................	.2	.3	.3	.3	.6	.6	.5	.5
Ash....................	3.0	-	2.7	-	7.7	-	3.1	-
Heating value, Btu/lb....	13,200	14,710	13,270	14,750	14,030	15,750	14,620	15,690
Free-swelling index......	5		5½		9+		9+	

Denver laboratory No.....	2071-A		2072-A		2071-B		2071-C	
Description.............	Coking test CP-143		Coking test CP-144		Coking test CP-145		Coking test CP-146	
Basis....................	As carb.	Maf	As carb.	Maf	As carb.	Maf	As carb.	Maf
Proximate analysis, percent:								
Moisture...............	7.2	-	6.7	-	7.0	-	6.8	-
Volatile matter........	32.7	36.8	34.4	38.3	32.1	36.1	31.5	35.4
Fixed carbon...........	56.4	63.2	55.5	61.7	57.1	63.9	57.8	64.6
Ash....................	3.7	-	3.4	-	3.8	-	3.9	-
Ultimate analysis, percent:								
Hydrogen...............	5.4	5.2	5.5	5.4	5.4	5.2	5.4	5.2
Carbon.................	75.4	84.6	76.0	84.5	75.8	84.9	76.1	85.2
Nitrogen...............	1.3	1.5	1.3	1.5	1.3	1.5	1.4	1.5
Oxygen.................	13.9	8.4	13.5	8.3	13.4	8.0	12.9	7.7
Sulfur.................	.3	.3	.3	.3	.3	.4	.3	.4
Ash....................	3.7	-	3.4	-	3.8	-	3.9	-
Heating value, Btu/lb....	13,200	14,810	13,370	14,860	13,270	14,870	13,340	14,920
Free-swelling index......	5½		6		6½		6½	

TABLE 15. - Gieseler plastometer data on Alaskan coals, composites, and blends

Test number	Denver Lab. number	Alaska Sample	Alaska Part	° C at 0.1 ddpm[1]	° C at 5.0 ddpm	Maximum fluidity ddpm	Maximum fluidity ° C	° C at 5.0 ddpm	° C at Solidification	Plastic range[2]	Fusion range[3]	Coke swelled into barrel, inches
342	2064	7	1	400	-	1.40	432 & 435	-	462	62	0	0
343	2065	7	2	393	-	1.65	429	-	456	63	0	0
344	2066	7	3	402	-	1.15	429	-	459	57	0	0
345	2067	7	4	387	-	2.90	435	-	462	75	0	0
346	2068	7	5	366	416	68	429	449	465	99	33	1/4" ball
347	2069	7	6	381	427	8.4	432	439	459	78	12	0
348	2070	8	-	363	411	150	429	454	465	102	43	1
350	2071	Composite representing entire bed		378	426	14	435	444	462	84	18	0
351	2072	Composite representing lower 13.75'		372	418	46	435	448	465	93	30	1/4" ball
352	2073	Composite representing lower 11.00'		366	415	88	429	451	465	99	36	1/2
353	2071-A	Charge for CP-143[4]		372	423	21	438	451	471	99	28	0
354	2072-A	Charge for CP-144[5]		372	418	60	438	454	468	96	36	1/2
355	2071-B	Charge for CP-145[6]		381	425	25	438	452	471	90	27	0
356	2071-C	Charge for CP-146[7]		381	421	28	441	452	471	90	31	1/8
302	2008-T	Sunnyside 85-15 blend for comparison		366	416	40	435	451	468	102	35	0

[1] Initial softening, the temperature at which a continuous movement of 0.1 ddpm is attained.
[2] The temperature range between initial softening and solidification.
[3] The temperature range over which the fluidity exceeds 5.0 ddpm.
[4] A blend: 85 percent 2071, 7.5 percent each of Red Indian and Coal Basin coals.
[5] A blend: 85 percent 2072, 7.5 percent each of Red Indian and Coal Basin coals.
[6] A blend: 80 percent 2071, 10.0 percent each of Red Indian and Coal Basin coals.
[7] A blend: 75 percent 2071, 12.5 percent each of Red Indian and Coal Basin coals.

TABLE 16. - 100-gram coking tests on Alaskan coals, composites, and blends--1963 series

Sample number	Coke yield, percent	Plus ¼ inch material after 15 drops		
		Number of pieces plus ¼ inch	Average weight per piece, grams	Percent retention[1]
2064...............	66.0	31	1.78	83.5
2065...............	63.4	34	1.71	91.8
2066...............	62.1	33	1.65	87.4
2067...............	62.3	38	1.57	95.5
2068...............	58.6	66	.84	94.5
2069...............	60.6	48	1.22	96.4
2070...............	56.8	83	.65	94.4
2071...............	60.5	46	1.27	96.2
2072...............	58.8	64	.88	95.7
2073...............	57.9	60	.91	94.1
2071-A (CP-143)....	62.9	40	1.51	95.7
2072-A (CP-144)....	61.3	41	1.44	96.1
2071-B (CP-145)....	67.3	47	1.38	96.4
2071-C (CP-146)....	67.9	40	1.62	95.7

[1] Percentage of coke yield.

Summary data from the bench-scale tests on the coals, composites, and blends also appear in table 17; detailed data have been presented in tables 15 and 16. The effect of the questionable portion, Laboratory No. 2067 (11.00 to 13.75 feet above the base of the seam), was judged not sufficiently serious to warrant exclusion. As the full seam (Laboratory No. 2071) had an acceptable free-swelling index, it was concluded to focus attention for the 50-pound coking tests on the full seam and the lower 13.75 feet--Laboratory Nos. 2071 and 2072, respectively.

In accordance with the major objective of this portion of the studies, Alaskan coal was substituted for the Sunnyside coal in the Fontana blend (85 percent Sunnyside, 7.5 percent each of Coal Basin and Red Indian coals). Fifty-pound coking tests were conducted on blends of (1) 85 percent of Laboratory No. 2071 (entire seam) with 7.5 percent each of Coal Basin and Red Indian coals, and (2) 85 percent of Laboratory No. 2072 (lower 13.75 feet of seam) with the same Coal Basin/Red Indian blending mix. When subjected to physical tests, the resultant cokes were so similar as to justify directing all additional testing toward the composite representing the entire seam. As a result, two additional 50-pound carbonization tests were conducted in attempts to further improve the coke. For these two additional tests, the full seam composite (Laboratory No. 2071) was blended with the Coal Basin/Red Indian mix in the proportions 80 to 20 and 75 to 25.

TABLE 17. - Summary of bench-scale coking properties of Alaskan coals and blends--1963 series

Denver lab. number	Description of samples	Maximum fluidity in Gieseler plastometer, ddpm	100-gram coking test: Plus ¼ inch material after 15 drops: Retention,[1] percent	100-gram coking test: Plus ¼ inch material after 15 drops: Average weight per piece, grams	Free swelling index
2064	17.30 - 18.95 feet from bottom of bed.	1.40	83.5	1.78	1½+
2065	15.60 - 17.30 feet from bottom of bed.	1.65	91.8	1.71	2
2066	13.75 - 15.60 feet from bottom of bed.	1.15	87.4	1.65	2
2067	11.00 - 13.75 feet from bottom of bed.	2.90	95.5	1.57	3+
2068	9.20 - 11.00 feet from bottom of bed.	68	94.5	.84	5+
2069	8.00 - 9.20 feet from bottom of bed.	.4	96.4	1.22	4½+
2070	0.00 - 8.00 feet from bottom of bed.	150	94.4	.65	5
2071	Weighted composite of entire bed.	14	96.2	1.27	5
2072	Weighted composite of lower 13.75 feet of bed.	46	95.7	.88	5
2073	Weighted composite of lower 11.00 feet of bed.	88	94.1	.91	5½
2071-A	85 percent DL 2071, 7.5 percent Coal Basin, 7.5 percent Red Indian coals.	21	95.7	1.51	5½+
2072-A	85 percent DL 2072, 7.5 percent Coal Basin, 7.5 percent Red Indian coals.	60	96.1	1.44	6+
2071-B	80 percent DL 2071, 10 percent Coal Basin, 10 percent Red Indian coals.	25	96.4	1.38	6½+
2071-C	75 percent DL 2071, 12.5 percent Coal Basin, 12.5 percent Red Indian coals.	28	95.7	1.62	6½+

[1] Percentage of coke yield.

The results of the four 50-pound coking tests are reported in table 18. The most important results are summarized as follows, together with results obtained earlier with the Fontana blend:

Test number	Fontana blend CP-136	Alaska full-seam, with indicated percentage of blending coals 15 CP-143	20 CP-145	25 CP-146	Lower 13.75 ft, with 15 percent blending coals CP-144
Coke yield, mf, percent	68.0	69.8	70.3	71.6	68.5
Average coke size.....inch..	1.64	1.58	1.62	1.55	1.51
Tumbler size stability.....percent..	56.8	53.3	50.8	54.0	51.7
Tumbler resultant retained on 0.25 inch screen.....do.....	88.7	84.7	84.2	85.7	86.7
Modified coke strength index	122.4	110.8	110.3	112.7	102.8
Net resultant coke factor	0.579	0.536	0.527	0.547	0.489

TABLE 18. - 50-pound coking test data on blends[1] with Alaska samples 7 and 8--1963 series

50-pound coking test and laboratory sample numbers	Base coal: Full seam CP-143, 2071-A	CP-145, 2071-B	CP-146, 2071-C	Lower 13.75 ft CP-144, 2072-A
Blending coal.....percent..	15	20	25	15
Coal data:				
Free swelling index	5.5	6	6	6.5
Gieseler plastometer:				
Maximum fluidity.....ddpm..	21	25	28	60
Temperature at, ° C:				
Initial movement (0.1 ddpm)	372	381	381	372
Maximum fluidity	438	438	441	438
Solidification	471	471	471	468
Oxygen, maf.....percent..	8.3	8.0	7.6	8.3
Heating value, moist, ash-free.....Btu/lb..	13,710	13,790	13,870	13,830
Calculated coking index	1.25	1.29	1.33	1.24
Coke data:				
Yield, percent:				
As carbonized	65.0	65.6	67.0	64.0
Moisture free	69.8	70.3	71.6	68.5
Moisture- and ash-free	68.5	68.8	70.2	67.3
Average size.....inch..	1.584	1.619	1.546	1.507
Apparent specific gravity	0.774	0.792	0.792	0.740
True specific gravity	1.900	1.897	1.897	1.887
Cell space.....percent..	59.2	58.3	58.3	60.8
Columbia tumbler test:				
Retained on ¼ inch screen (¼ inch index).....do.....	84.9	84.2	85.7	86.7
Size stability.....do.....	53.3	50.9	54.0	51.7
Modified coke strength index	110.8	110.3	112.7	102.8
Net resultant coke factor	0.536	0.527	0.547	0.489

[1] Equal percentages of medium-volatile bituminous Coal Basin and Red Indian coals used in blends.

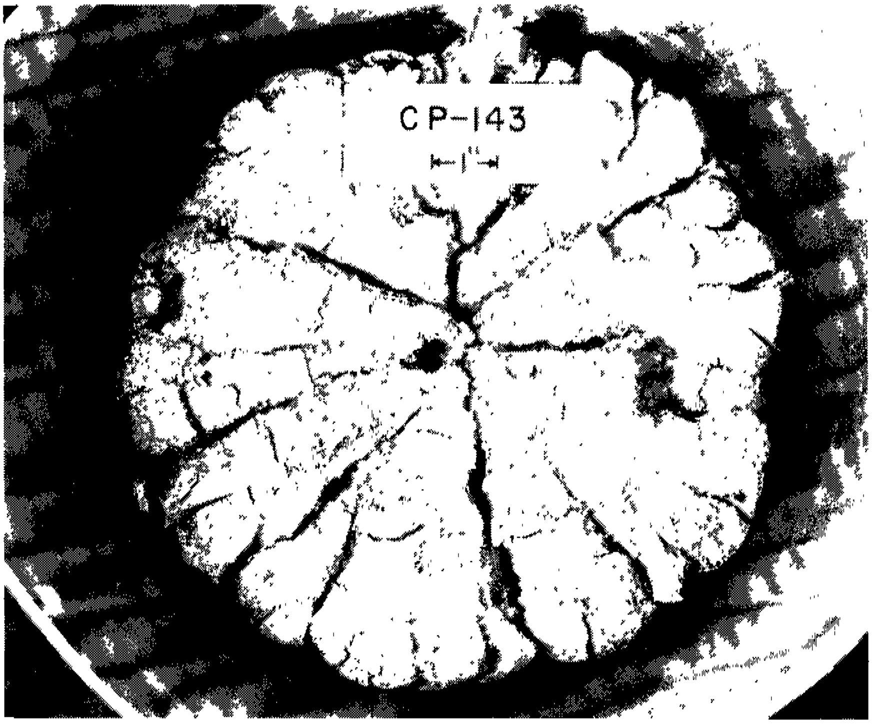

FIGURE 14. - Coke From a Blend Consisting of 85 Percent of a Composite of Alaska Samples 7 and 8, 7.5 Percent of Coal Basin Coal, and 7.5 Percent of Red Indian Coal.

The data indicate that the full-seam Alaska coal (samples 7 and 8 combined) would probably produce coke that would be slightly weaker than coke produced from Sunnyside coal, when each base coal is blended with 7.5 percent of Red Indian and with 7.5 percent of Coal Basin coals, both of which are medium-volatile bituminous in rank. Differences in coke yield and average coke size appear to be insignificant. Increasing the blending coals from 15 to 25 percent did not result in appreciable improvement. Further increases in blends were considered likely to be uneconomical. Subject to larger-scale testing and the use of alternate blending materials, coke from the Alaska coal should be reasonably useful for metallurgical purposes. The elimination of the poorly coking upper 5.20 feet of the Alaska coalbed did not increase coke quality (see test No. CP-144).

Figure 14 is a photograph of the coke produced by direct substitution of the full-seam Alaskan coal for Sunnyside coal in the Fontana blend (compare with figure 11).

Proximate and ultimate analyses of the cokes produced in the 50-pound coking tests with samples 7 and 8 are presented in table 19.

CONCLUSIONS

Field observations and laboratory and pilot plant data on eight coal samples from five locations along the Kukpowruk River, Arctic Northwestern Alaska, support the following conclusions:

1. Four of the five locations samples may be part of the same coal seam, which averages about 20 feet in thickness at the locations sampled. At the fifth location, the coal is 4.5 feet thick and is part of another seam.

2. The thicker coal seam is high-volatile A bituminous in rank, with appreciable coking properties. The sample from the thinner coal seam was found to be oxidized and to have no coking properties.

3. Coal from the thicker seam, when blended with selected higher rank coals and carbonized at 900° C in 50-pound lots, produced coke judged to approach metallurgical quality.

4. Limited oxidation studies on the lower half of the thicker seam at one location suggest that the Alaskan coal is likely to be storable for reasonable periods without excessive loss of coking properties.

TABLE 19. - Proximate and ultimate analyses of cokes made from Alaska coals--1963 series

Denver laboratory No.	2071-A-C		2072-A-C	
Coking test No.	CP-143		CP-144	
Basis	Mf	Maf	Mf	Maf
Proximate analysis, percent:				
Volatile matter	1.2	1.3	1.2	1.2
Fixed carbon	92.9	98.7	93.5	98.8
Ash	5.9	-	5.3	-
Ultimate analysis, percent:				
Hydrogen	0.4	0.5	0.5	0.5
Carbon	91.9	97.6	92.3	97.5
Nitrogen	1.4	1.5	1.5	1.6
Oxygen	.1	.1	.1	.0
Sulfur	.3	.3	.3	.4
Ash	5.9	-	5.3	-
Heating value, Btu/lb.	13,590	14,440	13,620	14,380

Denver laboratory No.	2071-B-C		2071-C-C	
Coking test No.	CP-145		CP-146	
Basis	Mf	Maf	Mf	Maf
Proximate analysis, percent:				
Volatile matter	1.3	1.3	1.0	1.1
Fixed carbon	92.6	98.7	92.9	98.9
Ash	6.1	-	6.1	-
Ultimate analysis, percent:				
Hydrogen	0.5	0.6	0.5	0.5
Carbon	91.5	97.5	91.5	97.4
Nitrogen	1.4	1.5	1.5	1.5
Oxygen	.1	.0	.1	.2
Sulfur	.4	.4	.3	.4
Ash	6.1	-	6.1	-
Heating value, Btu/lb.	13,620	14,500	13,540	14,410

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