PROCEEDINGS

of the

ILLINOIS MINING INSTITUTE

FOUNDED FEBRUARY, 1892

Sixty-ninth Year

1961

Annual Meeting

SPRINGFIELD, ILLINOIS

October 20, 1961
STUART COLNAN
President, 1961

Photo by Fabian Bachrach
<table>
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<th>Date</th>
<th>Name</th>
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<tr>
<td>Feb. 22, 1931</td>
<td>WILLIAM ORTMAN</td>
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<td>March 12, 1931</td>
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<td>H. C. PERRY</td>
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<td>March 24, 1932</td>
<td>C. E. KARSTROM</td>
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<td>ALBERT WEBB</td>
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<td>ERNEST L. STEPPAN</td>
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<td>Aug. 18, 1948</td>
<td>KENNETH DONALDSON</td>
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* Killed in Action
In Loving Remembrance

PAT HEAP. Sept. 23, 1948
F. E. FINCH. Nov. 2, 1948
J. E. BARLOW. Nov. 5, 1948
J. W. STARKS. Feb. 3, 1949
D. W. MARSHALL. March 1949
JAMES WHITE. March 17, 1949
W. W. PARPE. March 18, 1949
JAMES W. BRISTOW. April 14, 1949
GEORGE F. CAMPBELL. June 18, 1949
E. J. BURNELL. July 22, 1949
LOUIS W. HUBER. Aug. 7, 1949
JOHN RODENBUSH. Nov. 1, 1949
R. G. LAWRY. Dec. 1, 1949
ARTHUR C. GREEN. Dec. 8, 1949
M. J. CHOLLET. April 20, 1951
WILLIAM BURNETT. JR. June 14, 1951
E. C. ROEHLITZ. June 15, 1951
FRED J. BAILEY. Jan. 16, 1953
A. C. BASS. Feb. 10, 1953
A. R. JAMISON. Feb. 25, 1953
ANDREW JUNELL. March 4, 1953
HARVEY CARTWRIGHT. June 4, 1953
L. A. DUNBAR. July 30, 1953
R. W. WEBSTER. August 10, 1953
L. A. TROVILLON. Sept. 4, 1953
H. A. REID. October 20, 1953
GEORGE MEAGHER. November 6, 1953
WILLIAM J. McDOWELL. Dec. 12, 1953
L. E. YOUNG. Dec. 27, 1953
O. V. SIMPSON. March 25, 1954
CASPER D. MEALS. April 27, 1954
L. H. TICHETT. May 2, 1954
T. W. PEARSON. May 11, 1954
HARRISON H. JOHNSON Jr. July 20, 1954
BEN H. FIRTH. October 21, 1954
JACK BULLINGTON. October 29, 1954
LOWELL T. MALAN. December 23, 1954
H. KENNETH VOGEL. January 4, 1955
CHARLES H. DUESING. January 8, 1955
JOHN LAND. June 5, 1955
C. W. BROOKS. September 21, 1955
JOE LITTLEFAIR. September 27, 1955
O. J. FLESCHNER. December 10, 1955
GLENNA SHAFER
HENRY M. MOSES. April 1, 1956
CAPT. W. H. LEYHE. July 4, 1956
J. A. JEFFERIS. July 14, 1956
JOHN A. EMRICK. July 27, 1956
J. M. VANSTON, August 1956
ROBERT M. MEDILL. January 27, 1957
JAMES W. MORGAN. February 1, 1957
W. E. VAUGHN. February, 1957
JOSEPH F. JOY. February 19, 1957
FRANK H. REED. April 27, 1957
J. W. STEWART. June 17, 1957
JOHN E. JONES. July 1, 1957
L. C. STRAWER. July 23, 1957
F. A. CHAPMAN. October 6, 1957
N. C. McFADDEN. October 17, 1957
W. E. BARROW. October 28, 1957
GEORGE C. McFADDEN. Dec. 1, 1957
C. CHRISTIANSON. August 2, 1958
HUGH MERCER. Sept. 2, 1959
EDGAR R. PHILLIPS. Dec. 9, 1959
KIRK V. CAMMACK. December 26, 1959
L. BRUCE HOWARD. 1960
F. E. SNARR. Jan. 16, 1960
B. E. LEACH. January 22, 1959
BELA SCHONTHAL. March 10, 1959
EUGENE McAULIFF. June 2, 1959
LEE CONWAY. 1959
F. A. POWERS. February 3, 1960
W. M. DUNCAN. April 11, 1960
HARRY POLLACK. May 29, 1960
ARTHUR L. JEDLICKA. June 5, 1960
J. H. FLETCHER. July 18, 1960
W. H. BURKEY. Nov. 15, 1960
CLYDE H. JUSTICE. Feb. 12, 1961
A. J. BOYNTON. Aug. 17, 1961
JOHN C. ROLLO. Aug. 21, 1961
RUDOLPH G. WUERKER. Aug. 30, 1961
CHARLES H. DORSEY. Sept. 1961
WALTER M. JONES. Dec. 4, 1961
C. M. DONAHUE. Jan. 15, 1962
RALPH BUDD. Feb., 1962
ARCH CROSS. March. 1962
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Stuart Colnon
Chicago, Illinois

VICE-PRESIDENT
Robert J. Hepburn
Chicago, Illinois

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102 Natural Resources Building,
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R. H. Swallow***
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J. P. Weir**

*Term expires 1961
**Term expires 1962
***Term expires 1963
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G. H. Utterback*
W. A. Weimer**
R. P. Wilson***

*Term expires 1962
**Term expires 1963
***Term expires 1964
PAST PRESIDENTS OF ILLINOIS MINING INSTITUTE

FOUNDED FEBRUARY, 1892

1892-93 JAMES C. SIMPSON, Gen. Mgr., Consolidated Coal Co., St. Louis, Mo.
1893-94 JAMES C. SIMPSON, Gen. Mgr., Consolidated Coal Co., St. Louis, Mo.
1894-95 WALTON RUTLEDGE, State Mine Inspector, Alton, Ill.
1895-1911 Institute inactive.
1913-14 THOMAS MOSES, Supt., Bunsen Coal Co., Georgetown, Ill.
1915-16 WILLIAM BURTON, V. P., Illinois Miners, Springfield, Ill.
1917-18 PATRICK HOGAN, State Mine Inspector, Carbon, Ill.
1918-19 WILLIAM HALL, Miners Examining Board, Springfield, Ill.
1919-20 WILLIAM HALL, Miners Examining Board, Springfield, Ill.
1920-21 FRANK F. TIRRE, Supt., North Breese Coal & Mining Co., Breese, Ill.
1921-22 PROF. H. H. STOOK, Mining Dept., University of Illinois.
1922-23 JOHN G. MILLHOUSE, State Mine Inspector, Litchfield, Ill.
1925-26 E. G. LEWIS, Supt., Chicago-Sandoval Coal Co., Sandoval, Ill.
1926-27 W. E. KIDD, State Mine Inspector, Peoria, Ill.
1928-29 JOHN E. JONES, Safety Engineer, Old Ben Coal Corp., West Frankfort, Ill.
1929-30 PROF. A. C. CALLEN, University of Illinois, Urbana, Ill.
1932-33 CHAS. F. HAMILTON, Vice-Pres., Pyramid Coal Co., Chicago, Ill.
1934-35 C. J. SANDER, Vice-Pres., West Virginia Coal Co., St. Louis, Mo.
1936-37 W. J. JENKINS, Pres., Consolidated Coal Co., St. Louis, Mo.
1937-38 H. H. TAYLOR, Jr., Franklin County Coal Corp., Chicago, Ill.
1938-39 PAUL WEIR, Consulting Mining Engineer, Chicago, Ill.
1939-40 ROY L. ADAMS, Old Ben Coal Corp., West Frankfort, Ill.
1943-44 BEN H. SCHOLL, Binkley Mining Co., Chicago, Ill.
1944-45 GEORGE F. CAMPBELL, Old Ben Coal Corp., Chicago, Ill.
1945-46 JOSEPH E. HITT, Walter Bledsoe Co., St. Louis, Mo.
1949-50 T. G. GEROW, Truax-Traer Coal Co., Chicago, Ill.
1950-51 G. S. JENKINS, Consolidated Coal Co., St. Louis, Mo.
1951-52 CLAYTON G. BALL, Paul Weir Co., Chicago, Ill.
1952-53 WILLIAM W. BOLT, Pawnee, Ill.
1955-56 EARL SNERR, Freeman Coal Mining Corp., Hinsdale, Ill.
1956-57 PAUL HALBERSEBERG, Sahara Coal Co., Harrisburg, Ill.
1959-60 H. C. MCCOLLUM, Peabody Coal Company, St. Louis, Mo.
1960-61 STUART COLON, Bell & Zoller Coal Co., Chicago, Ill.
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The Opening Session of the Sixty-ninth Annual Meeting of the Illinois Mining Institute, held in the Grand Ballroom of the Abraham Lincoln Hotel in Springfield, Illinois, October 20, 1961, convened at 10:00 a.m., Vice-President R. J. Hepburn, presiding.

Vice-President Hepburn (The United Electric Coal Companies, Chicago, Illinois): Gentlemen, on behalf of Stuart Colton, our president, who is unable to be with us today, I would like to welcome you to our sixty-ninth annual meeting. We have a fine program prepared and I know it will be most interesting to all of us. Directly after the morning session, after a short recess, we will have a luncheon program which will replace the usual evening banquet. I urge you all to plan to attend this luncheon and get your tickets as soon as possible. In this morning's session we have several fine papers. W. A. Weimer, Engineer, Peabody Coal Company, will preside as chairman.

Chairman Weimer: Thank you, Mr. Hepburn, and members of the Illinois Mining Institute. The IMI gives us all the opportunity to pause about this time of the year, lay down our tools, visit with all our friends, and talk over our problems with our competitors. You will notice in the program we've had quite a change from last year or the years before. We have tried to compact the program by eliminating the afternoon technical sessions and moving up the dinner banquet at 9:00 p.m. so we have a luncheon banquet. We think that we are substituting quality for quantity and you all will get to hear our distinguished speaker and we will get an early adjournment. Adjournment will be some time before 4:00, giving us an opportunity to spend the evening at home and of course go to the ball game tomorrow.

We want you to pay particular attention to the way we run the program. Some of you probably won't like the change. If you like it or dislike it, will you talk to mem-
bers of the Executive Board, whose names appear on the back of the program, and give them your reactions—or to the five new members who will be introduced during the business meeting shortly after the luncheon. The tickets for the luncheon are on sale now and should be purchased immediately. After we adjourn from the technical session, you will have about an hour or so, so the salesmen can sell and purchase a drink, and then we will meet back in this room at 1:00 for the luncheon.

There is another change that I would like to tell you about while I have the opportunity here, and that is about the American Institute of Mining, Metallurgical and Petroleum Engineers' Coal Subsection formed in Southern Illinois about a year ago or slightly more. A group got together, mostly with Gene Mauck as the driving force. He saw the need for a rather "grass roots" meeting of the fellows at the mines who needed to get together and discuss their problems. Some of you know about it, but even some AIME members don't know about the organization. We have had several meetings at Johnson City, and at Benton, and Kentucky Lake. We usually try in the summer to have an afternoon of golf, or of course Kentucky Lake fishing, if available. Some of you might think that you are not eligible to join. There is one requisite—that you be a member of the American Institute of Mining Engineers. Some of you may think, well, maybe you can't get in. But while there are some educational requirements, for the most part the AIME is perpetuated by the members themselves. Even if your education is very limited, if you have contributed to the coal industry and get three present members of the AIME to sign your application, you can become a member. I would be pleased to have you give me your name and address if you are interested in joining the AIME or the Coal Subsection. Talk to some of the present members; we would be happy to have you at our meetings.

Our first speaker this morning is Mr. Robert E. Greer, Mining Sales Engineer for the Jeffrey Manufacturing Company of Columbus, Ohio. Mr. Greer graduated from Ohio State University in Electrical Engineering in 1948; he was with the Inland Steel Company and became assistant mines superintendent in 1955 when he began his career in the mining manufacturing business, and is presently with the Jeffrey Company. He has had several technical papers in the AIME publications and elsewhere. He has recently returned from a trip around the world and work in India. Mr. Greer.

R. E. Greer: Thank you. Gentlemen:
AN EQUIPMENT MANUFACTURER LOOKS AT FUTURE CUSTOMER NEEDS

R. E. GREER
Mining Sales Engineer
Jeffrey Manufacturing Co., Columbus, Ohio

Some of the people in the Coal Industry may be due to meet a deadly fate—they may become a statistic.

In 1960 over 73% of the national total energy in the United States was supplied by oil and gas. Oil accounted for 41.5%, gas for 31.5%, water power 3.9%, coal accounted for only 23.1% of this energy. This 23.1% is not an enviable percentage, considering that in the last century coal supplied about 100% of the energy.

The Coal Industry has been built upon hardships. In King Edward the First's time it was a capital offense to burn coal in London. In 1619 Dudley was driven from Worcester County in England when he tried to burn coal in his blast furnace because wood was scarce. In fact, only 150 years ago it was against the law to sell coal in Philadelphia.

The facts of the coal market and the hardships of Coal's history were brought up because they affect everyone here and in the industry right where it hurts—in the sensitive organ called the pocketbook.

Action is being taken to assure the future of the industry.

The Government has signed The Coal Research Act into law and allotted a million dollars for starting this project.

Bituminous Coal Research, Inc., has approved an $875,000 expenditure for research.

Manufacturers, meanwhile, are developing new and better equipment, etc., etc., etc. The following classified items will give you insight as to just what one equipment manufacturer, The Jeffrey Manufacturing Company, is doing in meeting the future needs of their customers.

Customer's Needs as Designed For:

Past—Customers in the past, like many here, received coal mining machinery that was sometimes just assembled. In many cases the true design was made after the machine was built so that the next machine would perform to a "limited" extent. The old approach of "if it breaks, make it stronger" served as a design concept and filled a need at that time.

Present—Design engineers of mining equipment now study basic applications and needs of the ma-

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chine before it is designed. Since every engineering design is a compromise, the ultimate compromise is the selling price. Is there a man here that would pay three quarters of a million dollars for a loading machine that would not breakdown between annual overhauls?

Think of your new Jeffrey underground equipment and consider the newer utilization construction with accessibility of all components as compared to equipment of a few years ago. The records show that the new machine can be put back into production much more rapidly and the replaced unit can be repaired in a shop under less stress, better working conditions and with enough time allowed to do the repair job right.

By refinement of electric motors and control, hydraulic components, etc., today's machine is vastly superior to its brother of a few years ago.

Future—Coal mining machinery of the future must be designed from the experience gained from past performance. If you were given the task of building a truck it would be folly to ignore the past history of trucks and not build upon the present state of the art.

Manufacturers of coal mining machinery of the future must build equipment that will operate with no down time between overhaul dates. This reliability in equipment is working every day in the airplanes that fly over your homes.

Mathematical formulas can be derived for mining equipment which will tell the operator when to overhaul the equipment and when it is time to replace a unit so as to save money by doing so.

Challenges of Future Mechanization

Methods, systems, equipment, labor, management and finance must all fit into any study of future mechanization as related to the preceding data.

Basically the most important future challenges for future mechanization are:

Transportation—If today's loaders and miners could operate continuously with no haulage problems, no down time and with good conditions, it is a well known fact that a small number of these units could produce all the 13½ million tons per operating day of our coal production. This becomes a major future challenge, since the basic problem is continuous haulage.

Continuous vs. Conventional Mining—The test era of the continuous miner is over. As a paralleling example, about three or four years ago plastic trailing cable was given trials in the mines. By official interest in these cables they were given preferential treatment and these test results were that the cables were five to six times better than the standard cable, but in less than three years the operating tests became equal and now the ratio is only 1 to 1.7 favoring the new cable.

This example was given to show a principle.

Records now indicate that in certain conditions a continuous miner must operate 103% of available face time to produce as much coal as the conventional section. This cannot be done, so future trends show that each type of mining must be evaluated carefully.

Remote Control—"Moon Min-
Adapting plans of extreme future dates is not to be totally ignored today, but the future equipment must bring dollars into the industry during our time. A "Tethered Area" concept vs. a true remote control is the first step in this program. This must come before a man inserts a taped or programmed plan into a "block box" at the portal in the morning and returns at night to shut the machine off and record the tonnages mined. The true "Tethered Area" idea will allow man to be near the machine and yet removed from the area where most of today's accidents happen. A need for remote control is recognized, but it must not be developed just because it is a "fashionable thing" to do. All the coal mining equipment must work together. To automatize just one unit gives no particular advantage—the teamwork of machines is as important as the teamwork of the men that run them.

Programmed Customer Needs—Basic Research

Basic to any and all research in a free economy is the profit idea. The cost of development of the product and the expected product life say how much value can be placed upon the product. By necessity, the market must be seen as it will exist five, ten or even fifteen years from today and plans laid accordingly.

Manufacturer's Responsibilities—The mining equipment of the future must sell for a price that will allow a reasonable profit and allow the purchaser to make the same reasonable profit by using the machine. Research must be paid for from the manufacturer's profit. Without research and new products, equipment manufacturers will cease to exist as such in a short time. By the same reasoning the customers of the manufacturer will face the same fate because of lack of new equipment from the manufacturer. If an entire industry decides on a level existence so that no one individual unit of the industry should advance, the entire industry can be by-passed, or may even cease to exist.

From the basic profit the manufacturer must provide service, parts supply, consultation and other services to the ultimate customer. The manufacturer, true, is interested in the basic fair profit, but he is the only one who can logically and practically furnish the previously mentioned items.

Customer's Responsibilities—The customer must aid the manufacturer as an ultimate service unto himself. Only he can return true information and data about complete performance of the equipment to the manufacturer to make sure the equipment is performing as designed and manufactured.

The customer must keep informed so as to know what is a reasonable performance from the equipment. He then has every right to demand and expect such performance from the equipment.

The responsibility of proper, justified records must be with the owner of the equipment. Accurate records are a "must" with present-day equipment and will be an economic factual basis for future designing of proper equipment.
How A Customer Can Select Future Mining Machines

The customer of tomorrow might well buy moon mining equipment or deep sea remote coal mining units that will bring the coal to the surface already washed and sized, but such sophisticated items are in the future. Meanwhile, back at the mine, a profit must be shown and progress must be gradual to tomorrow's mining machines.

Five factors in choosing future mining machines can be listed as follows:

1. Will the system integrate with the present system or will new mining plans have to be made?
2. Will the machinery be economical and produce a fair profit?
3. Can fair and accurate comparison with today's equipment be made so as to give an accurate comparison between present and future equipment?
4. What support in equipment or manpower is required or expected?
5. What effects on the market or what long-range economic results will be brought forth by use of the proposed equipment?

Recap of Future Customer’s Needs

The manufacturer must have a working knowledge of every part of the design and manufacture of his mining equipment. His knowledge of the future mining equipment must be sometimes dead reckoning, but logical and sequential step-by-step development through research must guide this reasoning.

The manufacturer must still build on experience when considering future machines as to economic value, economic need and many other things that will result at a future date in a machine that a customer will want and be able to afford, and one that will allow the customer to make a profit by its continuing use.

By retaining a fair profit from present-day machines, the manufacturer can pay all the expenses such as service, consultation and advice to the customer, with still enough to pay for research and development of future machinery. Without progress all those concerned with design, manufacture and use of the equipment cannot continue.

Customer Responsibilities—The customer should have records and data on his equipment as to maintenance and performance. These are just as essential as his profit and loss statements and can sometimes reflect profit and loss much in advance of the financial records.

The correct use and maintenance of mining equipment must be done by the customer to insure that he will receive full value from use of the equipment. The customer again must make a fair profit from the use of the equipment or he cannot have any justifiable reason for its use.

Mechanics and Progress for Future Plans—The design for the new equipment in mining must be compatible with present day equipment so that progress is an evolution rather than a revolution.

Programmed maintenance for production with a minimum of down time to develop an exacting schedule is a necessary future development.

Planned equipment replacement that allows new equipment per-
formance will keep the coal mines abreast of all developments and at a profitable return for the investment.

Future New Equipment—The haulage is an important item to design for future equipment. Conventional section equipment for mining machinery has not reached its ultimate. Both continuous and conventional units bear study in the future. Ideas and methods that could use equipment not yet built must be considered in the future by equipment manufacturers.

The equipment for the future could be almost universal in nature, i.e., one machine to be very versatile and do almost anything under any condition—or it could be of the compact concept which would allow low-cost specialized equipment to do specific jobs under given conditions.

In choosing the future equipment to mine over 58% of all the future minable coal in the world, which 58% is found in the North American continent, the best coal operators in the world will be those in the coal industry of today. Their records of production prove their worth.

For the best equipment manufacturers in the world, just look at the export records for this proof.

With all the foregoing facts, why would anyone not expect future cooperation between you, the customer, and us, the manufacturer, to maintain and better the past records?

Chairman Weimer: Do we have any questions? . . . We all know that as tight competition as we are in we can't buy good enough, or they can't make good enough, tools for us. We know that next year there will always be a better tool and we'll pay the money for it if it does the job. . . . Thank you, Mr. Greer.

Our next speaker is Mr. John A. Harrison, coal petrologist with the Illinois State Geological Survey at Urbana. Mr. Harrison was born in Arkansas, graduated from the University of Arkansas in 1940, and got his Master's degree at the University of Illinois in 1948. He was a geophysicist in foreign service in South America in 1936-37. He joined the Survey in 1941 and returned in 1946 after World War II. The past ten years he has been in charge of coal petrography. His paper is entitled Coal Petrography Applied to Coking Problems. Mr. Harrison.
COAL PETROGRAPHY APPLIED TO COKING PROBLEMS

JOHN A. HARRISON

Associate Geologist
Illinois State Geological Survey
Urbana, Illinois

ABSTRACT

Coal petrography classifications and methods of investigation, developed in various countries, are reviewed and compared. A procedure is described, in which one of these methods of investigation was used, whereby coke stability can be predicted from petrographic analyses of coal. An example is cited in which Illinois coals and blends containing Illinois coals have been tested using this procedure.

INTRODUCTION

The development of coal petrography during the last 50 years in various parts of the world has resulted in various methods of investigation and systems of classification. In the first part of this paper a number of classifications are discussed and their characteristics compared. The second part describes a procedure for predicting coke stability from petrographic analysis. This procedure combines certain previously developed methods of petrographic analysis with stability data obtained in standard A.S.T.M. test from pilot-scale coke tests. An example is given explaining its use in tests run on Illinois coals and blends containing Illinois coals.

METHODS OF CLASSIFICATION

Investigation procedures and resulting classifications in coal petrography may be divided into two main groups based primarily on the method of illuminating the coal sample used in microscopic studies, namely by transmitted and reflected light. The transmitted light method employs a process of passing light through a thin section of coal that has been ground to a thickness of normally less than 8 microns. In the reflected light method a beam of light is reflected off a polished surface of coal.

The microscope transmitted light method has been long associated with the Thiessen classification, which is based on a botanical concept (coal as an assemblage of plant remains). In like manner the microscope reflected light method has been associated with the Stopes classification, which is based on a lithologic concept (coal as a rock).

Stopes' description of hand specimens of coal (1919) was based pre-
dominantly on reflected light; however, she also made thin sections of the coal. Her classification, presented in 1935, in which she described the components that make up coal, was based predominately on microscope transmitted light method of study. For this reason the author has discussed the Stopes' classifications under the heading of microscope transmitted light method.

Since 1935 Stopes' classification generally has been accepted in Europe and throughout the world and microscope reflected light methods have been used to describe the components in her classification in many reports. This had resulted in the close association between her classification and the reflected light method.

The above does not preclude reflected light from Thiessen's classification or transmitted light from Stopes' classification, but general usage has established the relationship between classifications and methods of illumination.

**Microscope Transmitted Light Methods**

Thiessen (1920) stated that Henry Witham made the first thin sections of coal and reported on them in 1881-32. Many other workers, including J. W. Dawson (1859), W. Hutton (1883), C. W. von Guembel (1883) and H. Potonie (1906), have made significant contributions which greatly advanced the understanding of the nature of coal. The report of White and Thiessen (1911) was the first extensive, systematic description of thin sections of coal and original plants from which coal was derived, but no classification was proposed. R. Thiessen developed the classification and nomenclature based on thin sections of coal and transmitted light method of microscopic examination which are used at the U. S. Bureau of Mines and other laboratories in the United States. He defined his types and components over a period of years in numerous publications. One of his most systematic and detailed description of the types, subtypes and components was presented in 1937, but in this, as in previous publications, he failed to give specific quantities of components necessary to establish clearly the difference between coal types. Parks and O'Donnell (1956) reviewed Thiessen's work, designated percentages of components present in each of Thiessen's types and presented a formal classification (Table 1).

The two main components of coal defined by Thiessen were anthraxylon (1920) and attritus (1919). He accepted the term fusain, which had been defined by Grand'Eury (1882) and Stevenson (1911).

Anthraxylon is more than 14 microns thick, generally reveals some of the original plant structure and varies in color from orange to deep red, the depth of color increasing with increasing rank and thickness of the thin section. Microscopically similar material less than 14 microns thick is included with attritus in Thiessen's classification. The 14-micron lower limit was used by Thiessen and his coworkers for many years but was first published by Parks and O'Donnell (1948).

Attritus, a mixture of tightly packed plant remains of different morphological forms and origin, is subdivided into opaque attritus and translucent attritus. The predominant constituent in opaque attritus

*Play ball with the Advertisers who play ball with you.*
### TABLE 1 — TYPE CLASSIFICATION OF COAL ACCORDING TO THIESEN*  
(TRANSMITTED LIGHT)

<table>
<thead>
<tr>
<th>Types</th>
<th>Relative Amounts of Banded Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright (20% opaque matter)</td>
<td>Anthraxylon more than 5 percent and usually predominant component.</td>
</tr>
<tr>
<td>Nonbanded coals</td>
<td>Attritus usually subordinate but occasionally predominant.</td>
</tr>
<tr>
<td></td>
<td>Fusain often present but never abundant.</td>
</tr>
<tr>
<td>Banded coals</td>
<td>Anthraxylon more than 5 percent and occasionally equal to Attritus.</td>
</tr>
<tr>
<td>Semi-split (20% 30% opaque matter)</td>
<td>Attritus usually predominant component.</td>
</tr>
<tr>
<td></td>
<td>Fusain often present but usually in minor amounts.</td>
</tr>
<tr>
<td>Splint (30% opaque matter)</td>
<td>Anthraxylon more than 5 percent but usually in minor amounts.</td>
</tr>
<tr>
<td></td>
<td>Attritus always predominant component.</td>
</tr>
<tr>
<td></td>
<td>Fusain often present but usually in minor amounts.</td>
</tr>
<tr>
<td>Cannel</td>
<td>Anthraxylon less than 5 percent and usually absent.</td>
</tr>
<tr>
<td></td>
<td>Attritus always predominant component.</td>
</tr>
<tr>
<td></td>
<td>Fusain rare.</td>
</tr>
<tr>
<td>Boghead</td>
<td>Anthraxylon less than 5 percent and usually absent.</td>
</tr>
<tr>
<td></td>
<td>Attritus always predominant.</td>
</tr>
<tr>
<td></td>
<td>Fusain rare.</td>
</tr>
</tbody>
</table>


is opaque when viewed microscopically in a thin section by the transmitted light method. Translucent attritus contains varying amounts of translucent humic matter, spores, cuticle and resins, which are all translucent in thin section. Opaque matter may be present in minor amounts in translucent attritus. Figure 1 shows a thin section of coal containing both anthraxylon and attritus.

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Fusain generally shows the cell walls of some of the plant parts that made up coal. In thin section fusain is opaque or black, having attained a high carbon content during the early stage of coalification.

Marie C. Stops (1919) proposed a classification for coal that included the four banded ingredients: vitrain, clarain, durain and fusain. Her classification was based on macroscopic observations of hand specimens of coal. She also prepared thin sections of the four banded ingredients and recognized certain plant components in these thin sections. The following descriptions are a modification of Stops’ original descriptions of the banded ingredients:

**Vitrain** occurs in uniform, bright, black, vitreous bands and lenses usually a few millimeters wide. An arbitrary lower size limit of from 3 to 5 mm. has been placed on vitrain in macroscopic description of coal beds (International Committee for Coal Petrology, 1957). Vitrain breaks with a conchoidal fracture and does not soil the hands. It may be crossed with numerous cracks perpendicular to banding.

**Clarain** is made up of thin to thick bands and lenses of predominantly bright coal constituents stratified parallel to the bedding plane; however, a minor number of dull bands may be present. It breaks rectangular to the bedding plane in contrast to the conchoidal fracture of vitrain. It has a satin to silky gloss or luster on a relatively smooth surface.

**Durain** is dull and may even be grayish in appearance. It is hard, occurring in fine bands and lenses with a close, fine texture, and breaks with irregular to granular surface.

**Fusain** is black to grayish black, has a silky luster and fibrous structure, extremely friable when not impregnated with minerals. It resembles charcoal. It generally occurs as thin bands and lenses, but on occasion the lenses may be up to 3 inches thick and several feet in horizontal extent. It blackens the hands.

Stopes later (1935) published a more detailed classification and description of the banded ingredients and introduced the term *maceral* to designate elementary coal-forming substances, analogous to minerals in rocks. This classification was based primarily on microscopic study of thin sections in transmitted light. The classification is quite detailed, giving the rock types, macerals, and in simple terms the original nature of that part of the plant from which the maceral was derived. A modified version of Stopes’ classification is given in Table 2.

The group maceral vitrinite in bands more than 14 microns thick

*Value is apparent in the merchandise of our worthy Advertisers.*
TABLE 2—STOPES-HEERLEN SYSTEM OF CLASSIFICATION* (CAN BE USED WITH EITHER TRANSMITTED OR REFLECTED LIGHT)

<table>
<thead>
<tr>
<th>Lithotype</th>
<th>Maceral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitrain</td>
<td>Vitrinitite</td>
</tr>
<tr>
<td></td>
<td>1. Collinite</td>
</tr>
<tr>
<td></td>
<td>2. Telinite</td>
</tr>
<tr>
<td>Clarain</td>
<td>Variable composition of</td>
</tr>
<tr>
<td></td>
<td>1. Vitrinite — Distinctive</td>
</tr>
<tr>
<td></td>
<td>2. Exinite</td>
</tr>
<tr>
<td></td>
<td>a. Sporinite</td>
</tr>
<tr>
<td></td>
<td>b. Guttinite</td>
</tr>
<tr>
<td></td>
<td>c. Alginite</td>
</tr>
<tr>
<td></td>
<td>d. Resinite</td>
</tr>
<tr>
<td></td>
<td>3. Inertinite — Less Distinctive</td>
</tr>
<tr>
<td></td>
<td>a. Micrinite—fine-grained and massive</td>
</tr>
<tr>
<td></td>
<td>b. Sclerotinite</td>
</tr>
<tr>
<td></td>
<td>c. Semifusinite</td>
</tr>
<tr>
<td></td>
<td>d. Fusinite</td>
</tr>
<tr>
<td>Durain</td>
<td>Rich in</td>
</tr>
<tr>
<td></td>
<td>1. Inertinite — Distinctive</td>
</tr>
<tr>
<td></td>
<td>2. Exinite</td>
</tr>
<tr>
<td></td>
<td>May be present</td>
</tr>
<tr>
<td></td>
<td>3. Vitrinite — Less Distinctive</td>
</tr>
<tr>
<td>Fusain</td>
<td>Fusinite</td>
</tr>
</tbody>
</table>


corresponds to the anthraxylon of Thiessen. Exinite and inertinite have no corresponding terms in Thiessen's classification, but these macerals are included in the attritus of Thiessen. Cady (1942) introduced the term *phyteral* to designate general botanical constituents in coal, such as spore coat, cuticle, resin, etc. The phyterals are botanical terms similar to maceral (mineral) terms; e.g., the phyteral cuticle is similar to the maceral cutinite.

A more detailed classification...
based on transmitted light microscopy was proposed by Spackman (1958). Macerals having similar chemical and physical characteristics are assembled into Maceral Groups. These Maceral Groups can also be combined to form Maceral Suites based on similar group characteristics. Spackman gave an example of possible grouping under the Vitrinite Suite or Anthraxylous Suite, but did not include a complete classification for all Maceral Suites.

Microscope Reflected Light Method

Seyler (1929) stated that Dr. H. Winter in 1913 was the first to apply metallurgical techniques to the study of coal. R. Potonie (1926) a German petrographer, used essentially the same lithologic concept as that of Stopes in the petrographic study of coal. He, like most German petrographers, applied the metallurgical or reflected light method of study to polished surfaces of coal. The English petrographer Seyler (1943) attributes the great advancement of this method of study to Stach and Hoffman, who utilized the oil immersion lens in 1929 for microscopic examination of coal. Spelling of English terms was changed by German workers to adapt them to their language, i.e., vitrain became vitrit, vitrinite became vitrinit, etc. Abramski, Mackowsky, Mantel and Stach (1951) give this classification in detail.

Several official Russian organizations approved and published “Bituminous Coals, Method of Determining the Petrographic Composition 1960”. Table 3, based on reflected light methods of micropetrographic analysis, shows the official classification and nomenclature used in Russia by coal petrographers. The classification is similar to that of the English and German schools. It will be noted that the term leiptinite is used instead of exinite in the other systems. A new term has been added to describe part of the intermediate material between fusinite and vitrinite. Other systems use the term semifusinite for all this intermediate material, but the Russians use semifusinite for transitional material more nearly like fusinite and semivitrinite for transitional material more nearly like vitrinite.

A classification based on polished surfaces and reflected light method was introduced recently by Schapiro and Gray (1960) for use in applied petrography (Table 4). In many respects this classification resembles that of Stopes, but there are a number of differences. Schapiro and Gray used the term entity, which is similar to maceral in that the stem of the word refers to the same component in coal, but the ending is different. The group maceral vitrinite becomes the group entity vitrinoid. Reflectance values have been assigned to the group entities so that the reflectance values of vitrinoids, for example, vary from V0 to V70 and include all ranks of coal.

Correlation between Transmitted Light Method and Reflected Light Method

The need for an international understanding, if not an exact correlation, of coal petrography nomenclature was recognized at the Third Congress for the Advancement of Studies in Stratigraphy and Geology of the Carboniferous at Heerlen, Netherlands, in 1951. This led to the first meeting of the Interna-
### Table 3 - Russian Classification* (Reflected Light)

<table>
<thead>
<tr>
<th>Names of the Groups</th>
<th>Symbols for the Groups</th>
<th>Microcomponents</th>
<th>Symbols for the Microcomponents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Vitrinite</td>
<td>Vt</td>
<td>Collinite</td>
<td>Vt₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telnite</td>
<td>Vt₂</td>
</tr>
<tr>
<td>2. Semivitrinite</td>
<td>Sv</td>
<td>Semicollinite</td>
<td>Sv₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Semitelnite</td>
<td>Sv₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixtinite</td>
<td>Sv₃</td>
</tr>
<tr>
<td>3. Fusinite</td>
<td>F</td>
<td>Semifusinite</td>
<td>F₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Micritinite</td>
<td>F₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fusinite</td>
<td>F₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sclerotinitc</td>
<td>F₄</td>
</tr>
<tr>
<td>4. Leiptinite (Exinite)</td>
<td>L</td>
<td>Sporinite</td>
<td>L₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cutinite</td>
<td>L₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resinite</td>
<td>L₃</td>
</tr>
<tr>
<td>5. Alginate</td>
<td>Alg</td>
<td>Algcollinite</td>
<td>Alg₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Algotelinite</td>
<td>Alg₂</td>
</tr>
<tr>
<td>6. Mineral impurities</td>
<td>MI</td>
<td>Clay minerals</td>
<td>MI₁</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iron Sulphides</td>
<td>MI₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbonates</td>
<td>MI₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other mineral impurities</td>
<td>MI₄</td>
</tr>
</tbody>
</table>

*Bituminous Coal — Method of Determining the Petrographic Composition: GOST 9414-60, Moscow, 1960.

---

The glossary when completed will provide petrographers throughout the world with a clearer understanding of nomenclature used, regardless of the petrographic method employed.

A correlation between two basic classification, *e.g.*, the Thiessen-U.S. Bureau of Mines (transmitted light method) and the Stopes-Heerlen (reflected light method), was agreed upon at the Eleventh Meeting of the...
TABLE 1—CLASSIFICATION OF SCHAPIRO AND GRAY+ (REFLECTED LIGHT)
CLASSIFICATION OF COAL ENTITIES

<table>
<thead>
<tr>
<th>General Entity Categories</th>
<th>Entity Groups</th>
<th>Entity Types* and Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitrinite Suite</td>
<td>Reactive vitrinites</td>
<td>V0 to V21</td>
</tr>
<tr>
<td></td>
<td>Inert vitrinites</td>
<td>V22 to V70</td>
</tr>
<tr>
<td></td>
<td>Reactive semi-fusinites</td>
<td>SF0 to SF21**</td>
</tr>
<tr>
<td>Leiptinite Suite***</td>
<td>Exinoids</td>
<td>E0 to E15</td>
</tr>
<tr>
<td></td>
<td>Resinoids</td>
<td>R0 to R15</td>
</tr>
<tr>
<td>Inertinite Suite</td>
<td>Micrinoids</td>
<td>M18 to M70</td>
</tr>
<tr>
<td></td>
<td>Fusinites</td>
<td>F40 to F70</td>
</tr>
<tr>
<td></td>
<td>Inert semi-fusinites</td>
<td>SF22 to SF40**</td>
</tr>
</tbody>
</table>

MINERALS

<table>
<thead>
<tr>
<th>Mineral Suite</th>
<th>Sulphides</th>
<th>Pyrite, Marcasite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carbonates</td>
<td>Calcite, Siderite, etc.</td>
</tr>
<tr>
<td></td>
<td>Silicates</td>
<td>Illite, Kaolinite, etc.</td>
</tr>
</tbody>
</table>

*Organic types based on reflectance in oil.
**Estimated values, reactive group is about 1/3 and inert group about 2/3 of semi-fusinites total.
***Leiptinite includes coal substances derived from spore exines, plant cuticles, resins, and waxes.


International Nomenclature Committee on Coal Petrology held in Madrid, Spain, in June, 1960. Table 5 gives this correlation. As previously stated, Stopes' classification is based on a lithologic concept and Thiessen's on a botanical concept, making precise correlation of the two systems impossible.

Another comparison between British nomenclature (Stopes), U. S. Bureau of Mines nomenclature (Thiessen), and German nomenclature was given by Marshall (1955). Schopf (1956) also made comparisons between the petrographic entities of the two basic systems. Schopf stated, "Materials in coal that are identified or distinguished in coal petrology are here spoken of generally as coal petrologic entities." His entities consist of ingredients, con-

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### TABLE 5 - CORRELATION OF THE NOMENCLATURE THIESSEN-BUREAU OF MINES (THIN SECTION METHOD) WITH THE NOMENCLATURE STOPES-HEERLEN (POLISHED BLOCK METHOD)*

<table>
<thead>
<tr>
<th>Transmitted light system Thiesen-Bureau of Mines</th>
<th>Constituents of Attritus²</th>
<th>Reflected light system Stopes-Heerlen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Banded Components</strong></td>
<td><strong>Groups of Macerals</strong></td>
<td></td>
</tr>
<tr>
<td><strong>anthraxylon</strong></td>
<td>Macerals</td>
<td>Groups of Macerals</td>
</tr>
<tr>
<td>(translucent)</td>
<td>vitrinite more than 14µ in width</td>
<td>vitrinite</td>
</tr>
<tr>
<td><strong>translucent attritus</strong></td>
<td>vitrinite less than 14µ in width</td>
<td>exinite</td>
</tr>
<tr>
<td><strong>spores, pollen cuticles, algae</strong></td>
<td>sporinite, cutinite, alginate</td>
<td></td>
</tr>
<tr>
<td><strong>resinous and waxy substances</strong></td>
<td>resinite</td>
<td></td>
</tr>
<tr>
<td><strong>brown matter</strong> (semitranslucent)</td>
<td>weakly reflecting semifusinite</td>
<td></td>
</tr>
<tr>
<td><strong>opaque attritus</strong></td>
<td>weakly reflecting massive micinite</td>
<td></td>
</tr>
<tr>
<td><strong>fusain</strong></td>
<td>strongly reflecting resinite</td>
<td></td>
</tr>
<tr>
<td>(opaque)</td>
<td>granular micinite</td>
<td></td>
</tr>
<tr>
<td><strong>amorphous (massive) opaque matter</strong></td>
<td>fusinite less than 37µ in width, strongly reflecting</td>
<td>inertinite</td>
</tr>
<tr>
<td><strong>fusain, finely divided fusain, sclerotia</strong></td>
<td>massive micinite, strongly reflecting sclerotinite</td>
<td></td>
</tr>
<tr>
<td><strong>fusinite and semifusinite</strong></td>
<td>more than 37µ in width</td>
<td></td>
</tr>
<tr>
<td>Types of coal</td>
<td>Quantitative statements</td>
<td>Mikrolithotypes</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>bright coal</td>
<td>more than 5 percent anthraxylon</td>
<td>vitrit</td>
</tr>
<tr>
<td></td>
<td>less than 20 percent opaque attritus</td>
<td>clarit</td>
</tr>
<tr>
<td>semisplint coal</td>
<td>more than 5 percent anthraxylon</td>
<td>duroclarit</td>
</tr>
<tr>
<td></td>
<td>20-30 percent opaque attritus</td>
<td>vitrinite</td>
</tr>
<tr>
<td>splint coal</td>
<td>more than 5 percent anthraxylon</td>
<td>clarodurit</td>
</tr>
<tr>
<td></td>
<td>more than 30 percent opaque attritus</td>
<td></td>
</tr>
<tr>
<td>nonbanded coal</td>
<td>less than 5 percent anthraxylon</td>
<td>durit*</td>
</tr>
<tr>
<td>Boghead coal</td>
<td>less than 5 percent anthraxylon</td>
<td>boghead</td>
</tr>
</tbody>
</table>

1. An exact correlation of the two systems is not possible.
2. For the recognizable botanical entities (for instance "spores", "cuticle") the term "phyteral" may be implied.
3. Durite is part of banded coals with less than 5% vitrinite that would be placed to the (nonbanded) cannel coals by definition in the Bureau of Mines system.

*International Committee for Coal Petrology, Nomenclature Subcommittee, definitive table agreed to at Madrid (Spain) meeting, June, 1960.
Advantages and Disadvantages of the Transmitted Light and Reflected Light Methods

The following list of the advantages and disadvantages of these two methods represents the writer's own view; it is probable, however, that this view is shared by most coal petrographers. The nature of any petrographic investigation and rank of coal should determine the method of microscopic study employed.

Microscope Transmitted Light Method:

Advantages associated with thin section use:
1. Phyterals or botanical components that transmit light are more readily examined.
2. Because of this fact the origin of coal is easier to comprehend.
3. Conditions of preservation may be informative with respect to environmental conditions.

Difficulties associated with thin section use:
1. Obtaining thin sections of equal thickness is difficult, and as thickness influences the color of the translucent coal components, the "true color" of the component is difficult to ascertain in successive sections.
2. Because of this fact it becomes difficult to assign to specific colors numerical values that can be used in evaluating the effects of coal components in applied coal petrography.
3. Even though coal sections are very thin, some components may overlie other components and obscure them from view. This is especially true of attritus.

Microscope Reflected Light Method:

The reflected light method used on polished surfaces of coal can be advantageously used in carbonization, preparation, and other applied petrographic studies, as it can be applied to nearly all coals, including opaque coals that cannot be examined by transmitted light. The method is especially adaptable to studies of broken coal because polished surface briquettes having a flat, uniform surface are easily and quickly prepared. "Broken coal" refers to representative samples of any coal that has been broken during mining, as opposed to a column of coal cut from the coal bed. The representative sample is bound together by an adhesive to produce a briquette that can be polished and studied.

Disadvantages associated with the reflected light method are primarily those listed as advantages for the transmitted light method. Details of plant constituents and structures are not as easily observed and identified in coals by reflected light.

Combination of Transmitted and Reflected Light Methods

A method that uses a polished thin section of coal is advantageous because it utilizes the best features of both the transmitted and reflected light methods. This has been shown in basic coal research by Teichmuller (1954) and Kosanke.
### Table 6 — Classification Used by the Illinois State Geological Survey* (Reflected Light)

<table>
<thead>
<tr>
<th>Macroscopic</th>
<th>Microscopic</th>
<th>Macerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithotypes</td>
<td>Group Macerals</td>
<td></td>
</tr>
<tr>
<td>Vitrain</td>
<td>Vitrinite</td>
<td>Collinite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telinite</td>
</tr>
<tr>
<td>Clarain</td>
<td>Vitrinite</td>
<td>Sporinite</td>
</tr>
<tr>
<td></td>
<td>Exinite</td>
<td>Cutinite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alginite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resinite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waxes</td>
</tr>
<tr>
<td></td>
<td>Inertinite</td>
<td>Fusinite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Micrinite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seminitite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sclerotinite</td>
</tr>
<tr>
<td>Durain</td>
<td>Inertinite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exinite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vitrinite</td>
<td></td>
</tr>
<tr>
<td>Fusain</td>
<td>Inertinite</td>
<td>Fusinite</td>
</tr>
</tbody>
</table>

*Nomenclature as defined in Glossary of International Committee for Coal Petrology and based primarily on Stopes-Heerlen System of Classification.

and Harrison (1957). For this method of study a Leitz UAM microscope is equipped to illuminate the polished thin section of coal by passing light through it from below and reflecting a vertical beam of light off the surface of the sample from a light source above. The lights can be used singly or in a balance so that translucent and opaque components can be viewed simultaneously. Simultaneous viewing is important in making correlations between the two methods and in training technicians.

Classification used at the Illinois State Geological Survey

The nature of the project and rank of the coal being studied have

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been determining factors in the classification and nomenclature used in microscopic studies at the Illinois State Geological Survey in recent years. In projects concerning genesis of coal or identification and description of specific plant components, the Thiessen classification employing thin sections of coal and transmitted light has been used. For projects in applied research in coal petrography the polished surface and reflected light method has proved to be more satisfactory. The classification used at the Survey is essentially the same as that of Stopes and the nomenclature is that defined in the "Glossary of the International Committee for Coal Petrology." Table 6 gives the nomenclature used for reflected light studies, including the names of the macroscopic banded ingredients or lithotypes used at the Survey, and of the microscopic macerals making up banded ingredients. Minerals present in coal are grouped under the sulphides, carbonates and silicates.

Illinois coal consists mainly of clarain, vitrain and fusain, in that order. Durain has been reported in Illinois coals but the quantity probably is very small. Finding durain in Illinois coals is an extremely difficult problem.

Figure 2 shows a block of coal with clarain, vitrain and fusain designated. No durain is present. Figures 3, 4, and 5 are photomicrographs of the group macerals and macerals that make up the banded ingredients.

For carbonization studies at the Survey, macerals have been divided into reactive constituents and inert constituents. The reactive macerals are those that will soften, deform, give off gas, or in some manner lose their identity during the carbonization process. Inerts are not necessarily completely inert during carbonization, but they do retain their identity and can be recognized by microscopic examination of coke. Reflectance values have been as-
Fig. 4—Photomicrograph showing vitrinite, Vt, sporiinite, S, and cutinite, C, in reflected light. Vitrinite and exinite (sporiinite and cutinite) are the macerals that make up the banded ingredient clarain. Mag. approx. 200 X.

Fig. 5—Fusinite showing the cell wall structure, which appears white in this photomicrograph taken with reflected light. The white color indicates a high carbon content. Mag. approx. 200 X.

Signed to each group maceral and maceral throughout the entire range of coal rank (Table 7). The values are those used by Schapiro and Gray (1960) for their entity types.

**APPLICATION OF COAL PETROGRAPHY TO COKING**

Coal petrography has been applied to preparation, hydrogenation, gasification and carbonization for many years. Usefulness of petrographic data has been limited, however, because of the difficulty of providing engineers with petrographic data that could be understood in specific terms that could be utilized. A number of known facts relative to this utilization are listed below:

1. Numerous workers have demonstrated that the difference in reflectance of the group maceral vitrinite denotes a difference in the rank of coals from which the vitrinite was taken. One of the first was Seyler (1943) of England. He demonstrated that as the rank of coal increased, the reflectance increased also. Other contributors to this phase of the science are McCartney (1952), Huntjens and van Krevelen (1954) and Siever (1957). Other workers have contributed to this study, but a detailed account of their work is outside the scope of this paper. The significant point is that this relationship has been fully demonstrated.

2. The effect of the rank of the coal upon the coke produced has been known for many years, and coals of certain rank have produced a metallurgical coke acceptable to blast furnace operators at one location at a given time. Decrease in the amount of this rank of coal available in conjunction with an ever increasing demand for coke resulted in blending other coals to produce acceptable metallurgical coke.

3. Recognition that variations in the quantity of reactive coal components and inert coal components produced different coke characteristics came early in the science of coal petrography. Thiessen, Sprunk and O'Donnell (1931) recognized that coke produced from different parts of the Elkhorn coal bed would produce cokes of different characteristics as the result of differing petro-
### Table 7 — Maceral Reflectance and Carbonization Characteristics Used by the Illinois State Geological Survey*

<table>
<thead>
<tr>
<th>Reactives</th>
<th>Inerts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group Macerals</strong></td>
<td><strong>Macerals</strong></td>
</tr>
<tr>
<td>Vitrite</td>
<td>Vitrinite</td>
</tr>
<tr>
<td>Colinite</td>
<td>C0 to C21</td>
</tr>
<tr>
<td>Telinite</td>
<td>T0 to T21</td>
</tr>
<tr>
<td>Exinite</td>
<td>E0 to E15</td>
</tr>
<tr>
<td>Sporinite</td>
<td>S0 to S15</td>
</tr>
<tr>
<td>Cutinite</td>
<td>C0 to C15</td>
</tr>
<tr>
<td>Alginite</td>
<td>A0 to A15</td>
</tr>
<tr>
<td>Resinite</td>
<td>R0 to R15</td>
</tr>
<tr>
<td>Waxes</td>
<td></td>
</tr>
<tr>
<td>Fusible</td>
<td></td>
</tr>
<tr>
<td>Inertinite</td>
<td>Semifusinite†</td>
</tr>
</tbody>
</table>

*Nomenclature as defined in Glossary of International Committee for Coal Petrology and based primarily on Stopes-Heerlen System of Classification. Reflectance values of maceral varieties based on reflectance values of Schapiro, N. and Gray, R. J., 1960, Petrographic Classification Applicable to Coals of All Ranks: Proceedings of the Illinois Mining Institute, 68th year, pp. 85-97.

†Estimated values, reactive group is about ⅔ and inert group about ⅓ of semifusinite total. Ammosov, I. L., Eremin, I. V., Sukhenko, S. I. and Oshurkova, L. S., 1957, Calculation of Coking Charges on the Basis of Petrographic Characteristics of Coke: Koks i Khimia, No. 12, pp. 9-12.

Graphitic composition. Mott and Wheeler (1930) demonstrated that if the petrographic composition of the coke charge were changed by adding fusain in the proper amount and size, marked improvement occurred in the resulting coke. The literature contains many other reports to substantiate the fact that variation in petrographic composition of the coal will affect the coke produced.

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Use of Petrographic Analysis to Predict Coke Stability in One Rank of Coal

The basic problem in predicting stability of coke made from one rank of coal is obtaining the optimum ratio between reactives and inerts in the coal that will give the best coke, under standard conditions, and to express this ratio in usable numerical values. Conditions such as size of coal, charging temperature, final coking temperature and others affect the coke, and for a series of tests standards must be established.

A recent laboratory-scale investigation by Marshall, Harrison, Simon and Parker (1958) was conducted in which optimum conditions for the numerous variables of sample and coking conditions were established as standards. It was found that variations in petrographic composition, under standard conditions, does influence the character of coke produced. In one series of tests in this investigation the petrographic composition of the coke charge, in the laboratory-scale test, was varied by adding different amounts of fusain. The relatively pure "vitrain" had a ratio of reactives/inerts of 12.3 and the stability index was 52, which was low for this series of laboratory tests. Minus 150-mesh fusain was added to this basic sample in increments of 5 to 20 percent. Optimum coke was obtained by the addition of 10 percent additional fusain, giving an ratio of 5.1 and a stability index of 88. As more fusain was added,
the optimum ratio was exceeded and instead of an inert-deficient mixture an excess of inerts resulted in the mixture. A curve was developed by plotting the ratio $\frac{R}{I}$ against the stability obtained in coke tests (Fig. 6). Essentially the same curve was developed by plotting results of pilot-scale tests, but the stability number was not as high throughout the tests. Although only 7.5 percent additional fusain was needed to give an optimum stability of 41, the $\frac{R}{I}$ ratio on these larger scale tests was 5.7 (Fig. 6).

Subsequent coke tests, on the pilot-plant scale, of fine coal from which the inerts had not been removed at the preparation plant gave an optimum stability of 46.6 and a ratio of 5. Although the magnitude of the stability varied according to the scale of the tests, the trend was the same in each case and the optimum ratio of $\frac{R}{I}$ was about 5.

In these tests basic petrographic analyses and coke stability determinations gave the information necessary to produce curves that could be used in predicting coke stability of future tests on this rank of coal. The lower scale of the pilot-plant test (Fig. 6) has been used in predicting the stability of coke produced from Illinois No. 6 Coal alone with ex-

![Graph](image.png)

**Fig. 7—Curves by Russian workers (Ammosov et al., 1957):** (a) Optimim ratio between fusible (reactives) and inert constituents $\sum \frac{nk}{ok}$ in coals of different stages of metamorphism ($I_1$, $I_2$, etc.). (b) Dependence of the coking capacity coefficient $K$ (Strength Index) on the change in the metamorphic stages of the coal ($I_1$, $I_2$,-$I_3$, etc.) and the inert constituent content in the blend ($20$, $21$, $22$, etc.).

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excellent results. Stabilities predicted from petrographic analyses have not varied more than two stability numbers from the stability found in the A.S.T.M. stability tests.

Use of Petrographic Analysis To Predict Coke Stability from Blends Of Different Ranks of Coal

As previously stated, coal petrographers have encountered difficulty in providing petrographic data in numerical terms that could be applied directly to coking problems even though it has been well established that petrographic composition and coal rank affect the characteristics of coke. Ability to predict stability of coke produced from a single rank of coal on the basis of petrographic analysis has been demonstrated. Stability predictions become more difficult when coke is produced from a blend containing two or more ranks of coal. Each rank of coal that contains reactivives will assimilate an optimum amount of inerts to yield a coke of optimum stability. This optimum amount will vary according to the rank of coals and according to the blend. The optimum amount of inerts for a blend is not necessarily the average of the optimum amount of inerts for each rank of coal in the blend. This difficulty of predicting stabilities from blends of coal has been overcome to a promising extent, as reported by Ammosov et al. (1957), Eremin (1959) and Schapiro, Gray and Eusner (1961).

By using the polished surfaces of briquettes made from broken coal, petrographic composition of the representative sample of coal can be determined. Reflectance data of vitrinite present are related to the rank of the coals present. These data plotted against coke data obtained from standard A.S.T.M. coke tests for stability will result in a series of curves that can be used in predicting coke stability from unknown coke blends. Curves established by Ammosov et al. (1957) are given in figures 7 and 8. Those published by Schapiro, Gray and Eusner (1961) are given in figures 9, 10, and 11.

Siever (1957) found from reflectance studies that a coal of a given rank may contain more than one vitrinite variety. Schapiro, Gray and Eusner (1961) also found this to be true and, in addition, found that each vitrinite variety (vitrinoid type) will have an optimum ratio for the production of the best coke. These vitrinite varieties are plotted against the optimum ratio as shown in figure 9.

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Fig. 9—Optimum \( \frac{\text{Reactive}}{\text{Inert}} \) ratio for each vitrinite (vitrinoid) type (Schapiro, Gray and Eusner, 1961).

Fig. 10—Strength Index for vitrinite (vitrinoid) types depending upon the amount of inert present (Schapiro, Gray and Eusner, 1961).
Inert Index:

In predicting coke stability from a coal blend, one of the factors required is the Inert Index of the blend. The Inert Index is a relation between the total amount of inerts in the blend and the amount of inerts required for each reactive vitrinite variety (vitrinoid type) present in order to obtain optimum coke from the blend. This relation is expressed in equation 1 (Ammosov et al., 1957):

\[
\text{Inert Index} = \frac{\text{Total Reactives}}{\text{Total Inerts in Blend}}
\]

\[
= \frac{\text{Total Reactives}}{\text{Optimum } R \text{ ratio } I (Vt 1)} + \frac{\text{Total Reactives}}{\text{Optimum } R \text{ ratio } I (Vt 2)} + \cdots + \frac{\text{Total Reactives}}{\text{Optimum } R \text{ ratio } I (Vt 21)}
\]

where: (a) Total Reactives include all vitrinite, exinite, resinite, and about \( \frac{1}{3} \) semifusinite (Table 8); (b) Optimum \( \frac{R}{I} \) ratio is the ratio between Reactives and Inerts that will produce the best coke from one rank of coal or from a vitrinite of one reflectance value; (c) Vt 1 is vitrinite of one reflectance value (Schapiro and Gray, 1960); (d) Vt 21 is vitrinite having the highest reflectance value of all vitrinites included in the blend.
the Reactives (Schapiro and Gray, 1960).

If the Inert Index is less than 1.0, the sample is deficient in inerts and a higher stability can be obtained by the addition of inerts to the charge. If the Inert Index is more than 1.0, the samples contain more inerts than can be assimilated by the reactivcs and more reactivcs must be added to the charge to improve the coke stability (Schapiro, Gray and Eusner, 1961). Harrison (1960) has shown that the effect on the coke produced by altering the petrographic composition of a charge depends also upon the nature, size and amount of inert added. If inerts or reactivcs are added to the charge, it must be thoroughly mixed to obtain the proper relation between the macerals if the desired results are to be attained.

**Strength Index:**

The second factor needed for predicting coke stability is the **Strength Index** ($K$). A family of curves is obtained by plotting stability data for each vitrinite variety with varying amounts of inerts. Strength Index is determined from those curves. Curves developed by Schapiro, Gray and Eusner (1961) are shown in figure 10. The Strength Index for a coal blend is calculated by multiplying the Strength Index of each vitrinite variety (vitrinoid type) by the amount of the vitrinite variety present and dividing by the total reactivcs in the coal blend. This calculation is expressed in equation 2, Ammosov et al. (1957):

$$2. \quad \frac{K_{\text{Blend}}}{\text{Total Reactives in Blend}} = \left( \frac{K}{(Vt_1)} \times \text{Reactivcs} \right) + \left( \frac{K}{(Vt_2)} \times \text{Reactivcs} \right) + \cdots + \left( \frac{K}{(Vt_21)} \times \text{Reactivcs} \right)$$

where: (a) $K$ is the Strength Index; (b) Reactives include all vitrinite, exinite, resinite, and about $1/3$ semifusinite; (c) $Vt_1$ is vitrinite of each reflectance value (Schapiro and Gray, 1960); (d) $Vt_21$ is vitrinite having the highest reflectance value of all vitrinites included in the reactivcs (Schapiro and Gray, 1960).

Figure 11, from the work of Schapiro, Gray and Eusner (1961), is a plot of Strength Index against Inert Index (called Composition-Balance Index by Schapiro, Gray and Eusner) to produce a family of curves. Solution of equations 1 and 2 can be plotted on these curves and the coke **Stability Factor** read from these curves.

**Current Use of these Principles at the Illinois State Geological Survey**

The Survey is currently using the petrographic methods of analysis.
in conjunction with data obtained from cokes produced in a pilot-scale coke oven (Jackman et al., 1955) to gather more information about Illinois coals and coals blended with Illinois coals to be used to predict coke stability. The following is a brief description of the procedures used in petrographic studies.

A sample of a coal blend is first crushed in stages by mortar and pestle, to prevent excessive grinding of small sizes, until 100 percent of the coal passes a 28-mesh Tyler screen. A representative sample is briquetted with Armstrong C 7 as a binder and the briquette is then polished on a Buehler Automet Automatic polisher (Fig. 12).

Quantitative petrographic analyses are made with a Leitz BMe microscope, using an oil immersion objective at a magnification of 320×. Group macerals and macerals tabulated in a point count analysis are vitrinite, exinite, resinite, semifusinite, micrinite and fusinite. Mineral matter content also is determined. Reflectance petrographic analysis is made on a Leitz UAM microscope with an oil immersion objective at a magnification of 600×. A photoelectric cell is attached to the monocular tube of the microscope, which is in turn at-
attached to a Photovolt photometer (Fig. 13). A filter to give monochromatic light and a pin hole diaphragm is placed in the ocular of the monocular tube. The filter is a combination of two Eastman Kodak Wratten filters, numbers 58 and 77. The sample can be viewed through the binocular eyepieces and reflectance can be measured through the monocular eyepiece. Polished glass standards of definite reflectance values are used to standardize the Photovolt photometer throughout the entire range of reactivities. The amount of light reflected from the polished surface of the coal sample is registered by the photometer or on a recorder. Reflectance of the vitrinite is related to the rank of the coals present.

The actual calculations, based on the petrographic information, are demonstrated below by the results of an actual test on a blend of two different coals.

To fulfill the requirements of equations 1 and 2, the following information is needed; the source of the information is indicated:

**Information Needed**

1. Total inerts in the blend
2. Total reactivities in the blend
3. Vitrinite variety
4. Total reactivities for each vitrinite variety**
5. Optimum \( \frac{R}{T} \) ratio for each variety of vitrinite
6. Strength Index (K) for each vitrinite variety

**Source of Information**

- Petrographic analysis of inert constituents plus about \( \frac{2}{3} \) of the semifusinite
- Petrographic analysis of reactive constituents plus about \( \frac{1}{3} \) of the semifusinite
- Measured reflectance
- Petrographic and measured reflectance analyses
- Curve in Figure 9
- Curves in Figure 10

**Ammosov et al. (1957).**

**Each vitrinite variety is determined by measured reflectance values. The amount of exinite and resinite is prorated on the basis of the quantity of each vitrinite variety present. The total reactive for each vitrinite variety includes the vitrinite of one reflectance plus the prorated exinite and resinite.**

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TABLE 8—PETROGRAPHIC ANALYSIS OF SAMPLE

<table>
<thead>
<tr>
<th>Group Macerals, Macerals, and Minerals</th>
<th>Reactives (%)</th>
<th>Inerts (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitrinite</td>
<td>80.62</td>
<td></td>
</tr>
<tr>
<td>Exinite</td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td>Resinite</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Micrinite</td>
<td>9.01</td>
<td></td>
</tr>
<tr>
<td>Fusinite</td>
<td>3.01</td>
<td></td>
</tr>
<tr>
<td>Mineral Matter</td>
<td>2.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>84.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.51</td>
</tr>
<tr>
<td>1/4 Semifusinite</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>3/4 Semifusinite</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>85.01</td>
<td>14.99</td>
</tr>
</tbody>
</table>

TABLE 9—DATA FROM PETROGRAPHIC ANALYSIS AND CURVES IN FIGURES 9 AND 10 (IN PERCENT)

<table>
<thead>
<tr>
<th>Vitrine Varieties</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitrinite %</td>
<td>5.15</td>
<td>38.65</td>
<td>13.99</td>
<td>0.37</td>
<td>1.48</td>
<td>9.94</td>
<td>8.83</td>
<td>1.84</td>
<td>0.37</td>
<td>80.62</td>
</tr>
<tr>
<td>Exinite + Resinite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.42</td>
</tr>
<tr>
<td>prorated throughout</td>
<td>0.27</td>
<td>2.00</td>
<td>0.72</td>
<td>0.02</td>
<td>0.07</td>
<td>0.51</td>
<td>0.46</td>
<td>0.09</td>
<td>0.02</td>
<td>4.16</td>
</tr>
<tr>
<td>1/4 Semifusinite</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.28</td>
</tr>
</tbody>
</table>

Total Reactives for each Vitrinite variety | 5.42 | 40.65 | 14.71 | 0.39 | 1.78 | 10.45 | 9.29 | 1.93 | 0.39 | 85.01 |

Optimum \( \frac{R}{T} \) ratio for each Vt variety taken from Fig. 9 | 5.3 | 4.2 | 3.4 | 2.5 | 10.2 | 12.0 | 13.8 | 16.0 | 18.8 |

Strength Index for each Vt variety taken from Fig. 10 | 2.4 | 2.6 | 2.8 | 3.5 | 6.7 | 7.0 | 7.1 | 7.2 | 7.3 |

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The above petrographic analysis in Table 8 gives us our first two requirements: (1) Total inertinite in the blend = 14.99 percent; (2) Total reactivies in the blend = 85.01 percent.

Table 9 gives the remaining information needed to fulfill the requirements of the equations. Substituting these data into the equations 1 and 2 we calculate the Inert Index and the Strength Index:

1. Inert Index = \[ \frac{5.42}{5.3} + \frac{40.65}{4.2} + \frac{14.71}{3.4} + \frac{0.39}{2.5} + \frac{1.78}{10.2} + \frac{10.45}{12.0} + \frac{9.29}{13.8} + \frac{1.93}{16.0} + \frac{0.39}{18.8} \]

\[ = \frac{14.99}{17.04} \]

\[ = 0.88 \]

The Inert Index is less than 1, indicating that the blend does not contain a sufficient amount of inerts to obtain the best possible coke.

2. Strength Index = \[ 2.4 (5.42) + 2.6 (40.65) + 2.8 (14.71) + 3.5 (0.39) + 6.7 (1.78) + 7.0 (10.45) + 7.1 (9.29) + 7.2 (1.93) + 7.3 (0.39) \]

\[ = \frac{329.02}{85.01} \]

\[ = 3.9 \]

If these values are plotted on the curves in figure 11, the predicted stability for coke produced from this blend would be 54. The actual (tumbler) stability, obtained by coking the coal in the Survey's Pilot-Scale Oven and testing it according to the standard A.S.T.M. tests, was 55.8.

In the limited number of comparisons made to date the difference between the calculated stability and tumbler stability has not exceeded two stability numbers. These tests, however, have been restricted to only two southern Illinois coals. As stated previously, our present efforts are directed toward gathering information relative to other Illinois coals so that we can evaluate and add to the present curves.

Conclusions

Various classifications used in coal petrography have been reviewed and the advantages of each, for use in specific types of coal research, have been noted. The transmitted light method using thin sections of coal is most advantageous for the study of the botanical components that make up coal and for investigating problems related to coal genesis and environmental conditions during deposition and coalification.

The reflected light method using polished surfaces of coal is the better of the two basic methods of study for applied petrography, especially in carbonization.

Direct correlation between these two basic methods is impossible be-

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cause the transmitted light method is based on a botanical concept and the reflected light method on a lithologic concept. A comparison of the two methods is helpful, however, in understanding the nomenclature used in each.

Coal petrographic data from one rank of coal have been combined with stability data obtained from coke produced from this rank of coal, to provide a method whereby coke stability can be predicted if this rank of coal is coked alone.

In Russia and the United States two well known facts related to cokability of coal have been used in developing a process by which coke stability can be predicted if blends of two or more coals of different ranks are coked. Preliminary tests at the Illinois State Geological Survey using Illinois coals and blends containing Illinois coals have shown that this process is applicable to Illinois coals. Further tests are needed in a wider range of Illinois coals, but the process has great potential value in the field of carbonization.

* * *

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Chairman Weimer: Thank you, Mr. Harrison. After working around the mines all year, I enjoy being exposed to some of these big words. When he got into the Russian alphabet there with the n’s upside down and the h’s backwards, I was glad that somebody can work with the Russians.

Do we have any questions of Mr. Harrison?

Ralph Gray, (U. S. Steel Corporation, Monroeville, Pennsylvania): John, in your opinion, what significance do you attach to your test evaluation method in prospecting?

Mr. Harrison: There are several facets to the use of coal petrography. To answer your question specifically, if a company is interested in a block of coal they put down test holes. They will obtain a sufficient quantity of coal from these diamond drill cores so that an idea, and a fairly accurate idea, can be obtained about the type of Advertising in this volume makes it possible to print it. Patronize our Advertisers.
coke that can be produced from the block of coal even before the shaft or the slope is sunk. Also, the petrographic evaluation will be quite advantageous because it would release some of the time now being spent in pilot oven scale studies and permit additional research more exclusively suited to pilot scale. In other words, a good deal of time at present is used in making routine runs on pilot scale ovens. This petrographic technique will release some of the time so that other factors can also be tested.

The petrographer will make an analysis, he'll make his calculations and this in turn can be compared with the results that we get from a pilot scale. In fact, this is what we are doing at the present time.

William Berry (Bituminous Coal Research, Monroeville, Pennsylvania): John, you went into no nomenclature, etc., considerably. Can you give us an idea of the length of time required to take a sample of coal and come up with a prediction on the performance of the sample in coking?

Mr. Harrison: Well, this will vary, of course, depending upon how many people you have in your laboratory and whether you have to prepare your own samples and whether you have someone to polish, to do the study, help with the calculations, etc. In any case, however, your time is going to be much less on the petrographic evaluation than it will be on regular routine procedures commonly used at the present time. In other words, if I can get a sample, I have a boy working half-time preparing the sample; I get it under the microscope for reflections and measurements, etc., and within five to six hours I can have an answer for you.

Mr. Gray: There is application of petrography with reference to Mr. Greer's paper; something which has not been thought of a great deal, but may be found desirable. These petrographic combinations of coal have a very great effect on equipment, wear of parts and on hydraulic pressures. Both rank and composition affect this and may appreciably affect it. This might be something that equipment manufacturers may care to look into.

Mr. Harrison: That's a good idea, Ralph. Actually the subject of my paper this morning has been on coking. However, coal petrography is very important to other fields too. The composition and physical makeup of coal is a very important factor in many coal uses, and I think that applications to problems other than carbonization are important.

H. W. Jackman (Illinois Geological Survey, Urbana, Illinois): John, to your knowledge has petrography been applied to any of the properties of coke other than stability?

Mr. Harrison: I might give an answer as to what I think; then I will turn it over to someone else. As you have noticed here, coal petrography has been used in conjunction with empirical tests and these tests have considered the stability factor as something we want to determine. If you accumulate these empirical data for other properties, such as hardness, petrography can be used for that, too. In other words, it can be used for predicting other coke qualities, but if it has

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It is my understanding that stability is one of the main things in which you are particularly interested, but petrography can be used for other properties.

G. H. Cady (Illinois Geological Survey, Urbana, Illinois, emeritus): Coal petrography has been used in evaluating coal hydrogenation; that is, there are certain portions of the coal which will hydrogenate, certain portions which will not. I think that this is another application of petrography. Then there is a further application in the case of coal which has been subjected to ordinary cleaning processes. We have here at our speakers' table a man (Dr. McCabe) who has done quite a little work in the application of coal petrography to cleaning processes, in which it is quite apparent that under certain conditions these processes produced in certain sizes of the coal an abundance of vitrain and in other sizes of the coal an abundance of fusain, and it has been applied in that connection. Petrography has been used somewhat to control the composition of stoker coal so that in the study of performance it was found that when the coal is produced under certain conditions we have a superabundance of vitrain which tends to make the coal swell in the stoker. And we found that if other components of coals produced in other fractions of the cleaning process were added to those portions which were tending to swell, there was a tendency to overcome that swelling property of the coal. I think a good deal can be said for the understanding of coal petrology in various fields of coal preparation and utilization.

Mr. Harrison: Thank you, Dr. Cady. This is what I was trying to say but he says it so much better than I do. He has been working with coal petrography for many years.

Chairman Weimer: Thank you again, John. These fellows really get into the details of things. I think they help us all in that we can understand coal a little bit better. Maybe out of it will come some more markets.

Our third speaker is Dr. Louis C. McCabe, President of Resources Research, Inc., Washington, D.C. Dr. McCabe was also born in Arkansas, graduated from the University of Arkansas in 1931, has Master's and Ph.D. degrees from the University of Illinois, receiving the latter in 1937. He also started with the Illinois Geological Survey. It looks as if John Harrison was following Dr. McCabe, a few years later. Dr. McCabe went to work for the Mississippi Coal Corporation in 1928-30. He was with the Illinois Survey in 1927 and 1930-1931 before entering on active duty with the army. After that he became chief of the Coal Branch, U. S. Bureau of Mines, 1947-49. Later he was Director of the Los Angeles County Air Pollution Control District, in 1951-1955. He was Science Director of the U. S. Public Health Service in 1955 and is presently President of Resources Research, Incorporated, Consultants. He had foreign service during World War II and holds many decorations from both the United States and abroad. His topic is "Trends in Air Pollution Activity." From the foregoing you can see that he is well qualified to speak on this, Dr. McCabe.

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This subject of air pollution is controversial and one in which there are many experts. Almost every citizen considers himself an expert in the field so there are some rather vigorous discussions pro and con about the proper interpretation of many of the problems in air pollution. This morning I would like to illustrate some of the more common and some of the less common problems. You may remember that in 1938, here in Illinois, the coal industry first became aware that air pollution was a serious matter when Ray Tucker, now Mayor of St. Louis, put through regulations setting the sulphur and ash content of coal burned in St. Louis. For many of the operators in the Illinois coal fields this was a severe blow.

Yesterday I visited the Missouri Botanical Gardens, where I conferred with Dr. F. W. Went, the Director. He said that they have now brought back many of their plants from the country, where they had to take them before the coal regulations were adopted. This includes orchids and other pollution-sensitive plants. It is Dr. Went's conviction that St. Louis has one of the cleanest atmospheres in the United States now.

The sources of air pollution are many and varied; that is the reason there are difficulties in control. There is always a tendency to oversimplify problems of this sort and an individual experiencing one of the air pollution problems in one area is inclined in think that the cause and the solution are the same in another area. This isn't so. The natural sources of air pollution are always with us. Volcanic dust, dust storms, forest fires and plant pollen are some of these. Plants give off literally millions of tons of organic compounds largely in the gaseous state which may condense to liquid droplets that scatter light, producing the blue color of many mountain and desert areas and the red of the sunset. All our major fuels can cause air pollution if burned improperly. At the Missouri Botanical Gardens I saw a gas burner under test in a greenhouse. The manufacturer had in mind operating the gas furnace and exhausting directly into the greenhouse, but it was found that whatever is done, exhaust gases injure the plants. It has been suggested that a dual chamber furnace might provide complete combustion, but this is probably unrealistic.
In recent years, certainly the last fifteen, everyone has become very much aware that there are more problems in air pollution than simply smoke. The coal industry bore the brunt of smoke prevention initially since users of coal were considered the main source of air pollution. St. Louis and Pittsburgh were known as smoky cities. The equipment manufacturers and the users of coal have since made great strides in burning coal. We no longer see coal bearing the full burden of air pollution. The chemical industry is receiving attention as a source of air pollution. Gob pile fires are a source of complaint; aluminum reduction, reduction of other metals and petroleum refining require control. Perhaps the most recent source of pollution to receive attention has been the automobile exhaust.

In Los Angeles County, California, a very thorough job of controlling dust, chemical plants and petroleum refinery effluents has been done, and now the problem appears to be reduced to one source. The exhaust from some 3-4 million automobiles is now the major problem. Those of you who have been in Los Angeles realize the significance and urgency of the air pollution problem.

The diesel bus, of course, comes in for a considerable amount of criticism because persons standing on the curb get the full effect of the exhaust. From the standpoint of air pollution, the diesel is not as serious as the automobile itself.

Power plants burning sulfur-containing gas from refineries in the Los Angeles area once discharged blue plumes of SO₂. This no longer occurs because the refinery gases are scrubbed free of hydrogen sulfide, which was the principal source of sulphur compounds. Los Angeles County requires control of dust, fumes and smoke but the automobile exhaust is still to be controlled and Los Angeles still has smog.

The Jersey meadows are known by their smell to all travelers to New York. In 1958 I directed a survey of the New York metropolitan area. At that time there were regulations prohibiting burning dumps in New Jersey, but enforcement was not too effective. This is a sore spot in many communities.

When I first went to Los Angeles as the Air Pollution Control Officer in 1947, combustible rubbish was burned in 55 or 60 public or private dumps. Some of them burned 400-500 tons of combustible rubbish a day. They were closed out rather rapidly. Many operators

Fig. 1—Smoke and fly ash discharge from an apartment house incinerator.
went to sanitary fill, which is a good answer if cheap land is available. Los Angeles has now largely run out of land to bury waste and has built public incinerators to end the burning of rubbish in home and other small incinerators.

Boxcar burning was a source of smoke that was quite common in the Buffalo area four or five years ago. It is now abated. The company which retrieved the trucks and iron from worn out boxcars would turn over about six to eight of these cars each morning, set them on fire and lay down a terrific smoke screen.

A common air pollution problem in New York City is the apartment house incinerator (Figure 1). Anyone living on the thirtieth floor of an apartment building complains of the air pollution from the incinerator discharging from an adjoining twenty-five story building. There are 11,000 apartment house incinerators in New York and they are a major source of air pollution.

There were sixty grey iron foundries in Los Angeles in 1947 and they discharged excessive quantities of dust. In the beginning they had trouble financing control equipment. Capital investment in the plant may have been $100,000 when built, but at that time it cost $25,000 to put in a bag house for control. The big cost was in bag house fabrics which were in development and had short life. High temperature cloth is now available and in-

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Fig. 3—Smoke from an automobile wrecking yard.

installations cost from $8,000 to $10,000. All the foundries have them now. The fumes from asphalt plants cause damage to vegetation when they are discharged near gardens or greenhouses. The burning of old rubber tires is particularly objectionable (Figure 2). Burning of automobile bodies (Figure 3) has been a problem in many cities. In New York City two incinerators have been built to burn eight or ten cars at a time on continuous conveyors. These incinerators have dual combustion chambers and precipitators.

On the sidewalks of New York on the west side near 59th Street and Henry Hudson Parkway a few years ago there was a heavy fallout of cinders from one of the city's power plants (Figure 4). Nothing was done to control the fly ash and it covered the sidewalks and cars with heavy deposits. Periodically the city sent men around to shovel off the cinders from roofs within eight or nine blocks of the power plant. There were two such old power plants, one on the east side and the other on the west side of Manhattan, producing electric power for the subways. Last year the Consolidated Edison Company bought the plants and put in precipitators to control the fly ash.

There has been some difference of opinion between New Jersey and New York City officials whether or not the air pollution moves across

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the common state boundary. Figure 5 is a picture of smoke from a smelter in New Jersey which very well illustrates that the plume does travel for miles and miles under certain atmospheric conditions. There is no doubt about the movement across the state line.

Figure 6 illustrates what happens on a clear day when there is no inversion. The plume rises and produces the effect of greater stack height. This is termed a lapse condition. Normally under daytime conditions the temperature will decline from the earth outward at about 5.4°F per 1,000 feet because of the decrease in barometric pressure with height. If lapse conditions always prevailed, there would not be severe difficulties with air pollution.

Fig. 4—Soot and fly ash cover sidewalk near a power plant on Manhattan’s West Side.

Fig. 5—Interstate transport of air pollution: fumes being carried across Arthur Kill to Staten Island, New York.

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Figure 7 illustrates inversion due to radiation of heat from the earth. In this particular situation the air at ground level is cold and the air represented by the bright upper fifth of the photograph is warm. Under these conditions the pollution is held in the cold dense air layers near the earth. As soon as the sun has been up for a few hours, warming the ground, turbulent mixing will occur and the pollution will dissipate.

Smog in Los Angeles causes eye irritation and injury to sensitive leafy crops such as lettuce and spinach. A few years back the crop injury in Los Angeles County was estimated to be $3,000,000.00 a year. By the change of crops for the substitution of less sensitive varieties this difficulty has to some extent been overcome. Another factor in relieving the crop loss in Los Angeles County has been the encroachment of subdivisions in the groves and truck garden areas.

Now, I wish to take just a few minutes to discuss some of the things that appear to be developing in air pollution. Los Angeles County was the first county to impose rather comprehensive regulations regarding all types of air pollution. As early as 1948 a limit was placed on the sulphur dioxide that could be discharged from stacks. This was .2 per cent or 2,000 parts of SO₂ per million parts of air. This was to prevent injury to truck gardens in the refinery and sulphuric acid plant areas.

The Public Health Service entered the air pollution field in 1955.
by an act of Congress which provided funds for research, collection and dissemination of information, and for surveys in certain demonstration areas. The appropriation the first year was about $3 million. Since 1955, the appropriation has grown to $8 million for 1962. There is $5 million available for general air pollution and $3 million is earmarked for specific research on the automobile exhaust. The Public Health Service must report to Congress in two years on the effect of auto exhaust upon health.

The California State Legislature a little more than a year ago, passed a law requiring that afterburners be put on automobiles when they are available. The statute has required all 1962 model automobiles to have a blow-by device. This device recycles the gases from the crankcase back into the carburetor where they are fed to the cylinders and burned. It is reported to remove about one third of the objectionable unburned gases. It is rather interesting that the research in California has shown that normally about seven per cent of the gasoline goes through the automobile engine unburned.

It may not be too long before Los Angeles County and the State of California particularly will adopt a regulation requiring some sort of control device for all the gases from

Fig. 7—Air pollution held near ground under inversion conditions. New Jersey-New York; Hudson River in center.

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the exhaust as well as from the crankcase. However, the public is very alert to the development difficulties. If they are required to put on a device that costs $150 and its life is three months, there will be a lot of unhappy people. At this time seventeen devices are being tested. For the most part they employ a catalytic oxidation process but there are a few of them that use a burner or spark plug to ignite the exhaust. It would not be surprising if some such device or a new approach to the exhaust control becomes a universal requirement in the years ahead.

The Federal Government is requiring blow-by devices to be put on all government purchased cars. The Secretary of Health, Education and Welfare has called on the automobile industry to put the blow-by device on all new cars within two years.

In 1960, about $11 million was spent for research in air pollution. It has been estimated by the National Air Pollution Advisory Committee that by 1965 the United States will be spending $30 million a year for research on air pollution. This does not include the control equipment installed by industry but does include research by the Federal Government, by the states, counties, cities and industry.

Los Angeles County has in recent years put in an alert system for warning the public when there is an excessive amount of air pollution. The alerts apply to carbon monoxide, oxides of nitrogen, sulphur dioxide and ozone. The system provides for first, second, and third alerts depending on the levels of contamination that are found in the atmosphere. There are six or seven instrument stations around the country that record and transfer the data into the central headquarters. When the first alert is indicated, which is infrequently, certain processes are directed to stop operating and the county has the authority to enforce the regulation. At the second alert, there is a provision for stopping other operations, including the reduction of automobile traffic. In the event of a third alert, the Governor is requested to declare a state of emergency and take certain actions provided by the California Disaster Act.

The U.S. Public Health Service is financing research to the limit of its funds and will continue to do so. The states are interested more and more in the problem. I do not know just how many of the states have passed laws on the subject but probably twenty to twenty-five of them have done so. As I see the problem as it affects the coal industry, there are some things you might be concerned about. If, like Los Angeles and other areas, your state shows an interest in limiting sulphur dioxide in the air, your coal market will suffer.

The Government Industrial Hygienists have set maximum allowable concentration of five parts per million of sulphur dioxide for eight hours as being safe for workmen. An individual who is unaccustomed to sulphur dioxide will experience eye burning at five parts per million. The odor is first observed by most individuals at three parts per millions parts of air. Los Angeles County now limits the sulphur content of fuel in the seven worst smog months to one half per cent. If that were introduced any place where
coal is burned, the upset in markets would be drastic. I do not know of any coal in this country that could consistently meet such a standard.

There is a lot of medical work now being done. There is some indication that small amounts of sulphur dioxide reduce the volume intake in the respiratory tract of small animals. Whether SO₂ affects man in the same manner is not known. In spite of the extensive work that has been done with the significance of sulphur dioxide, more research is needed on the effects, if any, on man from very low concentrations in the ambient air.

It is very probable that air pollution will follow the same pattern that developed in pollution of water 100 years ago. We did not have knowledge of the organisms causing yellow fever and typhoid but it was suspected that sewage dumped untreated was the cause. Sewage and water treatment was initiated and these diseases almost disappeared.

Chairman Weimer: Thank you, Dr. McCabe. Does anybody have any questions for Dr. McCabe? I had one on the automobiles and trucks but he answered it very well, in that they are trying to find some kind of after burner for the fumes of the trucks and automobiles. I have another one that is coming to our attention: With Mr. Kruschev setting off bombs that are going to rattle his own windows, and in St. Louis the radio tells us how many counts of micro-curies are in the air every day and that the cows are giving atomic milk and mothers are afraid to let the babies have the milk. I wonder if Dr. McCabe can tell us just what the danger is, and how much danger there is, in something like that. We are all so confused about it that I would be glad to know what he thinks.

Dr. McCabe: I didn't touch on radioactive fallout at all; generally, that is not in the area in which we work. But I take the fundamental view that any radiation is bad for you. Experts, of course, allow a certain amount of radiation that may be safely accumulated in a man over his lifetime. The radiation of long life, when deposited in the bone marrow of man, has caused a type of cancer. In addition to that, any radiation which you get all the time from the sun, and so on, may cause changes in the cell. Some experts in the field predict there will be an increase in the birth rate of abnormal children if there is exposure to excessive radiation.

Chairman Weimer: Thank you. Any other questions for Dr. McCabe?

W. G. McCulloch (Roberts & Schaefer Co., Chicago, Illinois): Louie, you showed the plume coming out of the Consolidated Edison plant. You had the United Nations building in the background. I was in New York one day in December when that plume turned over horizontally and went into the intake of the ventilating system in the ventilating system in the United Nations Building.

Dr. McCabe: That problem has been with the United Nations for several years. I remember that protests came to Mr. Truman at one
time. He said it was not American property and that it was an international problem. Since then Consolidated Edison has tried to get an allocation of natural gas and that was turned down by the Supreme Court. On the other hand, Los Angeles received approval for natural gas to reduce the smog. Los Angeles during seven months of the year cannot burn residual fuel oil because of the sulphur limitation.

Chairman Weimer: Any further questions for Dr. McCabe? Mr. Greer has just returned from India, I understand, and I want to ask him if he sold any machinery and if it is true that they carry out coal in baskets on their head over there.

Mr. Greer: Yes, they do carry it out on their heads. We saw one fellow who had a great big dragline out there working and another one right beside him. The one beside him was down and there was a whole bunch of little women around him with baskets on their heads carrying the coal out and we asked him why he couldn't fix it and he said he couldn't afford to—those women were cheaper than fixing the dragline. They have some seams that make your eyeteeth water because of the fact that they are up on end but are extremely thick. The seams will run 120 to 150 feet in thickness and you are standing on the edge of the pit; as far as you can see, there is coal.

Chairman Weimer: Are there any other questions of any of the speakers? ... Then, on behalf of the Illinois Mining Institute, we want to thank the three speakers here this morning. It will take three-quarters of an hour to clear the room and set it up for a banquet. Now, most of the papers this morning have pointed toward our distinguished speaker for the luncheon. He is going to speak on "Coal's Potential," and there are still tickets for sale downstairs. If there is nothing further to come up, we'll stand adjourned until 1:00 p.m.
The business meeting was convened following Luncheon held in the Grand Ballroom of the Abraham Lincoln Hotel. Mr. Gene Moroni (Old Ben Coal Corp., Benton, Illinois) presided in the absence of the Institute President.

**Chairman Moroni:** Because of several items on the agenda we want to get our program under way. After that fine luncheon, we have the order of business for the Illinois Mining Institute and after that, of course, we have the real dessert of the day. The Illinois Mining Institute presently has gone from the long to the short in the organization. I think, from Stuart Colnon, who is six feet four, to Gene Moroni, who is five feet five. However, to get the business going, it is fine to see so many fellow members of the Illinois Mining Institute here and we welcome each and every one of you.

The first order of business is usually the reading of the minutes of the last session. Those minutes have been published and we will dispense with the reading with your permission. At this time we’ll have the Secretary’s report to be given by Jack Simon for George Wilson.

**SECRETARY’S REPORT**

**Acting Secretary-Treasurer Jack A. Simon** (Illinois State Geological Survey, Urbana, Illinois): Mr. Chairman, I’ll try to make this very brief. Membership last year: There were 719 paid members of the Institute, 80 life members and four honorary members. This is a total membership of 803 which was seven less than the preceding year. At the annual meeting this year, there was a total registration as of noon today of 417, which is about the same as last year. With those comments, I’ll conclude the Secretary’s report and move into the Treasurer’s report.

Copies of the Treasurer’s report have been furnished to the members of the Executive Board and a number of additional copies are available for anyone wishing to examine the report. The Institute continues to hold U. S. Government bonds in the amount of $19,000 and a $1,000 Missouri Pacific bond, for a total of $20,000 worth of bonds, which is unchanged from last year. The cash balance in the bank is $2,000.61, which is $1,547.60 less than last year. This represents in part a deficit, but is partially due to payment to the University of Illinois scholarship fund, the Institute’s contribution for 1960-61 and also for 1961-62 within this past fiscal year, the previous year’s payment.
having been made after the annual meeting last year. The actual deficit has resulted from continually rising costs of publication of the Proceedings and continually declining revenue from advertising. This has been at least partially corrected for the future by the first increase in advertising rates in many years. Indications are that this will mean no decline in our advertising support, and the indications are excellent that the Institute will be operating well in the black.

I would like to make a brief statement on the activities of the advertising committee, of which the Secretary's office is just an assisting facility. Members of this committee normally get into high gear on the advertising for the Proceedings after the annual meeting. As of Thursday of this week, on an automatic return from ad solicitations by mail there were 41 pages of advertising on hand, which happens to represent 41% of the number of pages in the 1960 Proceedings. We are hopeful again to be able to get out the Proceedings as early in 1962 as we possibly can and every effort will be made to do that. As most of you know, the advertisers in the Proceedings have made possible the operation of the Institute and we say it often, but we say it very meaningfully, that they certainly deserve our support. The advertising committee of the Institute has been working harder every year, as I'm sure you can fully appreciate, because as the advertising gets a little harder to get, they've had to work a little harder and they really have done a magnificent job. These men are listed in the advertising section of the Proceedings, but it is felt their names should be recorded as part of the official record:

John Broadway, Chairman
W. D. Butts
Wm. Campbell
R. A. Dodds
Ray L. Fiedler
Carl T. Hayden
R. J. Hepburn
L. B. Hyett
W. A. Patty
R. Y. Spikings
Norman Syljebeck
R. A. Taucher

I know that George Wilson and I, acting as the Secretary's secretary, have been very appreciative of the magnificent effort that these men make. Working with George Wilson this past year, Joe Schonthal and John Broadway have been particularly helpful in making affairs of the Institute go along the line and we all appreciate that effort. I would like to bring to your attention the fact that Gene Moroni agreed on very short notice to take over the job of Master of Ceremonies or Conductor of Business at this meeting and we're very appreciative of that also. That's all I have, Mr. Chairman.

Mr. Moroni: Thank you very much, Jack. Our next order of business is the report of the Nominating Committee. I think Joe Schonthal is chairman of the committee and will make the report.

REPORT OF THE NOMINATING COMMITTEE

Mr. Schonthal: This is the report of the Nominating Committee. We, the undersigned, constituting the Nominating Committee, offer the following nominations for officers for the ensuing year and for mem-

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bers of the Executive Board to serve three years:

**OFFICERS**

**President:** Robert W. Hepburn, The United Electric Coal Cos., Chicago, Illinois.

**Vice-President:** J. P. Weir, Paul Weir Co., Chicago, Illinois.

**Secretary-Treasurer:** George M. Wilson, Illinois State Geological Survey, Urbana, Illinois.

**EXECUTIVE BOARD**

David Flota, Sahara Coal Co., Harrisburg, Illinois.


Respectfully submitted,

Wm. C. Campbell
L. B. Hyett
Jos. Schonthal

Mr. Moroni: Thank you very much, Joe. Are there any other nominations from the floor? If not, the chair will entertain a motion to elect the officers as proposed by the nominating committee. (Moved, seconded and approved.)

Gentlemen, you have elected by acclamation the new slate of officers as proposed by the Nominating Committee. I think they should have a good round of applause to send them off on their mission. (Applause.)

As you notice, I have an excellent ghost writer here on my left. I have to refer to the notes in the book. The next order of business is the report of the scholarships and the introduction of the students who are attending school under these scholarships. At this time, I would like to call on Dr. T. A. Read, Head, Department of Mining and Metallurgy at the University of Illinois. Dr. Read.

### SCHOLARSHIP REPORT

**Dr. Read:** It is a great pleasure to be here again to present the scholarship report. First I would like, as usual, to express our great gratitude to the Illinois Mining Institute for continuing this financial support to needy students that makes it possible for them to obtain engineering training at the University of Illinois. First, I would like to introduce Mr. Lanny L. Richter, holder of an IMI scholarship, a senior; another IMI scholarship holder, Mr. Edwin L. Klasser, a sophomore; Mr. Larry T. Tabaka, also a sophomore. Another scholarship holder, with a scholarship supported by the Sahara Coal Co., is Mr. Thomas E. Finch, a junior. Finally, the Old Ben scholarship is held by Mr. Donald W. Gentry, a freshman who was not able to be here because of academic requirements.

Last year, perhaps not many of you know, your Executive Board took a very generous action in making available to the Mining Department at the University of Illinois some funds for the support of coal mining research. And I would like to make a brief report on the research work that this has gone to support. First of all, I would like
to introduce the people who are responsible for this research: Prof. Fred D. Wright and Prof. George Eadie. I'm very sorry to have to report that we lost the services of Prof. R. J. Wuerker who was a long time member of the Illinois Mining Institute and who passed away last August in California after an illness of several months.

The research program which has been supported by the Institute falls into three main categories: Mine ventilization research, operations research, and research in the field of rock mechanics. The ventilization program has been concerned with the study of air flow through gob areas and in bleeder around the gob by the use of a plexiglas scale model of part of the underground workings of a mine. Another phase of the ventilization research has been the development of a program for use on a digital computer for solving ventilization problems, which previously had been handled by the less powerful techniques of analog computers. In the field of operations research, we have developed or are in the process of developing a digital computer program for predicting jig performance from washability studies. Thirdly, the rock mechanics studies are aimed primarily at the problem of roof control. That consists of two phases: First, an analytical study for relating the strength of roof materials to physical property measurements made on diamond drill cores. Secondly, the study for relating the strength of roof rock and the strength of pillars. We are very grateful for this financial support, which together with financial support by the University, has made it possible for us to initiate and partly carry out these programs. We would like very much, however, to be able to accelerate the rate of this research and are very eagerly looking for additional support for these programs. We would certainly appreciate anything any of you could do to help us in obtaining support from other agencies. Thank you.

Mr. Moroni: Thank you, Dr. Read. Is there anyone here to represent Dr. George B. Clark of the Missouri School of Mines in Rolla? Well, if not, I think mention should be made of the fact that the Illinois Mining Institute does support one scholarship at the Rolla School of Mines which has been awarded. Also attending the session today are some students sponsored as guests of the Sahara Coal Company. Maybe these young fellows would rise also, please.

Gentlemen, the next order of business is the introduction of guests seated up here at the head table. And I beg your indulgence and forgiveness for having to refer to the notes to introduce them because I'm not acquainted with all of them. At the left end of the table, Fred Wilkey, long time Secretary of Illinois Coal Operators Association; next to him is John Broadway, Chairman of the Illinois Mining Institute Advertising Committee; Dr. R. A. Glenn, Manager of the Chemical Division of Bituminous Coal Research, Inc.; Bill Weimer, Peabody Coal Company, session chairman this morning; R. D. Greer, of Jeffrey Manufacturing Company, and John A. Harrison of Illinois Geological Survey. I think we all know our faithful Secretary, George Wilson, Secretary of the Institute.

*Our Advertisers are our friends and fellow members. Consult them frequently.*
and Jack Simon. Beginning at the right end of the table is the young man who has come a long way in the Coal Industry. He is a newly appointed Director of the Department of Mines and Minerals in the State of Illinois, William J. Orlandi. Next to him is Vice-President of Operations of Freeman Coal Company, Gene Mauck. We have next one of our honorary life members, well known in the Coal Industry, Dr. Gilbert H. Cady. Next to him is Dr. T. A. Read, whom you just heard, Head of the Department of Mining and Metallurgical Engineering at the University of Illinois; next to him is Robert J. Hepburn, Vice-President of the United Electric Coal Companies and newly elected President of the Institute. We have next Dr. Louis C. McCabe, Resources Research, Incorporated. The gentleman to my right will be the speaker of the day, Mr. George Lamb, and I'll tell you a little more about him in just a few moments.

Gentlemen, is there any old business to come before the Institute at this time? Is there any new business to anyone's knowledge that should be brought before the meeting? Under new business we have a presentation to be made and I would like to call on Mr. Bob Hepburn to make that presentation.

Mr. Hepburn: This is indeed a pleasure for me, to be asked to bestow upon Mr. Fred Wilkey an honorary life membership in the Institute. This award is made occasionally to men who have served the coal industry of the State and the honor is being bestowed on Fred in recognition of his thirty-four years of service as Secretary of the Illinois Coal Operators Association. Fred has been a member of this Institute since 1929. He was born in Sullivan, Indiana, and is now retired to an Indiana farm. It is certainly a pleasure to confer this honor of the Institute on Fred for his many years of service to the Illinois coal industry. I think this time, Fred, you can't argue back at us.

Mr. Wilkey: I'm afraid not. Well, I don't have much to say except that this is a great honor and I'm truly grateful. I have enjoyed my thirty-odd years as a member of this Institute and I'm glad that they didn't read off anything about me that so many of you men know about me, but I shall cherish this and never forget my many, many years in the Illinois coal industry. A great many changes have taken place, especially in the labor front. Of course, I have to say that because that's been my particular forte, but that is true of selling and production and everything else. When I like many others, started in, everything was hand loading. Today, everything is highly mechanized. We have fewer men and the industry is continuing to change in productive methods and sales methods and so on. The uses of coal are changing. So time marches on. I'm very grateful to you, gentlemen. Thank you.

Mr. Moroni: Thank you, and congratulations again to you, Mr. Wilkey, and thank you, Bob.

Gentlemen, we'll move along now to what, as I said, is the dessert of the day. We are very fortunate in having with us a gentleman who is well known in the coal industry. He comes originally from Idaho. To give you a little of his past history,
I'll go back only to the war years. He was chief economist of the Solid Fuels Administration during the World War II period. During 1944-46 he was Assistant Director at the United States Bureau of Mines. From that time, for the next fifteen years he was with Consolidation Coal Company in Pittsburgh, Pennsylvania, as Manager of Business Surveys, and as of April of this year, by request of the Secretary of Interior, Mr. Udall, in a personal request to the President of the United States, the office of Director of Coal Research was created and Mr. George Lamb was appointed to be that Director. It is a very great pleasure, at this time, to introduce Mr. George A. Lamb.
COAL'S POTENTIAL

GEORGE A. LAMB

Director, Office of Coal Research
United States Department of Interior
Washington, D.C.

It is a pleasure to speak before the Illinois Mining Institute at its 69th Annual Meeting. I feel honored to be on your program. In addition, I am grateful for the opportunity to tell you about the activities of the Office of Coal Research.

More important than my talk, however: I have a message to convey. This is from a man who a few years ago as a congressman was on a special committee of the Interior Committee in the House which held hearings on the coal situation. It was called the special coal research committee. As a result of the findings of this committee, we have the Coal Research Act under which our office operates. I refer to Secretary Udall. He asked me to convey a brief message on his behalf:

“When I learned recently that George Lamb, Director of Coal Research in the Department of Interior, was scheduled to address your meeting, I asked that he convey my greetings and a message to you.

“Yours is one of the oldest and most active among organized trade groups in the entire country. I firmly believe that much benefit can accrue to an industry which has banded together under the principles of a free society and functioned so ably over these many years.

“It is a genuine pleasure to convey my greetings through Mr. Lamb and to express through him the hope that the efforts being made by individuals and organizations like yourself, as well as others associated with the coal industry will bring substantial results in the future.

“We are confident that the government, acting in cooperation with the coal industry and organizations like yours, will be able, through their combined efforts, to do much toward alleviating the present conditions which prevail in the industry and to bring about a new level of prosperity to the industry nationwide. This will enable the industry to cope with the increasing energy demands which will be made upon it in the years ahead by the requirements of our expanding economy in a free and growing America.

“As President Kennedy said in his special message on natur-
al resources. ‘Wise investment in a resource program today will return vast dividends tomorrow, and failures to act now may be opportunities lost forever. Our country has been generous with us in this regard—and we cannot now ignore her needs for future development.’”

Stuart Udall
Secretary of the Interior

Six months back, my appointment as Director of Coal Research was announced by President Kennedy and Secretary Udall. It was the middle of the summer before most of our staff were on hand; thus, the Office has had limited time to gain operating experience. However, there has been exciting activity during this short period, not only in performing day-to-day tasks, but also in attempting to visualize how this young Office will develop to aid the coal industry’s progress as it moves toward its expanding market potential.

Most encouraging has been the wide interest shown in OCR. Proposals on coal research began to appear not long after the President’s signature was affixed to the coal research bill in July 1960. Sixty proposals had been filed by the time I was appointed in April. More than one hundred fifty proposals have now been received, including several from the University of Illinois.

The four slides I am going to show indicate the broad source and subject matter of these proposals.

These proposals, coming from many organizations and individuals, represent a cross section on research thinking and provide an indication of how coal may have to move to better its place in the energy market. They indicate three major utilization fields that offer additional tonnage volume. First is power generation, which is followed by gasification and liquid fuels, with related proposals on chemical and other uses. I shall comment later on projects in the field of mining.

<table>
<thead>
<tr>
<th>TABLE I—SOURCES OF THE FIRST 130 RESEARCH PROPOSALS RECEIVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLLEGES AND UNIVERSITIES........................................</td>
</tr>
<tr>
<td>PRIVATE RESEARCH ORGANIZATIONS..................................</td>
</tr>
<tr>
<td>COAL-SPONSORED RESEARCH ORGANIZATIONS.............................</td>
</tr>
<tr>
<td>PRIVATE-INDUSTRY COMPANIES........................................</td>
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<tr>
<td>PRIVATE INDIVIDUALS................................................</td>
</tr>
<tr>
<td>THE COAL INDUSTRY..................................................</td>
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</tbody>
</table>

Our Advertisers are selected leaders in their respective lines.
TABLE II—RESEARCH AREAS SUGGESTED BY THE FIRST 130 PROPOSALS

<table>
<thead>
<tr>
<th>FIELD OF UTILIZATION</th>
<th>Number of Proposals</th>
</tr>
</thead>
<tbody>
<tr>
<td>COAL GASIFICATION AND CARBONIZATION</td>
<td>18</td>
</tr>
<tr>
<td>COMBUSTION METHODS AND EQUIPMENT</td>
<td>11</td>
</tr>
<tr>
<td>ELECTRICAL APPLICATIONS</td>
<td>8</td>
</tr>
<tr>
<td>(Mine-mouth Power, RR Electrification, High-voltage</td>
<td></td>
</tr>
<tr>
<td>Transmission, Heat Pumps, etc.)</td>
<td></td>
</tr>
<tr>
<td>COAL CHEMICALS</td>
<td>6</td>
</tr>
<tr>
<td>IMPROVED COKING METHODS AND FUELS</td>
<td>5</td>
</tr>
<tr>
<td>LIQUID FUELS</td>
<td>5</td>
</tr>
<tr>
<td>(Includes Adding Fine Coal to Oil, Gasoline, etc.)</td>
<td></td>
</tr>
<tr>
<td>FLY ASH UTILIZATION</td>
<td>5</td>
</tr>
<tr>
<td>NEW USES</td>
<td>5</td>
</tr>
<tr>
<td>(Includes Fuel Cells, Sewage, and Soil Treatment, etc.)</td>
<td></td>
</tr>
<tr>
<td>AIR POLLUTION</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>66</strong>*</td>
</tr>
</tbody>
</table>

*51% of all proposals received.

and preparation, as well as those in marketing and economics.

A large part of the future increase in the use of coal is expected to come from the expansion of the industry’s two largest growth markets—steel and the electric utilities. And the optimists would have us believe that coal need merely bide its time to be carried to prosperity by the demands of these two basic customers!

But we all know from bitter experience that even “assured” markets—as the railroads and domestic consumers once were—can be lost through lack of progress and lack of research. And coal’s projected growth markets are not “assured”; instead, they are potentials that will require development.

The electric utilities can and will use the energy fuel that results in the lowest generated cost of electricity. Any appreciable change in the relative costs of coal, oil, gas, and nuclear energy would result in the gain or loss of millions of tons of market!

Processes are now available or under development to make steel directly without the use of coal.

*Play ball with the Advertisers who play ball with you.*
Even in conventional steel-making methods, improved procedures reduce the quantity of coal required to produce a ton of steel each year. And, for that matter, the projected growth of the steel industry itself is not the assured matter it once appeared. For the first time in history, the American steel industry is facing external competition—from aluminum, from plastics, and from imported steel from other countries. Its future growth and its increased use of coal will depend on its own ability to meet this competition and upon the ability of the coal industry to supply a better and cheaper product.

Thus, a vital function of the Office of Coal Research is to aid in finding better and cheaper ways of mining and preparing coal, delivering it to the consumer at lower cost, and improving the efficiency and convenience of its utilization. The increase of from one-half to one billion additional tons per year forecast by many prognosticators is largely dependent on results of research which must be done now and in immediate as well as more distant years.

During the past three years, bituminous production has stayed around 110 million tons. This figure is considerably below the 500 million tons which the industry has stated it must produce in order to maintain its plant and equipment and to meet the needs of an emergency demand. The need to raise anthracite output is clear. To assist in the development of a stronger coal market in the immediate years, the Congress created the Office of Coal Research. Although this tremendous assignment is shared with the industry itself and with other agencies of Government and private business, the eventual success or failure of the Office of Coal Research will be measured by its contribution to the development of expanded coal markets.

The duties of the Office of Coal Research are defined in very broad terms by Public Law 86-599 as being “To encourage and stimulate the production and conservation of coal in the United States through research and development by authorizing the Secretary of the Interior to contract for coal research, and for other purposes.”

Although basic research may be required in certain areas of investigations, we fully intend to concentrate in the areas of applied research (research directed toward practical applications of science) and development (systematic use of scientific knowledge directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes).

This Office will diligently follow the intent of Congress in contracting for scientific, technical and economic research and its practical application. Emphasis is on getting research developed to the point of commercial realization within the shortest time possible. In this sense, our contract effort has an immediacy about it which goes beyond the bounds of a normal program of applied research.

However, it is not possible to engage in scientific research, even applied research, in a field so broad as coal, without being confronted with the need for some possible basic research in a specific area, or tied to a specific piece of work in progress or contemplated.

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TABLE III—RESEARCH AREAS SUGGESTED BY THE FIRST 130 PROPOSALS
FIELD OF MINING AND PREPARATION

<table>
<thead>
<tr>
<th>Research Area</th>
<th>Number of Proposals</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREPARATION, TREATING, BRIQUETTING</td>
<td>10</td>
</tr>
<tr>
<td>CRUSHING, GRINDING, PULVERIZING</td>
<td>7</td>
</tr>
<tr>
<td>MINING METHODS</td>
<td>7</td>
</tr>
<tr>
<td>SAMPLING AND TESTING</td>
<td>6</td>
</tr>
<tr>
<td>SULFUR AND ASH REMOVAL</td>
<td>6</td>
</tr>
<tr>
<td>NEW MINING EQUIPMENT</td>
<td>4</td>
</tr>
<tr>
<td>NEW PRODUCTS FROM ADJACENT STRATA AND REFUSE</td>
<td>3</td>
</tr>
<tr>
<td>UNDERGROUND GASIFICATION</td>
<td>2</td>
</tr>
<tr>
<td>MINE SAFETY METHODS AND EQUIPMENT</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>45*</td>
</tr>
</tbody>
</table>

*35% of all proposals received

There is no conflict between this Office and the Bureau of Mines, as the three basic differences listed below indicate:

1. OCR's major effort will be directed toward short-range research and development.

2. OCR will direct its major contract research effort to areas in which the promise of success can be measured by the most immediate economic impact on the coal industry.

3. Office of Coal Research work is performed solely by contract at this time. In the future there may be some merit in a limited program of grant-aid for specific work. No laboratories or other facilities will be operated for "in-house" research.

Because of these basic differences in program and method of approach, the Office of Coal Research will complement the research activities of the USBM.

What are the objectives of the Office of Coal Research and how do we propose to achieve them? Broadly stated, our prime objective is to maximize the value of the coal industry to the national economy. These words can be clarified by saying that we want to see new uses of coal developed and present uses expanded. Potential is to be exploited. In large measure, our suc-
cess will be measured by the volume of tonnage expansion, and our efforts will be shaped accordingly. But if commercial markets for other products associated with coal can be developed, this is another measure of success.

One example in the field of mining and preparation would be the development of a use for mine refuse. Another would be the recovery of valuable minerals from coal and the surrounding strata. Still another could be the commercial removal of methane from the Coal Measures themselves.

I am sure we can agree that increased research in the bulk utilization of coal is highly desirable. But transportation, marketing, and other economic aspects of the coal-producing and coal-consuming industries are also important and require research consideration.

Some fear has been expressed that mining and preparation would be neglected in the research program. This is not the case. Any proposal that improves the position of coal in the energy market—through lowered production or preparation cost—or through product up-grading, which permits its usage in new market areas—will be considered. But I repeat my statement made before the Southern Research Institute. The Office of Coal Research offers no subsidy. It offers instead an investment in coal's future, and an opportunity to make the fullest possible use of a most valuable natural resource—just that and no more. OCR does not offer a panacea for the private ills of individual groups.

Although increased coal volume is a major consideration in our program, this does not mean that we are not interested in projects that offer little or no tonnage potential. Some projects may correlate with or be vital to other projects that do offer such potential. As an example, a proposal concerning coal chemicals might offer prospects of only limited tonnage increase—but it might result in a profitable undertaking that could help support a proposal of appreciable tonnage impact—or it might develop a new product of special importance to the nation.

Thus the concept of an integrated program or complex is developed. Each proposal will be considered as a probable component in the complex, and some will necessarily precede others in the development of the integrated program. Proposals which must be passed over for the present may be again considered at a later date.

The Office of Coal Research will conduct no projects with its own staff. Instead, it will provide funds for research and development projects through contractual arrangements with universities and colleges, research organizations, mining and manufacturing firms, qualified and equipped individuals, and with other Government agencies. When appropriate, OCR may also co-sponsor projects with other agencies or organizations. Work is to be done under contractual arrangements covering particular activities and time for accomplishment, as differentiated from grants sometimes made to nonprofit institutions.

While all information, uses, products, processes, patents, and other developments resulting from research under Public Law 86-599 must be held available to the public, the spirit of the legislation dictates
DEPARTMENT OF THE INTERIOR
OFFICE OF COAL RESEARCH

TABLE IV—RESEARCH AREAS SUGGESTED BY THE FIRST 150 PROPOSALS
FIELD OF ECONOMICS AND MARKETING

<table>
<thead>
<tr>
<th>Area</th>
<th>Number of Proposals</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUDIES OF U.S. MARKETS</td>
<td>11</td>
</tr>
<tr>
<td>STUDIES OF EXPORT MARKETS</td>
<td>4</td>
</tr>
<tr>
<td>MINE-TO-CONSUMER TRANSPORTATION STUDIES</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>*<em>19</em></td>
</tr>
</tbody>
</table>

*14% of all proposals received

a considerate treatment of patent policy. Therefore, the decision on patent title will be determined with reference to the equities of the situation. Title to all patents developed as a result of contractual research will be decided on an individual basis. Where justified by unique experience, qualifications or background knowledge, the contractor may be allowed to obtain title to the resulting patents and royalty rights thereto, subject to issuance of royalty-free licenses to the United States Government and issuance of licenses to domestic users for reasonable royalties. The interests of individuals and organizations proposing a program for contract research will be protected. Information contained in contract proposals will be held in strictest confidence by OCR and its employees.

The function of the OCR staff involves making such studies and investigations as are necessary to evaluate the merits of proposed success of a given proposal, the validity of cost, the impact of success, and a minimization of any duplication of effort. Those proposals which meet the requirements of the OCR program will be negotiated and recommended to the Secretary of the Interior for final contract approval.

All proposals received will be given a careful evaluation by the technical staff of OCR, utilizing, in many cases, the technical competence and knowledge of our general advisory committee and the professional consultants in each area of interest appointed for this purpose. Several of these consultants and committee members are here today.

Evaluation of some projects may require a considerable degree of study. A prime factor in the evaluation of any proposal will be its effect, if successful, on improving the position of the coal industry in the national economy. As previously mentioned, the correlation of the proposal with other OCR projects

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will also be considered, as will the time required to obtain results. Those evaluated as likely to produce the earliest practical results will receive primary attention. At the same time, a proposal that fails to appear promising today might be the key to a sure-tonnage project next year because of certain developments in the meantime. Other factors given consideration include, but are not limited to, the competence of the contract proposer and members of his staff, the availability and completeness of the required facilities, compatibility with other research work now going on or conducted in the past, and cost of the work to be performed.

Following the award of a contract, the Office of Coal Research will maintain close liaison with the contractor to assure quality of work, progress toward contractual objectives, cost control, avoidance of duplication of effort, integration with other contract work, and development of new areas for research, and finally will seek ways to ensure the application of the end results of such research.

The General Technical Advisory Committee, composed of top-flight representatives of coal and associated industries, has suggested the following areas of impact, and programs presently in development closely correlate with their suggestions: (a) transportation of coal; (b) recovery of chemicals from coal; (c) exploitation of steel-making market; (d) development of smaller industrial heating plants; (e) gasification and liquid fuels; (f) coal preparation as it affects "a" through "e"; and (g) promotion of coal use in electric power generation.

While increased coal production and use are major considerations in the over-all program, OCR may consider projects that offer only limited tonnage potential—if they correlate with or are vital to other projects which do offer greater potential.

No initial research and development program can be pinpointed precisely as to its final outcome, but by fiscal 1963, research accomplished should show the feasibility of initial projects. This will permit greater concentration of effort in promising areas and a more comprehensive integration of respective programs in the mining, preparation, marketing, transportation, and utilization areas.

Our staff will do a painstaking job in contract evaluation. The need for coal research is great, and our budget is limited. We want to buy the greatest possible benefit to the national economy, to the coal industry, and to the American taxpayer with every dollar spent.

As Secretary Udall very appropriately stated on March 2, 1961, "We view the activities of this Office as an action program designed to bring about the expanded use of coal, and in so doing to promote the economic health of the nation and materially assist in meeting the economic and social problems currently existent in the depressed coal mining areas of our country," and toward this end "our nation should make the fullest and best possible productive use of the abundant heritage we possess in our rich coal resources.

"Here, we feel, is a challenge to test the ingenuity and abilities of the industry, our educational and research institutions, and individuals throughout this broad land. I have every confidence that, given the necessary tools with which to

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work, we will meet the challenge and in so doing accomplish the outstanding objectives of the President’s natural resources program to the lasting benefit of the coal industry and coal miners of America.”

A larger market for coal is a potential; it will be realized through hard work on the part of the coal industry together with vision reflected in research and development.

• • •

Mr. Moroni: Thank you very much, Mr. Lamb. Are there any questions that anyone would like to ask? Mr. Lamb has indicated to me that perhaps as a result of his visit and his message here today, the Office of Coal Research would be pleased to entertain more proposals than have been received from this area. So, gentlemen, you and the organizations which you represent may have ideas, some which may be way out in left field. We all have some time or another had preconceived notions of what we think coal could or could not be used for. If you have an idea, these people are here to serve us and you. So don’t hesitate in the least bit to send them your ideas whether or not you think they are acceptable. Thank you very much.

Before we go into the conclusion of the meeting, we are supposed to hand the gavel over to the new president but we don’t have the gavel so I guess we’ll just have to shake hands.

Mr. Hepburn: Mr. Chairman, Directors, and Members, I want to thank you for this honor and I’ll certainly do everything I can to have a successful 1962. I think this will end our proceedings and we’ll see everybody again tonight, and next year. The meeting is adjourned.

(The meeting was adjourned at 3:00 p.m.)
NOTE ON CHARGING TEMPERATURE AND COKE QUALITY—REPRESENTATIVE STUDY RESULTS OF AMERICAN, AUSTRALIAN AND JAPANESE COALS*

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N.S.W., Australia

ABSTRACT

A laboratory-scale investigation of the carbonization characteristics of a group of American, Australian and Japanese coals has revealed a significant relationship between oven charging temperature and coke quality. The latter appears to be particularly related to the rate of heating up to and within the plastic range of the coal. It is suggested that coke-strength variations are in part conditioned by rate of heating in relation to plasticity and gas evolution characteristics of the coal, which in turn reflect the petrographic constitution, type distribution and rank of the seam.

Oven charging at temperatures within or above the plastic range has a markedly deleterious effect upon the mechanical strength of coke produced from some of the coals; others yield superior cokes when charged at higher temperatures. Much may be achieved in the control of coke quality through careful selection and preparation of the raw coal.

INTRODUCTION

During the past few years, the Coal Research Group of the Department of Geology and Geophysics, University of Sydney, has been engaged upon studies designed to assist in the better development and more economic utilization of the solid fuels. One of the most comprehensive fields of investigation in which studies are still proceeding is that of carbonization; the principal concern has been to investigate the factors affecting carbonization and to improve coking characteristics in

relation to metallurgical coke production. The seams studied to date include both established coking coals and some generally regarded as poorly coking and unsuitable for industrial use: they have been drawn from American, Australian and Japanese coalfields.

In 1955, the senior author, with a group of American coworkers from the Illinois State Geological Survey, carried out an intensive laboratory-scale investigation of the petrographic and coking characteristics of the Illinois No. 6 and No. 5 coals (1). Subsequently, the Sydney research group embarked upon an extended project of utilization studies of some Australian seams which are of similar character to the Illinois coals; interim statements of certain early results were submitted to the Institute of Fuel (Australian Membership) Symposium at Newcastle, N.S.W., in 1959 (2,3). More recently the project has been greatly expanded to cover a wider range of both individual and blended coals, particular emphasis being placed upon the blending potential of selected Australian and Japanese seams.

In all this work, it is recognized that the laboratory-scale study results cannot be integrated directly with those of full scale industrial practice, but experience has shown that they may be correlated. Consequently, the laboratory methods permit a relatively rapid, economic and critical assessment of the factors affecting coking characteristics, and establish trends which may serve as useful guides to improved industrial practice.

**Coking Potential.**

Broadly, the many related and mutually modifying factors which appear to affect the coking potential of a coal may be grouped as (a) inherent petrological, physical and chemical characteristics of the raw material; (b) induced modifications of these characteristics brought about in the preparation of the oven charge; and (c) conditions under which the coal is carbonized. Within and between these groups all factors are subject to mutual variation; consequently critical assessment of coking potential demands comprehensive, exhaustive and controlled studies.

The present paper deals only with one limited aspect of the influence of carbonization conditions upon coke characteristics, namely, the effects of charging temperature upon the mechanical properties of the resultant coke. Other conditions and standards adopted for these tests have been based upon much more comprehensive studies, discussion of which is beyond the scope of the present paper.

However, it should be stated that detailed studies have shown that coal particle size consist is often a very significant factor in determining the physical qualities of the coke produced. Under the conditions of study developed, the majority of normal, medium- to high-volatile bituminous coals which have been investigated to date appear to yield most satisfactory cokes when the raw material is reduced by controlled breakage to pass \( \frac{1}{8} \)" mesh, with the minimum production of finer sizes. Standardized procedures of size reduction, however, do produce differences in final consists, a response to variations in the physical and petrographic characteristics of the seam material.

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The methods of laboratory-scale production testing and evaluation developed for the coking studies of the Illinois seams have been described elsewhere (1), and compare closely with those more recently applied to similar investigations of the Australian and Japanese coals. For the purposes of the present study, coal charges of approximately 700 grams, prepared according to a standard procedure, were coked under various conditions of charging temperature, final soaking temperature, and length of coking period. The coal charges, contained in closed, cylindrical refractory retorts, were heated in a silit-rod (Globar) type of electrical furnace with accurate thermostat and program control. All coke runs were made in quadruplicate. The “strength” characteristics of the resultant cokes were examined by laboratory-scale adaptations of the industrial shatter, tumbler and micro-mechanical tests.

The combination of “strength” tests used was considered to be most suitable in the circumstances, as shatter and macro-tumbler stability index results are conditioned largely by the macro-structure of the coke (joints, cracks, pore-dimensions and “wall”-thickness) while micro-mechanical strength and macro-tumbler hardness largely indicate the strength of the coke substance itself. That these laboratory tests were adequately discriminatory is evident from the study results summarized in figures 1-8.

In the following discussion, “optimum” as referred to coke quality implies maximum attainable values for the mechanical strength indices. Unfortunately it is seldom that all these strength indices attain their respective maxima under precisely similar conditions. Consequently the “optimum” of quality in any coke must represent a compromise, most suited to the consumer’s particular requirements. Similarly, “optimum” conditions of coking are described by those particular circumstances in the thermal cycle which appear to contribute to the development of the highest mechanical strength indices.

FACTORS IN THE THERMAL CYCLE OF COKING

The factors considered to be of importance in the thermal regime include (a) oven temperature at charging, (b) rate of heating (both particularly in relations to the plastic range of the coal), (c) final coking temperature, (d) period of coking, both overall and at final temperature of carbonization.

Limitations of space preclude any adequate discussion of all these factors, although they are certainly important and mutually disturbing. However, as an essential introduction to the main theme (the effects of oven temperature at charging upon mechanical strength characteristics of the coke produced), the following brief and qualified résumé of the general effects of the other factors in the thermal cycle is included.

Final Coking Temperature

For the majority of “normal” bituminous coals examined so far, increased final coking temperature is accompanied by improvements in coke quality in respect of both macro- and micro-mechanical indices, until a particular “optimum” tem-
perature of coking is attained. Carbonization temperatures above the "optimum" for each particular coal, invariably have resulted in severe deterioration in the macro-mechanical indices of the coke. In the laboratory studies, for most of the coals prepared under "standard" conditions, the particular "optimum" temperature of final carbonization lies between 1000°C and 1200°C, although in some cases further improvement in mechanical strength may be induced by even higher temperatures.

In the case of the Illinois coals, "optimum" final coking temperature proved to be 1850°F (1010°C); for the Australian and Japanese coals, 1200°C has emerged as the most nearly satisfactory temperature of final coking.

Duration of Coking

The majority of the coals studied appear to yield "optimum" cokes when "soaked" at the final coking temperature for a relatively short period. In the laboratory studies, periods of more than two hours at maximum temperature of carbonization were usually accompanied by definite deterioration in the coke strength, although this invariably improved again with further extension of time to approximately 10 hours. As such prolonged "soaking" was not considered practicable, the two-hour final soaking period was adopted as standard.

Under "standard soaking" conditions, the coke produced usually exhibited a "steely", bright lustre and a minimum of breeze.

Rate of Heating

In coking, rate of heating must be related to the initial temperature and heat capacity of the oven on charging, the oven temperature increment per unit of time, and the thermal conductivity of both the coal charge and the progressively developing zone of coke, quite apart from the thermal characteristics of any reactions involved.

The influence of oven charging temperature upon coke-strength characteristics is discussed later as the principal theme of this paper. It is sufficient to observe here that the higher the oven temperature upon charging, the more rapid is the initial rate of heating, a factor which appears to be of particular importance in relation to the plastic temperature range, plasticity and volatile evolution characteristics of the coal.

In the laboratory studies, the initial rate of heating of the charge was increased by introducing the coal into the oven at successively higher temperatures. Thereafter, dependent upon the characteristics of the equipment available, standard rates of temperature increase were maintained at 3.6°C/min. (American coals) and 3.4°C/min. (Australian and Japanese coals) to 1000°C, followed by slightly reduced rates of heating to the maximum "soaking" temperatures. These figures closely approximate mean rates of temperature increase established in pilot oven studies, and were accepted as "standard" but subject to later investigation.

CHARGING TEMPERATURE AND COKE QUALITY

Representative analyses of the American, Australian and Japanese coals which formed the subject of this study are quoted in Table I.
TABLE I—ANALYSES OF COAL

<table>
<thead>
<tr>
<th>Seam</th>
<th>Prox. An. (% d.a. coal)</th>
<th>Ult. An. (% d.a. coal)</th>
<th>B.S. Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 6 Coal, Illinois</td>
<td>7.8</td>
<td>8.6</td>
<td>34.8</td>
</tr>
<tr>
<td>No. 5 Coal, Illinois</td>
<td>5.2</td>
<td>10.9</td>
<td>31.4</td>
</tr>
<tr>
<td>Liddel Coal, N.S.W.</td>
<td>3.0</td>
<td>8.0</td>
<td>36.8</td>
</tr>
<tr>
<td>Borehole Coal, N.S.W.</td>
<td>2.5</td>
<td>9.9</td>
<td>32.6</td>
</tr>
<tr>
<td>Bulli Coal, N.S.W.</td>
<td>1.1</td>
<td>7.2</td>
<td>22.2</td>
</tr>
<tr>
<td>Akahira, Japan</td>
<td>2.8</td>
<td>5.5</td>
<td>41.8</td>
</tr>
<tr>
<td>Futase, Japan</td>
<td>3.0</td>
<td>8.4</td>
<td>38.2</td>
</tr>
<tr>
<td>Takashima, Japan</td>
<td>2.2</td>
<td>5.9</td>
<td>43.6</td>
</tr>
</tbody>
</table>

Liddell and Borehole of New South Wales, are quite comparable in chemical constitution and similar in overall petrographic character; the Bulli coal of New South Wales and the three Japanese samples were respectively of somewhat higher and lower rank.

Standard charges of each of these eight coals (controlled bulk and size consist) were introduced into the coking oven, of which the initial temperature was increased by successive increments to the particular final coking temperature adopted as optimum for each coal. In all cases, after charging, the oven temperature increase was maintained at the standard, controlled rate until the soaking temperature was attained.

With the exception of the Bulli and Takashima coals, all those examined revealed generally similar trends in the relationship between coke strength and oven charging temperature. In general, the majority of the strength indices improved progressively, reaching maxima for various particular charging temperatures ranging between 400°C and 1000°C; the decline in the strength index beyond the maximum was frequently precipitate. In the case of the Bulli coal, increased charging temperatures produced an initial deterioration in the strength indices of the coke, which thereafter improved to their particular maxima before declining rapidly. The Takashima coal in general exhibited deterioration in macro-strength indices and improvement in micro-strength characteristics with increased charging temperature.

Though frequently having pronounced effects upon the other strength characteristics, the temperature of oven charging assumed...
most critical significance in relation to shatter and stability indices—both measures of the coke macrostructure. Severe deterioration of one or both of these indices is not infrequently accompanied by slight improvements in the strength of the coke substance, as is made evident by increased micro-strength and resistance to abrasion.

The American Coals

The most significant feature of these study series, results of which are shown graphically in figures 1 and 2, was the critical effect of charging temperatures in excess of 450°C and 540°C respectively on the shatter and stability indices. Progressive increases in charging temperature from 25°C to these critical values were accompanied by modest though erratic general improvements in shatter and some reduction in stability for the No. 6 coal; a general, gentle, but varying deterioration in all macro-strength indices occurred in the case of the No. 5 coal.

When charging was carried out at temperatures progressively higher than those indicated, both shatter and stability indices of the cokes produced from each of these coals exhibited a general and rapid decline. In each case the deteriorations were accompanied by slight improvements in resistance to abrasion and micro-mechanical strength, the trends being more strongly marked in the higher ranges.

It appears significant that in each case the critical charging temperature (450°C for No. 6 coal and 540°C for No. 5 coal) is within or just adjacent to the plastic temperature range of the coals. It is considered that when charged at successively higher temperatures, these coals are subjected to an ever-increasing rate of temperature increase up to, through, and above the plastic range, and are thus afforded less and less time for volumetric and other adjustments before the "setting" temperature is reached. The consequent accumulation of stresses and the development of increased jointing and fracturing is indicated by the decrease in macro-mechanical strength.

The toughness or hardness of the coke substance (resistance to abrasion and micro-mechanical strength) does not appear to be related to the heating rate in any particular range, and increases slowly with the rise of charging temperature.

Apart from the effects upon strength, increases in charging temperature were accompanied by marked and progressive improvement in the colour and lustre of the resultant cokes, which were also of rather smaller size consist.

The Australian Coals

As in the case of the American coals, charging temperature again assumed particular and critical significance in relation to coke shatter and tumbler stability indices, but serious and progressively increasing impairment of these factors did not occur until it exceeded 800°C. Unlike the Illinois seams, there was no serious and continuing decline in macro-strength of the coke produced, with charging temperatures immediately above the coal plastic range. However, the Liddell coal (Fig. 3) did exhibit a slight depression of all three macro-mechanical strength indices associated with a charging temperature of 500°C.
which is slightly above the setting point. Progressive increases in charging temperatures to 800°C were accompanied by definite improvements in the macro- and micro-strength indices of the coke produced. Higher charging temperatures induced serious deterioration in macro-strength.

The Bulli coal (Fig. 5) returned a severely weakened coke when charging was carried out at temperatures of 200°C (very low macro-tumbler indices) and 400°C (depressed shatter and micro-mechanical strength); charging at increasing temperatures between 400°C and 800°C produced general and progressive improvements in the coke strength with well defined deterioration thereafter. Optimum micro-strength was obtained from coke produced by charging at air temperature. The plastic range of Bulli coal is approximately 390°C to 480°C.

The Borehole coal showed continuous and progressive improvement in all macro-strength indices of coke produced with increase of charging temperature up to 800°C (Fig. 4); thereafter shatter index declined abruptly, although tumbler stability did not deteriorate until the charging temperature exceeded 1000°C. Charging temperatures above 800°C were accompanied by accelerated improvement in coke micro-strength.

In each of these coals, the higher charging temperatures were accompanied by considerable improvement in both colour and lustre of the coke produced.

The Japanese Coals

For the three Japanese coals, variations in charging temperature produced three generally quite different trends in overall and particular variation of coke strength. The Akahira coal behaved in a manner broadly comparable with the Illinois coals Nos. 5 and 6; the Futase revealed trends rather similar to those of the Borehole coal of New South Wales; the Takashima coal could not be readily compared with any other coal as yet studied.

The Akahira was the only one of the eight coals discussed here which did not show an essentially parallel trend of shatter and stability indices throughout the greater part of the charging temperature range. The results of the macro-mechanical tests of the Akahira cokes suggest that a progressive increase in charging temperature to 1000°C brings about the formation of a joint or fracture system in the coke which is progressively more susceptible to rupture from impact but progressively less susceptible to abrasion. Micro-strength indices improved slightly and erratically with increased oven temperature at charging.

In the case of the Futase coal (Fig. 7) all macro-strength indices improved with increased charging temperature up to 600°C; thereafter the shatter index declined rapidly, followed by tumbler stability for temperatures exceeding 800°C. Micro-strength variation was erratic and not evidently significant.

The Takashima coal yielded a coke of superior macro-mechanical strength if charged to a cold oven. Progressive increases in the initial oven temperature to 800°C brought about a very substantial and progressive decline in these characteristics, after which there was a slight improvement. A somewhat erratic
but definite improvement in micro-mechanical strength is evident in
response to increased charging temperatures.

Variations in the appearance and size characteristics of Akahira and Futase cookes correspond closely with those of the American and Australian groups. The Takashima, however, showed no significant variation throughout the range in either friability or the fragmentary character of the coke yield; only lustre improved as higher charging temperatures were employed.

SUMMARY AND CONCLUSIONS

From this present brief review of as yet incomplete studies, it is evident that the program of temperature increase during carbonization has a profound and possibly particular effect upon the mechanical properties of the coke produced from any “coking” coal. Optimum qualities of macro- and micro-strength are seldom developed together under any single coking regime. Consequently, both coke producer and consumer must accept a compromise on quality characteristics, according to their particular requirements and the inherent limitations to controlled coking. On the other hand, it is evident that much may be achieved in the control of coke quality through careful selection and preparation of the raw coal.

For certain high volatile bituminous coals (e.g., Illinois Nos. 5 and 6, and Futase), charging to the oven at temperatures even modestly in excess of their plastic range may well induce serious deterioration in the macro-strength characteristics of the coke. Other bituminous coals may, with minor exceptions, yield substantially improved cookes when charged to an oven of which the temperature is 300 or 400°C higher than the plastic range (e.g., Liddell, Borehole and Bulli). Some coals may yield cookes which apparently deteriorate progressively in macro-strength characteristics with any increase of charging temperature above that of an air-cold oven.

No significantly progressive deterioration in coke micro-strength characteristics has been observed as accompanying increased oven temperature on charging. On the contrary, in the majority of cases, the strength of the coke substance appears to improve with increased initial oven temperatures, particularly in the higher ranges.

It is suggested that variations in coke character may be significantly influenced by rates of heating as related to the plastic range, plasticity characteristics, and gas evolution characteristics of the coal concerned; these in turn reflect the petrographic constitution, type distribution and rank of the seam. Further work is proceeding in this field of investigation.

REFERENCES


DIRECT FIRING OF COAL SLURRY

ABSTRACT

Extensive test run at New Jersey power plant demonstrates feasibility of burning coal-pipeline product directly. Cyclone furnaces in regular service are fed with coal slurry at 70-30 solids-to-water ratio.

Call it a breakthrough, a milestone or whatever, the recent commercial-scale test on burning coal slurry at the Werner plant of Jersey Central Power & Light Co., South Amboy, N. J., is big news for coal. Two cyclone furnaces at the Werner plant burned nothing but pipeline slurry for a period of several weeks in late October and early November. There is some reduction in burning efficiency, as expected, but this is more than compensated by the overall economy that direct firing of slurry can provide.

The Objectives

One of the principal incentives in the test program was the desire for lower costs in transporting coal from the mines to East Coast power plants. The ultimate objective is a pipeline from the coal fields in northern West Virginia and western Pennsylvania to the New York-Philadelphia areas. In addition to lower transportation costs, direct firing of slurry eliminates much expensive coal-handling equipment. In a plant designed for the use of slurry, there would be no need for railroad sidings, barges, docks, coal towers, pulverizers, conveyors and the like.

The successful demonstration at the Werner plant is the culmination of joint research among Consolidation Coal Co., Babcock & Wilcox Co., Texas Eastern Transmission Corp. and Jersey Central Power & Light Co. The slurry burned at South Amboy actually passed through Consol's 108-mi pipeline from Cadiz, Ohio, to Cleveland. It was carried by barge from Lake Erie to Newark, N. J., via inland canals and the Hudson River, and stored in tanks at Pitt-Consol Chemical Corp. The slurry was transported in barges to the power plant and pumped into a 1,000,000-gal storage tank. It was pumped, as received, from the storage tank to a surge tank, thence directly to the burner nozzles in the cyclone furnaces.

The coal consumed in the test amounted to 10,000 tons of minus 8-mesh, prepared at Georgetown preparation plant of the Hanna Coal Co., a division of Consol. It was pumped through the pipeline to Cleveland at a concentration of

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Fig. 1—This is coal slurry, containing 70% coal and 30% water, being introduced into the ignition zone of a cyclone furnace in on-line operation of a power plant at South Amboy, N. J. This may be the giant step leading to the construction of a coal pipeline to the East Coast from northern West Virginia and western Pennsylvania.

60% solids, by weight. Storage in Cleveland permitted decantation of some of the water, resulting in a slurry containing approximately 70% solids.

There has been no difficulty in maintaining the suspension since the slurry handles and stores much like oil. If settling is evident during a long period of storage, an air lance

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may be employed to reconstitute the mixture.

The Cyclone Furnace

The Babcock & Wilcox cyclone furnace firing coal slurry is the ultimate in simplicity and economy. It requires a minimum investment in equipment and a minimum of labor. The dry coal handling equipment, which is eliminated in the slurry-firing method represents from 5 to 7% of total investment, saving about $3,500,000 in a typical 500,000-Kw station.

As explained by Neil W. Eft, research engineer, Babcock & Wilcox, the slurry with no auxiliary fuel is introduced at low pressure (35 psi) into the front of the cyclone furnace through a simple pipe and spray nozzle. The fuel is distributed in the furnace in a hollow conical spray. Hot primary air at 700°F is introduced tangentially behind and around the coal nozzle. Spinning around the coal nozzle, the primary air vaporizes the water from the finer coal particles and accelerates them into a tangential path. Ignition of the finer particles takes place almost instantaneously.

Hot secondary air, five times the volume of the primary air, and spinning around the cyclone in the same direction, is introduced immediately after the ignition zone. Centrifugal force throws the coal particles to the outer wall of the furnace. Temperature in the furnace is 3,000°F—hot enough to liquefy the ash which then flows down the furnace walls into a slag pit. Studies show that an entering particle of coal is dried, burned and slagged in 1/100 sec. Water in the slurry goes up the
stack as vapor. There is less vapor than in a gas-fired boiler.

Although ignition of the coal-water mixture is more difficult and the maximum temperature reached is lower than with dry coal, these natural differences due to the character of the fuel are not overly detrimental to the combustion process. The B&W cyclone furnace is the only type of equipment available today to burn coal slurry directly.

Many generating stations are equipped with pulverized coal-fired boilers which cannot use coal slurry directly. Coal suitable for these stations should contain less than 20% moisture. This means that about 60% of the water in coal slurry must be removed before the coal can be pulverized and burned.

At the Alliance (Ohio) research center of B&W a cooperative program between Consol and B&W has already shown that the excess moisture in coal slurry can be removed in either a disc filter or a solid-bowl centrifuge. The reduction in moisture content not only increased the efficiency of the steam boiler but also permits the coal to be conveyed and pulverized using the equipment.

Fig. 3—Cyclone furnace is the ultimate in simplicity and economy. Slurry which requires minimum handling, is pumped directly into input line at left. Hot gases leaving the cyclone enter the boiler unit to generate steam.

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Fig. 4—Source of the new fuel is the Georgetown preparation plant of Hanna Coal Co., near St. Clairsville, Ohio. Slurry for South Amboy test actually passed through Hanna’s 108-mi pipeline to Cleveland.

currently available in many plants. The removal of this water does require additional capital investment.

However, an entire existing plant can easily convert to this new fuel and take advantage of the reduction in transportation costs. The effect of this on the nation’s electric utility industry is of far-reaching economic significance.

Pipeline to the East

“Texas Eastern now considers its primary objective to be the pipeline transportation of energy in whatever form it is needed,” declares T. W. Thagard, vice president, Texas Eastern Transmission Corp., in explaining that his company’s interest in this project was stimulated by the fact that its operations had already been diversified to include handling energy in forms other than natural gas.

Two of the basic requirements for economic pipeline transportation are large reserves at the supply end and large volume requirements at the market end. Virtually unlimited coal reserves exist in many parts of the country, and certainly the electric generating stations have large volume requirements, not only today but expanding constantly with the increasing use of electricity. With these two essentials already in existence there is every reason to expect growth in coal pipelining.

Pipeline transportation provides unrivaled reliability. Furthermore, transportation rates on the movement of tonnages between points by all methods tend to become more

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stable with increased competition. In the event of a national emergency, a high-capacity eastern coal-pipeline system already in operation would be of tremendous value to the security of the nation.

In pointing to the successful operation of the Cadiz-to-Cleveland pipeline, which to date has transported more than 5 million tons, Eric H. Reichl, director of research and development, Consolidation Coal Co., says continuing research has resulted in the ability to increase the percentage of solids in coal-pipeline streams from the original 50-50 to the present 60-40. Other advances in the art have been made that stabilize the slurry so that it handles much like fuel oil in conventional tankage and tank cars.

Joseph Pursglove, Jr., president, Pitt-Consol Chemical Co., foresees a pipeline to the East possibly as large as 30 in. in diameter.

With regard to the actual demonstration at the Werner plant, John E. Logan, vice president—operations, Jersey Central Power & Light, points out that in burning slurry the company expects to encounter some reduction in boiler efficiency, but that overall financial benefits can be realized from its use.

In making the plant available, Mr. Logan said, JCP&L acted in the interest of the entire utility industry. Electric companies the country over followed the test with great interest.

Fig. 5—Destination is the Werner plant to which the slurry was transshipped by barge. Pumps are lowered into barge to transfer slurry to 1,000,000-gal. oil storage tank for subsequent direct firing.
RECENT PROGRESS IN THERMAL DRYING
ULTRA-FINE COAL

RAYMOND E. ZIMMERMAN
Vice President
Paul Weir Company
Chicago, Illinois

ABSTRACT
Over 150 tph of filter cake containing up to 30 percent surface moisture is being dried to 5 percent surface moisture at a coal preparation plant in Turkey. Heat consumption is 3,173,000 Btu per ton of water evaporated.

A great deal of information has already been published concerning the many devices used to dry coal with heat. Most of these dryers do a satisfactory job on particular size ranges of coal. The trend today appears to be in favor of the fluidized bed type for treating slack coal sizes, and, unquestionably, this type of dryer is doing an excellent job.

However, in addition to the requirements for drying slack sizes of coal, an increasing problem is presenting itself in this country in the need for drying ultra fine sizes—the minus 0.5-mm or 28-mesh range. This is a result of the rapid spread of froth filtration plants used to remove this material from cleaning plant slurry or recirculating water.

Either the economics of coal recovery or stream pollution laws, or a combination of both, has dictated the need to recover these fines. Whatever the reason, its recovery has intensified the problem of removing moisture from the recovered coal.

The best we can usually expect from either centrifuges or vacuum filters is to reduce the moisture of flotation coal down to 20-30 percent. Beyond that thermal drying is required—by no means an easy task. Handling 20 to 30 percent moisture ultra fines, usually in the form of filter cake, is difficult. Evaporating the large quantities of water involved and preventing high dust loss after it is dried are problems of the first magnitude.

There are a few dryers on the market today that can properly handle this difficult material. Perhaps one of the solutions is not to dry it in its present form, but to pelletize it first—pelletize and dry in one operation. Research is being conducted at the present time to develop a practical and economical way of doing this.

Another good way to handle froth
flotation concentrates, or ultra fines, is to concentrate it to pulp densities of from 60 to 65 percent solids and burn it directly in power plant boilers. Experimental work on this possibility is being carried on by one of the larger coal companies in this country in connection with long distance pipelining of coal.

However, as advantageous as these methods may be, the fact remains that in many situations it will still be desirable to thermally dry minus 0.5-mm filter cake.

Drying 150 tph of Filter Cake

This article describes a thermal dryer installation where this is being accomplished successfully. It involves drying the product from a froth flotation plant treating as much as 120 to 150 tph of minus 0.5-mm coal.

The drying is being accomplished in Buttner dryers, manufactured by Buttner-Werke AG., Germany. They were installed under the direction of the Paul Weir Co. at Zonguldak, Turkey, in connection with the operation of the washery at Zonguldak.

Zonguldak coals are extremely friable and, although of high volatile bituminous coal quality, are somewhat similar to Pocahontas coals in their friability. As a consequence, the washery itself, handling 800 tph (short tons) run-of-mine feed, was designed to handle as much as 65 to 70 percent minus \( \frac{1}{4} \)-in. Since the minus 0.5 mm, therefore, amounted to a very sub-
Substantial tonnage of raw coal, it was desirable and necessary to provide a froth flotation plant. Tonnage to this plant ran from 120 to 150 tph.

The flotation plant filter cake product contained from 20 to 30 percent surface moisture. The large percentage of the washery product represented by this high moisture product required that it be thermally dried, regardless of whether it was to be mixed with coarser sizes or shipped by itself.

This was accomplished in two parallel Buttner dryer systems of the Rema-Rosin type. This type of dryer is frequently called a "rapid recirculation" dryer and, in fact, is quite similar to what we in the United States call a "flash dryer."

Figure 1 is a general view of the washer. Primary and secondary dust collectors are on the roof of the drying plant. Since the plant is in the heart of the town of Zonguldak, it was essential that dust collection equipment be highly efficient.

Two Drying Circuits

There are two parallel heat drying circuits in the plant, as shown in figure 2. Each consists essentially of furnace (1), drying column (2), primary collectors (3), secondary collectors (4), exhaust fan and wet collector (5), entrainment trap (6), exhaust stack (7), wet coal feed hopper (8), paddle mixers (9), rotary air lock (10), rotary slinger (11), wet coal feed conveyor (12), dried coal

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product conveyor (13), secondary dried coal (dust) conveyor (14), primary furnace air blower (15), secondary furnace blower (16), and tertiary furnace blower (17).

Details of the bottom of the drying column are shown in figure 3. The saxophone shape (a) takes the heated gases from the furnace outlet (b). These gases come from a furnace which burns dust from the secondary dust collectors. The furnace has a combustion section and an air tempering section where air is sucked in through louvres in automatically controlled proportions depending upon the temperature requirements. A refractory brick-constructed gate (c) permits the furnace to be sealed off during shutdown periods. The insulated 36-in. diameter stainless steel drying column (d) is approximately 50 ft high, and curves (e) into parallel primary cyclone collectors where the bulk of the product is collected. Electric heating elements (o) at this curved section prevent any possible build-up of damp coal.

Wet coal (filter cake) (f) is fed to the dryer column by a rotating slinger (g) which throws the coal into the column and gives a final chance to break up any lumps of cake still existing. A heating element (o) at this point prevents wet coal from sticking to the feed chute. A rotary air lock (h) prevents the escape of hot gases and excessive air leakage. A double paddle mixer (i) and a second paddle mixer (k) take wet coal feed from hopper (m). A dried product, to be mixed with the wet feed, can be fed through a section of pipe (l) if desired. This was seldom found to be necessary—generally only when filter cake moisture neared 30 percent.

![Fig. 3—Schematic view of the bottom of the drying column, including the feed arrangement.](image-url)

![Fig. 4—Wet coal is fed through a rotary airlock (center) to a feed slinger (lower left) which passes it into the bottom of the drying column (right).](image-url)

The rotary lock, slinger and section of the drying column are shown in figure 4.
Table I—GENERAL DATA

Location of dryer installation............ Zonguldak, Turkey
Type of dryers .................................. Two Buttner "Rema Rosin" Flash dryers
Kind of feed .................................. Bituminous Coal Froth Flotation Filter Cake
Size of feed .................................. 28 mesh x 0
Feed moisture .................................. 25.2% (Surface)
Product moisture ............................. 5–6% (Surface)
Dry dust collectors ........................... Two van Tongeren multiclones per dryer
Exhaust fan and wet scrubber .............. Eck, dual inlet, water injection type, capacity 33,000 cfm @ standard conditions.
Furnace ......................................... Refractory lined, air cooled, suspended arch, with a combustion chamber and an air mixing chamber, and automatic ash removal. Capacity, 62,000 Btu
Burner ......................................... Twin pulverizer fuel burners using dust product from multiclones. Fuel oil burner used for initial start up.

Table I summarizes general basic data concerning the Zonguldak dryer installation. Figure 5 is a schematic arrangement of the secondary dust collectors. They are multiclones of the van Tongeren design. They consist of two sets of four each of approximately five ft diameter cyclones. Intake gases and dust pass into a manifold (a) from the primary cyclone collectors. Dust drops (b) into hoppers (c) through rotary locks (g) and thence onto a conveyor (h) where fuel for the furnace passes into a hopper (i). Any excess dust combines with the dried coal. Exhaust gases (c) pass through a collector duct (e) and thence down (k) into the exhaust fan. Special plates (d) will rupture in the event of an accidental explosion. There is very little chance of this taking place and, in the course of our operations it did not happen at any time.

Fig. 5—Schematic arrangement of secondary dust collectors.

Our Advertisers, who make this volume possible, will appreciate your inquiries.
Dust Collection

Figure 6 is a cross section of the combined exhaust fan and wet dust collector. The drive shaft (a) from a direct-connected motor operates impeller blades (b) of the Dr. Eck design. The blades are made of Thermax. The casing (c) is lined with acid-resistant tiles. There are two suction inlets (d), air inlets (e), water injection spray nozzles (f) and water and slurry outlets (g). Air volume is regulated by a spinning device (h) which can be adjusted by remote control from the plant control station. At 115°C, it was exhausting 82,500 cfm of gases and vapor and pulling 22 in. of water gauge.

Gases and vapor from this fan are discharged into an entrainment trap at the bottom of the exhaust stack. This and the stack is shown in figure 7, a photograph of one end of the heat drying plant. The entrainment trap is simply a cyclone in which the wet vapors, entering tangentially, cling to the sides of the cyclone and water containing slurry discharges at the bottom, the gases and purer water vapor dis-

Fig. 6—Cross section of the combined exhaust fan and wet dust collector.

Fig. 7—One common stack serves both dryers.

Fig. 8—Size distribution curve of feed to the dryers. Fifty six percent is minus mesh and 15 percent is minus 800 mesh.
charging up the stack. One common stack serves both dryers.

Figure 8 is a curve showing the size distribution of the heat dryer feed, or the froth filtration plant product. It is practically all minus 20-mesh material, 56 percent under 48-mesh and 15 percent through 200 mesh. This is a typical analysis under normal conditions, although in actual practice the feed frequently varied in the direction of much greater percentages of minus 200 mesh.

Material and Heat Balance

Figure 9 is a material balance in diagrammatic form of the feed input distribution during the plant acceptance tests. Of 82.6 tph feed input at 25.2 percent surface moisture, the dried coal product at 5.7 percent moisture amounted to 75.6 percent of the feed. Nineteen and a half percent was evaporated as water vapor. The furnace consumed 3.9 percent, dust loss amounted to 0.02 percent, and slurry from the wet collector accounted for 0.98 percent of the feed.

The heat balance is shown in diagrammatic form in figure 10. Total heat consumption is 1678 Btu per lb of water evaporated, distributed as follows: 69 percent to evaporate the water; 8.08 percent to heat the coal, 13.55 percent is heat loss in the exhaust gases; conduction and radiation losses are 2.4 percent; 3.14 percent is used in heating the air coming in with the coal feed, and 3.83 percent is lost in heating the furnace.

A summary of pertinent data obtained during the plant's acceptance tests are shown in Table II. Here it
is indicated that 3,173,000 Btu were required to evaporate a ton of water. The final dust loss up the stack amounted to only 0.073 grains per cu. ft. The wet scrubber slurry contained 860 lb. per hour of the feed (dry basis) which was sent back to the washery for recirculation. Power consumed was 395 kwh. Moisture in the dried coal product was 5-6 percent.

Actually it was entirely possible to produce a bone dry product, however it was determined that when the product moisture was reduced below five percent it became too dusty to handle at the loading point into bunkers or railroad cars. It is also believed that some hazard would result from possible spontaneous combustion if the moisture content was made less than five percent.

The above description of the Buttner dryer installation at Zonguldak attempts to describe the basic design of the plant, the processing involved and the results achieved. The plant did a remarkably good job on an extremely difficult feed and unquestionably proved to be a successful way of drying ultra fine coal.

Greater efficiency could be achieved in dust collection by more sophisticated equipment. Electrostatic precipitators are successfully being used in Europe in similar installations, but for the particular job at Zonguldak the equipment described was found satisfactory.

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UNDERGROUND SPOTLIGHT... 1961

ABSTRACT

Highlights of the 1960 production year, with a record of steady advances in continuous mining, substantial gains in several states during the year, and some interesting exceptions to current trends—and a look at developments in underground mining in 1961, with an eye to the future.

The small increase in bituminous coal production in 1960 was reflected in a gain of 1.5 million tons of underground output during the year. With total production at 415.5 million tons of bituminous coal and lignite for 1960, underground mining contributed 284.9 million tons toward that total. This was equal to 69 percent, the same as in 1959, and of this total, 86.7 percent was mechanically loaded—a new all-time record for the second straight year.

In terms of tons, production for the year from underground bituminous hand-loading operations was 39.1 million tons, 1.5 percent lower than in 1959; the total output mechanically loaded was 245.8 million tons, up to 0.9 percent over the previous year.

Again, productivity rose over the 10-tons-per-manshift mark, exceeded for the first time in 1959 for underground mines. In 1960, the productivity rate for underground mines was 10.64 tons per manshift, an increase of 5.6 percent.

Six states showed an underground productivity rate of better than 10—Illinois, Indiana, West Virginia, Ohio, Utah, and Kentucky. Illinois again had the highest rate in the Nation, with an all-time record output of 17.3 tons per manshift, followed by Indiana with 11.96, West Virginia with 11.78, Ohio with 10.95, Utah with 10.71, and Kentucky with 10.61.

West Virginia was the National leader again in terms of underground tonnage of bituminous coal produced, mining a total of 109.2 million tons, just a shade under the 1959 output of 109.4 million tons by this method. Kentucky passed the state of Pennsylvania for the first time, producing 44.5 million tons to the Keystone State’s 44.1 million tons. For Kentucky, this was an increase of 6.9 percent; for Pennsylvania it represented a slight decrease of 1.3 percent below the previous year. Greatest percentage gain, however, occurred in Alabama, where production of 10.4 million tons of bituminous coal repre-
sented a 13 percent rise over 1959 production.

A Look At 1961

To date, overall bituminous coal production in 1961 has gone about as predicted at the first of the year. The first two quarters were quite slow, reflecting the general state of the Nation's economy, and the question is whether the pick-up in the second two quarters will be enough to compensate for the lower production level of the first six months.

At the end of the first six months, production was down 13.4 percent below 1960; at the end of July, this had been cut to a 12 percent drop; at the end of August, the industry had a record showing only a 10.5 percent fall from the comparable 1960 period. By the end of September, it was down to 9 percent; and as October ended, the deficit was less than 8 percent. Projecting this upward climb to the end of 1961, it appears that the bituminous coal industry will just slip over the 400-million-ton mark again, with pretty good 1962 prospects for a rather
TABLE I—DATA ON MAJOR STATES PRODUCING COAL
BY UNDERGROUND METHODS, 1960

<table>
<thead>
<tr>
<th>State</th>
<th>Production Millions of Tons</th>
<th>Tons Per Man-Days</th>
<th>Avg. Value Per Ton-Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>10.4</td>
<td>7.8</td>
<td>$7.61</td>
</tr>
<tr>
<td>Illinois</td>
<td>23.3</td>
<td>17.4</td>
<td>4.00</td>
</tr>
<tr>
<td>Indiana</td>
<td>4.8</td>
<td>12.0</td>
<td>4.29</td>
</tr>
<tr>
<td>Kentucky</td>
<td>44.5</td>
<td>10.6</td>
<td>4.69</td>
</tr>
<tr>
<td>Ohio</td>
<td>9.2</td>
<td>11.0</td>
<td>4.49</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>44.1</td>
<td>9.0</td>
<td>6.07</td>
</tr>
<tr>
<td>Tennessee</td>
<td>3.9</td>
<td>6.7</td>
<td>3.68</td>
</tr>
<tr>
<td>Utah</td>
<td>5.0</td>
<td>10.7</td>
<td>6.35</td>
</tr>
<tr>
<td>Virginia</td>
<td>25.8</td>
<td>9.4</td>
<td>4.50</td>
</tr>
<tr>
<td>W. Virginia</td>
<td>109.2</td>
<td>11.8</td>
<td>5.14</td>
</tr>
</tbody>
</table>

Source: Bureau of Mines, U.S. Department of the Interior

substantial gain—in the neighborhood of 20 million tons.
States which show an increase in bituminous coal production so far in 1961 over 1960 are Maryland, Montana, New Mexico, Tennessee, and Wyoming. Since these are all, for the most part low production states and all but two are primarily strip-mining areas, it appears likely that at the end of 1961, the industry will again see a gain in the percentage of total output mined by stripping, and a corresponding percentage decline in coal originated by underground mines. If this proves to be the fact, it would be well to remember that by far the major portion of the production still must be mined underground, and there is no likelihood of any change in the near, remote, or distant future.

Continuous Mining Still Climbing

As has been reported earlier, overall bituminous coal output in 1960 was only 0.8 percent over the previous year, and underground production was up 0.5 percent—but output by continuous mining machines showed an increase of 18.4 percent in 1960 over 1959. Expressed in production tonnage, this increase was over 12 million tons. Final Bureau of Mines statistics for 1960 show that bituminous production by continuous miners reached 77.9 million tons, compared with 65.8 million tons in the previous year. In addition, the Bureau re-

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TABLE II—TRENDS IN UNDERGROUND METHODS OF BITUMINOUS COAL AND LIGNITE PRODUCTION, 1958-1960

<table>
<thead>
<tr>
<th>Underground Mines</th>
<th>Thousand Net Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1958</td>
</tr>
<tr>
<td>Continuous mining only</td>
<td>12,151</td>
</tr>
<tr>
<td>Mixed (continuous and conventional mining)</td>
<td>109,577</td>
</tr>
<tr>
<td>Conventional mining only:</td>
<td></td>
</tr>
<tr>
<td>With mechanical loading</td>
<td>124,105</td>
</tr>
<tr>
<td>With hand loading only</td>
<td>41,051</td>
</tr>
<tr>
<td>TOTAL UNDERGROUND</td>
<td>286,884</td>
</tr>
</tbody>
</table>

*Estimated.

ports that during 1960, manufacturers of continuous mining machines sold 128 units, foreshadowing another increase when 1961 production figures are analyzed.

Gains were registered in output from continuous mining machines in all six leading states in terms of production of bituminous coal by this method. The leading state, West Virginia, showed a 21 percent increase in output in 1960, rising to 31.6 million tons by this method in 1960 and 26.0 million tons in 1959. The increase was almost as substantial in the second state, Pennsylvania, where total output from continuous mining machines in 1960 was 27 million tons and 1959 production was 22.7 million tons of bituminous coal, for an increase of 19.2 percent. Other leading states showed these increases in 1960 over 1959: Illinois, up 16.3 percent to almost 7 million tons; Kentucky, up 29.1 percent to 3.9 million tons; Ohio, up 6.1 percent to 3 million tons; and Utah, up 26.6 percent to 1.5 million tons. These six states accounted for 95 percent of all bituminous coal output from continuous mining machines. It is interesting to note, however, that in New Mexico, where continuous mining machines were not used until 1959, the end of 1960 found that 81.2 percent of all underground production was from continuous miners, and the percentage is sure to have grown during 1961, since this was one of the five states showing a production increase at the end of October, 1961.

All in all, production from continuous mining machines in 1960
accounted for 27.4 percent of all underground production, and 18.8 percent of production by all methods combined—both new records.

Conventional Mining Methods in 1960

Total mechanically loaded underground output, all methods, was primarily accomplished in nine states in 1960. These nine, West Virginia, Pennsylvania, Kentucky, Illinois, Virginia, Alabama, Ohio, Utah, and Indiana, contributed 239.7 million tons of the 245.8 million mechanically loaded in 1960, or 97.5 percent of the total. Gains were registered in Kentucky, Virginia, Alabama, Utah, and Indiana, with the largest percentage gain registered in Alabama—12.3 percent—and the largest tonnage increase made in Kentucky, with 1.5 million tons over the previous year.

Excluding continuous mining machines from underground mechanical loading, however, shows a different picture. Here, measuring output loaded by mobile loading machines, scrapers, and conveyors equipped with duckbills or other self-loading heads, there was a decline of 5.1 percent below 1959 production. Total 1960 production by these machines was 163.3 million tons, compared with 172 million in 1959. Kentucky, Alabama, Virginia, and Utah showed increases over the previous year, while the greatest decline came from Pennsylvania with a drop of 24.1 percent below 1959 output. Alabama showed the greatest gain, with 8.5 million tons loaded in 1960 and 6.9 million tons loaded by machines in 1959, for an increase of 22.6 percent.

Examining final statistics for output hand loaded in 1960, some increases were still made in spite of the general decline in favor of mechanization. Kentucky and Colorado gained considerably in output hand-loaded into conveyors, although their gains are only relative, since total output loaded by this method in the country in 1960 was only 4.5 million tons, and six states accounted for 84 percent of that total. Considerably larger in terms of tons is hand loading into mine cars, still a significant portion of underground production. In 1960, output by this method was just over 39 million tons, about the same as in the previous year. Kentucky, West

Fig. 1—Continuous mining machine.

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Virginia, and Alabama showed increases over 1959 totals, with the biggest increase coming in Kentucky. Already the leading state in output by this method, in 1960 Kentucky production loaded by hand into mine cars was 11.9 million tons, up 13.9 percent over the 10.5 million tons loaded in 1959. In West Virginia, an 8-percent increase was registered, and Alabama had a 23.5-percent increase in output loaded into mine cars by hand.

Equipment Developments In Underground Mining

Since 1961 was the year of another American Mining Congress "Coal Show," there was considerable activity among the manufacturers of underground mining equipment. Some of these activities are reflected in the summary of equipment displayed at Cleveland this year:

Permissible Mine Tractor.—A 10,000-lb. permissible mine tractor was shown, on which all four wheels drive and carry an equal load, regardless of uneven ground, through use of a unique wheel suspension.

Continuous Mining Machines.—Several continuous miners were displayed during the year, with improvements and innovations claimed for all. Particular emphasis was placed on machines for low-seam coal. One such machine, designed for use in coal from 36- to 54-inches thick, is only 30 inches high, and another is only 20 inches high.

Bug Duster.—A bug duster, designed for use on cutting machines, was presented during the year and was said to contain many improvements. It is mechanically operated.

Fig. 2—Shuttle car.

Fig. 3—Roof bolter.

Fig. 4—Face drill.

Fig. 5—Circular miner.

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being driven from the main bevel gear, which in turn is powered by the main motor of the cutting machine. This relieves strain on the hydraulic system, and is said to provide greater reliability in conveying dust away from the cutting chain.

Coal Drilling Machine.—One machine can drill holes 11 feet deep in a height range from about 22 inches to 9 feet and horizontally 8 feet to each side of the machine’s centerline; another utilizes a new type of drill head which is said to apply thrust within one foot of the face, with one man operating both drilling and shooting due to the speed of the drill.

Fire Fighting Machine.—Utilizing the foam-plug principle which has been developed in recent years, this portable system for controlling Class A and B mine fires produces a wall of moist, quenching foam through a roll of plastic tubing that can be unrolled up to distances of 250 feet.

Other Developments

Warning for Suspicious Roof Condition.—A process using sound waves to detect defects in roof and to give preventive warnings has been presented in a paper by two Bureau of Mines scientists. The process, similar to radar or sonar sounding devices, induces sound waves into the roof, and the waves are then reflected by inner non-conformities and inconsistencies of the roof structure.

Design and construction of a pilot portable transmitter is now underway, which can be used in gaseous or dusty mine atmospheres, with the results read and interpreted by regular mine personnel. According to the inventors of the device, its sound waves can pass easily through material as much as 5 feet thick.

Hydraulic Mining Developments.

—The Department of the Interior has announced a joint venture of the Bureau of Mines and the Northern Pacific Railway Company to survey the possibilities of mining State of Washington bituminous coal by hydraulic methods. The large-scale research program will be carried out at Roslyn, Washington, at a mine owned by Northern Pacific. Bureau and railroad officials hope that hydraulic mining will prove to be the answer to the difficult problems of mining coal from the steeply pitching seams found in the Roslyn area.

Experimental work with hydraulic mining has also been done on a large scale at a drift mine owned by Rochester & Pittsburgh Coal Company under lease to the Bureau. Here, the coal is Pittsburgh seam bituminous, in a relatively flat seam about 65 inches thick, and overlain by about a foot of slate. Using maximum pressure of 4,000 psi and 300 gallons per minute, one test showed a production rate of about 12 tons mined in approximately 15 minutes.

Work is also being done in the anthracite fields of eastern Pennsylvania on hydraulic mining, but it is too early for an adequate analysis of test results.

Looking At 1962

Each year expert opinion writes that “tomorrow will be better,” and frequently the same experts at the end of the year are busy explaining just what happened to cause their
predictions to go astray. Cyclical conditions, incipient recessions, altered consumer marketing patterns, Government controls, lack of Government controls—all are cited as explanation of "just what went wrong."

At this early date, it could be that 1962 will be the year to please all these experts. For it seems logical that the year just ahead will enjoy a continuation of the rise in the economic activity which started at midyear 1961. Most experts again are calling for a prosperous year for business and the country.

If they are right, it will be a good year for coal. And since underground mining accounts for over two of every three tons mined, that means a good year for the underground mines of the country. Conditions seem to favor this view.
ARTICLE I.

NAME AND PURPOSE.

The Illinois Mining Institute has for its object the advancement of the mining industry by encouraging and promoting the study and investigation of mining problems, by encouraging education in practical and scientific mining, and by diffusing information in regard to mining that would be of benefit to its members.

ARTICLE II.

MEMBERSHIP.

Section 1. Any person directly engaged or interested in any branch of mining, mining supplies, mining appliances, or mining machinery may become an active member of the Institute. Any person desiring to become a member of the Institute shall fill out a blank for that purpose, giving his name, residence, age, and occupation. This application shall be accompanied by one year’s dues of $3.00. Each application for membership shall be submitted to the Executive Board, who shall make an investigation as to the qualifications of the applicant, and shall be authorized to elect to membership and issue a certificate of membership to such applicant subject to the ratification of the next regular meeting of the Institute.

Section 2. Any person of distinction in mining may be elected an honorary member of the Institute by two-thirds vote of the members present at any regular meeting. Any member who has been an active member of the Institute and shall have retired from active business in mining may become an honorary member.

Section 3. The annual dues for active members shall be $3.00 and any person in arrears on August 1, of the current year, after having been sent two notifications of dues, shall be dropped from membership. Members in arrears for dues will not receive the printed proceedings of the Institute.

Section 4. Any active member may become a life member by the payment of $50.00 and shall be exempt from further payment of dues during his lifetime.

ARTICLE III.

OFFICERS.

Section 1. The officers shall consist of a President, Vice-President, Secretary-Treasurer and twelve Executive Board members. The services of all officers shall be without compensation.

Section 2. Nominations for officers and the executive board shall be made by nominating committee of three (3) appointed by the Presi-
idem at least thirty days before the annual November meeting, provided that anyone can be nominated on the floor of the meeting for any office for which an election is being held.

Section 3. The President, Vice-President and Secretary-Treasurer shall be elected by ballot, annually, at the regular November meeting and shall hold office for the ensuing year.

Four Executive Board members shall be elected by ballot, annually, at the regular November meeting and shall hold office for the ensuing three years.

To make effective this change, at the regular November meeting in 1938, in addition to the four Executive Board members who shall be elected for the three year term, there shall also be elected by ballot eight other Executive Board members, four for a two year term and four for a one year term.

Section 4. In case of death, resignation, or expulsion of any officer, the executive board may fill the vacancy by appointment until the next regular meeting, when the vacancy shall be filled by regular election. In case of a vacancy in the office of president, the duties shall devolve upon the vice-president.

Section 5. The executive board shall consist of the officers and twelve other board members.

ARTICLE IV.
DUTIES OF OFFICERS.

Section 1. The president shall perform the duties commonly performed by the presiding officer and chairman. He shall, with the executive board, exercise a general supervision over the affairs of the Institute between sessions.

Section 2. The vice-president shall preside in the absence of the president and perform all the duties of the president in his absence.

Section 3. The secretary-treasurer shall keep a record of each meeting, shall read and file all resolutions and papers that come before the Institute, sign all orders for money, and shall purchase necessary supplies.

He shall keep a true record of all money received by him and payments made on account of the Institute. He shall pay out no money except on an order signed by himself, and shall retain these orders as vouchers. He shall give bond in such sum as the Institute may provide, the premium on said bond being paid by the Institute.

He shall act as editor-in-chief for the Institute and may furnish the newspapers and other periodicals such accounts of our transactions and discussions as are proper to be published. His own judgment is to prevail in such matters unless objection is lodged at a regular meeting or by the executive board.

The retiring president shall act ex-officio in any capacity for the ensuing year.

Section 4. The president shall appoint an auditing committee annually to audit the accounts of the secretary-treasurer, and said audit shall be submitted to the November meeting of the Institute.

Section 5. The Executive Board shall perform the duties specifically prescribed by this constitution; it shall supervise the expenditures.
and disbursements of all money of the Institute, and no expenditure other than current expenses shall be authorized without first having the approval of the Executive Committee; it shall act as program committee for each meeting to determine what is to be published in the proceedings and shall perform such other duties as may be referred to them by regular or special meeting of the Institute.

ARTICLE V.
MEETINGS.

Section 1. Regular meetings shall be held in June and November of each year and on such days and in such places as may be determined by the executive board of the Institute. Notice of all meetings shall be given at least thirty days in advance of such meetings.

Section 2. Meetings of the executive board shall be held on the call of the president, or at the request of three members of the executive board, the president shall call a meeting of the board.

ARTICLE VI.
AMENDMENTS.

Section 1. This Constitution may be altered or amended at any regularly called meeting by a majority vote of the members present, provided notice in writing has been given at a previous semi-annual meeting of said proposed change of amendment.

ARTICLE VII.
ORDER OF BUSINESS.

At all meetings, the following shall be the order of business:
(1) Reading of minutes.
(2) Report of executive board.
(3) Report of officers.
(4) Report of committees.
(5) Election of new members.
(6) Unfinished business.
(7) New business.
(8) Election of officers.
(9) Program.
(10) Adjournment.

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<td>43-M</td>
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5. Sturdily built, unit assemblies assures low maintenance.

*Trade Mark of The Cincinnati Mine Machinery Co.

Lee-Norse Company
CHARLEROI, PENNSYLVANIA
Specialists in Coal Mining Equipment
Extra-Strength "POWERSTEEL" Stands Up Better

In today's fast tempo in coal production, there's no time for downtime of equipment. You can insure against shutdowns by using the best machines—and highest quality, longer-lasting wire rope. B&B Yellow Strand "POWERSTEEL" is made of higher-carbon-content steels—to stand the abuse of tough loads and steady operation—built to give greatly increased service. Get the extra-service built into Yellow Strand "POWERSTEEL" and be sure of longer rope life. Stocks on hand for immediate delivery. Broderick & Bascom Rope Co., 4203 Union Blvd., St. Louis 15, Mo.
CINCINNATI MINE...pioneered and developed the DUPLEX BIT...still the finest double-ended bit offered.

"CINCINNATI" offers the broadest line of precision reversible, double-ended bits for every cutting problem. When you do business with "CINCINNATI", you are assured of a dependable source of supply. The Cincinnati Duplex Bit excels in exacting detail as to size and shape which gives longer life to Chain Lock and Holder. Also assures proper bit gauge which reduces load on machine to a minimum and cuts down operating costs on all equipment. For your special protection every bit is electronically tested for size or any imperfections. Remember...There Is Only One Duplex Bit.

CINCINNATI MINE MACHINERY CO.
CINCINNATI 23, OHIO

Specialists in cutting equipment for over 35 years
14 H & P Fluid Bed Dryers are now in successful operation or under construction. This represents 2760 TPH total capacity.

H & P Fluid Bed Dryers range from 70 to 480 TPH; evaporation rates are from 5.5 to 33 TPH. They perform well on coal in the 1½" x 0 range, with outstanding results on difficult Centrifuge and Filter Cake mixtures.

*For truly superior performance, select the H & P Fluid Bed Dryer.*

Phone or write for further information and request Brochure 159.

**HEYL & PATTERSON, inc.**
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Would you like to read a copy of O-B Haulage Ways regularly? It is a magazine written for and sent to 8000 mine men each month, free of charge. Use the coupon to tell us where to send your copy.

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MANSFIELD, OHIO

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Kennametal Roof Bits assure speed and efficiency of rotary drilling in medium, hard, and severe roof. Available in several tip and shank designs.

Kennametal Drill Bits are produced in 20 tip and shank designs, for low cost drilling in coal, clay, slate, shale.

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KENNAMETAL* CARBIDE BITS
stay sharp longer...reduce costs

Kennametal has pioneered and developed the most extensive line of carbide-tipped mining bits and accessories...engineered and designed for economical service in any cutting or drilling condition. Tough Kennametal tips stay sharp longer, take harder knocks than any other tungsten carbide. Kennametal representatives—men with years of actual mining experience—will help you select the right bit for each job and demonstrate proper application, in the mine.

See your Kennametal Representative or contact KENNAMETAL INC., Mining Tool Division, Bedford, Pennsylvania. Phone Bedford 623-5134.

*Trademark 33518

INDUSTRY AND KENNAMETAL
...Partners in Progress
The Dutch State Mines

HEAVY MEDIUM CYCLONE WASHER

for fine coal, 3/4-inch to 48 mesh

Now available to coal producers in the United States exclusively through Roberts & Schaefer

- Cleans coal cleaner than by any other cleaning system.
-Delivers coal with higher Btu, lower ash.
-Maintains rigid uniformity of quality.
-Obtains maximum recovery of fine coal.
-Washes at any specific gravity you want.
-Operates at highest efficiency regardless of size distribution, particle shape or percentage of near gravity material.
-Produces no measurable degradation of the coal.
-Assures effective specific gravity separation independent of viscosity due to accelerated shearing forces within the cyclone.
-Holds magnetite consumption to a minimum.
-Operates at maximum efficiency through all ranges of capacity.

A Roberts & Schaefer engineer will be glad to show you how you can get the advantages of heavy medium cyclone washing by an installation in your present facilities... or in a completely new plant.
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HOT ROLLED BARS, COLD FINISHED STEEL, PIPE
BOLTS, NUTS, RIVETS, SCREWS AND WASHERS

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For conventional and continuous mining systems - AC or DC

CUTTERS—Rubber-tired machines for cutting anywhere in the seam, moving anywhere in the mine. Three heights—29", 40 1/2", 42".

LOADERS—For high capacity loading at the face or behind continuous miners. Four basic heights—24", 26 1/2", 34", 38".

LOCOMOTIVES—For main line haulage—from 60 hp, two motors to 660 hp, four motors.

SHUTTLE CARS—All Goodman cars, from the low (26') to the high (54'), are known for structural strength and capacity.

CONTINUOUS MINERS—Goodman miners have put face efficiency on a new profit level in scores of mines. The 330 for coal from 48" to 66", the 400 series for coal from 66" up.

BELT CONVEYORS—The Goodman Ropewall conveyor that has revolutionized conveyor haulage. Also available, extensible belt conveyors for use with continuous miners and loaders.

Other Goodman coal mining machinery: COMPRESSOR TRUCKS, CHAIN CONVEYORS, SHAKER CONVEYORS and SHORTWALLS.

"Use Genuine Goodman Replacement Parts"
Get **Constant Haulage** with

**NC-1 MINE CAR TRUCKS**

**WILLISON AUTOMATIC COUPLERS**

**NATIONAL RUBBER CUSHIONED DEVICES**

*Constant Haulage means volume haulage . . . every minute your mine is operating ... no costly, undue delays if equipment breaks down.

Modern mine cars . . . equipped with National car components . . . save you minutes, hours, pennies, dollars . . . and increase mine production! Check your National representative for details.

**NC-1 Mine Car Trucks.** Special load carrying springs with friction snubbing mechanism control vertical and transverse oscillations.

**Willison Automatic Couplers.** Automatically couple at either end, over wide gathering range, permit higher speeds with greater safety.

**Rubber Cushioned Device (Longitudinal).** Gear shown absorbs end-to-end impacts, gives soft cushioning action that stretches equipment life.

**Rubber Cushioned Device (Vertical).** Takes place of steel load-carrying springs in mine cars to provide smoother ride, greater speeds.

Mine Sales • Transportation Products Division

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Rugged Construction... Moderate Speeds...

Typical Applications:
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The towering stack identifies the new 238,000-kilowatt (net capability) unit addition to the Meredosia Power Station of CIPS. The unit consumes more than half a million tons of coal annually. Giant barge unloader in the foreground unloads ten tons of coal in one scoop.

From Coal... To Kilowatts

Every time a CIPS customer pushes a button, flips a switch or turns a dial to put his electric service to work, he’s using Illinois coal.

CIPS power stations are now burning an average of more than 110,000 tons of Illinois coal a month to convert water into superheated steam. This steam turns the turbine-generators which produce the electricity used daily in central and southern Illinois homes, businesses and industries.

Illinois coal mines ... and the kilowatts they help produce ... work together for the progress of Illinois.
HENDRICK SCREENS
for every coal production requirement

Hendrick Wedge Wire Screens—ideal for screening, sifting, dewatering and filtering operations where it is important for screen openings to be minutely fine yet have excellent draining qualities. Also available with riffle top markings to increase agitation and screen life.

Hendrick Cascade Wedge Wire Screens—unexcelled for screening and dewatering coal. Cascade’s unique “step” construction eliminates flooding caused by overloads... increases the weight of solids processed as well as the amount of water in screen underflow. Can be mounted on any equipment presently using profile type screens. Openings from 1/4 to 1 1/2 MM in stainless steel.

Hendrick Perforated Metal Screens—clean-cut holes prevent time delays caused by blinding. Precise uniformity of mesh and high product strength assure extra long screen life—cut down time losses due to deck changes.

HENDRICK WEDGE SLOT

TAPERED “12” is ideal for heavy-duty dewatering service on shakers and vibrators; in chutes, drags, sluiceways; in wash boxes and heavy media separators.

TAPERED “9” is the new companion to the TAPERED “12” profile. Designed for similar installations where more open area is required.

PROFILE B. For dewatering sludge, silt and fine coal on shakers, vibrators, classifiers, dryers, filters, anti-stream-pollution equipment.

PROFILE D. For heat dryers and dewatering of irregular shaped grains; also for retarding surge of water and material.

Hendrick Perforated Screens For Centrifugal Coal Dryers
Hendrick produces a complete line of perforated screens for every type of Centrifugal Dryer.

Partial List—Standard Perforations

<table>
<thead>
<tr>
<th>Perforations</th>
<th>Standard Gage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MM</td>
<td>22-20</td>
</tr>
<tr>
<td>.036&quot;</td>
<td>22</td>
</tr>
<tr>
<td>3/64&quot;</td>
<td>20-18</td>
</tr>
<tr>
<td>1/16&quot;</td>
<td>16-14</td>
</tr>
<tr>
<td>3/32&quot;</td>
<td>16-14</td>
</tr>
</tbody>
</table>

HENDRICK Manufacturing Company
Carbondale, Penna.

Perforated Metals • Perforated Metal Screens • Wedge-Slot and Wedge Wire • Architectural Grilles • Mitco Open Steel Flooring • Shur-Site Treads • Armorgrids • Hendrick Hydro Dehazer
COMPLETE LINE—CARMET makes a mining tool for every mining operation... every service condition. There's a CARMET Bit designed for universal machines and continuous miners of every make. And, when a need for a new or improved bit design exists, CARMET is ready with the answer.

TOTAL PRODUCTION CONTROL—CARMET manufactures the complete mining tool... from start to finish. Research and development are by CARMET, plus the total research experience of Allegheny Ludlum. Final tool assembly is in CARMET's own shops. And the carbide, of course, is CARMET Carbide... famous for quality.

LOCAL DISTRIBUTORS—CARMET Tools are sold through local distributors, members of local business communities. They carry a complete line in stock for you. Call on them... it's to your advantage. Their success depends on helping solve your mining tool problems.

ON-THE-SPOT TECHNICIANS—There's a staff of experienced mining experts ready to work with you through the local distributor. Bet you know at least one of the men listed here. All have worked in mining, and they're ready to work with you... at the mine face or anywhere else.

MECHANIZED MINING EQUIPMENT INCREASES TONNAGE—REDUCES COSTS

THE 6-CM...
JOY'S NEWEST CONTINUOUS MINER
Mining 5 to 5½ tons per minute, the 6-CM can mine any seam without changing or adjusting parts. Fast, gathering-arm cleanup works independently of ripper head and conveyor for auxiliary cleanup.

MOBILE CUTTERS
Built in three sizes for high, medium and low coal, these rugged trackless machines can make cuts anywhere in the face and stay ahead of any loader.

LOADERS
JOY offers loaders for all seam heights with capacities up to 20 tons per minute. The 14BU-10 line is available in basic heights of 24”, 33”, and 38”. High seam and hard rock units also available.

SHUTTLE CARS
A new line of shuttle cars, the 18-SC, hauls twice as much with a new 6-wheeled design that bends in the middle. Available in several heights to suit your seam.

Write for Bulletins
The Original ROLLING RING CRUSHER
MEETS THE DEMANDS of the
COAL INDUSTRY

* Capacities 1 Ton to 600 Tons per Hour *

Type "AC" for reducing egg and nut to domestic stoker sizes. This crusher produces a product containing no oversize and a small percentage of fines.

The "S" type crusher for reducing efficiently R. O. M. or lump to screenings in one operation. These crushers were designed to give constant and continuous operation.

Model 15 x 9 American Sample Crusher, for capacities up to 2,000 lbs. per hour. For larger capacities, we recommend the American "13" Series (capacities up to 6 tons per hour). Also available with new Sampling Hopper.

Our engineers will welcome the opportunity to discuss the detailed mechanics of these units. Put your reduction problems up to us.

Write For Laboratory Bulletin

AMERICAN PULVERIZER COMPANY
1248 Macklind Ave. St. Louis 10, Missouri
Built better to last longer

When all the facts are in, it's clear that no other interwoven belting can match U.S. Royal Gold Burro. This new belting has not only been made highly fire resistant without sacrificing strength, but its high-visibility gold cover insures maximum safety in dimly lit underground areas.

And unlike other belting, whose strength members are covered by only one layer of base yarn, the yarn-dipped, all-PVC Royal Gold Burro has an extra layer of cotton-nylon fillers beneath its tough cover to give maximum protection to its extremely high-strength nylon tension members.

Extra strands of filament nylon on the belt's edges provide greater rip and tear resistance, add to Royal Gold Burro's excellent toughness and training characteristics.

Low-cost Royal Gold Burro Belting is available in standard widths and in lengths to 1,200 ft. For further information and on-the-spot assistance, call your nearest US Distributor.

While inferior belts (left) have only one base layer to protect tension members after the PVC layer is worn through, the Royal Gold Burro (right) has an extra layer of cotton-nylon fillers to give added protection to the tension members — longer life to the belt. Note central placement of nylon tension members for maximum pulling strength.
SUPER FLEETMASTER

An all job, all wheel, all Nylon Tire with extra body strength and extreme tread toughness for additional milage and service in the toughest off-road jobs. Ideal on front wheels when mated with the CONTRAKTOR on drive wheels. It is easy steering because of the massive center rib and also is highly resistant to sideslipping.

CONTRAKTOR

Specifically designed for all mining operations or wherever rock service conditions predominate. Also available in SRT (Steel Reinforced Tread) which protects the All Nylon Cord Body from cuts, snags and ruptures in the tread and shoulder areas, provides tremendous savings in down time and more carcasses for retreading.

JAKE’S TIRE & RECAP

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Jake Sells the Best and Repairs the Rest
This Jeffrey Conveyor
(Rope Belt Type)
is VERSATILE

Install it above or below ground—to handle coal, salt, gypsum, ore, clay, shale, sand, gravel and other materials. You'll find it surprisingly low in first cost and easy to install. Easy to relocate, too.

Belts last longer on these Jeffrey rope type belt conveyors, because of the spring action of the flexible support as loads pass over troughing idlers. And the Permaseal Idlers are sealed to keep out dirt; prelubricated for years of maintenance-free operation.

For bulletin 970 containing detailed information on these conveyors, write The Jeffrey Manufacturing Company, 953 North Fourth Street, Columbus 16, Ohio.

If it's conveyed,
processed or mined
it's a job for Jeffrey.
KOL-GLO
The first and only real improvement in Coal Spray Oil in years. Eliminates discoloration.
Blended and sold only by
CENTRALIA PETROLEUM COMPANY

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for
That "Special" Coal

ANTI-FREEZE OIL
We can supply any viscosity oil to suit your particular requirements.
24-hour service by transport truck
or
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Phone 5645
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HARRY M. JOHNS
NEW CP ROOF BOLTING UNIT
features "AUGEROMATIC" dust collection system!

RBD-30SD-579 completes entire bolting cycle
in less than 3 minutes . . . trams itself anywhere!

The new RBD-30SD-579 Roof Bolting Unit has an all new "Augermatic" thru-the-auger dust collection system with a capacity of 24 feet of 1 1/2" hole. Push-button traming controls, handle-mounted for ease of positioning unit. Drill motor, with 30% more power, is fully enclosed . . . permits unit to complete cycle from drilling to bolt setting in less than 3 minutes. 40% increase in gear strength means beefed-up capacity in auger and bolt setter gear train. Internal spindle drives drill at efficient speed for Tungsten Carbide cutter heads. External spindle drives low-speed bolt setting socket. Operates on 250-500 volts, ac.

A Kentucky mine averaged 100 roof bolting installations per shift, drilling 1 1/4" to 1 1/2" holes to 42" depth in formations of rock, slate and shale.
Modernizing or building new... count on LINK-BELT

for new efficiencies in coal preparation

Link-Belt can incorporate a single unit into your present system, or design and build a completely new plant to produce better coal at lower cost. With more than 60 years' experience, plus a complete line of coal handling and preparation equipment, no contract is too large or small for us to handle. Our service begins with the planning stage, continues through design, fabrication and erection of complete facilities to operation.

For individual units or complete plants, low-cost coal handling and preparation procedures will be tailored to your requirements. For an analysis of your needs, call your nearest Link-Belt office. Or write for Book 2655.

LINK-BELT
COAL PREPARATION AND HANDLING EQUIPMENT

LINK-BELT COMPANY, Chicago 9, Birmingham 9, Cleveland 20, Denver 2, Denver 4, Huntington 9, W. Va., Indianapolis 6, Kansas City 8, Mo., Louisville 8, Pitts-burgh 15, Seattle 4, St. Louis 1, To Serve Industry There are Link-Belt Plants, Warehouses and District Sales Offices in All Principal Cities. Export Office, New York 7, Australia, Harrickville (Sydney); Brazil, Sao Paulo; Canada, Scarborough (Toronto 13); South Africa, Springs, Representatives Throughout the World.
More Tonnage from WHYTE STRAND

WIRE ROPE

These ropes tried and proved on hundreds of installations like yours are built of the finest steels and Internally Lubricated.

Give these ropes a real trial on your equipment. Save time and money—order WHYTE STRAND. Stocked by Macwhyte Wire Rope Company and Macwhyte distributors.

Manufactured by MACWHYTE WIRE ROPE COMPANY KENOSHA, WISCONSIN, MFRS. OF WIRE, WIRE ROPE, AND BRAIDED WIRE ROPE SLINGS

<table>
<thead>
<tr>
<th>USE</th>
<th>ROPE DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>Shaft Hoists</td>
<td>6x25 Filler Wire, 6x21 Filler Wire; PREformed Whyte Strand with Fiber Core</td>
</tr>
<tr>
<td>Incline or Slope Hoists</td>
<td>6x19 Scale, 6x21 Filler Wire, 6x7; PREformed Whyte Strand with Fiber Core</td>
</tr>
<tr>
<td>Mining Machines and Loaders</td>
<td>6x36 Warrington Scale PREformed Whyte Strand with Fiber Core or PREformed Whyte Strand* IWRC</td>
</tr>
<tr>
<td>Stripping and Loading, Shovels</td>
<td>6x25 Filler Wire, 6x41 Filler Wire; Lang Lay PREformed Whyte Strand* with IWRC</td>
</tr>
<tr>
<td>Stripping Draglines</td>
<td>6x21 Filler Wire, 6x25 Filler Wire; Lang Lay PREformed Whyte Strand* with IWRC</td>
</tr>
<tr>
<td>Shaft Sinking</td>
<td>18x7 Non-Rotating &quot;Kilindo&quot; PREformed Whyte-Strand</td>
</tr>
<tr>
<td>Blast Hole Drilling</td>
<td>6x21 Filler Wire &quot;Hi-Lastic&quot; Drilling Line</td>
</tr>
<tr>
<td></td>
<td>6x7 Mild Plow Steel Sand Line</td>
</tr>
<tr>
<td>Car Pullers</td>
<td>6x25 Filler Wire, 6x19 Scale; PREformed Whyte Strand* with IWRC</td>
</tr>
<tr>
<td>Scrapper Loaders, Tuggers and Slushers</td>
<td>6x19 Scale, 6x25 Filler Wire; PREformed Whyte Strand* with IWRC</td>
</tr>
</tbody>
</table>

*Whyte Strand is stocked in either PREmium or Monarch grades. PREmium is used for application where additional tensile strength (15% over Monarch) is indicated for greater factor of safety.

Get WHYTE Strand PREformed Internally Lubricated WIRE ROPE

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Diagonal-Deck
Coal Washing Table Doubles Capacity

Here is a revolutionary concept embodying twin DIAGONAL-DECK* construction in floating suspension. All the advantages of the famous DIAGONAL-DECK Table are duplicated in each of the "77's" twin decks. In addition, the decks in floating suspension are actuated by a single head motion that operates quietly and smoothly with power consumption of less than 3 H.P.

The SuperDuty* DIAGONAL-DECK Table continues to lead the field where single deck tables are required.

CONCENCO* FEED DISTRIBUTORS — The Concenko Revolving Feed Distributor is used wherever equal distribution of feed to batteries of tables or other machines is desired. This heavily fabricated, all steel distributor operates with a 1 H.P. motor.

LEAHY SCREENS — The New Model E Leahy* No-Blind* Vibrating Screen has no equal in fine mesh screening—recovery of heavy media—desanding. Leahy screens are built in...open, totally enclosed or dust proof types with single or double surface.

Now available with FlexFlex* integrated screen jacket heating for high capacity and efficiency in screening damp coal at fine meshes.

CONCENCO SPRAY NOZZLES—These handy nozzles are simple, flexible and economical. All you do is drill holes, clamp on and get results. They can be definitely aligned for washing, sluicing or spraying according to the need. They are removed or replaced in a moment's time.

CONCENCO SUPERSORTER—The Concenko SuperSorter is a multiple cell giant classifier for the hydraulic classification of coal table feeds and the cleaning of coal.

* Trade Marks Registered

The Deister Concentrator Company, Inc.
The ORIGINAL Deister Company
INCORPORATED 1906
941 GLASGOW AVENUE FORT WAYNE, INDIANA
Coal Washing Tables — Vibrating Screens — Feeders — Classifiers — Spray Nozzles
Explosives
Blasting Agents
Blasting Supplies

HERCULES POWDER COMPANY
INCORPORATED
FIRST NATIONAL BUILDING
JOPLIN, MISSOURI
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Why you can slash haulage costs with LO-ROPE belt conveyors

Long-Airdox's development of the "Lo-Rope" principle to perfect modern wire rope side frame design offers many important benefits. Savings in time and labor for installation and maintenance plus greater load-carrying capacity reduce haulage costs to a minimum.

In this design, precision roller bearings are combined with a highly effective labyrinth seal to provide an idler roll that's unequalled in performance. Low idler drag holds pull requirements to a minimum. The floating nylon labyrinth seal offers the advantages of a modern sealed bearing while retaining free-turning and re-greasing ability.

Here are a few more reasons why you can move more coal more profitably with a Long-Airdox "Lo-Rope" belt conveyor.

Reduced labor costs—conveyor stays aligned—platform rocker support stands can't walk out of position.

Increased belt capacity—fixed deep troughing angle (20°, 27°, or 35°) gives greater payload without spillage.

Belt stays centered—design provides automatic self training.

Automatic leveling of belt—made possible by adjustable support stands. Blocking for uneven bottom is eliminated.

Conveyor moves simplified—the "Lo-Rope" has fewer components.

Belt ing lasts longer—no possible contact with idler or stand connections to wire rope.

For complete information, write the Long-Airdox Company, Division of Marmon-Herrington Company, Inc., Oak Hill, West Virginia.
ENSIGN ELECTRICAL EQUIPMENT FOR A.C. MINING

300 KVA Ventilated Underground Power Transformer

Neutral Grounding Resistor

Disconnecting Junction Box with High Voltage Plugs and Kirk Interlock

Multi-Circuit Low Voltage Underground Distribution Box

High Voltage Underground Switch House

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Northern Illinois and Northern Indiana
HEADQUARTERS
for the finest in construction and mining
equipment

ALLIS-CHALMERS
Tractors, Motor Graders, Motor Scrapers, Gas Engines, Diesel Power Units and Generators Tracto-Shovels and Tracto-Loaders, Side Booms

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Wire Rope

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All size Shovels, Cranes and Draglines Rock Drills Hydro Cranes

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Heavy-Duty Trailers

PACIFIC CAR AND FOUNDRY
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