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Analyses and Other Properties of Oregon Coals as Related to Their Utilization

by

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FOREWORD

Many people, now living in Oregon, do not realize that back in 1904 and 1905 the homes and offices of the San Francisco Bay district of California were heated by coal shipped from the Coos Bay district. In those days Oregon coal production totaled over 100,000 tons a year.

Much of the coal was loaded on coastwise steamers at docks within a few hundred feet of the portals of the coal mines. About the same time the Southern Pacific Railroad was mining coal for its steam locomotives from its own mine. It is understood that this property, the Beaver Hill mine, was developed to a depth of more than 2,000 feet down the dip.

The advent of petroleum and natural gas (the latter piped directly to the San Francisco Bay district and sold at a very low figure) has wiped out that region as a market for Oregon coals. Oil also displaced coal for use by the Southern Pacific. At present oil is perhaps the most popular fuel for domestic heating in the metropolitan area of Portland, not because it is cheaper but because it is easier to use.

In recent years Oregon coal production has averaged around 8 or 10 thousand tons per year and supplies only a market in the vicinity of the mines themselves; moreover, Oregon coal has had to compete with hogged fuel, which is virtually a waste product.

Hogged fuel 1/ now seems to be growing slightly more costly as the forests are cut back, and owing to labor trouble the supply has been unsatisfactory at some points. For these reasons, there is evidence that in the Coos Bay district there is some change-over from hogged fuel to coal.

The Oregon State Department of Geology and Mineral Industries, wishing to obtain essential facts in regard to Oregon coals, in order to be in a position to encourage more widespread utilization of this important natural resource, was fortunate in making a cooperative arrangement with the Federal Bureau of Mines for a factual study of the better known Oregon coal fields and veins that were accessible for sampling and study.

1/ - According to the chapter on Fuels in the Mechanical Engineers' Handbook, "Hogged fuel is sawmill refuse that has been fed through a disintegrator or 'hog' by which the various sizes and forms are reduced to a practically uniform size or chips, or rather shreds. In this condition it can be handled much more conveniently and fired with higher efficiency. It is sold in 'units' of 200 cubic feet. Sawmills usually have a surplus above their own requirements for power of about $\frac{1}{2}$ unit for each 1,000 feet of logs handled. The average unit of 200 cubic feet weighs 4,000 pounds and contains 42 percent moisture. Sawdust is sold in similar 'units'".

This department bore the expense of the field work conducted by engineers of both organizations, and the Bureau of Mines carried out and assumed the cost of the laboratory studies.

This bulletin covers the result of recent investigations of Oregon coals. Analyses, the results of burning tests, and other technical data are included, as well as conclusions that should tend to change what might be described as a defeatist attitude toward our coals on the part of many people in Oregon. In our opinion our coals will be an increasingly valuable mineral resource in this State.

Earl K. Nixon, Director

Portland, Oregon,
February 1940

ANALYSES AND OTHER PROPERTIES OF OREGON COALS AS RELATED TO THEIR UTILIZATION

By H. F. Yancey 2/ and M. R. Geer 3/

INTRODUCTION

Large reserves of coal, situated for the most part convenient to cheap tidewater transportation, constitute one of Oregon's important mineral resources, yet the present production of coal in the State is restricted to that required to meet a small local demand. Thus, a potentially valuable industry stands essentially undeveloped, largely because of the competitive position of Oregon coal in the fuel market of the State - a market in which fuel oil, wood fuel, water power, and coal from other States compete actively with it.

Any attempt to broaden the market for local coals in the face of this competition will be more likely to be successful if guided by sound knowledge of their physical and chemical properties. These properties affect the performance of coal in every one of its uses and therefore can be made to serve as invaluable guides in directing a particular coal toward the specific use or uses for which it is best adapted.

Purpose and Scope

The investigation herein recorded was undertaken with the objective of making available to producers, consumers, and the general public detailed information on the physical and chemical properties of the coals currently mined in Oregon. Toward this end, samples were collected at the seven operating properties in the State and at two prospects, and each coal was subjected to standardized laboratory tests. These tests included chemical analyses, both proximate and ultimate, and determination of heating value; friability tests to determine resistance to breakage or degradation in size on handling; slacking or weathering tests to measure the tendency to slack or disintegrate on exposure to the weather after mining; and determination of the yields of products obtained by low-temperature carbonization. In addition, one coal was selected for a laboratory hydrogenation test to determine its suitability for liquefaction by this process, and one coal was subjected to float-and-sink tests to estimate the feasibility of cleaning it mechanically. Burning tests were made of two coals, using an overfeed-type domestic stoker.

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Acknowledgments

The investigation recorded in this report was conducted jointly by the Bureau of Mines, United States Department of the Interior, and the Oregon Department of Geology and Mineral Industries. The chemical analyses, slacking tests, and hydrogenation test were made by H. M. Cooper, chemist, W.A.Selvig, senior chemist, and H. H. Storch, principal physical chemist, respectively, all of the Central Experiment Station of the Bureau of Mines, Pittsburgh, Pa. Friability tests, low-temperature carbonization assays, float-and-sink tests, and burning tests were made at the Bureau's Northwest Experiment Station, Seattle, Wash. Grateful acknowledgment is made to Earl K. Nixon, director, Oregon Department of Geology and Mineral Industries, who initiated the investigation and assisted in its supervision; and to J. E. Morrison, formerly mining geologist, of the same department, for his assistance in sampling.

COAL FIELDS OF OREGON

The occurrence of coal has been noted at numerous localities in western Oregon, from the Columbia River on the north to central Curry County on the south, and several deposits are known in the central and eastern parts of the State. The Federal Geological Survey has investigated and reported on the more prominent coal fields, but little is known of the other areas. The following brief descriptions of the coal fields of the State have been drawn largely from publications of the Geological Survey, and wherever possible references to the more complete and detailed original reports have been included.

Coos Bay Field

The Coos Bay field, situated on the coast in southwestern Coos County is roughly 30 miles in length north and south, and 11 miles in width at its broadest part; it embraces an area of about 250 square miles. From the standpoint of both production and reserves it is by far the most important field in the State and is the only field from which coal has been produced on a commercial scale.

The geology of the field has been described by Diller and others in several reports.4/ Structurally the field is composed of two arches or anticlines separating four basins in which the coal-bearing measures occur. Folding of the strata has been moderate; dips of over 45° are rare and faults of large displacement uncommon. The Arago formation in which the coal beds are found is composed of sandstones and shales of Eocene age, the sandstones predominating near the coal beds.

The difficulty of correlating the strata of one basin with those of another, or even with those exposed at other points in the same basin, prevents more than a mere estimate of the total number of beds present in the field. At most points two to five or more beds are known. The Newport bed, called the Beaver Hill in some localities, has been the most productive and is being worked now at two mines. Other of the more important beds still being worked are the Southport and the Riverton or Timon. In general, the beds are 4 to 7 feet or more thick and are composed of benches of clean coal separated by rather thick partings of clay or soft shale; bone or impure coal occurs locally in varying amounts within the workable benches of coal and frequently over- or under-lies the minable portion of the bed.

4/ - Diller, J. S., The Coos Bay Coal Field, Oregon: Geol. Survey 19th Ann. Rept., part 3, 1897-98, pp. 315-376.
Diller, J. S., and Pishel, M. A., Preliminary Report on the Coos Bay Coal Field, Oregon: Geol. Survey Bull. 431b. 1911, 38 pp.
Diller, J. S., Coos Bay Folio (No. 73): Geol. Survey Geol. Atlas of the United States, 1901, 5 pp.
Smith, George Otis, The Coal Field of the Pacific Coast: Geol. Survey 22d Ann. Rept., part 3, 1900-1901, pp. 505-512.

Eden Ridge Field

The Eden Ridge field is situated at the southwestern end of Eden Ridge in southern Coos County, 25 miles east of the coast and just north of the Rogue River Divide in Tps. 32 and 33 S., R.11 W. The area over which the coal beds had been mapped is less than 10 square miles, but additional exposures outside this area indicate that the field probably is of much greater extent.

As the only deposit of bituminous coal known in Oregon, Eden Ridge was explored with considerable enthusiasm over 30 years ago. Although the field had been prospected extensively before 1910, it is still accessible only by trail, and no coal has ever been produced commercially.

The geology of the field has been described by Lesher 5/. The coals, like those of the Coos Bay field 25 miles northwest, occur in an Eocene formation known as the Arago. At Eden Ridge the strata have been tilted into a shallow elliptical basin, around whose edges the coal seams outcrop. Moderate dips of 15° or less prevail over most of the area. Four faults cut the strata in the basin, and a maximum vertical displacement of 800 feet was observed at one point.

Seven beds of coal are exposed in the field. The upper three have been mapped in some detail, but the lower beds (which presumably are of greater areal extent) have not been traced. The beds average about 6 feet in thickness but contain an unusual amount of impurities associated with the coal. Shale, bone, and coal grade into each other both vertically and horizontally, and benches of clean coal over 1 foot thick are rare. According to Lesher, one of the beds exposed in Squaw Basin is of different character, however; it contains over 5 feet of clean coal accompanied by only a 4-inch parting of clay.

The fact that commercial development did not follow the extensive prospecting of this field, even though the coal is higher in rank than that mined at Coos Bay, is mute evidence of the discouraging character of most of the beds.

Eckley and Shasta Costa Fields

Coal has been found in northern Curry County along the Sixes River in the vicinity of Sugarloaf Mountain and the town of Eckley, as well as at the mouth of Shasta Costa Creek on the Rogue River near the town of Agness. In these localities coal is found near the base of the Arago formation and is therefore of Eocene age. The Arago formation is not continuous between Eckley and Shasta Costa Creek, and hence the two occurrences of coal are considered as separate fields. The geology of the districts has been described briefly by Diller 6/.

In neither locality has enough prospecting been done to determine either the areal extent of the beds or their workability. At Eckley the beds have

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5/ - Lesher, C. E., The Eden Ridge Coal Field, Coos County, Oregon: Geol. Survey Bull. 541-I, 1914, pp.23-42.

6/ - Diller, J. S., Port Orford Folio (No.89): Geol. Survey Geol.Atlas of the United States, 1903, 7 pp.

been crushed and displaced so badly that not even their true thickness has been established. At Shasta Costa Creek the structure is less complex, but the coal is of poorer quality.

Rogue River Valley Field

A belt of coal-bearing strata several miles wide and nearly 100 miles long occurs in the valley of the Rogue River between the Cascade and Klamath Mountain ranges in southwestern Oregon. The belt begins on the north near Evans Creek in T. 33 S., R. 2 W., and extends southwesterly through the Siskiyou Mountain Divide into California. The coals have been prospected in the vicinity of Ashland, at points east of Medford, and on Evans Creek. Some coal has been produced for local consumption from time to time, particularly at properties near Medford.

This field also has been described briefly by Diller. 7/ Exploratory work has not been extensive enough to determine the geologic structure of the area, the number and extent of the beds. Continuity of a particular bed over the entire length of the field is improbable, a more likely circumstance being the occurrence of a number of beds having only limited extent. The coal occurs in the Umpqua formation, which is of Eocene age.

The characteristic feature of the beds in this field is the unusually large number of partings or bands of impurity that accompany the coal. Bands of coal, generally not over 6 inches in thickness, are interstratified with partings of shale, carbonaceous shale, and bone throughout the entire thickness of the beds. As many as 60 separate and distinct strata may be identified in a bed 12 feet thick; the number and thickness of the bands of impurity equal or exceed those of the coal bands.

At most points the beds dip gently northeastward, and the few faults noted are not of great displacement. Diller noted an increase in the quantity and quality of the coal in the beds as they are followed northeasterly down the dip.

Other Coal Deposits

The foregoing are the better known fields of Oregon - those in which development or prospecting has established the presence of coal over a considerable area. In addition to these fields, there are within the State a number of localities at which coal has been found but has not been prospected thoroughly enough to assure its extent. Coal occurs east of Salem in Marion County, near Wilhoit in Clackamas County, in the vicinity of Heppner in Morrow County, and near St. Helens in Columbia County; it is also reported in Clatsop, Tillamook, and Lincoln Counties.

7/ - Diller, J. S., The Rogue River Valley Coal Field, Oregon: Geol. Survey Bull. 341, 1909, pp. 401-405.

PRODUCTION AND RESERVES

Production of coal from the Coos Bay field, the only field in Oregon from which coal has been produced commercially, was begun about 1855. Table 1 shows the annual production from 1880 to 1920. By 1880, the earliest year for which data are available, annual output had reached over 40,000 tons, and during the following 15 years it ranged from 30,000 to 75,000 tons. In 1896 and 1897 the yearly production reached 100,000 tons, a figure not exceeded again until 1904, the year of maximum production, in which 111,540 tons were mined. The record since 1905 is one of generally declining output, and although no published figures are available for years leter than 1920, an estimate places the production in 1938 at less than 10,000 tons.8/

In none of the Oregon coal fields except the Coos Bay has there been enough development to justify an estimate of reserves. Campbell 9/ has estimated the reserves of that field to be 1,000,000,000 tons. The total production from the beginning of mining to the close of 1920, namely, 2,380,000 tons, is thus less than 0.3 percent of the estimated reserves.

Table 1.--Production of coal in Oregon, net tons, 1880-1920.1/

Year	Production	Year	Production	Year	Production
1880	43,205	1895	73,685	1910	67,533
1881	33,600	1896	101,721	1911	46,661
1882	35,000	1897	107,289	1912	41,637
1883	40,000	1898	58,184	1913	46,063
1884	45,000	1899	86,888	1914	51,558
1885	50,000	1900	58,864	1915	39,231
1886	45,000	1901	69,011	1916	42,592
1887	37,696	1902	65,648	1917	28,327
1888	75,000	1903	91,144	1918	13,328
1889	64,359	1904	111,540	1919	18,739
1890	61,514	1905	109,641	1920	20,717
1891	51,826	1906	79,731		
1892	34,661	1907	70,981		
1893	41,683	1908	86,259		
1894	47,521	1909	87,276		

1/ Data from Mineral Resources, Bureau of Mines, 1924, pp. 588-589.

8/ - Libbey, F. W., Progress Report on Coos Bay Coal Field: Oregon State Department of Geology and Mineral Industries, Bull.2, 1938, p.9

9/ - Campbell, M. R., The Coal Resources of the World: 12th Internat. Geol. Cong., 1913, p.538.

DESCRIPTION OF MINES

In the brief descriptions that follow there is included for each property sampled the places in the mine at which samples were taken, detailed sections of the bed at these points, and notations showing what portions of the bed were included in each sample. In addition, descriptions of the mines themselves and the methods employed in mining and preparing the coal at each are given.

Southport Mine

The Southport mine, operated by James H. Flanagan, is situated 6 miles south of Marshfield in the Coos Bay field of Coos County. Present workings are in the NE¼ sec.22, T.26 S., R.13 W., but the portal is in the SE¼ of the section, at an elevation of 105 feet. The mine is situated 1/2 mile from possible rail and water transportation on the Southern Pacific R.R. and Isthmus Slough, respectively, and the same distance from the highway.

The Southport bed, in which the mine operates, is a member of the Arago formation and at this point strikes N.20° E. and dips 8°E. The bed was measured and sampled May 27, 1933, by S. H. Ash and May 3, 1939, by M. R. Geer and J. E. Morrison, as described below:

Sections of Southport Bed in Southport Mine

Section	A		B	
Laboratory No.	A-90058		B-40027	
Roof, hard, smooth sandstone:	Ft.	in.	Ft.	in.
Bony		[a] 2½	. . . .	. . . .
Coal, sulphur streaks		[a] 2	. . . .	. . . .
Coal, firm	1	5	1	3
Bony		[a] 1	. . . .	. . . .
Shale parting, sandy, soft		[a] 8		[a] 8
Coal, firm	2	6	1	4
Coal, sulphur streaks	. . .	. . .		1-1/4
Coal	. . .	. . .		8-1/4
Coal, bony, hard	. . .	. . .		3-1/2
Floor, sandstone, overlain by soft shale or bone				
Thickness of bed	5	1/2	4	4
Thickness in sample	3	11	3	8

[a] Not included in sample

Section A was taken in the Morrisoul room, 2,300 feet from the portal. Section B was taken in 9 room pillar, 1st north entry above the counter, 2,400 feet northwest of the portal. Cover at these points is 60 to 80 feet.

Mining at this property dates back nearly 60 years, and during its life the mine has been developed by a system of drifts, slopes, and inclines aggregating over 6,000 feet in length. The room-and-pillar system of mining is used, with entries or drifts driven roughly on the strike of the bed and rooms turned to the rise. Coal is mined by cutting out by hand the soft shale parting, which is gobbed, and then breaking out the upper and lower benches of coal with picks and wedges. Some black powder is used where necessary.

The output of the mine, which averaged 10 tons per day in 1938, is brought to the tipple in trips of two 1-ton cars, where it is passed over 3-inch round-hole, 3/4-inch bar, and 5/8-inch square-hole screens to produce egg, nut, pea, and slack sizes, all of which are sprayed with water to remove fine-size, adhering impurities that detract from the appearance of the coal.

Thomas Mine

The Thomas mine, operated by the Thomas Coal Co., is situated 10 miles south of Marshfield in the Coos Bay field of Coos County, in SE$\frac{1}{4}$ sec.9, T.27 S., R.13 W., at an elevation of 200 feet. It is 1 mile from a possible rail connection with the Southern Pacific R.R. and a similar distance from the highway.

The Beaver Hill bed in which the mine operates is a member of the Arago formation and at this point strikes N.40°E. and dips 30°E. The bed was measured and sampled at the face of 13 room, 60 feet above the gangway and 600 feet north of the portal, by M. R. Geer and J. E. Morrison, May 5, 1939. Cover at this point was 100 feet. The section of the bed is shown below:

Section of Beaver Hill Bed in Thomas Mine

Laboratory No.	B-40028	
Roof, soft shale	Ft.	in.
Coal (immediate roof) . . .	[a] 1	
Clay, firm		[a] 4
Coal, bony		[a] 1-1/2
Clay		[a] 1-1/4
Coal	2	10
Bone, soft		[a] 2
Clay, firm		[a] 8
Bone, soft		[a] 2
Coal, some bony	1	6
Bone (immediate floor). . .		[a] 8
Floor, shale		
Thickness of bed	7	6-3/4
Thickness in sample	4	4

[a] Not included in sample

Southport Mine.

Views of track, tipple, and bunker.

Room-and-pillar mining is practiced, with rooms turned up the pitch from a drift 650 feet in length driven northeasterly along the strike of the bed. The dip of the bed, 30°, is adequate to allow the use of chutes lined with sheet iron to convey coal from the room face to the gangway. The soft shale roof of the bed must be protected by leaving up about 1 foot of roof coal; and, similarly, bony coal is left as the immediate floor. The remainder of the bed is mined by cutting out by hand and gobbing the center mining seam of bone and clay and then removing the upper and lower benches of coal by pick. Only a little stumping powder is used. From 6 to 10 inches of bony coal and clay underlying the roof coal is taken down with the upper bench and gobbed.

At the tipple the production of the mine, which averaged 10 tons per day in 1938, is passed over 3-inch bar, 1-1/2 inch round-hole, and 3/8-inch round-hole stationary screens to produce lump, nut, pea, and slack sizes for the market.

Overland Mine

The Overland mine, operated by the Overland Coal Co., is situated in the Coos Bay field, Coos County, 10 miles south of Marshfield. It is 1-1/2 miles from possible rail and water transportation on the Southern Pacific R.R. and Isthmus Slough, respectively, and a like distance from the highway.

The Beaver Hill bed, in which the mine operates, is a member of the Arago formation and at this point strikes N.20°E. and dips 30°SE. The bed was measured and sampled at two points by M. R. Geer and J. E. Morrison on May 8, 1939, as described below:

Sections of Beaver Hill Bed in Overland mine

Section Laboratory No.	A B-40064		B B-40065	
Roof, soft shale, underlain by 8 inches of bone	Ft.	in.	Ft.	in.
Bone (immediate roof)		[a] 8		[a] 8
Clay parting, firm		[a] 6-1/2		[a] 6
Bone		[a] 2		[a] 2
Clay parting, firm		[a] 1-3/4		[a] 2
Coal, hard, bright	2	5-1/2		10-1/2
Nigger head	. . .	. . .		[a] 2-1/2
Coal, hard, bright	. . .	. . .	1	5
Bone, soft		[a] 2	. . .	. . .
Clay mining, firm		[a] 9		[a] 10
Bone, soft		[a] 1	. . .	. . .
Coal, some bony	1	3	. . .	. . .
Coal, dull	. . .	. . .		9
Bone	. . .	. . .		[a] 8
Bone (immediate floor)		[a] 10		[a] 10
Floor, shale, overlain by 10 inches of bone				
Thickness of bed	7	3/4	7	1
Thickness in sample	3	8-1/2	3	1/2

[a] Not included in sample

Section A was taken at the face of No. 1 room, 100 feet above the 1st south entry and 95 feet south of the slope; cover at this point was 150 feet. Section B was taken in No. 4 room neck, 1st south entry, 250 feet south of the slope; cover here was 225 feet. The analysis of a composite sample made by combining samples B-40064 (section A) and B-40065 (section B) is given under laboratory No. B-40066.

Two earlier mines on this property, which are now abandoned, were drift mines. The present mine is a slope operation. From the portal at an elevation of 175 feet the slope is driven on the full dip of the bed (which averages 30° but is locally as high as 46°) for a distance of 400 feet. From the slope bottom the 1st south entry has been turned off and at the time of sampling had been driven a distance of 250 feet. Room-and-pillar mining is followed, with rooms 30 feet wide on 50-foot centers turned up the pitch from the entry. Sheet-iron-lined chutes carry the coal from the room faces to the gangway, where it is loaded into cars, trammed by hand to the slope bottom, and hoisted to the surface in two-car trips.

In mining, about 8 inches of material ranging from bone to bony coal is left up to protect the soft shale roof, and 10 inches of bone, which provides a smooth mining floor, is left down. The remainder of the bed is extracted by first cutting out by hand the center band of clay and bone, which is gobbed, and then breaking out the upper and lower benches of coal by picking. Only a little powder is required. Some 16 inches of bone and clay lying directly under the roof coal must be taken down and gobbed.

On the surface the coal is dropped by rope down an incline to the tipple, where it is sprayed with water as it is passed over 1-3/4 inch bar, 1-1/4-inch square-hole, and 7/8-inch square-hole stationary screens to produce lump, nut, pea, and slack sizes for the market. The production of the mine averaged 15 tons per day in 1938.

Alpine Mine

The Alpine mine, operated by the Alpine Coal Co., is situated in the Coos Bay field of Coos County, 1/2 mile west of Riverton in NW$\frac{1}{4}$ sec.17, T.28 S., R.13 W., and adjacent to the Coquille River, which is navigable at this point.

The Riverton bed, in which the mine operates, is a member of the Arago formation and at this point strikes N.23°E. and dips 11°E. The bed was measured and sampled at two points by M. R. Geer and J. E. Morrison, May 4 and 5, 1939, as described below:

Alpine Mine

Upper, entrance to slope.

Lower, view of track from
slope to bunker;
U.S.Highway 101 and
Coquille River in
background.

Sections of Riverton Bed in Alpine mine.

Section Laboratory No.	A B-40029		B B-40030	
Roof, soft to firm sandstone, underlain by 1 to 20 inches of shale and bone:	Ft.	in.	Ft.	in
Shale, brown [b]		[a] 1	[a] 1	3
Bone, coal streaks [c]	....			[a] 5
Coal, bone streaks		4-1/2	....	
Coal		7		7
Bone		[a] 2		[a] 2
Coal		3		7
Bone		[a] 1	....	
Shale, firm	....			[a] 1
Coal	2	1	1	6
Floor, 10 inches of smooth shale underlain by sandstone.				
Thickness of bed	3	7-1/2	4	7
Thickness in sample	3	3-1/2	2	8

[a] Not included in sample.
[b] Immediate roof in Section A.
[c] Immediate roof in section B.

Section A was taken in the crosscut connecting the slope and aircourse between the 4th and 5th south entries, 650 feet from the portal. Section B was taken at the face of the slope, 750 feet from the portal. Cover at these points was about 140 feet. The ultimate analysis of a composite sample made by combining samples B-40029 (section A) and B-40030 (section B) is given under laboratory No. B-40031.

The mine is opened by a slope started from an elevation of 100 feet and driven, at the time of sampling, 750 feet on the full dip of the bed. Entries driven both north and south from the slope and aggregating 4,000 feet in length have developed the property. From the entries rooms 25 to 40 feet wide on 65-foot centers are driven up the pitch to a depth of 200 feet. A small electric hoist on the entry, from which a rope is carried around a sheave at the room face, provides power for pulling empty cars up the rooms. Cars holding 1,500 pounds of coal are gathered on the entry by mules, hauled to the slope, and hoisted in two-car trips. Pillar recovery is limited to about 50 percent by the nature of the roof, which is a massive but somewhat loosely consolidated sandstone that caves badly during pillar extraction. The seam is mined by cutting out by hand the center 7-inch bench of coal with its enclosing bone bands; the upper and lower benches of coal can then be picked out without shooting.

At the tipple the coal is sprayed with water as it is passed over improvised vibrating screens having 3-inch round-hole, 1-inch square-hole, and 1/8-inch square-hole openings to produce lump (which is hand-picked on the screen) nut, pea, and buckwheat sizes. The mine averaged 20 tons per day in 1938.

Gilbert Mine

The Gilbert mine is in the Coos Bay field, Coos County, 3 miles west of Coquille in the NW$\frac{1}{4}$SW$\frac{1}{4}$ sec.3, T.28 S., R.13 W., at an elevation of 150 feet.

The mine is developing the upper portion of an unnamed bed, which strikes N.65°E. and dips 25°SE. The exposed portion of the bed was measured and sampled in the 1st entry, 40 feet south of the slope, by M. R. Geer and J. E. Morrison, May 6, 1939, as described below:

Section of upper bench of unnamed bed in Gilbert mine

Laboratory No.	B-40026	
Roof, smooth sandstone:	Ft.	in.
Bone, coal streaks		[a] 4
Shale, firm		[a] 2
Coal, friable		4-1/2
Shale, gray, hard		[a] 1
Coal, hard	2	10
Floor, immediate, soft carbonaceous shale, underlain by 10 feet of bone, shale, and coal, interstratified.		
Thickness of bench	3	9-1/2
Thickness in sample	3	2-1/2

[a] Not included in sample

The bed, although nowhere completely exposed, is thought to be about 14 feet thick, but only the upper 4 feet is being worked. At the time of sampling the mine was under development, and some 50 feet of slope and 60 feet of entry had been driven. The production was being sold as run-of-mine coal.

Riverton Prospect

An abandoned prospect in the Coos Bay field 2 miles northwest of Riverton, Coos County, in NE$\frac{1}{4}$ sec.12, T.28 S., R.14 W., was sampled by M. R. Geer and J. E. Morrison on September 14, 1939. The bed, which is unnamed, strikes N.-S. and dips 50°E.; it is opened by a drift driven 50 feet in a southerly direction at an elevation of about 75 feet. A section of the bed is given below:

Section of unnamed bed in Riverton prospect

Laboratory No.	B-43482	
Roof, sandstone:	Ft.	in.
Coal, bony, hard		8
Coal, hard		5
Bone, hard		1/4
Coal, friable, bright . . .	1	7
Floor, sandstone.		
Thickness of bed	2	8-1/4
Thickness in sample	2	8-1/4

Waldo Hills Mine

The Waldo Hills mine, operated by the Waldo Hills Coal Co., is in Marion County, 12 miles east of Salem, in sec.33, T.7 S., R.1 W., at an elevation of 420 feet.

The mine operates in an unnamed bed that strikes E.-W. and dips 0° to 25°S. The bed was measured and sampled on the left rib of the slope, 125 feet south of the portal, by M. R. Geer and J. E. Morrison, May 15, 1939, as described below:

Section of unnamed bed in Waldo Hills mine

Laboratory No.	B-40250	
Roof, firm sandy shale:	Ft.	in.
Shale, soft, brown		[a] 5-1/2
Coal, friable		2-1/2
Bone and shale		[a] 2
Coal, friable		1-1/2
Clay, gray, plastic		[a] 1
Coal, bright, friable		3-1/2
Clay		[a] 1/2
Coal, shale streaks		2-1/2
Shale, firm		[a] 3
Coal		4-1/4
Shale, soft, gray		[a] 6
Coal, bone streaks	1	
Shale		[a] 1/2
Coal, bright		3
Bone		[a] 2
Coal, bony		9-1/2
Bone, soft		[a] 7-1/2
Floor, smooth firm shale.		
Thickness of bed	5	6-3/4
Thickness in sample	3	2-3/4

[a] Not included in sample.

At the point of sampling and elsewhere in the mine the bed was highly irregular, the partings and benches of coal occurring more in the form of lenses than as continuous strata; hence the above section is only roughly representative of the bed.

At the time of sampling the property was under development, and a slope 150 feet long and a short drift were the only work completed. The bed dips 25°

to the south at the slope portal, but flattens to 0° at the face of the slope.

Provision was being made to screen the coal at 1-1/2 inch round-hole and 1/8-inch square-hole sizes.

Black Bear Mine

The Black Bear mine, owned by the Crater Coal Co., is in the Rogue River Valley field, Jackson County, 5-1/2 miles southeast of Medford in the W½ sec.36, T.37 S., R.1 W., at an elevation of 2050 feet.

The mine develops an unnamed bed, which strikes N.50°W. and dips 15°NE. The upper portion of the bed was measured and sampled at the face of a room advanced 50 feet up the dip from a point in the drift 800 feet southeast of the portal, by E. K. Nixon, J. E. Morrison, H. F. Yancey, and M. R. Geer, May 11, 1939, as described below:

Section of upper bench of unnamed bed in Black Bear mine

Laboratory No.		B-40115
Roof, sandstone underlain by 16 inches of bone and coal:	Ft.	in.
Coal		6
Shale, brown, firm		a 1-1/2
Bone		a 1
Coal		4
Bone		a 2-1/2
Coal		1-1/2
Bone		a 2-1/2
Coal		6-1/2
Bone		a 4
Shale, brown		a 2
Coal, bone streaks		2-1/2
Bone		a 1/2
Coal		a 1/2
Bone		a 3/4
Coal, bright		4-1/4
Bone and shale		a 5-1/2
Coal		3-1/4
Bone		a 1/2
Coal		5
Bone, soft		a 1-3/4
Bone, hard		a 2-1/2
Shale, gray		a 1/2
Coal		5-1/4
Bone		a 3-1/2
Shale, light gray		a 1/2
Shale, dark gray		a 1-1/2
Coal, bony		3-1/2
Shale and bone		a 2
Clay, light (center parting)		a 3

(continued, following page)

Section of upper bench of unnamed bed in Black Bear mine
(continued)

	Ft.	in.
Floor, main, sandstone, overlain by 6-foot lower bench of bone, shale, and coal		
Thickness of bench	6	6-1/4
Thickness in sample	3	5-3/4

[a] Not included in sample.

The lower portion of the bed is 6 feet thick and is similar in character to the upper bench but contains a smaller proportion of coal.

A drift driven about 900 feet in a southeasterly direction in the lower part of the bed and one small room in the upper portion of the bed were the extent of the mine workings at the time of sampling. Operation of the mine had been suspended.

A small tipple on the property is provided with 3/4-inch bar and 3/16-inch square-hole stationary screens to separate the coal into lump, nut, and slack sizes.

St. Helens Prospect

An abandoned prospect drift 4 miles north of St. Helens, Columbia County, in sec.18, T.5 N., R.1 W., exposes an unnamed bed at an elevation of about 300 feet. The bed is of undetermined thickness and strikes N.-S. with a dip up to 5°W. The portion of the bed exposed in the drift was measured and sampled at a point 50 feet west of the portal by M. R. Geer and J. E. Morrison, September 16, 1939, as described below:

Section of unnamed bed in St. Helens prospect

Laboratory No.	B-43483	
Roof, undetermined[b]:	Ft.	in.
Clay, gray, soft		[a] 5
Coal		[a] 2-1/2
Clay, gray, soft		[a] 3
Coal		[a] 4-1/2
Clay, gray, soft		[a] 3
Coal		[a] 4
Clay, brown		[a] 4
Coal		[a] 1
Clay, gray, sandy		[a] 10
Bone		[a] 5
Clay, gray, sandy		[a] 6-1/2
Bone, coal streaks	[a] 1	10
Coal	1	
Bone		[a] 2
Floor, undetermined[b].		
Thickness in drift	7	1/2
Thickness in sample	1	

[a] Not included in sample.
[b] Neither the roof nor floor of the bed was exposed. The section measured is overlain by at least 12 feet of clay and coal.

ANALYSES OF SAMPLES

Coal analyses have little value unless the type of sample they represent is known. Two kinds of samples are in common use - mine or face samples and samples of delivered coal. As most of the analyses presented in this report are of mine samples and these often must be interpreted in terms of delivered coal, it is well to establish the relationship between the two types of samples. Mine or face samples are taken in the mine by cutting a uniform channel 4 to 6 inches wide and 2 or 3 inches deep from the roof to the floor of the seam, as described in detail in Technical Paper 1, Federal Bureau of Mines. In so doing all partings or bands of impurity three-eighths inch or thicker and all roof and floor materials are carefully excluded from the sample. A mine sample therefore tends to represent the best quality of coal that can be produced. In fact, the sampler is more careful than the miner in excluding impurities and even more exacting than some mechanical cleaning plants. Consequently, mine samples usually contain a lower percentage of ash than can be attained in commercial shipments. This fact must be borne in mind when analyses of mine samples are interpreted in terms of delivered coal. The relationship of mine and tipple samples is discussed in the various coal-analysis technical papers of the Federal Bureau of Mines.

Samples of delivered coal, as differentiated from mine samples, are taken as cars or trucks are loaded for shipment at the mine or unloaded at their destinations. They therefore represent the commercial product as shipped and hence contain any impurities that are not removed in preparing the coal. Samples of delivered coal frequently contain 2 or 3 percent more ash than face samples. Rarely, however, one or more sizes of delivered coal contain as low or even lower percentages of ash than the mine samples, due to a segregation of coal from the cleanest portion of the bed in those particular sizes.

Only mine or face samples were taken in this investigation. Sampling of delivered coal was not feasible, for some of the mines were not producing and others were producing only very little coal as the sampling was carried out in the late spring. However, analyses of delivered coal from one mine sampled in 1933 are included in this report.

The analyses of mine samples are given in table 2, which is arranged geographically with respect to counties and towns. Each analysis is given for three conditions, as follows: (1) As received, (2) moisture free, and (3) moisture and ash free. The as-received condition represents the sample as received at the laboratory. The sample was put into an airtight can in the mine, and hence it contained all of the moisture, both that inherent and characteristic of the particular coal and any extraneous water present on the coal face at the point of sampling. The moisture-free condition represents the composition and heating value of the moisture-free or dry coal, that is, excluding all of the inherent and extraneous moisture removed by drying at 105°C. The moisture- and ash-free condition represents approximately the composition and calorific value of the coal substance itself, free of moisture and all associated ash-forming constituents. Thus, conditions 2 and 3 do not represent the coal as it occurs naturally in the bed and hence are useful only for comparative purposes. Condition 1, or the as-received analysis, represents the natural coal in the bed and therefore is the most useful of the three in judging the quality of commercial shipments, allowance being made, of course, for the lower ash content of mine samples compared with that of delivered coal.

Table 2.--Analyses of mine samples

Location, county and town	Mine	Bed	Location in mine	Sample: Condition [1]	Sample: Laboratory No.
1	2	3	4	5	6
COLUMBIA COUNTY					
St. Helens, 4 miles north of.	St.Helens Prospect	Unnamed	Face of drift,50 feet west of portal	1 2 3	B-43483
COOS COUNTY					
Coquille, 2½ miles west of.	Gilbert	Unnamed	1 south entry, 40 feet south of slope	1 2 3	B-40026
Marshfield, 6 miles south of.	Southport	Southport	Morrisoul room, upper works,2300 feet north of portal	1 2 3	A-90058
Do.	do.	do.	9 room pillar, 1 north entry, 2400 feet north of portal	1 2 3	B-40027
10 miles south of.	Thomas	Beaver Hill	13 room, 60 feet above entry, 600 feet north of portal	1 2 3	B-40028
11 miles south of.	Overland	do.	1 room, 100 feet above 1 south entry, 95 feet south of slope	1 2 3	B-40064
Do.	do.	do.	4 room neck, 1 south entry 250 feet south of slope	1 2 3	B-40065
Do.	do.	do.	Composite of B-40064 and B-40065	1 2 3	B-40066
Riverton, 1/2 mile west of	Alpine	Riverton	Crosscut off slope between 4 and 5 south entries	1 2 3	B-40029
Do.	do.	do.	Face of slope, 750 feet from portal	1 2 3	B-40030
Do.	do.	do.	Composite of B-40029 and B-40030	1 2 3	B-40031
2 miles west of.	Riverton Prospect	Unnamed	Face of drift,50 feet south of portal	1 2 3	B-43482

[1] 1, sample as received; 2, dried at a temperature of 105° C.; 3, moisture and ash free.

Sample laboratory No.	Proximate percent: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate percent: Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Air-dry loss, percent	B.t.u.	Ash softening temperature, °F.	Agglomerating index	Subbituminous rank or lignite
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
B-43483	29.4	29.2	25.4	16.0	2.4	6.3	38.3	.5	36.5	18.0	6690	2230	NAa	Lignite
	----	41.4	35.9	22.7	3.3	4.3	54.2	.7	14.8	----	9470			
	----	53.5	46.5	----	4.3	5.5	70.2	.9	19.1	----	12250			
B-40026	16.4	35.0	36.9	11.7	.6	6.0	52.7	1.2	27.8	8.1	9260	2370	NAa	B
	----	41.9	44.1	14.0	.7	5.0	63.1	1.4	15.8	---	11080			
	----	48.7	51.3	----	.8	5.8	73.3	1.7	18.4	---	12880			
A-90058	17.2	33.6	40.8	8.4	.6	6.2	56.1	1.2	27.5	3.3	9880	2080	---	B
	----	40.6	49.2	10.2	.8	5.1	67.8	1.5	14.6	---	11940			
	----	45.2	54.8	----	.8	5.7	75.4	1.6	16.5	---	13290			
B-40027	16.7	33.4	40.4	4.5 (9.3)	.5	6.0	55.6	1.3	27.1	7.7	9720	2100	NAa	B
	----	40.2	48.3	11.5	.6	4.9	66.8	1.6	14.6	--	11670			
	----	45.3	54.7	----	.7	5.5	75.5	1.8	16.5	---	13180			
B-40028	16.9	34.6	42.8	5.7	.5	6.2	57.5	1.4	28.7	9.1	10080	2340	NAa	B
	----	41.7	51.5	6.8	.6	5.2	69.3	1.6	16.5	---	12140			
	----	44.8	55.2	---	.7	5.6	74.3	1.8	17.6	---	13030			
B-40064	16.7	35.7	42.2	5.4	.7	---	----	---	----	6.4	10150	2330	NAa	B
	----	42.8	50.7	6.5	.9	---	----	---	----	---	12190			
	----	45.8	54.2	---	.9	---	----	---	----	---	13030			
B-40065	18.5	33.4	41.2	6.9	.7	---	----	---	----	7.6	9760	1990	NAa	B
	----	41.0	50.6	8.4	.8	---	----	---	----	---	11970			
	----	44.8	55.2	---	.9	---	----	---	----	---	13070			
B-40066	17.9	34.4	41.5	6.2	.7	6.3	57.0	1.3	28.5	7.0	9960		NAa	B
	----	41.8	50.7	7.5	.9	5.2	69.4	1.5	15.5	--	12130			
	----	45.2	54.8	---	.9	5.6	75.1	1.7	16.7	---	13120			
B-40029	19.3	32.8	40.3	7.6	.7	---	----	---	----	9.4	9250	2320	NAa	B
	----	40.6	50.0	9.4	.8	---	----	---	----	---	11460			
	----	44.8	55.2	---	.9	---	----	---	----	---	12650			
B-40030	19.6	32.6	40.9	6.9	.6	---	----	---	----	10.1	9310	2340	NAa	B
	----	40.5	50.9	8.6	.7	---	----	---	----	---	11580			
	----	44.3	55.7	---	.8	---	----	---	----	---	12670			
B-40031	19.3	32.6	40.9	7.2	.6	6.1	53.8	1.4	30.9	9.8	9280		NAa	B
	----	40.4	50.6	9.0	.7	4.8	66.7	1.7	17.1	---	11500			
	----	44.4	55.6	---	.8	5.3	73.3	1.9	18.7	---	12640			
B-43482	10.1	36.1	37.8	16.0	4.3	5.5	55.1	.9	18.2	3.5	10080	2070	NAb	A
	----	40.1	42.1	17.8	4.8	4.9	61.3	1.0	10.2	---	11220			
	----	48.8	51.2	----	5.9	5.9	74.6	1.2	12.4	---	13650			

Location, county and town	Mine	Bed	Location in mine	Sample: Condition [1]	Sample: Laboratory No.
1	2	3	4	5	6
JACKSON COUNTY					
Medford, 5½ miles southeast of.	Black Bear	Unnamed	Face of room 800 feet southeast of portal, 50 feet above drift.	1 2 3	B-40115
MARION COUNTY					
Salem, 12 miles east of.	Waldo Hills	Unnamed	Slope, 125 feet south of portal.	1 2 3	B-40250

Sample laboratory No.	Proximate percent: Moisture	Proximate percent: Volatile matter	Proximate percent: Fixed carbon	Proximate percent: Ash	Sulfur	Ultimate percent: Hydrogen	Ultimate percent: Carbon	Ultimate percent: Nitrogen	Ultimate percent: Oxygen	Air-dry loss percent	B.t.u.	Ash softening temperature, °F.	Agglomerating index	Subbituminous rank or lignite
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
B-40115	9.1	30.0	31.8	29.1	1.5	4.8	47.9	.9	15.8	4.1	8560	2280	NAb	A
	---	33.0	35.0	32.0	1.7	4.1	52.7	1.0	8.5	---	9410			
	---	48.6	51.4	----	2.5	6.1	77.5	1.5	12.4	---	13850			
B-40250	22.0	25.1	39.0	13.9	.8	5.9	48.0	.6	30.8	11.3	8280	2710	NAa	B
	----	32.1	50.1	17.8	1.0	4.4	61.5	.7	14.6	----	10610			
	---	39.1	60.9	----	1.2	5.3	74.8	.9	17.8	----	12900			

In the table, columns 7 to 11 give the proximate analysis and columns 11 to 16 the ultimate analysis. The calorific value or heat of combustion, in British thermal units per pound, is given in column 18. Column 19 shows the ash-softening temperature, which represents the temperature at which a cone of coal ash fuses to a spherical lump when heated in a furnace in a slightly reducing atmosphere. This determination is a rough indication of the clinkering tendencies of a coal. The agglomerating index and rank of coal, shown in columns 20 and 21, respectively, will be discussed under Rank of Coal.

A noticeable feature of the table of analyses is the similarity in the composition of the Coos Bay coals. Except for the coal from the Riverton prospect, which is lower in moisture and somewhat higher in ash and sulfur content, these coals are similar in composition, in heating value, and in the softening temperature of their ash. An analysis typifying the Coos Bay coals would show 17 percent moisture, 8 percent ash, less than 1 percent sulfur, an ash-softening temperature of 2,200° F., and a heating value of 9,700 B.t.u. per pound, on the as-received basis.

The Waldo Hills coal is similar in character, although somewhat higher in moisture content and consequently lower in heating value. This coal is the only one having a high ash-softening temperature, namely, 2,710° F. Coal from the St. Helens prospect is distinguished by its decidedly higher moisture content and consequent lower heating value, and the Black Bear coal is marked by an unusually high percentage of ash.

Table 3 gives the analyses of delivered lump, nut, and slack coal sampled at the Southport mine, Marshfield, Oregon, in 1933 by S. H. Ash of the Federal Bureau of Mines. These analyses, when compared with those for the corresponding mine samples shown in table 2, illustrate the relationship between the two types of samples. The nut and slack sizes of delivered coal contain particles of impurity excluded from the mine samples and hence are higher in ash content, but the lump coal is derived largely from the cleanest coal in the bed and therefore contains a lower percentage of ash than that shown by the mine samples.

All of the Coos Bay coals are associated with friable impurities, such as shale and clay, which tend to break up in mining and contaminate the finer sizes of coal; hence these sizes are generally higher in ash content, and correspondingly lower in heating value, than the coarse coal. Washing of the coal would, of course, remedy this condition. A washability examination of coal from the Beaver Hill bed was made by the Northwest Experiment Station of the Federal Bureau of Mines in cooperation with the University of Washington in an earlier investigation.10/

10/ - McMillan, E. R., and Bird, B. M., Coal-Washing Problems of the Pacific Northwest: University of Washington Eng.Exp.Sta. Bull. 28, 1924, pp.221-228.

Table 3

Proximate analyses of delivered coal from Southport mine, Marshfield, Oreg.

Size of coal	Condition[1]	Moisture, percent	Volatile matter, percent	Fixed carbon, percent	Ash, percent	Sulfur percent	B.t.u. per pound	Ash-softening temperature, °F.
Lump [2]	1	16.3	34.6	41.1	8.0	0.6	9,990	2130
	2	----	41.3	49.2	9.5	.7	11,950	
	3	----	45.7	54.3	----	.8	13,210	
Nut [2]	1	16.0	32.8	39.5	11.7	.6	9,600	2130
	2	----	39.1	46.9	14.0	.7	11,440	
	3	----	45.4	54.6	----	.8	13,290	
Slack[2]	1	20.2	29.9	33.9	16.0	.5	8,320	2190
	2	----	37.4	42.5	20.1	.6	10,430	
	3	----	46.8	53.2	----	.8	13,050	

[1] 1, Sample as received; 2, moisture-free; 3, moisture and ash free.

[2] Lump, over 1-1/2-inch round-hole screen; nut, through 1-1/2-inch round-hole and over 5/8-inch square-hole screens; slack, through 5/8-inch square-hole screen.

RANK OF COAL

All of the coals sampled are of subbituminous or lignitic rank. The designation of rank shown in column 21 of table 2 is in accordance with the system of classification of coals by rank adopted by the American Society for Testing Materials 11/. Briefly, the classification of subbituminous and lignitic coals is based upon their heating value and their weathering and agglomerating properties. Coals of these ranks weather or slack on exposure to the air after mining. They do not agglomerate (that is, they do not form a coherent button in the volatile-matter determination of the proximate analysis), and they have a heating value of less than 13,000 B.t.u., on the moist mineral-matter-free basis. The moist mineral-matter-free B.t.u. of subbituminous A coals is 13,000 to 11,000, of sub-bituminous B coals 11,000 to 9,500, and of lignites less than 8,300.

Weathering properties are discussed more fully in a following portion of this report. Agglomerating indices are given in column 20 of table 2. The symbols NAa and NAb both indicate a nonagglomerating coal.

FRIABILITY

Friability, as the term is applied to coal, refers to the tendency of a coal to be broken or suffer degradation in size during the handling incident to mining, transportation, and use. It is a composite physical property embracing the over-all effects of hardness, cleavage, fracture, and elasticity. The larger sizes of coal still command a premium on the domestic market, hence the friability of a coal - its tendency toward reduction in size on handling - is a factor of economic importance to producers and jobbers of coal. Only recently has it been possible to assign numerical values to relative degrees of friability by means of a laboratory test.

A sample for friability tests was obtained in each mine at the same localities as were selected for taking analysis samples. If one sample for analysis was taken, the friability sample came entirely from that one place; if two analysis samples were taken, the friability sample was made up of equal amounts of material from the two sampling locations. In either instance, the sample was composed of about 5 pounds of pieces 1-1/2 inches to 1 inch in size, screened from material representing the full minable thickness of the bed, and it was sealed in a can until tested.

The friability test employed is a tentative standard method of the American Society for Testing Materials 12/. Briefly, the test is designed to simulate in the laboratory the forces of impact and attrition experienced by coal in actual handling. A 1,000-gram sample of coal carefully screened between 1-1/2 and 1-inch square-hole screens is tumbled for 2,400 revolutions in a special jar mill

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11/ - A.S.T.M. Standards on Coal and Coke, 1938, p.104; 1938 Supplement to Book of A.S.T.M. Standards, p.157.

12/ American Society for Testing Materials, Tentative Method of Tumbler Test for Coal Proc.: vol.37, part 1, 1937, pp.827-831 fitted with lifters that alternately lift and drop the coal. After tumbling, the coal is removed from the mill and screen-sized with six screens ranging from 1 inch to 48 mesh in size. From the screen analysis, the friability index is calculated as the percentage reduction in average particle size caused by tumbling in the jar mill. Thus coals that break up readily in the mill are greatly reduced in average particle size and yield a high friability index, but tougher coals that resist degradation in size come from the mill with nearly the same average size of particle as the original feed coal and hence give a low friability index.

Table 4 gives the friability indices of the coals tested; they range from 13.4 percent for the St. Helens lignite to 37.6 percent for two of the Coos Bay coals. Values in this range are typical of the sub-bituminous coals of the West. They are similar to the friability indices of anthracite, commonly called "hard coal" because of its ability to withstand breakage, and decidedly lower than those for the friable low-volatile bituminous coals, some of which have friability indices up to 90 percent. The friability indices of the Oregon coals indicate that they will, under ordinary conditions, withstand breakage well in mining and preparation and consequently yield a relatively large proportion of the coarser sizes of coal.

Table 4.--Friability indices of Oregon coals, averages of four determinations.

Mine	Bed	Friability, percent
St. Helens prospect	Unnamed	13.4
Gilbert	do	21.2
Southport	Southport	27.6
Thomas	Beaver Hill	27.3
Overland	do	32.0
Alpine	Riverton	29.9
Riverton prospect	Unnamed	37.6
Black Bear	do	31.0
Waldo Hills	do	37.6

Purely from the standpoint of the external forces that cause degradation in size on handling - the forces simulated in the friability test - these coals also would withstand handling in the operations that follow after a coal is prepared, such as storage, transportation, and use. However, the degradation in size that occurs in these subsequent operations is, with subbituminous coals, determined more by their weathering or slacking properties than by their friability.

SLACKING CHARACTERISTICS

Subbituminous coals and lignites show a pronounced tendency to disintegrate or slack on exposure to the weather, particularly when alternately wetted and dried or subjected to hot sunshine. This troublesome property of low-rank coals is attributable to their high moisture content. When they are exposed to dry atmosphere after removal from the mine they lose moisture rapidly. As the moisture is lost from surface layers, shrinkage causes stresses that result in cracking and disintegration. Slacking, like the handling of a friable coal, causes the formation of excessive amounts of fine material at the expense of the coarser sizes, thus decreasing the value of the coal for some uses. Storage of coals that slack readily is unsatisfactory not only because of the loss of the more valuable coarse sizes but also because slacking greatly increases the tendency of coal to ignite spontaneously, owing to the increased surface area exposed.

A laboratory test developed by the Federal Bureau of Mines 13/, in which natural slacking is accelerated to permit laboratory determination of slacking characteristics, was applied to the Oregon coals. Samples for this test were obtained at each location in the mine chosen for taking the analysis sample, the coal being obtained in the form of pieces approximating 1-1/4-inch cubes selected from material representing the full minable thickness of the seam. Essentially, the test consists in drying 500 to 1,000 grams of the sample for 24 hours under controlled conditions of temperature and humidity. The sample is then immersed in water for 1 hour and again dried for 24 hours. After the second drying period the coal is sieved on a 3-mesh Tyler standard sieve to determine the amount of degradation in size caused by slacking. The percentage of material passing the 3-mesh sieve, adjusted for the amount of undersize due to normal breakage during screening, is the slacking index.

Table 5.--Average slacking indices of Oregon coals

Mine	Bed	Slacking index, [1] percent
St. Helens prospect	Unnamed	29.9
Gilbert	do.	29.4
Southport	Southport	24.9
Thomas	Beaver Hill	50.1
Overland	do	37.7
Alpine	Riverton	66.8
Riverton prospect	Unnamed	6.4
Black Bear	do	15.0
Waldo Hills	do	34.3

[1] Average of 2 to 4 determinations.

13/ - Fieldner, A. C., Selvig, W. A., and Frederic, W. H., Accelerated Laboratory Test for Determination of Slacking Characteristics of Coal: Bureau of Mines Rept. of Investigations 3055, 1930, 24 pp.

Slacking indices for the Oregon coals, shown in table 5, range from a low of 6.4 percent for the Riverton prospect to a maximum of 66.8 percent for coal from the Alpine mine. Coals having slacking indices of less than 5 percent are considered nonslacking, and indices of 5 to 15 percent represent coals that slack slightly. Moderate slacking is indicated by indices from 15 to 35 percent, and coals having indices of over 35 percent are strongly slacking.

Experience with subbituminous coals that are strongly slacking indicates that they cannot be stored without excessive degradation in size owing to slacking unless the loss of moisture can be prevented during dry weather. When the relative humidity is high, as during the winter months in western Oregon, storage of these high-moisture coals is more satisfactory. The resistance of a coal to the forces causing degradation in size during mining, transportation, and storage is, in general, well-defined by the laboratory friability and slacking tests.

LOW-TEMPERATURE CARBONIZATION ASSAY

A laboratory study of the low-temperature carbonization of Oregon coal was undertaken to provide information on this method of processing low-rank coals to obtain premium fuel. Duplicates of each analysis sample were retained for this work. Where more than one analysis sample was taken the duplicates were combined in equal proportions to obtain an average sample for the mine.

Low-temperature carbonization of coal may be defined as the heat treatment of coal in the absence of air at temperatures of 450° to 700° C. as distinguished from the usual high-temperature carbonization at temperatures of 900° to 1200° C. The principal aim of the process is to produce a smokeless, easily ignitable solid fuel for domestic use and at the same time to recover a maximum yield of liquid byproducts. The solid fuel obtained from coking coals is a coke containing 7 to 15 percent volatile matter and from coals that do not coke a char of similar volatile content. Ordinarily the char, or a major portion of it, depending on the size of the coal originally charged, must be briquetted to convert it into a form suited to domestic use. The usual byproducts of gas, tar, and light oil are recovered, but the yield of tar is about twice as high as is obtained in normal byproduct coking.

Low-temperature carbonization has been considered an ideal means of converting high-moisture subbituminous and lignitic coals into premium fuels for domestic use; however, much of the cost of the process must be borne by the coke, as the value of the tar and oil is determined largely by the price of fuel oil. Enough inducement to warrant general application of the process on a commercial scale must await possible future changes in the value of the products, both solid and liquid. Only two plants surrounded by especially favorable conditions are now being operated in this country. One is operated by the Pittsburgh Coal Carbonization Co. of Pittsburgh, Pa., and the other is the plant of the Lehigh Briquetting Co. at Dickinson, N.Dak. A detailed discussion of the technical and economic aspects of commercial low-temperature carbonization is not included in this report because these factors have been described in a previous publication of the Federal Bureau of Mines 14/.

14/ - Fieldner, A. C., Low-Temperature Carbonization of Coal: Tech.Paper 396, Bureau of Mines, 1926, 46 pp.

Details of the low-temperature assay procedure used will be found in a previous publication 15/. Briefly, 250 grams of coal crushed to pass 10 mesh is placed in a specially designed aluminum retort, to which are connected in series an ice-cooled tar receiver, a condenser, a glass tube filled with activated charcoal to entrap any tar and light oil mists escaping the condenser, and a gas receiver. The retort is heated to a maximum temperature of 550° C. and maintained at that temperature for 2-1/2 hours. The distillation products pass from the retort, the oils, tar, and water being caught in the condensing system or the activated charcoal and the gas collected in the gas receiver. Later the water is separated from the oils and tar so that the quantity of the four products of the assay (namely, char, tar and oils, gas, and water) can be measured. The gas is analyzed to determine the constituents present and to enable its calorific value to be calculated.

Table 6 presents the results of the low-temperature assays. The figures for each mine are averages of duplicate assays. The results were calculated to the as-received basis from the air-dry basis on which the laboratory determinations were made.

Agglutinating tests on the original samples indicated that all of the coals are noncoking. This finding was borne out by the assays, for all of the coals produced noncoherent granular chars rather than cokes. In fact, visual examination revealed no difference in appearance between the carbonized char and the original coal. Analysis, however, showed that carbonization effects a decided change in chemical properties. As an illustration, the analysis and heating value of the char produced from the coal from the Thomas mine are shown in the following tabulation, in comparison with corresponding figures for the original coal:

Analyses and heating values of Thomas mine coal and resulting char, as-received basis

	Coal, percent	Char percent
Moisture	16.9	1.1
Volatile matter	34.6	11.6
Fixed carbon	42.8	77.8
Ash	5.7	9.5
Sulfur	.5	.4
B.t.u. per pound	10,080	13,200

15/ - Yancey, H. F., Johnson, K. A., and Selvig, W. A., Friability, Slacking Characteristics, Low-Temperature Carbonization Assay, and Agglutinating Value of Washington and Other Coals: Tech. Paper 512, Bureau of Mines, 1932, pp.61-84.

Table 6.--Results of low-temperature carbonization assay, calculated to as-received basis.

Product	St. Helens prospect	Gilbert	Southport	Thomas	Overland	Alpine	Riverton prospect	Black Bear	Waldo Hills
Moisture in coal, percent	29.4	16.4	16.7	16.9	17.9	19.3	10.1	9.1	22.0
Yield, percent									
Char	46.7	55.3	57.3	55.3	55.4	55.0	60.4	69.7	58.6
Gas	10.3	9.1	9.1	9.3	9.7	10.3	10.8	6.3	7.6
Tar and Oil	7.1	11.9	10.9	10.7	8.4	5.8	11.7	9.2	3.7
Water	36.8	24.1	23.0	25.0	27.0	29.0	17.6	15.8	30.8
Total	100.9	100.4	100.3	100.3	100.5	100.1	100.5	101.0	100.7
Yield, per net ton of coal									
Char, pounds	934	1106	1146	1106	1108	1100	1208	1394	1172
Gas, cubic feet (wet) 1	2949	2982	3110	3048	3195	3179	3236	2326	2453
Tar and oil, gallons	17.0	28.4	26.1	25.7	20.2	13.8	28.2	22.1	8.7
Gas analysis, volume, percent 2									
CO_2	40.1	26.4	25.4	23.7	25.7	29.5	30.2	16.3	28.6
Illuminants	2.8	2.5	1.4	3.7	2.5	2.6	3.8	3.9	2.4
CO	8.5	10.3	9.2	11.5	9.8	10.8	6.7	7.3	11.8
H_2	17.4	17.7	20.3	15.8	17.9	15.5	13.3	17.0	18.3
CH_4	26.7	35.1	36.1	36.6	36.0	33.0	33.7	45.7	34.5
C_2H_6	3.3	7.0	5.1	6.6	6.7	6.7	11.1	7.4	2.0
N_2	1.2	1.0	2.5	2.1	1.4	1.9	1.2	2.4	2.4
Gross B.t.u. of gas 1, 3 cu.ft.	456	609	572	633	611	578	662	733	519

1 At 60° F. and 29.92 inches of mercury.
2 Calculated to air-free basis.
3 Calculated from analysis.

As the foregoing results indicate, carbonization eliminates the moisture and much of the volatile matter and in consequence increases the proportion of fixed carbon and ash and materially benefits the heating value. The char, which contains only hygroscopic moisture, is thus a high-quality fuel, easily ignitable, smokeless, and high in heating value. The yield of char is lowest for the St. Helens lignite because of its high moisture content and low rank, and highest for the Black Bear coal because of its relatively low moisture content and high percentage of ash. It should be stressed that since all of the coals yield chars rather than cokes, a commercial low-temperature carbonization operation would necessarily have to include provision for briquetting most if not all of the char to render it suitable for domestic use.

The quantity of gas produced on carbonization is similar for all of the coals, but its composition differs and the heating value ranges from 733 B.t.u. per cubic foot for the Black Bear coal to only 456 B.t.u. for the St. Helens lignite. This circumstance bears out the usual relationship between rank of coal and quality of gas; the lower-rank coals yield gas containing more CO_2 than coals of higher rank. The yield of tar and oil ranged from 3.7 percent for coal from the Waldo Hills mine to 11.9 percent for the Gilbert coal. The character of the tar and oil was not determined.

HYDROGENATION OF COAL

By means of hydrogenation - a process in which coal is treated with hydrogen under high temperature and pressure - the products now obtained from petroleum can be produced from coal. Gasoline and fuel oil are being produced on a commercial scale by coal hydrogenation in Germany and England. The hydrogenation process is expensive, however, and liquid fuels obtained from coal are more costly than those derived from petroleum. Consequently, commercial application of the process in this country must await the time when our reserves of petroleum approach exhaustion, thus necessitating a supplementary source for the more expensive liquid fuels. Nevertheless, in anticipation of the time when the hydrogenation of our coals may be required, the Bureau of Mines is testing various ranks and types of American coals to determine their amenability to the hydrogenation process.

A 40-pound sample of coal from the Thomas mine was sent to the Central Experiment Station of the Bureau, Pittsburgh, Pa., for a small-scale hydrogenation test. The coal was hydrogenated for 3 hours in a 1-liter rotating bomb at a temperature of 430° C. and an initial (cold) pressure of 1,500 pounds per square inch of hydrogen. Eighty-eight percent of the coal, on the moisture-free basis, was liquefied, and 12 percent remained as an unliquefied residue. Of this residue, about 5 percent was ash and 7 percent unliquefied coal. Of the 7 percent of unliquefied coal, 5 percent was of such a nature that it probably could have been liquefied had a higher pressure of hydrogen been employed. These tests indicate that this coal would be satisfactory for full-scale commercial hydrogenation.

More detailed information on the hydrogenation of coal and on the procedure employed in this test will be found in previous publications of the Federal Bureau of Mines 16/.

16/ - Storch, H.H., Hirst, L.L., Golden, P.L., and others; Coal Hydrogenation; U.S. Bureau of Mines Experimental Plant: Jour. Ind. Eng. Chem., vol. 29, 1937, pp. 1377-1380. Fieldner, A.C., Annual Report of Research and Technologic Work on Coal, Fiscal Year 1937: Bureau of Mines, Inf. Circ. 6992, 1938, pp. 37-39. Annual Report of Research and Technologic Work on Coal, Fiscal Year 1938: Bureau of Mines, Inf. Circ. 7052, 1939, pp. 38-44.

FLOAT-AND-SINK TESTS OF COAL FROM THE BLACK BEAR MINE

Consideration was given to the possibility of improving the quality of coal from the Black Bear mine, 5-1/2 miles southeast of Medford, by mechanical cleaning. This coal contains such a large proportion of associated impurities that mining would not be warranted under ordinary circumstances. However, coal shipped into the Medford area carries a high freight rate and consequently brings a price that offers considerable incentive to the operation of a local mine. For this reason, a washability examination of the coal was undertaken, despite the fact that both the analysis of the mine sample and the character of the bed indicated that the problem was forbidding.

A sample consisting of 1,600-pounds of material representing the upper 8 feet of the bed and about 1,100 pounds from the lower 6 feet of the bed was sent to the laboratory for examination. Ash analyses of the two lots of material were made before the float-and-sink tests to determine roughly the relative quality of the two portions of the bed. These analyses showed that the upper portion of the bed contains 51 percent ash on the moisture-free basis and the lower portion 62 percent, thus indicating that the lower portion of the bed contains decidedly more impurity and, of course, correspondingly less coal. Calculations based upon subsequent float-and-sink tests indicated that the lower portion of the bed probably contains little more than half as much material of under 1.70 specific gravity as that found in the upper part of the bed. The natural advantages inherent in mining the full height of the seam (nearly 14 feet) probably would be more than offset by the difficulty of handling the larger amount of impurity in the bottom portion of the bed. Consequently, the float-and-sink tests were confined to the material from the upper 8 feet of the bed, the remainder of the material being excluded as too impure to warrant examination.

The section of the upper portion of the bed is shown on pages 15-16. All of the materials indicated in the section (that is, all of the partings and bands of impurity, as well as the coal) were included in the sample; also included was 1 foot 10 inches of coal and bone directly overlying the section shown. Thus the sample represents the product that would be obtained in mining this portion of the seam if no impurities were removed and gobbed underground. Partial cleaning of the coal at the face probably would not be feasible because of the large number and relative thinness of the partings.

As received in the laboratory, the sample contained a small percentage of material coarser than 3 inches in size. These lumps, composed largely of impurities, were broken to pass a 3-inch round-hole screen and added to the balance of the material, thereby limiting the range of sizes to that suited to treatment in coal-washing jigs.

A float-and-sink test was made on 500 pounds of the 3-inch to 0 material, in two sizes, namely, over and under 20 mesh, using specific gravities of 1.40, 1.50, and 1.70. The resulting specific-gravity fractions of the 3-inch to 20-mesh oversize were then screened at 1-inch and 1/4-inch round-hole size, and the percentage of ash in each size of material was determined. From the information obtained, the specific-gravity composition of each size component in the raw coal was calculated. The slight inaccuracies involved in screen sizing after the float-and-sink test, owing to size degradation of the sink 1.70 fraction during the manipulation, rather than testing each size of the raw coal separately, are not important in a preliminary investigation of this type.

A second float-and-sink test was made on a portion of the 3-inch to 0 material crushed to pass a 1/2-inch round-hole screen to determine what increase in yield of clean coal could be made if all of the coal were crushed to a size suitable for tabling or other cleaning processes adapted to fine coal.

Table 7 shows the results of the float-and-sink tests for each size of material in the original sample and for the product crushed to 1/2-inch size. The table is arranged to show, for each size of material, the weight percentage occurring within each specific-gravity fraction, its ash content, and the cumulative weight and percentage of ash at each specific gravity.

Inspection of the figures in the table shows immediately that every size of the Black Bear coal contains an unusually large proportion of heavy impurities high in ash content. More than half of the material is over 1.70 in specific gravity. Consequently, yields of float coal, even at high percentages of ash, are small, and a low-ash product is out of the question.

Table 7.--Results of float-and-sink tests on coal from Black Bear mine

Product [1]	Specific gravity	Weight, percent	Ash, [1] percent	Cumulative Weight percent	Cumulative Ash, [2] percent
3 inch to 1 inch	Under 1.40	9.3	15.5	9.3	15.5
Weight, percent, 43.2	1.40 to 1.50	16.4	23.5	25.7	20.6
	1.50 to 1.70	24.4	37.3	50.1	28.7
	Over 1.70	49.9	73.0	100.0	50.8
1 inch to 1/4 inch	Under 1.40	13.5	13.2	13.5	13.2
Weight, percent, 41.5	1.40 to 1.50	16.0	23.7	29.5	18.9
	1.50 to 1.70	18.3	40.4	47.8	27.1
	Over 1.70	52.2	75.2	100.0	52.2
1/4 inch to 20 mesh	Under 1.40	28.5	9.7	28.5	9.7
Weight, percent, 10.4	1.40 to 1.50	15.2	24.3	43.7	14.8
	1.50 to 1.70	14.6	39.5	58.3	21.0
	Over 1.70	41.7	74.5	100.0	43.3
Through 20 mesh	Under 1.40	25.1	7.1	25.1	7.1
Weight, percent, 5.9	1.40 to 1.50	12.5	19.5	37.6	11.2
	1.50 to 1.70	10.5	36.4	48.1	16.7
	Over 1.70	51.9	73.9	100.0	46.4
Composite, 3 inch to 0	Under 1.40	13.5	12.6	13.5	12.6
Weight, percent, 100.0	1.40 to 1.50	15.6	23.5	29.1	18.4
	1.50 to 1.70	19.6	38.6	48.7	26.6
	Over 1.70	51.6	74.1	100.0	51.0
All crushed to pass 1/2 inch	Under 1.40	19.8	10.8	19.8	10.8
	1.40 to 1.50	13.8	22.8	33.6	15.7
Weight, percent, 100.0	1.50 to 1.70	15.1	39.0	48.7	22.9
	Over 1.70	51.3	74.9	100.0	49.6

1 Moisture-free basis
2 All round-hole sizes except 20 mesh.

A convenient method of interpreting the float-and-sink data is to establish the highest percentage of ash that probably would be tolerated in a commercial product, and then to determine, by means of interpolation between the figures for the several specific gravities, the yields of float coal of that ash content in each size of the raw coal. As 20 percent ash, on the moisture-free basis, is the upper limit for coals currently marketed in Washington, it may logically be applied to this coal. Utilizing this limit in ash, table 8 shows the yield of float coal in each size, expressed both as a percentage of that size and as a percentage of the total 3-inch to 0 material. It gives, in addition, the specific gravities at which each separation would have to be made to obtain a 20-percent-ash product, and, finally, the estimated recovery of washed coal to be expected from an actual washing operation. The estimate of washed-coal recovery is based upon the assumption that a washer would recover 80 percent of the float coal of 20-percent ash shown to be present by the float-and-sink test. The efficiency of 80 percent is necessarily speculative, for no comparative data are available on washing coal as difficult to clean as is the Black Bear.

Table 8 shows that the yield of float coal at 20 percent ash ranges from 23.5 percent of the 3-inch to 1-inch size to 56 percent of the material between 1/4 inch and 20 mesh in size. For the 3-inch to 0 coal as a whole, the yield of float coal is 33 percent at a specific gravity of 1.53. An actual washing operation probably would recover 26.4 percent of washed coal having 20 percent ash, made up of about one-third 3-inch to 1-inch material and two-thirds 1-inch slack.

Table 8.--Yields of float coal and washed coal having 20 percent ash, coal from Black Bear mine

Screen size [1]	Weight, percent	Specific gravity of separation	Float coal containing 20 percent ash [2] Percent of size	Float coal containing 20 percent ash [2] Percent of total raw coal	Estimated recovery of washed coal of 20 percent ash,[2] percent of total raw coal
3 to 1	43.2	1.49	23.5	10.2	8.2
1 to 1/4	41.5	1.52	32.0	13.3	10.6
1/4 to 20 mesh	10.4	1.65	56.0	5.8	4.6
Through 20 mesh	5.9	1.70 +	54.0	3.2	2.6
3 to 0	100.0	1.53	33.0	33.0	26.4
Through 1/2 inch	100.0	1.60	43.0	43.0	34.4

[1] All round-hole sizes except 20 mesh.
[2] Moisture-free basis.

The bottom line of table 8 gives the data for crushing all of the coal to pass 1/2 inch before washing. A separation at 1.60 specific gravity yields 43 percent of float coal having 20 percent ash, and washing on a table probably would allow the recovery of 34.4 percent of cleaned coal at that ash content. An 8-percent gain in the yield of washed coal at 20 percent ash is thus possible if the material is crushed to 1/2 inch rather than 3 inch.

Summarizing, a yield of 26.4 percent or about one-fourth of washed coal of 20 percent ash probably could be attained in washing a 3-inch to 0 size. By crushing to 1/2 inch this yield could be increased to 34.4 percent or about one-third of washed coal.

Naturally, the cleaned product obtained in a washing operation must bear the total cost of mining and preparing all of the raw coal. If most of the material must be rejected as refuse, as in the case of this coal, and the total cost of the operation borne by the remaining one-fourth or one-third of cleaned coal, the cost of the product becomes prohibitive. Consequently, the extremely low yields of high-ash washed coal obtainable at the Black Bear mine would seem to preclude any possibility of a profitable operation. This conclusion is, naturally, based entirely upon the character of the sample examined. If additional prospecting should develop an area of coal containing materially less impurity, washing of the coal might become feasible.

BURNING TESTS

In May 1938, 1-ton samples of coal from the Southport and Alpine mines were sent to the Northwest Experiment Station of the Bureau of Mines, Seattle, Wash., for burning tests. These tests were made on an overfeed-type domestic stoker installed in a vertical, six-section, hot-water boiler, such as is used for heating residences. The stoker and boiler, as well as the test procedure, are described in Bureau of Mines Report of Investigations 3379. 17/

Two tests were made on each coal, one with the stoker feed-gate set for intermediate rate and the other at maximum rate; however, owing to the coarseness of the two coals, the intermediate rate test on each coal corresponded to the minimum feed rate with other coals previously tested that had been crushed to a smaller screen size.

The appearance of the retort and the flame condition in the boiler were about the same with either coal. Both burned with a rather long, yellow, sootless flame, without visible smoke. Smoke-density readings taken during the tests, at the top of the chimney, showed an absence of smoke in all but test 59, during which too small an amount of air was supplied. Even under this condition the smoke density was only 4 percent.

The chief difference in the behavior of the two coals was in the character of the ashes produced. The coal from the Southport mine had an ash-softening temperature of 2170° F., and that from the Alpine mine softened at 2600 °F. This difference was shown in the character of the ashes obtained in the tests. The Southport coal formed larger clinker, which were more completely fused, than did the Alpine coal. The ashes obtained in the test on the Alpine coal were more friable and porous; such clinker as was formed was friable rather than glassy and occurred in smaller pieces than that from the Southport coal.

17/ - Yancey, H. F., Johnson, K. A., Lewis, A. A., and Cordiner, J. B. Jr., Burning of Various Coals Continuously and Intermittently on a Domestic Overfeed Stoker: Bureau of Mines, Rept. of Investigations 3379, 1938, 30 pp.

Inspection of the heat-balance statement shown in table 9 reveals that a rather high recovery of useful heat was obtained with both coals despite their low heating values. An over-all efficiency of 78.2 percent was obtained with the Southport coal when 12.1 pounds was burned per hour. At the maximum burning rate (21.5 pounds per hour) the efficiency of the stoker and boiler was 69.5 percent. These efficiencies do not differ greatly from the corresponding values of 74.9 and 71.3 percent obtained with the Alpine coal.

Substantially the same efficiency could be obtained with either coal. Although the low heating value of these coals naturally limits the rate of heat output obtainable on burning them, they can be used satisfactorily and efficiently for house-heating purposes with equipment similar to that employed in conducting these tests.

No tests of the Oregon coals to determine directly their suitability for use as industrial steam coals were included in this investigation, for this would entail large-scale burning tests in an industrial boiler installation. However, the generalization can be made that similar coals are used successfully in Washington and elsewhere as steam coals. In many instances these coals compete directly with bituminous coals mined in the same or adjacent localities. Tests of 13 Washington coals, including one very similar in character to the Coos Bay coals, in a powdered-coal boiler plant 18/ demonstrated that even coals high in moisture and low in heating value can be utilized successfully with reasonably high efficiency as pulverized fuel. Thus, the properties of the Coos Bay coals and the experience in burning similar coals elsewhere indicate that they probably would be suitable for industrial use as steam coals. Their principal limitation would be their lower rate of heat output, a factor of prime importance only when burning capacity is limited.

18/ - Wilson, George Samuel, Yancey, H. F., and Daniels, Joseph, Preliminary Tests of Thirteen Washington Coals in a Powdered-Coal Boiler Plant at the University of Washington: Univ. of Washington Eng. Exp. Sta. Bull. 58, 1931, 27 pp.

Table 9.--Principal results of burning tests of Southport and Alpine coals, using an overfeed domestic stoker installed in a hot-water boiler.

Coal	Southport		Alpine	
Test No.	58	59	60	61
Feed rate, pounds per hour	12.1	21.5	12.6	21.7
Output, B.t.u. per hour	88,400	137,200	77,900	124,900
Analysis of coal, as fired				
Moisture, percent	17.2	17.1	17.7	18.7
Ash, percent	11.7	12.9	16.4	16.8
B.t.u., per pound	9,350	9,210	8,250	8,080
Ash-softening temperature, °F.	2,170	2,170	2,600	2,600
Heat balance, percent				
Efficiency	78.2	69.5	74.9	71.3
Losses:				
Combustible in ashes	4.6	9.4	7.0	7.2
Combustible in soot	.3	.4	.2	.2
Heat in dry flue gases	7.7	6.7	7.5	10.3
Combustible in flue gases	.0	4.4	.0	.0
Moisture and hydrogen in coal	6.6	6.7	7.0	7.5
Radiation and unaccounted for	2.6	2.9	3.4	3.5
Total	100.0	100.0	100.0	100.0
Excess air, percent:				
Coal fired	73	.3	79	64
Coal burned	82	12	93	77

SUMMARY

This report presents the results of analyses, friability tests, slacking tests, and low-temperature carbonization assays of coals from nine mines and prospects in the state of Oregon. Other laboratory work described includes a washability examination of one coal, a hydrogenation test of one coal, and the burning of two of the coals on an overfeed-type domestic stoker.

Eight of the coals examined are subbituminous in rank, and one is a lignite. None of the coals has coking properties. The Coos Bay coals, which comprise most of those studied, are characterized by a relatively high moisture content, a moderate percentage of ash, low sulfur content, and a heating value of 9,260 to 10,080 B.t.u. per pound, as received.

All of the coals have low friability indices, thus indicating that they will withstand well the forces of impact and attrition that produce breakage and degradation in size during handling.

Slacking tests showed that all of the coals will weather or slack to some extent when exposed to the elements after mining. Most of the coals are classed as strongly slacking and therefore will not withstand storage during dry weather unless the loss of moisture can be prevented.

On low-temperature carbonization in the laboratory the coals yield 16 to 37 percent water, 4 to 12 percent tar and oil, 6 to 11 percent gas having a heating value of 450 to 730 B.t.u. per cubic foot, and 47 to 70 percent char. The char is low in moisture and volatile matter, contains a moderate percentage of ash in most cases, and in general has a high heating value, namely, over 13,000 B.t.u. per pound. In short, it is a high-quality, smokeless fuel.

A washability study showed that coal from the Black Bear mine contains such a large proportion of associated impurities that the yield of cleaned coal possible by washing, even if a high-ash product were tolerated, would be prohibitively low - probably from one-third to one-fourth of the coal mined.

Under laboratory conditions, 88 percent or more of the dry Thomas coal can be liquefied by hydrogenation, indicating that this coal would be technically suitable for full-scale commercial hydrogenation.

Burning tests of the Southport and Alpine coals on an overfeed-type domestic stoker and hot-water boiler demonstrated that the Coos Bay coals can be burned satisfactorily and with high efficiency on equipment of this type.

CONCLUSIONS

The laboratory tests recorded in this report have shown that the Oregon coals, particularly those of the Coos Bay field, are suited to both low-temperature carbonization and hydrogenation processes; however, these methods of utilization, although technically sound, probably are not economically feasible at the present. Their commercial application is reserved for the day when liquid fuels and carbonization byproducts will bring a substantially higher price on the market. Thus, Oregon coals, in common with virtually all other noncoking coals, must turn for immediate markets to combustion in their natural form.

The Coos Bay coals are typical subbituminous coals. As such, and as shown by laboratory tests, they are subject to the limitations imposed by their rank. These limitations are principally their relatively low heating value and their tendency to weather or slack if stored during dry weather. They have the advantage, however, of being relatively nonfriable and hence yielding a large proportion of the coarser sizes, which still command a premium in price on the domestic market.

Despite their natural disadvantages, subbituminous coals are mined in considerable quantities in the United States. Moreover, in many instances these coals are marketed successfully in the face of competition from higher-rank coals mined in the same or adjacent localities. In Washington, about 370,000 tons of subbituminous coal were mined in 1938. This coal, much of which is similar in character to the Coos Bay coals, not only supplied local markets but moved into the highly competitive Seattle market where it met competition from bituminous coals. In Colorado, the Denver region produces over 2-1/2 million tons of subbituminous coal annually. This coal is similar in character to the Coos Bay coals and finds a ready market for domestic heating and steam coal.

Thus, the actual use of similar coals in other parts of the country bears out the conclusion based upon the results of laboratory tests that the Coos Bay coals are suitable for both domestic heating and industrial uses.

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