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CURRENT STATE-OF-THE-ART IN DRYING
LOW-RANK COALS

By
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It is well accepted that Alaska's oil resources will make a substantial impact on the Nation's energy picture, but Alaska's coal resources promise to play a far greater role in the future.

Certain points in favor of future coal development are:

First, the coals in general are low in sulfur (0.2 percent S), (Figure 1) and are thus environmentally most desirable. Second, the coal is accessible for surface mining with thick seams, exceeding at times 50 feet, in both the Nenana and beluga coal fields. Third, the Nenana coal field is already served by a railroad, while the Beluga coal field is potentially accessible to ocean shipping because of its proximity to the sea. Advancements in technology will permit mining of coking and noncoking coals in the Arctic Alaska Coal fields.

Fourth, Alaska needs a sustained activity to provide employment to Alaskans. Of the solid natural resources, coal is probably the best known, and the development of coal resources would benefit Alaskans immensely by providing additional employment and needed low-cost energy for the Fairbanks area. It could also spur the development of other associated industries. Fifth, the present boom in employment in Alaska, due to the activities associated with construction of the Trans-Alaska Pipeline (and possibly a future gas pipeline) will of necessity be curtailed at the conclusion of these activities. Development of Alaska's coal reserves could provide a significant employment cushion when the oil construction employment begins to decrease. Sixth, Alaskan coals could meet the energy needs of the Western United States, and Japan has long been trading with Alaska, and has shown considerable interest in Alaskan coals.

Figure 1. Comparative analyses of coal from the Nenana and Beluga Fields.

	Nenana Coal Field Healy Creek (2)	Beluga Field, Chulitna River Basin (2)
Moisture, percent	19.0	24.4
Volatile Matter, percent	38.7	30.1
Fixed Carbon, percent	29.1	28.7
Ash, percent	13.1	16.7
Heating Value, BTU/lb.	8565	7160
Moisture-ash-free BTU/lb.	12633	12177
Sulfur, percent	0.2 (Av.)	0.2

Preparing Alaska's coal for marketing

It is obvious that there are many points in favor of development of Alaskan coal resources, but increased production will have to be for markets outside Alaska, i.e., the Western States, or Japan. In the more readily accessible Beluga and Nenana coal fields, the coal is of subbituminous rank, with moisture as high as 22 to 28 percent, and 7 to 25 percent ash. Although there are seams of low ash content, systematic development will require benefic-iation of at least a part of the coals. The long-distance haulage requires that both ash and moisture of these coals be lowered, thereby reducing transportation costs and producing a high premium quality coal. The changing energy picture makes the transportation of Alaska's coal to the lower states or to Japan a real possibility, and could be comparable to the trans-portation of Wyoming and Montana coal to Texas or Chicago.

The primary problems confronting the development of these low-rank coals is in prepar-ation of the coals for market. Apart from washing some of these coals to reduce ash content to a lower level, reduction in moisture is needed for achieving greater economy in long-distance transportation to markets and to pave the way for effective marketing of these coals.

Success in attaining these two objectives, i.e. reducing ash and moisture, could make the development of Alaska's coals feasible. Achievement of these objectives would also render the coal immune to reabsorption of moisture after drying, and prevent its spontaneous combustion.

Research on drying of low-rank coals, such as lignites and subbituminous coals, has been conducted for nearly half a century. Although partial drying of Dakota lignite is practiced for freeze-proofing by mixing partially dried coal with run-of-mine coal, full scale drying of low rank coals has never been practiced commercially in this country. The reasons are (1) drying of low rank coals by conventional methods results in severe degradation of coal particles: (2) dried coals are thus dusty and difficult to handle, (3) reabsorption of moisture in storage and transit defeats the drying process. In addition the dry coal particles will react with ambient oxygen, and heat up enough to ignite. It appears that large-scale development of Alaskan coals may have to await solutions to these problems. Our Mineral Industry Research Laboratory at the University of Alaska is making a comprehensive literature search seeking solutions to these problems and identifying areas of research that should be undertaken.

Drying low-rank coals

Three systems of drying low-rank coals have received greatest attention: (1) high pressure steam dehydration otherwise called the Fleissner system, (2) hot oil dehydration system, and

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(3) the entrained or fluidized bed drying system, applicable to only finer coal particles.

Much of the research on upgrading of low rank coals by drying has been concentrated on Dakota lignite. This work was pioneered by the Department of Chemical Engineering of the University of North Dakota, and the Grand Forks Energy Research Laboratory of the U.S. Bureau of Mines. Irvin Lavine presented his Ph.D. dissertation before the American Chemical Society in 1930 and it was the forerunner in this field of research. Of the several patents discussed in the dissertation, a process patented by Fleissner (3) received much attention. Normal atmospheric drying of lignite is accompanied by slacking. When a lump of lignite is allowed to dry, the outside layer loses its moisture more rapidly than the interior, and it shrinks. The cracked outer layer peels off, exposing the interior to drying forces, and the process repeats itself until the entire piece disintegrates.

In his experiments Lavine subjected lignite to high-pressure steam followed by aeration. The resulting processed lignite showed very little degradation; the moisture content of the air-dried product was lower than that of raw lignite, and also the lignite showed lower moisture than if air-dried. This suggests that steam-processing involves a change in colloidal structure of the coal, i.e., collapse of capillaries due to the combined effect of temperature and pressure. The pioneering research was further continued at the University of North Dakota and Grand Forks Energy Research Laboratory of the U.S. Bureau of Mines.

Cooley and Lavine (4) further refined the process and improved the qualities of the product by the addition of emulsified asphalt to the steam. Harrington, et. al. (5) constructed a Fleissner system pilot plant, capable of drying one ton in two eight-hour shifts. Their work showed that processed lignite has an improvement ratio of 1.48, whereas subbituminous coal has an improvement ratio of 1.25, due to its lower moisture content. They found that dried subbituminous coals are equivalent to non-coking bituminous coal. The response to the treatment was better in some coals than in others. After detailed experiments, they concluded that for medium haul distances, say 250 miles, treated subbituminous coals would be more economical than fresh coals.

It must be remembered that these conclusions were applicable to conditions 42 years ago. In addition, they concluded that the treated coal had improved physical properties which were an added benefit. This study was the most comprehensive yet undertaken in evaluating the process variables and economic possibilities of the process.

Banbridge and Stachwell (6) investigated the drying of Victorian brown coal using the Fleissner system. They confirmed that the coal can be dried without disintegration. The

Fleissner-dried coal has better weathering qualities than corresponding raw coal or air-dried coal, and considerable quantities of water can be removed from the coal in a liquid form. They suggest that the amount of liquid expelled depends upon the type of coal and increases with treatment pressure and, to a lesser extent, on time. They suggest further research on the effect of process variables that result in most desirable mechanical properties of the dried product.

Effect of lignite source

Oppelt, et. al (7) concentrated their investigation in obtaining precise information on net thermal requirements for this Fleissner method of drying North Dakota lignites. They found large differences in the amount of liquid water removed from various lignites and suggest that structure and response to heat treatment of colloidal materials forming the lignite substance are different depending on the source of lignite. Oppelt, Kube and Kamps (8) studied drying of lignite with steam pressures to 1,500 pounds per square inch absolute, and temperature of 590° F (Figure 2). (The earlier work involved only pressures of 200 to 370 p.s.i.a.). They did not find any significant advantage in pressures in excess of 400 p.s.i.a. At the highest pressures employed (1,500 p.s.i.a.) the moisture could be reduced to nearly zero, but the material is hygroscopic and picks up moisture to the level attained at 400 p.s.i.a. Thin sections of lignite treated at 400 p.s.i.a. showed maximum alteration adjacent to exposed surfaces. At the highest temperature pressure conditions, much bloating occurred. It was observed that woody, nearly barklike sections of lignite were less readily affected, while the amorphous appearing sections were more responsive to bloating.

The portion of water removed in liquid form was directly related to the processing temperature-pressure level, and ranged from 53.4 to 60.3 percent. Lumps dried at 1,500 p.s.i.a. retained their form for over a year when exposed to the atmosphere. Although a portion of the film-like surface spalled, the honeycombed interior did not. In the same period similarly exposed lignite which had been dried at lower temperatures would have weathered more, while untreated lignite would have disintegrated.

In Alaska, W. E. Dunkel conducted experiments in high pressure dehydration. A report prepared by March (9) gives details of the tests. Coal was subjected to a high temperature, 375° - 390° in a closed container. Heat exchange was accomplished by circulating hot aviation engine oil through heating coils in the drier. The oil was heated by passing coils through an oil-fired-heat-pak-type boiler. The coal was dried to a moisture content of 13.8 percent from an initial moisture content of 31.8 percent.
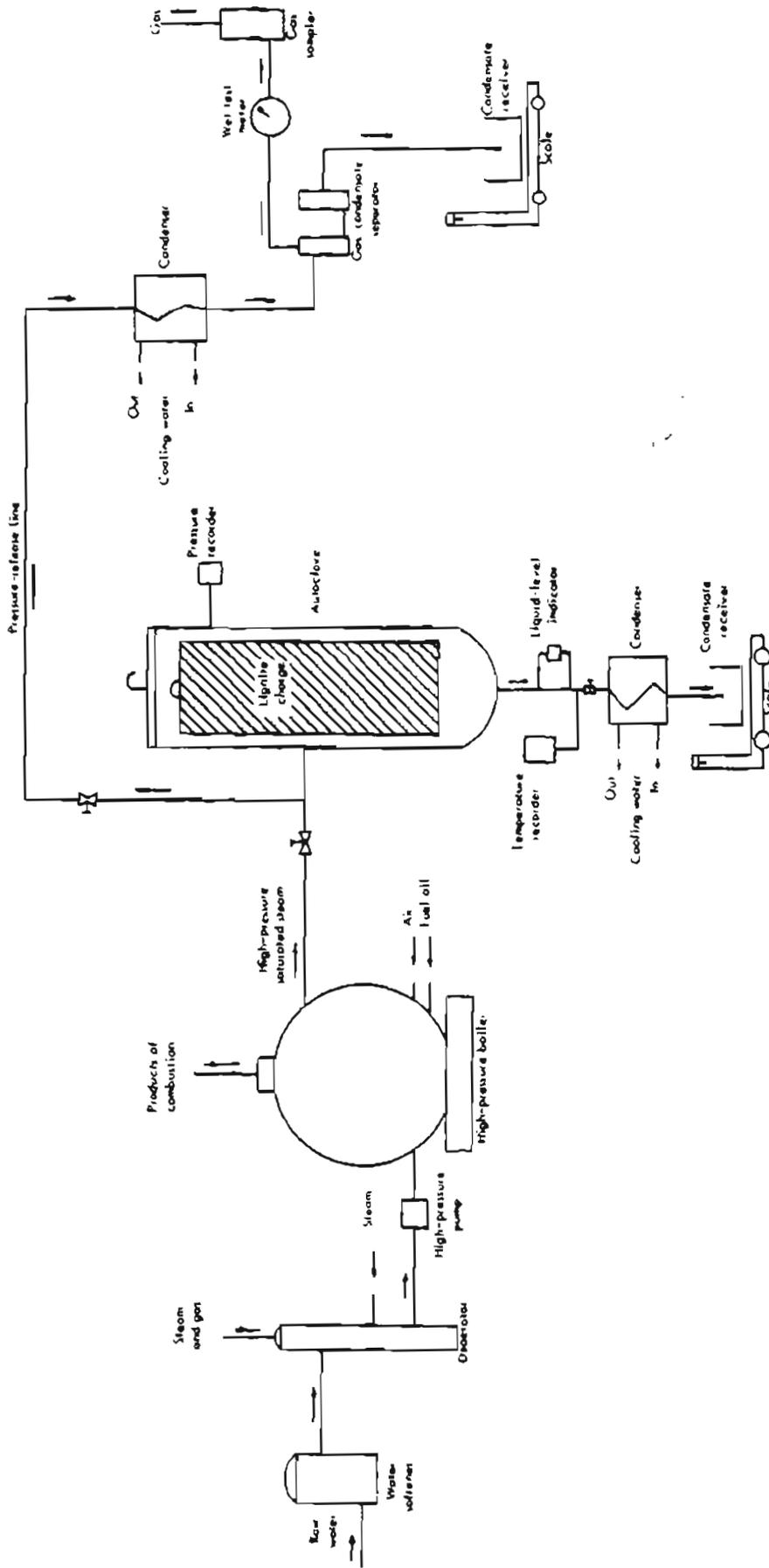
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Figure 2.   Schematic Flow Diagram of High-Pressure Experimental Fleissner Drying Unit, after Oppelt, Kube & Kamps (8).

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More recent research has been aimed at protecting dried coal by making it nonhygroscopic by an oil surface-coating. Research at both the University of North Dakota and the Research Council of Alberta has been in this direction. Coal is immersed in a hot, high-boiling-point oil. The moisture in the product is a function of immersion temperatures and immersion time. The major cost factor is the oil retained on the coal. Attempts have been made to reduce this oil by centrifuging. The Grand Forks Laboratory and the University of North Dakota have both done excellent work on dehydration of lignite.

Parry and Wagoner (10) investigated drying fine low-rank coal in the entrained or fluidized state. They found that 90 percent of the moisture in coals can be removed in high temperature gases with absolutely no effect on coal substance. Further drying resulted in devolitization of the coal. Considerable degradation of coal particles is reported, caused by rapid evolution of moisture and shrinkage of coal. Their tests included subbituminous 'C' and lignitic coals from a variety of sources including subbituminous coal from the then Suntrana mine in the Nenana coal field of Alaska. Alaskan coal showed least degradation; lignite from Greece showed most degradation due to the drying process. It was shown that degradation is not only a function of locality but also of size of particles dried. Larger coals showed much higher degradation due to rapid shrinkage of particles and consequent disintegration of the weakened pieces. Disintegration was hastened by particles colliding in the boiling bed. The dried products were, however, of uniform characteristics despite the source.

In pneumatic or entrained drying, fine coal is suspended in a rapidly moving stream of hot gases. A cyclone separator separates the dried coal from hot gases. Due to limitations imposed by the short retention time and the high gas velocity (maintained so that the larger pieces will be entrained) minus-1/8 inch is the most suitable size. Minus-1/4 inch particles will only lose small quantities of water, and may be considered as the largest size suitable for this process. Two pneumatic driers have been constructed in North Dakota by Baukal-Noonan, Inc. for treating minus-one inch lignite, reducing the product moisture to 18 percent from 36 percent in the feed; this product is mixed with mined lignite to freeze-proof it during winter months.

Combined drying and water-proofing was investigated by Schnoch (11) as early as 1939. Lignite was first coated with light petroleum oil. The oil-coated coal particles were heated in a closed vessel to 410°F. A product with a moisture content as low as four percent water could be produced. Oil absorbed by the coal particles was about two percent.

Burr, et. al. (12), have investigated variables that effect the removal of moisture by

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immersing coal particles in hot oil (SAE 20). Temperature of the bath was maintained between 310° F and 320° F, and spheres of coal were immersed in it. Process variables studied were diameter of coal particles and drying time. Moisture could be reduced, but depended on drying time and diameter of the particles. The dried particles, however, showed deterioration ranging from slightly cracked to complete disintegration.

Recent research on low-rank coals has been to evaluate storage and handling character-istics of dried coals, (Paulson 13, Sondreal 14). Dried low-rank coal is hot, dusty, and highly reactive to oxygen because of elevated temperatures and new surfaces produced during drying. Their observations were made on two carloads of dried lignite, and one carload of dried subbituminous coal.

Continuing investigations have been on the behaviors of dried coal in transportation and storage when coated with oil (15). Subbituminous coals were dried from 26 to 16 percent moisture, cooled to 115° F and sprayed with oil, from 2 to 6 gallons per ton; and lignite was dried from 39 to 20 percent moisture, cooled to 85° F and sprayed with oil at rates from 1 to 2 gallons per ton. It was found that increase in moisture during transit was minimal even after subjected to two inches of rain. Exposure of the tops of the railroad cars to air did not cause heating problems, but leakage of air into the coal from the bottom caused fire. Dried coal consumes oxygen in ambient air, and heats up slightly. Further restoration of oxygen through circulation can cause the coal to heat up and start fires. Properly stockpiled coal at Grand Forks, using proven techniques, maintained a stable temperature for nearly a year.

Additional research is needed to evaluate the effectiveness of these and other processes for upgrading Alaskan coals by washing followed by dehydration.

Acknowledgement

References

1. Wahrhaftig, Clyde, et. al., Coal Deposits on Healy and Lignite Creeks, Nanana Coal Field, Alaska, U.S.G.S., Bull. 963E, 1951.

2. Barnes, F. F., Geology and Coal Resources of the Beluga Yentna Region, Alaska, U.S.G.S., Bull. 1202C, 1966.

3. Lavine, Irvin, Gauger, A.W., and Mann, G. A., "Studies in the Development of Dakota Lignite, III: Drying of Lignite Without Disintegration," Industrial and Engineering Chemistry, December 1930, p. 1347.

4. Cooley, A. M., and Lavine, Irvin, "Development of Dakota Lignite, VIII: Oil Steam Atmosphere for Dehydrating Dakota Lignite." Industrial and Engineering Chemistry, Vol. 23, February 1933, p. 221.

5. Harrington, L. C., Parry, V. F., and Koth, A., "Technical and Economic Study of Drying Lignite and Subbituminous Coal by the Fleissner Process," U.S.B.M., T.P. 633, 1942.

6. Bainbridge, J. R., and Satchwell, Keith, "Experiments in Fleissner Drying Victorian Brown Coal, "Fuel in Science and Practice, Vol. 26, No. 2, 1947, p. 28.

7. Oppelt, W. H., Ellman, R. D., Ongstad, O. L., and Kube, W. R., "Experiments in Fleissner Drying of North Dakota Lignite," U.S.B.M., R.I. 5122, April 1955.

8. Oppelt, W. H., Kube, W. R., and Kamps, T. W., "Drying North Dakota Lignite to 1,500 Pounds Pressure by the Fleissner Process," U.S. Bur. Mines, R.I. 5527, 1959.

9. March, James P., Report of Coal Drying at Colorado Station Nov.-Dec. 1957, Using Dunkle Prototype Dryer, Unpublished report, Jan. 1958.

10. Parry, V. F., and Wagner, E. O., "Drying Fine Coal in Entrained and Fluidized State"., Mining Engineering Sept. 1950.

11. Schoch, E. P., Oil Dehydration of North American Lignite II. Plant Design and Economic Considerations, Transactions of the American Institute of Chemical Engineers, Vol. 35, 1939, pp. 541-561.

12. Burr, Alex C., et. al., "Rate of Drying of Lignite in Hot Oil at 315°F, North Dakota Academy of Science Proceedings, Vol. 2, 1949, pp. 32-36.

13. Paulson, L. E., Cooley, S. A., and Ellman, R. C., "Shipment, Storage, and Handling Characteristics of Dried Low-Rank Coals, " Lignite Symposium, 1973.

14. Sondreal, Everett, and Ellman, Robert C., "Laboratory Determination of Factors Affecting Storage of North Dakota Lignite," U.S. Bur. of Mines, R.I. 7887, 1974.

15. Paulson, L. E., et. al, "Experiences in Transportation of Dried Low Rank Western Coals, presented at SME Fall Meeting, Salt Lake City, Utah, Sept. 1975.