PROCEEDINGS

of the

ILLINOIS MINING INSTITUTE

FOUNDED FEBRUARY, 1892

Eighty-ninth Year

1981

Annual Meeting

SPRINGFIELD, ILLINOIS

October 22-23, 1981

WALTER S. LUCAS

PRESIDENT, 1980-81

THE COAL MINER

True — he plays no grandstand role in life
But his importance is vital, great and just:
For without his toil in earth's caverns deep,
Civilization would soon crumble into the dust.

AD 1964 From his poem — Vachel Davis

(Dedicated on State Capitol Lawn, Springfield, Illinois, October 16, 1964)

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of

All Deceased Members

of the

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Bob Bade

Richard Baldwin

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Hardy Rush

Wyatt Timmons

William P. Young

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1962-63	JOHN P. WEIR, Weir Co., Chicago, IL.
1963-64	E. T. MORONI, Old Ben Coal Corp., Benton, IL.
1964-65	JOHN W. BROADWAY, Bell & Zoller Coal Co., Chicago, IL.
1965-66	B. R. GEBHART, Freeman Coal Mining Corp., Chicago, IL.
1966-67	C. A. BROECKER, Ayrshire Collieries Corp., Indianapolis, IN.
1967-68	JOSEPH CRAGGS, Peabody Coal Co., Taylorville, IL.
1968-69	CLAYTON F. SLACK, Sahara Coal Co., Inc., Chicago, IL.
1969-70	JOSEPH Q. BERTA, Truax-Traer Coal Co., Pinckneyville, IL.
1970-71	R. F. DONALDSON, United Electric Coal Cos., Chicago, IL.
1971-72	CECIL C. BAILIE, Old Ben Coal Corp., Benton, IL.
1972-73	E. MINOR PACE, Inland Steel Co., Sesser, IL.
1973-74	ARTHUR L. TOWLES, Zeigler Coal Co., Johnston City, IL.
1974-75	DALE E. WALKER, Southwestern Illinois Coal Corp., Percy, IL.
1975-76	M. V. HARRELL, Freeman United Coal Mining Co., Chicago, IL.
1976-77	JOHN J. SENSE, Tosco Mining Corp., Pittsburgh, PA.
1977-78	BILL F. EADS, Monterey Coal Co., Carlinville, IL.
1978-79	WILLIAM E. WILL, Peabody Coal Co., Evansville, IN.
1979-80	CHARLES E. BOND, Consolidation Coal Co., Springfield, IL.
1980-81	WALTER S. LUCAS, Sahara Coal Co., Inc., Harrisburg, IL.

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LUNCHEON MEETING
FRIDAY AFTERNOON

PROCEEDINGS OF

THE ILLINOIS MINING INSTITUTE

Eighty-Ninth Annual Meeting

Springfield, Illinois

Thursday and Friday, October 22-23, 1981

OPENING SESSION

The opening session of the 89th Annual Meeting of the Illinois Mining Institute convened at 2:20 p.m., Thursday, October 22 in the Lincoln Room of the Holiday Inn East. Walter S. Lucas, President of the Institute, presided.

President Lucas: First I would like to welcome you all to the 89th Annual Meeting of the Illinois Mining Institute. It is a distinct pleasure for me to be your president this year. I am particularly gratified by the work of the Program Committee because I think they have put together an absolutely excellent program. I am sure you will enjoy the papers.

Before we get started on the technical session there are a few announcements I would like to make. We have an excellent speaker for tomorrow's luncheon. It will be Mr. Ken Tempelmeyer, who is the Dean of the College of Engineering and Technology at SIU. I am sure that we will all want to hear Dean Tempelmeyer. Remember in the morning we will have a quick business session and another excellent program before the luncheon tomorrow.

Now I would like to turn this session over to our technical chairman, who is Linda A. F. Dutcher, from Carbondale. She is a consulting geologist, and she has extensive practical experience in both the fluorspar areas in southern Illinois as well as in coal; she was formerly with CONSOL. So with that I would like to turn over the meeting to Linda, who will in turn introduce the speakers. Thank you.

Linda Dutcher; It's my pleasure to be able to welcome you to our afternoon opening technical session on behalf of the Program Committee of the Illinois Mining Institute. We appreciate the fact that you have come here today and perhaps have left some pressing problems behind to join with us. I think the fact that the Institute has been in existence for 89 years shows that the Illinois mining community does rely on the Institute to update their knowledge in current matters and to listen to the interpretation and com-

ments of people who have had experience in areas in which they are concerned.

Today we have four speakers who are completely committed to doing this again for you. These are all invited speakers, and we hope that you will find their papers of interest to you. We have allowed some time after each talk for questions or discussion as you wish.

Our first speaker is Sue Massie, who is Executive Director of the Abandoned Mined Lands Reclamation Council. Sue received her formal training in landscaping architecture at the University of Illinois. Before 1978, when she joined the council, she was a partner in a land planning firm of Massie and Massie and Associates. She started her career with the Reclamation Council designing and supervising reclamation projects, and then earlier this year she was appointed to the position of Director of the Abandoned Mined Lands Reclamation Council. Sue's talk is going to be on the techniques of abandoned mines reclamation.

Sue Massie: Thank you, Linda. Today I would like to provide you with an overview of the activities of the Illinois Abandoned Mined Lands Reclamation Council in its continued efforts to solve environmental problems caused by past coal mining in the state. I would like to review the types of problems and the number of problems we are addressing in Illinois and also discuss some of the techniques we are using on those specific problems in order to abate severe conditions and to reclaim land that is more useable for the people to enjoy; to do that I am going to rely on a number of slides.

ILLINOIS' PROGRAM TO RECLAIM ABANDONED MINED LANDS

SUE MASSIE
Executive Director, Abandoned Mined Lands Reclamation Council
Illinois Department of Mines and Minerals
Springfield, Illinois

INTRODUCTION

The Illinois Abandoned Mined Lands Reclamation Council is preparing for a substantial abandoned mine reclamation program. Using funds collected from coal operators by the Office of Surface Mining, problem sites will be reclaimed in order of their severity. The long history of coal mining in Illinois, combined with the State's relatively recent regulation of mining practices has left nearly 20,000 acres with severe safety and environmental problems. The Reclamation Council will be reclaiming these sites using a variety of reclamation techniques.

HISTORY OF COAL MINING IN ILLINOIS

The State of Illinois has a long history of coal production. In 1673, the explorers Marquette and Joliet first recorded finding coal in the bluffs along the Illinois River near Ottawa. Extracted using hand tools, coal from the outcrops provided early settlers with fuel for their personal use. The State's first commercial mine opened in 1810 near Murphysboro in Jackson County. Within a few years, the fuel demands of St. Louis, the largest city in the west, transferred the center of the emerging industry to St. Clair and Madison Counties. In 1833 the first government records documented 6,000 tons of coal hauled in wagons from the Belleville area to St. Louis. Statewide coal production also increased rapidly. In 1840, 17,000 tons of coal were produced primarily in the four counties of St. Clair, Madison, Sangamon, and Scott, however, coal was also mined in 15 other counties.

Development of the railroads beginning in the 1830's stimulated coal production. Providing the necessary transportation and promoting the development of industry which consumed the coal, production reached one million tons in 1864 and over 12 million tons in 1890. Largely mined by hand and hauled by man or mule until this time, significant developments in mining technology soon revolutionized the industry. The steam turbine began providing electric power for mining machines and haulage.

Innovations in technology also assisted surface mining in Illinois. The nation's first commercial surface mine opened in Danville in 1866 and used animals to drag scrapers. A power excavator was first used in 1885, also in Vermilion County. By 1911, a new shovel dipper was stripping even deeper overburden. In successive years larger and more efficient equipment such as the giant shovels, draglines, and excavating wheels allowed surface mining

in much of Illinois' coal field. In 1940, more than 20 counties were being surface mined. From 1920 when surface mine production accounted for only .5% of the State's production, surface mining developed so that in 1963 over half of the State's production of 50 million tons was surface produced in more than 20 counties.

REGULATION OF SURFACE EFFECTS OF COAL MINING

Coal mining became a tremendous industry during the 1900's, affecting thousands of acres of land each year. There was, however, no regulation of those surface mining practices or requirements for post-mining land reclamation. As early as 1929, three legislative proposals were introduced to provide for surface reclamation. Those controversial bills and at least 27 others were subsequently introduced in the State Legislature but failed to become law. After 23 years of intense debate, the first State law regulating surface mining was enacted in 1962. "The Open Cut Land Reclamation Act" required among other things, minimal regrading, covering acidic materials and seeding. At the time this initial regulation was adopted, more than 100,000 acres of land had been affected by surface mining. Although many of the areas had revegetated and stabilized naturally or by volunteered reclamation, 15,000 acres remained severely degraded with mine yards, spoil, gob, slurry and toxic water impoundments.

The State progressively strengthened regulations of surface reclamation by legislation in 1968, 1971, and 1975. Surface affects of deep mining, however, were unregulated until 1972 when the Pollution Control Board implemented control requirements. By that time, over 4,000 mines had operated in Illinois and 5,000 acres at 500 mine sites had severe environmental problems. Open mine shafts, collapsing structures, gob, and slurry covered the areas. Although State regulation had controlled the continued degradation of existing and future coal mine operations, the pre-law sites continued to threaten public health and safety, pollute the environment, create visual blights, and keep 20,000 acres from beneficial land use.

RECLAMATION OF ABANDONED MINED LANDS

Recognizing the extreme problems caused by the previously unregulated coal mining in Illinois, the legislature also responded. The Abandoned Mined Lands Reclamation Act became effective on July 1, 1975. The Act established the Abandoned Mined Lands Reclamation Council to implement a program of identifying and reclaiming the pre-law lands. Thorough inventories were made of the abandoned mine sites and two large projects were soon initiated. At Staunton in Macoupin County and at Nokomis in Montgomery County, large deep mine refuse areas were reclaimed. At the same time, federal legislation was being prepared. P.L. 95-87, the Surface Mining Control and Reclamation Act was passed in 1977. Although enacted primarily to provide national regulation of coal mining, the Act includes as Title IV, a reclamation fund and provisions for State abandoned mined land programs. The reclamation fund is collected from coal operators by

the Federal Office of Surface Mining at a production rate of 35¢ per ton for surface mine coal and 15¢ for deep mine coal. Portions of the reclamation fund can be returned to the State for reclamation purposes. Return of the funds, however, was made contingent on the State implementing and maintaining a federally acceptable program of regulating active coal mines.

Although the federal law was implemented in 1977, the requirement of Illinois' regulatory primacy has prevented the Reclamation Council from obtaining all of the earmarked funds. During the last three years, however, the Reclamation Council has been able to receive approximately $5 million of these funds for reclamation work on sites which threaten public health, safety, and welfare.

The Reclamation Council has used these funds to abate 23 emergency conditions including mine refuse fires, methane gas leaks, and buildings which are collapsing from subsidence of old mines. At each of these sites, the most effective and timely abatement methods were used. Some of the most dramatic work has been at mine subsidence locations, where buildings are nearing collapse. Appropriate methods to relieve the intense ground pressures have included supporting structures on beams, independent of the collapsing ground (Figure 1). In other cases, trenching and backfilling around effected structures has been necessary to reduce the compression on the building.

Fig. 1 — Two homes in the Williamson County village of Energy where mine subsidence effects were abated by supporting the buildings independent of the ground.

Fig. 2 — In Carlinville, the concrete tipple of the Old South Mine was demolished prior to filling two mine shafts and reclaiming the site.

Fig. 3 — At the abandoned Little John Mine site in Knox County, various methods of reclaiming gob, slurry, and spoil are being investigated.

Another 23 projects have been funded by the Office of Surface Mining. The projects involved 34 abandoned mines where open or improperly filled mine openings threaten public safety. Methods of exploration, filling, and sealing have been developed to permanently seal these shafts. While addressing mine openings at three sites, associated reclamation work was done. Smoke stacks and mine structures were demolished and disposed of. Mine refuse was disposed of by burying, covering, or removal.

The Abandoned Mined Lands Reclamation Council is preparing for the permanent abandoned mine program. With the anticipated schedule, the Council will be receiving reclamation funds totaling $7 to $15 million annually beginning during 1982. The funds will allow for reclamation of the severe environmental problems within Illinois. Consistent with the federal law, the Council will be reclaiming abandoned mine sites in order of the severity of their safety and health problems. Planning for these future projects is now underway.

Future reclamation sites will have various mine conditions. Mine shafts, mine gas, buildings and fires will continue to be present. Unsafe dams impounding toxic water will occur. These conditions will be controlled using standard engineering practices (Figure 2). Other conditions provide opportunities for various reclamation techniques. Mine refuse left from coal cleaning operations may have coal recovery potential. Slurry ponds and gob piles within project sites will be carefully tested for carbon content before sites are engineered for reclamation.

Various alternative materials for neutralizing and enhancing toxic refuse will be evaluated (Figure 3). For particular sites, the use of digested municipal sludge, dredgings from nearby rivers and lakes, and chemical byproducts will be considered. Use of these materials can provide a secondary benefit to reclamation in disposing of waste materials.

Linda Dutcher: Thank you, Sue, for the interesting slides and a review of the activities going on in reclamation of abandoned mines in Illinois. This is the first time I appreciated that you are dealing with non-coal land, and I think you have shown us that the project is in capable hands. Thank you very much.

Our next speaker with two hats — Richard Semonin, is Assistant Chief for administration and research for the Illinois State Water Survey and also a professor of meteorology of the Laboratory for Meteorological Research at the University of Illinois.

He received his degree in meteorology in 1955 from the University of Washington. Since then he has written over 100 reports on weather radar, cloud physics, and field meteorologic measurement projects from aircraft over the large areas. He is a member of a number of professional societies, just one of which I will mention; he is in the meteorological society and presently is Chairman of their Board of Ethics. He has served recently in a review team for the national acid precipitation assessment plan, and he

recently reviewed for the Department of Energy the modeling work that they had proposed on acid rain under the memorandum of intent with Canada. His talk today is entitled, "Acid Rain in North America; Is It a Problem?

Richard Semonin: Thank you very much, Linda. I don't have colorful slides, but I do have a few graphs that I will use as I go along that will hopefully put the question, if you will, of acid rain in perspective. I am sure that many of you read *Fish and Wildlife, Illinois Bass Fisherman,* and *Sports Illustrated*, which was the most recent one that talked about acid rain, of all things. I would perhaps like to give you a little view of what we think is happening with the acid rain picture in the United States.

ACID RAIN: IS IT A RECENT PROBLEM?

RICHARD G. SEMONIN
Assistant Chief, Illinois State Water Survey
Champaign, Illinois 61820

ABSTRACT

A reassessment of data on chemistry of Illinois precipitation for 1953-1954 revealed excessively high values, as compared to current measurements, of the elements calcium and magnesium. This feature was also found in the 1955-1956 data for the United States. The most likely explanation for this feature is that much of the U.S. experienced a severe drought with accompanying duststorms during the 1950's. The precipitation events during the drought partially scavenged the high ambient loadings of crustal dust leading to high concentrations of calcium and magnesium. The pH of 1953-1956 precipitation samples, calculated by an ion-balance equation, is shown to be very sensitive to the concentration of these cations as well as the pollutant-related sulfate and nitrate anions. In an attempt to depict the non-drought acid rain distribution in the 1955-1956 period, a reduction of the calcium and magnesium concentrations was made and pH values recalculated. The resulting pattern of pH for 1955-1956 shows a much larger areal extent of acid rain in the eastern U.S. and conforms relatively well to currently observed values. These results suggest that the downward pH trend since the mid-1950's due to the increase of acid-forming emissions is much smaller than previously estimated. The basic influence on the precipitation chemistry of a major drought was not considered previously. The drought-corrected pH trend is small and may well be within the errors of the total measurement and analysis system.

INTRODUCTION

The considerable concern over acid rain has partially arisen because the limited sampling of data since the 1950's has been interpreted to show a rapidly worsening condition over eastern North America (becoming more acid over a larger area). Cogbill and Likens (1974) presented the distribution of calculated precipitation pH from the National Center for Atmospheric Research (NCAR) network (Lodge, *et al.*, 1968) for 1965-1966 and made comparisons with the earlier 1955-1956 data of Junge (1958) and Junge and Werby (1958). The area enclosed by isopleths of low pH was described as expanding concentrically from east-central Pennsylvania during the period from 1955-1956 to 1965-1966. These data and their interpretation, with additions for 1972-1973 by Cogbill (1976) have been widely used to estimate the trend of precipitation acidity over the northeast United States. Further, the trend derived from these data has also been used to indicate the possible impact on precipitation quality of future increased

atmospheric emissions from fossil fuel combustion.

Unfortunately, continuous measurements over a 25-year period or longer are not available on a regional scale. In order to address the question of a temporal trend, data acquired at one point in time must be compared to data obtained at another time. Obviously, the individual measurements must be comparable in quality for a valid comparison. Preferably, identical instrumentation for sample collection, and identical chemical analytical methods should be employed throughout the period over which the trend is to be calculated. Until recently none of these preferred conditions have been met. I will examine, then, an interpretation of past data, bearing in mind the limitations imposed, and present a somewhat different picture of changing precipitation chemical quality.

APPROACH TO THE PROBLEM

The measurement or calculation of pH is a reflection of the physical presence of hydrogen ion in a precipitation sample. The hydrogen ion concentration can be estimated (calculated) by measurement of the concentrations of all major ions in a precipitation sample and solving an ion balance equation for the hydrogen ion concentration.

The measured ion concentrations in ueq L^{-1} are used in the equation

$$[H^+] = [SO_4^{2-}] + [NO_3^-] + [CL^-] = [HCO_3^-] + [OH^-] + [CO_3^{2-}] - [Ca^{2+}] + [Mg^{2+}] + (NH_4^+] + [Na^+] + [K^+] \quad (1)$$

to calculate $[H^+]$ and, thus, pH. Samples are assumed to be in equilibrium with atmospheric carbon dioxide which leads to

$$[HCO_3^-] = K_H K_1 P_{CO_2}/[H^+] = K_H K_1 P_{CO_2}[OH^-]/K_w$$

and

$$(CO_3^{2-}] = K_2[HCO_3^-]/[H^+]$$

For 25°C, $K_H = 0.034 \times 10^6$ ueq $L^{-1}atm^{-1}$ and $K_1 4.5 \times 10^{-1}$ µeq L^{-1}(Harned and Davis, 1943), $K_2 = 4.7 \times 10^{-5}$ ueq L^{-1} (Harned and Scholes, 1941), and $K^w = 10^{-2}$ (µeq L^{-1}) (Robinson and Stokes, 1959). Assuming $P_{CO_2} = 320 \times 10^{-6}$ atm, it can be shown that $[HCO_3^-] \simeq 490\ [OH^-]$ and for samples with pH < 8, $[HCO_3^-] > 213\ [CO_3^{2-}]$. Therefore, the terms for $[OH^-]$ and $[CO_3^{2-}]$ in equation (1) can be neglected for precipitation samples, producing an equation which is quadratic in $[H^+$.]

This approach is necessary when pH measurements are not reported and is generally useful since it demonstrates the role of each of the ionic species in the final determination of pH. Cogbill and Likens (1974) used a version of this method which included terms to subtract seawater contributions to the observed precipitation chemistry. In this paper, no correction for seawater is attempted, but rather H^+ is estimated directly from an imbalance between the sums of the measured cations and anions.

PRECIPITATION CHEMISTRY TRENDS AT THREE LOCATIONS

Event samples for 63 precipitation occurrences at Champaign, Illinois, for 1977-1978 were obtained using a wet-dry collector (Galloway and Likens, 1976) mounted at the top of a 10m tower. This was also the collecting platform for a part of the Larson and Hettick (1956) 1953-1954 data collected at the same locale. In the 1953-1954 study, hardness (i.e., (Ca^{2+} + Mg^{2+})) was the reported quantity and, thus, at some following places in this paper, the sum of these two ions is considered as opposed to their individual concentrations.

The median concentration values for 1977-1978 resulted in a calculated pH of 4.09. The calculated pH agrees quite well with the median measured pH of 4.02. This agreement between measured and calculated values for the recent period of data provided confidence in the pH equation, and the ion concentrations for the 1953-1954 data were also used in the equations to yield a pH of 6.52. These pH values indicate an increase in free acidity of more than two orders of magnitude over the 25-year period, 1953-1978.

Building upon this information, the Junge data from 1955-1956, reported as annual averages, were used in a comparison with recently acquired MAP3S data for the East (MAP3S Precipitation Chemistry Network, 1977, 1979). The 1977-1978 MAP3S data from Cornell University, at Ithaca, New York, and Pennsylvania State University at State College were compared with the 1955-1956 mean values obtained for Williamsport, Pennsylvania. The values for Cornell and Pennsylvania State show little difference for the same sampling period, and the mean values were used to represent the central and north-central part of Pennsylvania, which includes Williamsport. The calculated pH values were 4.18 for 1977-1978 and 4.67 for 1955-1956.

A third comparison was made between the University of Virginia MAP3S site at Charlottesville and the Junge site at Roanoke, Virginia. A pH value of 4.19 was calculated for 1977-1978 compared to 4.43 for 1955-1956.

A summary of the data at these three locations is shown in Table 1. For the Illinois station, between 1953-1954 and 1977-1978 the sum of the calcium and magnesium concentrations decreased by almost 72 μeq L^{-1}, compared to decreases of 48 and 17 at the central Pennsylvania and Virginia sites, respectively. The nitrate and the sulfate concentrations at all locations changed much less than did the calcium and magnesium.

Table 1 — Summary of Concentration Changes (μeq/L) between mid-1950's and mid-1970's.

	(Ca^{2+} + Mg^{2+})	(NO_3^-)	(SO_4^{2-})
IL	-71.6	+9.6	+14.4
NY & PA	-47.7	+6.4	-17.1
VI	-16.5	+9.7	- 1.8

Likens *et al.* (1979) attributed a decreasing trend of pH to increased

emissions of SO_2 and NO_x resulting in increased sulfuric and nitric acid levels in precipitation. The data in Table 1 suggest that the pH difference between the 1950's and 1970's is more likely due to the dramatic decrease of the sum of calcium and magnesium rather than to an increase of the acid-related sulfate and nitrate.

SENSITIVITY TESTS WITH THE pH MODEL

The Junge data from 1955-1956 were utilized in equation (1) to calculate pH at each site in the contiguous U.S. The magnesium ion concentration was not measured by Junge, but it was estimated by Stensland (1979) from the calcium concentration using calcium to magnesium regional ratios calculated primarily from the data of Lodge *et al.* (1968). The ratios were calculated with the ion concentrations in mg L^{-1}. Ratios of approximately 4 were calculated over the entire eastern U.S. from the Dakotas eastward to Maine and southeastward to Georgia. The weighted average values of nitrate and ammonium were calculated directly from the quarterly data of Junge (1958) and the corresponding precipitation data at each sampling site.

A comparison of calculated and measured pH values for more than 1000 European and more than 1000 U.S. samples was made and the results suggested an empirical correction was needed for calculated values to achieve agreement with measured values. The empirical correction decreases the calculated pH values. For calculated $pH \geq 6$, the empirical correction results in a decrease of 0.7 pH unit. With values of calculated $pH \leq 4.8$, a reduction of 0.15 pH unit appears appropriate. A chemical explanation for the empirical correction is not yet available.

The results from the calculation of pH using equation (1), the empirical correction, and the foregoing approximation for magnesium were used to develop Fig. 1. The pH pattern shows low values over southwestern Pennsylvania and Vermont, and a strong gradient from pH 4.5 to a pH 6.4 extending westward to Illinois. Small areas of $pH > 7$ were calculated for east-central Wyoming and extreme southern Texas. This pattern, while similar to that of Cogbill and Likens (1974), does not indicate as large an area of acid rain.

The more recent measurements of the calcium were, on average, only about ⅙ of the mid-1950's values for the three locations. To test the sensitivity of pH to this result, values were calculated for the 1955-1956 data assuming a reduction of the calcium concentrations by a factor of 6. Since magnesium was calculated by specifying regional calcium/magnesium ratios, it too was reduced by a factor of 6. The results of these calculations, including the empirical correction of pH, are shown in Fig. 2. It is immediately obvious that pH is very sensitive to the concentrations of calcium and magnesium. The pH 4.4 isopleth extends southward through Wisconsin to central Illinois and southeastward to North Carolina leaving the continent from the southeast Virginia coast. Without the adjustment for abnormally high calcium and magnesium, the pH 4.4 isopleth in Fig. 1 was closed over eastern Ohio, northeastern West Virginia, northern Virginia, and southwest Pennsylvania.

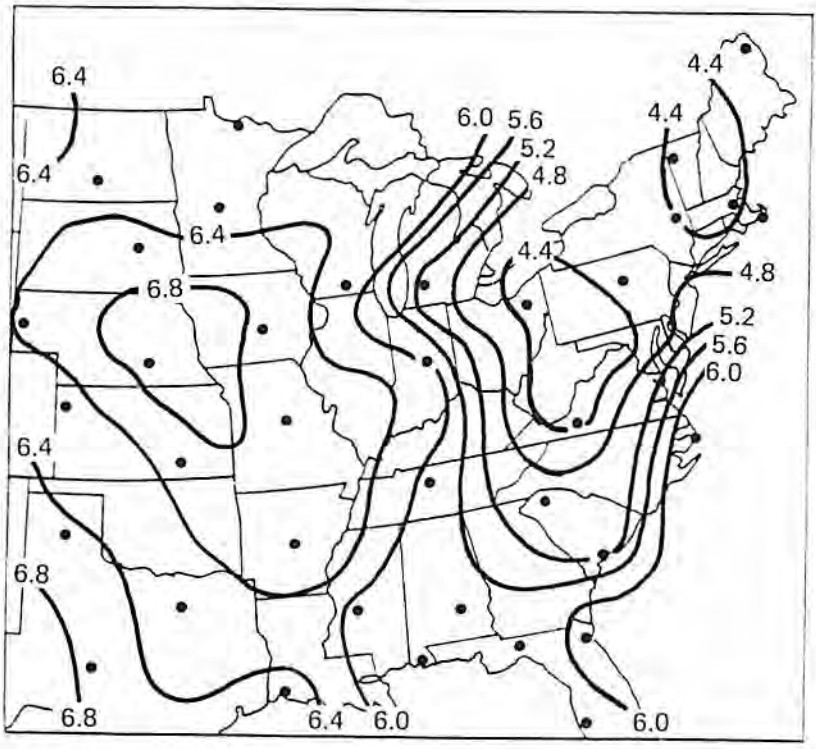

Fig. 1 — The 1955-1956 pH distribution derived from the Junge data using estimated magnesium concentrations and an empirical correction factor (see text).

SUMMARY AND DISCUSSION

The values shown in Table 1 for the concentration changes of the sums of calcium and magnesium, nitrate, and sulfate in the three geographical areas of Illinois, central Pennsylvania, and Virginia are worthy of further discussion and a search for an explanation. The consistently negative change of the calcium-magnesium sum is of particular importance since these ions play such an important role in determining the hydrogen ion concentration. The observed changes may be attributed to: 1) different collection and sample handling techniques; 2) different chemical processing and analysis methods; and 3) a natural change of the ambient ion concentrations in precipitation. Each of these possibilities is now discussed.

COLLECTION TECHNIQUES

The collection techniques over the past two decades evolved from a funnel exposed to precipitation by an observer in 1955-1956 to the

automated wet-dry collectors currently used. It is possible that in the 1955-1956 network operations the funnel was occasionally placed in position before the onset of precipitation. On those occasions, it is possible that dry deposition influenced the measured concentration. However, dry deposition certainly was minimized from the 1953-1954 Illinois data by uncovering and rinsing the collections surface with ammonia-free water just prior to the onset of precipitation (Larson and Hettick, 1956). In spite of this care, Illinois results demonstrated the largest change of the calcium-magnesium sum. While these comparisons between the 1953-1954 Illinois data and the 1955-1956 network data do not prove the quality of the latter data, it certainly demonstrates the consistency of the decrease of calcium and magnesium in the three study regions with the use of two different sampling methods.

Chemical Processing

Changes in chemical processing and analysis techniques are not likely to account for the observed changes in the calcium-magnesium concentrations. The concentrations of the major ions in the 1955-1956 data set were

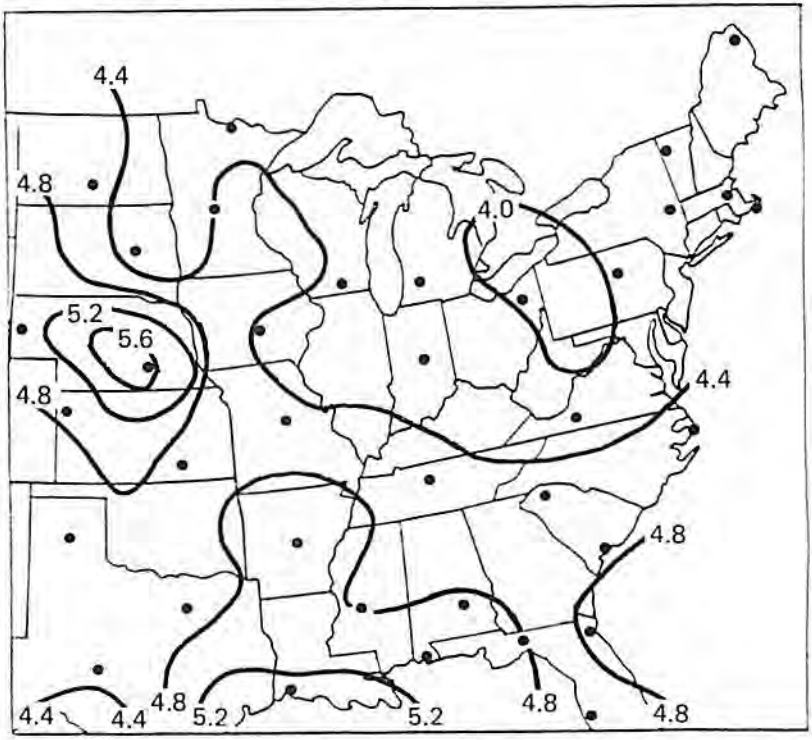

Fig. 2 — The pH distribution for 1955-1956 after correcting for assumed anomalously high concentrations of calcium and magnesium.

well above the detection limits of the methods used. While methodologies have evolved to increase the sample analysis through-put, improve the detection limits, and increase the sensitivity of the analyses, the concentrations reported in this study are considered likely comparable and not due to analytical differences.

Natural Changes Of Ion Concentrations

We must now consider the possibility that the higher concentrations of calcium and magnesium in the 1950's precipitation samples as compared to more recently measured values were due to natural causes. The primary source of these two ions is resuspended crustal dust scavenged by precipitation, and a possible explanation for their relatively high concentration may lie in the extensive drought experienced in the U.S. during the early and mid-1950's. The cumulative precipitation departure from normal for the period July 1955 through June 1956 is shown in Fig. 3. A major precipitation drought is very evident over the central and lower Great Plains, although nearly the entire area from the Great Basin east to Illinois and

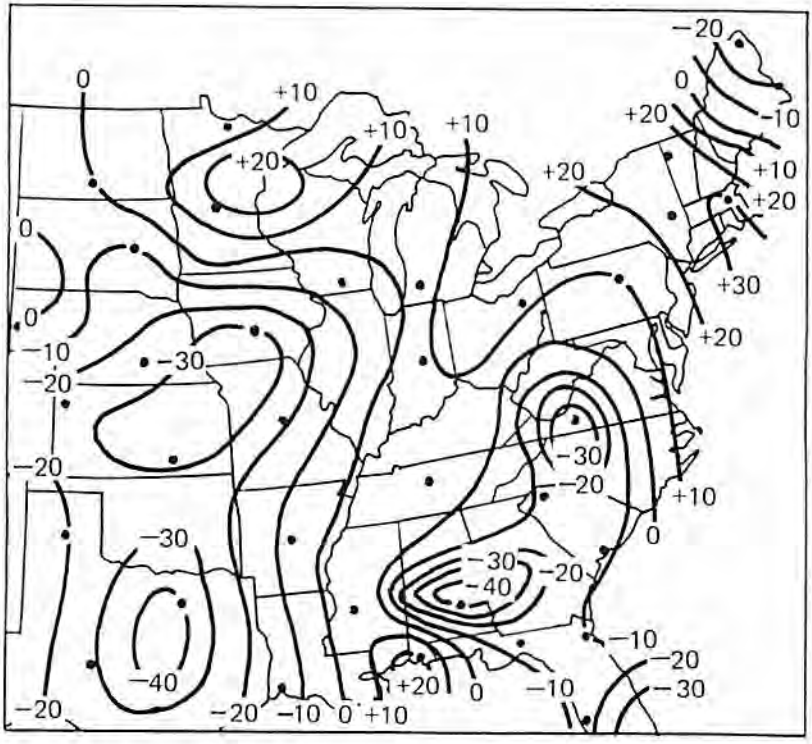

Fig. 3 — The cumulative precipitation departure (cm) from normal for the 12 months July 1955-June 1956.

from Canada to Mexico experienced less than normal precipitation. The southeastern states (from Virginia to Alabama and Florida) also experienced drought conditions. It is reasonable, then, to expect that precipitation chemistry over large regions of the U.S. can be altered by the scavenging of dust originating in the lower Great Plains or elsewhere.

A study of the summaries of national weather in the Monthly Weather Review issues for the July 1955 through June 1956 period suggests that several duststorm events occurred. July 1955 was characterized by a heat wave in the central and northeast U.S. with a major duststorm reported in Texas in the previous month. In August 1955 and until July of 1956, dry weather prevailed over a major portion of the U.S. resulting in the large area of deficit precipitation shown in Fig. 3. In December 1955, and in February, March, and April of 1956 severe duststorms were reported throughout the Great Plains states. Lesser dust events were reported in the months prior to December 1955.

The removal of natural dust from the atmosphere by precipitation can lead to excessive concentrations of those elements in relative abundance in the soil. For example, Junge and Werby (1958) reported an area of mean

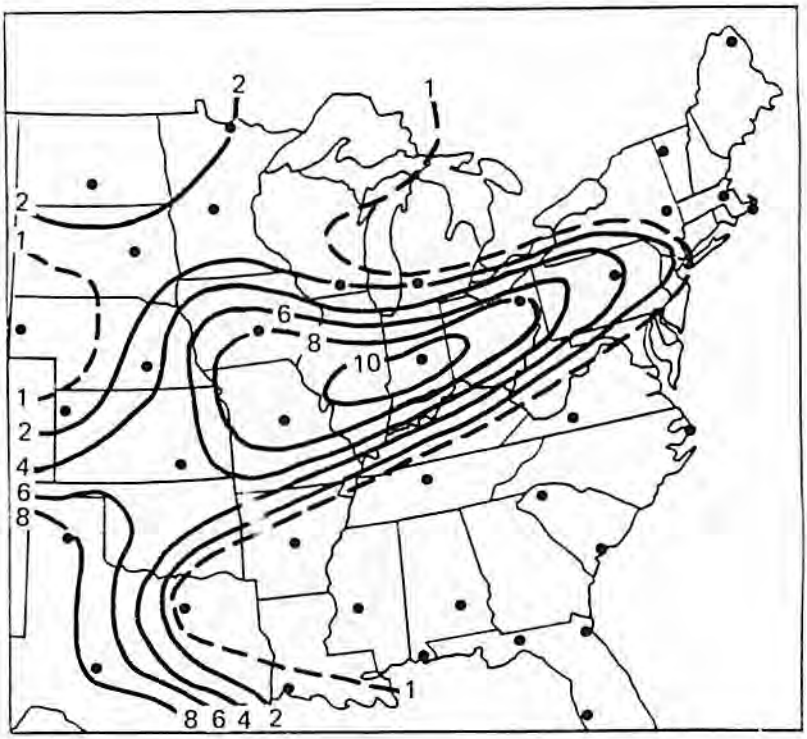

Fig. 4 — The calcium concentration (mg L^{-1}) for December 1955 from the Junge network.

annual concentration of calcium over southwest Colorado and northwest New Mexico of about 4 mg L^{-1} with the area from the Dakotas to south Texas having greater than 1 mg L^{-1}. By way of contrast, the December 1955 calcium concentrations shown in Fig. 4 reveal values in excess of 1 mg L^{-1} extending through the Great Lakes and Ohio River Valley into New York with values >10 mg L^{-1} over central Indiana. These observed December values are 2 to 5 times the average annual levels reported by Junge over the Great Plains region. The 1978-1980 observed precipitation-weighted mean calcium concentrations from the NADP network show values less than 1 mg L^{-1} over the entire U.S. with most values less than 0.5 mg L^{-1} (National Atmospheric Deposition Program, 1978, 1979a, 1979b, 1979c, 1980).

This interpretation of the available precipitation chemistry and meteorology strongly suggests that the resuspended dust associated with major duststorm events during the 1953-1956 sampling period altered the precipitation chemistry. The abnormally high concentrations of crustal dust elements biased calculated pH to higher values than in the absence of such events. When the excess soil loadings of the 1950's are adjusted within

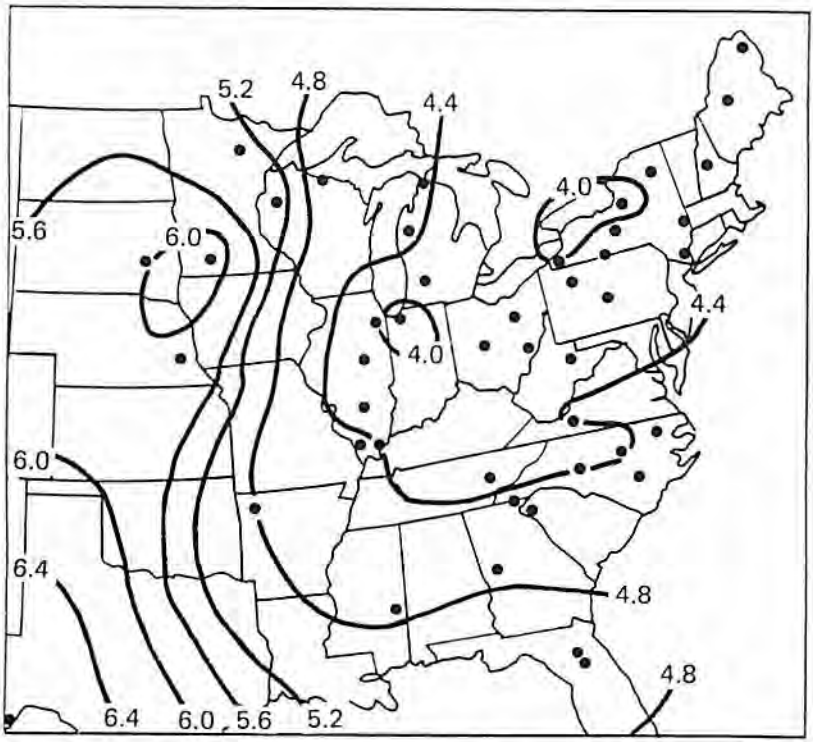

Fig. 5 — Distribution of median pH distribution from the NADP network as of September, 1980. Individual stations may have between < 10 and > 100 measurements. More than 4000 samples were used to arrive at this map.

reason to non-drought conditions, newly calculated pH values are not terribly different from those in recent years. There is no *dramatic* change of pH in the northeastern U.S. between 1953 and 1980. The recent measurements from the NADP network are shown in Fig. 5. A comparison between the patterns of Fig. 2 and Fig. 5 reveals that the pH 4.4 isopleth in 1955-1956 extends generally north-south through Wisconsin to west-central Illinois, thence east-southeastward to central North Carolina, curving northeast off the Atlantic coast. The current measurements show the same isopleth entering lower Michigan, extending west and south through central Illinois, and then east-northeastward leaving the coast in Delaware. The central core of lowest adjusted pH was centered over western New York, western Pennsylvania, and northeast Ohio in 1955-1956 with little change shown for the present conditions in Fig. 5.

CONCLUSION

If this reanalysis represents a realistic interpretation of the past data, there are three substantive issues to be considered. First, the sampling of the 1955-1956 data was carried out during an anomalous climate event and are suspect for use in ascertaining long-term trends. They certainly should not be compared with non-drought data. Second, naturally occurring materials such as soil aerosols are as important to a full interpretation of the spatial distribution of acid precipitation and its temporal trend as are the anthropogenically produced pollutants. Third, inspection of both Fig. 2 and Fig. 5 shows that nearly the entire eastern U.S. was already within an acid rain regime (that is, pH <5.6) in the 1950's. The pH change since the 1950's appears to be less than 0.5 pH unit. In fact, the change is hard to estimate considering the errors pointed out by Liljestrand and Morgan (1979) of calculating pH from measured ion concentrations.

If acid rain is an environmental problem, it is one that we have lived with for more than 25 years. The recently identified potential impacts on forests, aquatic systems, soils, water resources, structures, and crops should have surfaced in the literature prior to the 1970's if the required change for such impacts is 1 or 2 pH units. The interpretation of past and recent data presented here shows that such a dramatic change of pH is unlikely to have occurred in the past 25 years and that acid rain in the eastern U.S. pre-dates the 1950's.

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Richard Semonin: We have produced a little brochure because we have had so many questions on this. I have brought a limited number of them, and I'll leave them up here if any of you would like to have one. Thank you.

Linda Dutcher: Thank you, Dick for that interesting update. I think it is an illustration of how important understanding the sampling techniques are to this type of problem. This is something we have been hearing a lot about, and I know some of you have questions.

Question: Have there been any studies any place in the world that is not heavily industrialized like ours to see what the natural acidity of the rain is.

Richard Semonin: Yes, as a matter of fact there are some sights being selected around the world at the most removed places one could imagine. To try to get a handle on this the first data that I know about are from a very small island in the south Indian ocean, at least 2,000 miles from the nearest industrialized land area. The rainfall there is showing a median pH of about 3.9. We thought of this before I started getting numbers. We went to Hawaii because we thought that was as remote as we could get, and we spent a summer there measuring the rainfall chemistry. We found again that the pH varied from 3.9 to about 4.4. Some of it is due to local sulfur emission; I think we can safely pin that down, but a good share is actually natural from the ocean as far as we can tell.

Question: Have you seen any work that deals with a decreasing of the ozone layer and increasing of the level of radioactive material in the atmosphere?

Richard Semonin: That is really a very technical question and one of the more controversial subjects. As the Canadians and the representatives of United States get into negotiations, they are basing a lot of their findings on modeling numerical simulation of what is going on. The chemistry that is involved in this simulation is all linear. If you increase sulfur dioxide by two, you are going to increase sulfate loading by two, then you are going to decrease the pH by so much, and vice versa. There is more and more evidence that says that chemistry is not linear at all, and that the results are going to be entirely different when we consider these other oxidants and substances, which are not considered at all. The other thing that disturbs me, and I hope I have convinced people here, is that to discuss acid rainfall you can't just discuss sulfate, but you have to look at calcium, magnesium, nitrate, and all the other elements that go into the make up the chemistry of a sample. And unfortunately again, all the Canadian-United States work is being done to address the sulfur problems and equating that directly with the acid rain problem, and I think that is very poor. Thank you.

Heinz Damberger: Dick, could you comment on these findings in the ice of the Antarctic or Arctic where they determined paleoacidity and how this might fit into this whole picture?

Richard Semonin: That's an interesting question, Heinz, and I believe there are problems first with some of the chemistry involved because of the pressures of the icecaps in Greenland and Antarctica. The first results that came out seem to indicate that there were alkali rains early on, and people were using those measurements as an argument for indicating the beginning of the industrial revolution and the gradual pollution of the atmosphere. Since then, further analyses have indicated indeed that in past times the rainfall was just as acid as it is today. And I believe without doubt, if you look at some of the precipitation that is associated with volcanic eruptions and other natural sources nearby, you will find there is a great deal of acidic components in that rainfall. I think that the definition of acid rainfall, is that the pH is at 5.6. If you take a glass of pure, distilled water and set it on

a table, it will absorb enough carbon dioxide from the atmosphere to make a weak acid with a pH of about 5.6. Then they immediately say that if you have rain with a pH less than that, it is more acid, and therefore somebody did something to the rain. That is not exactly true because I can tell you as a meteorologist that if it wasn't for impurities in the atmosphere, it would not rain. That is a meteorological physical circumstance. In other words in order to get rain, to get drops to form clouds, which in turn form rain or snow, you have to have impurities, such as little particles of clay, (some pollutants serve well) or amonium sulfate particles. Condensation occurs around them to make the rain; and as soon as I put those impurities in, I have changed the chemistry entirely from the pure, distilled water. So, it doesn't surprise me that if you look back through the stratigraphy of ice cores you will find acid conditions.

Linda Dutcher: Thank you very much, Dick.

Since we have a minute or so here, I thought I would tell you about one speaker that we didn't invite. He has published recently in *Epilog*, which is an official publication of the EPA. His studies show that burping cows rank as the number one source of air pollution in the U.S. Ten cows burp enough gas in a year to provide space heating, water heating, and cooking requirements for a small house. Unfortunately, I am quoting here again, there is no existing technology available for controlling these hydrocarbon emissions.

Our next speaker is known to many of you. Clark Ashby has held a professorship at the University of Chicago, and he is presently at Southern Illinois University. He received his formal education at the University of Chicago, the University of California at Berkeley, and then in 1950 he received his Ph.D. after returning to the University of Chicago. He has done research at the California Institute of Technology and was recipient of a Fulbright Research Scholarship to Australia in 1955. He has also worked as a plant physiologist with the U.S. Department of Agriculture and the Forest Service. Clark is going to present to you some of the work he has been involved with over a long period of time; he has been very active in conveying his feelings about this problem to the public and the mining community in Illinois. He will speak on "The Root of Our Reclamation Problems".

Clark Ashby: Thank you. I should mention that Clay Kolar, who is out today getting soil samples for pH measurements and Gary Philo, who is out collecting acorns for our tree planting program that will soon be starting, also contributed greatly to this paper. Some of the views we express may not be those of other state agencies, but I trust they will stimulate thinking and in the long run prove helpful.

First let me say that we assume that although improvements are possible in reclamation, these improvements could make better use of the total overburden resources possible and reduce the operation presently required.

THE ROOT OF OUR RECLAMATION PROBLEMS[1]

W. CLARK ASHBY, *Professor*, CLAY A. KOLAR, *Researcher*
and GARY R. PHILO, *Researcher*
Department of Botany,
Southern Illinois University, Carbondale, IL 62901

RECLAMATION AND REGULATION

We assume improvements are possible in reclamation. These improvements could be to make better use of the total overburden resources, to reduce operations presently required and to enhance vegetation success. Lessened overburden handling and greater success in reclamation would benefit our economy and society by easing reclamation costs.

Regulation, state and federal, is now part of the reclamation scene. A chief goal of regulation should be to have mine soils from present mining at least as productive as mine soils from pre-law mining. We do not know whether anyone has been keeping that score. It looks to us as though the regulators have struck out on tree growth, maybe can get an occasional man on base with pasture, and the game had to be called on cropland because there was no league team for comparison of pre-law cropland on mine soils. Why has regulation of reclamation not achieved greater success than it has?

We submit that regulation has been directed toward illusionary goals. Plant life requirements have been overlooked or misunderstood. Emphasis has been placed on restoring what was there before — topographic features and weathered soil horizons. The cast overburden has been treated as a waste material rather than as a resource often more valuable than the soil it underlies.

Reclamation should be guided by positive rather than negative goals. These goals should be not just to replace a tilled field or a pasture in the short term, but to build a long-term resource. "Permanent" features of the soil such as moisture-supplying potential and slope should out-weigh non-permanent features such as rock.

Current reclamation regulations emphasize grading and segregation and replacement of stone-free surface materials. Both sets of requirements may be counter-productive by creating an unfavorable rooting medium and by limiting potential soil-water storage. Probably the chief limiting factors of revegetation success in reclamation are inadequate root growth, and associated limited available water supply.

SOIL BUILDING

Soil building for good plant growth should include physical and

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[1]*Research was supported by Sahara Coal Company, Inc. Tree seedlings were chiefly supplied by Illinois Department of Conservation.*

chemical features for development of an efficient and effective root system. This paper focuses on physical rather than chemical soil properties. The same physical characteristics needed for good rooting are associated with good drainage, favorable aeration, and adequate water entry and storage. There is no necessity for original contour, rock-free soils, or other requirements which somehow have crept into the regulations.

Small differences in physical condition of soil can make very big differences in plant growth. Traffic on soil destroys the voids and capillaries which are essential to movement of air and of gravitational water in drainage. Loss of these soil pores affects the hydrologic cycle to decrease infiltration, percolation and drainage. This leads to decreased usable soil water storage and to increased flooding and sedimentation on and off site.

The likelihood of sealing the soil surface is accentuated by replacing fine-textured top dirt. In southern Illinois the ancient, weathered and acidic surface materials are mostly silts and clays which readily re-compact. Selection of equipment for moving dirt which leads to minimal traffic is important. For example, front-end loaders with truck haul may be better than scrapers, which were designed to compact surfaces in road, airport, and other types of construction.

Presumed benefits of original contour and top dirt replacement are cosmetic, convenience in later farming, and sentimental. Some people like to look at manicured landscapes, some farmers are reluctant to alter traditional farming methods which are, however, rapidly being altered by other forces, and the change of the old landscape and ownership patterns as a result of mining is paralleled by consolidation of farming units, accelerated land clearing, stream re-routing, highway construction, and other features of our mechanized age.

ROCK IN MINESOILS

Another factor of interest in reclamation success is presence of stone or rock. Illinois has stringent limitations on percent rock, without differentiating kinds of rock. There are many benefits from including mineral resources other than top dirt in the rooting medium after reclamation.

A stone-free surface is much more susceptible to erosion than one with occasional coarse fragments. These fragments impede the flow of water and protect finer soil particles, seed, and fertilizer from being dislodged and washed away. Much more water moves into the soil when its flow is checked. A soil-stone interface also serves as an alternate flow pathway for water movement into the soil. As coarse fragments on or near the surface disintegrate, the infiltration and percolation rates increase still more.

Rock in a soil serves as a support to bear the weight of heavy machinery. One rock rests on others which rest on many which rest on the bedrock. Shales and sandstones rapidly weather to furnish channels for movement of air, water and roots, as well as furnishing fresh minerals important in nutrient relations. Weathering of limestones is usually slower.

Suitable rock lower in the subsoil offers vertical surfaces for movement

of water and of roots in the horizontally-layered soils after grading. As the rocks weather they become channels of primary importance for root growth and vertical movement of water. Rocks also store available water for plant growth. Coarse fragments of shale or sandstone have available water storage greater than the compact subsoil materials from many pre-mining soils.

USING TREES FOR BIOASSAY OF RECLAMATION SUCCESS

Many people would be surprised to learn that trees are sensitive indicators of environmental quality. Most of our crop plants have been selected to grow under a wide variety of conditions, though with limits. Trees in nature are sorted out to a fine degree by competitive interactions in suitable environments. Trees thus serve well to assay factors potentially limiting plant growth on reclaimed lands. The findings from earlier reclamation plantings can well serve as a standard for stripmine productivity against which to measure today's reclamation performance.

Numerous pre-law tree plantings have made superior growth on mine soils. For example, a 23-year-old tulip tree stand planted on mine banks under black locust made excellent growth with highly desirable soil development. The earlier rock weathered away to give channels for root growth, aeration and water entry into the deeper soil horizons. In this and other plantings more trees have survived then are desirable for best tree growth.

Only a few plantings are available which were made on flattened banks. Several kinds of trees grew relatively well on land flattened by dragline during tandem mining 30 years earlier. This type of grading apparently affected root growth less than would be expected from grading as typically carried out under recent reclamation requirements.

Even grading by bulldozer may not ultimately be detrimental if suitable spoil resources are used. A 4-year-old black walnut sapling made excellent root and top growth on graded spoil which had been planted to pasture after grading (Fig. 1). The shales and sandstones of the overburden weathered to give a very superior rooting medium. Good vertical and horizontal root system development were evident. Despite the desirable rooting medium, other trees in this planting will later be limited in growth by self-girdling from roots twisted in poor planting.

Use of bulldozers in grading is believed to result in widespread compaction of replaced surface soils. This can be seen in clods moulded by the tracks. Another problem for revegetation success is that even with the heavy bulldozer traffic, uneven settling is characteristic of graded fields. Poor drainage leads to ponding, release of soil nitrogen and death of roots from anaerobic conditions during flooding, and later invasion of weeds when the ponded waters dry up. Intensive leveling is not an unmixed blessing and may be of scant benefit for varied types of reclamation.

Rubber-tired scrapers used in "topsoil" replacement were designed for highway construction or in building-site preparation. They can compact

Fig. 1 — Black walnut grows very poorly on sites with restricted soil layers. The excellent growth of this 4-year-old sapling can be attributed to numerous channels for water movement and root growth from weathering of sandstone and shale fragments in the graded spoil.

Fig. 2 — Availability of water should be a major criterion in building post-mining soils. Roots cannot grow into compacted mined or unmined subsoils to obtain water even if moist. Recognition of compaction problems may lead to new understanding of reclamation needs.

much more than bulldozers, and are especially damaging when the load is dumped in shallow layers of soil over which the scrapers run repeatedly with later loads. A soil pit in Illinois 1104 stone-free land shows subsoil compaction and limited rooting (Fig. 2). Coarse fragments and their weathered residues would improve water relations and rooting. The top dirt in this photo has been loosened by cultivation and probably by freezing and thawing.

We have used several criteria in evaluating reclamation practices. One is first-year percent survival. Although percent survival is a good index of favorable growth conditions, too much emphasis in reclamation requirements on survival can lead to excessive numbers of trees and later growth stagnation.

A second set of criteria is third-year survival and growth. We compared graded and ungraded spoil and unmined fields for survival and growth of twenty kinds of trees. First-year survival on graded sites was sometimes comparable to the other sites. By the third year, however, marked reduction in percent survival and growth was found on the graded site for many species. A few species did not show adverse effects after three years.

ROOT-SYSTEM DEVELOPMENT

Another index is root-system development. We compared two-year root growth of chestnut oak and black walnut on graded and ungraded spoil (Table 1). Root growth for these and about 15 other species was markedly better on the ungraded spoil. For many species the top growth did not show these differences after two years. The few plots available to date with replaced (and graded) "topsoil" had root growth no better than the graded spoil.

Table 1. Root and shoot growth in two years on graded and ungraded spoil.

Species	Root Depth (cm)		Top Height (cm)	
	Ungraded	Graded	Ungraded	Graded
Chestnut oak	57	28	26	28
Black walnut				
seedling	84	21	53	21
seed	54	38	29	18

The morphology of these root systems is equally as striking as the rooting depths (Fig. 3). On graded spoil the roots tend to grow nearer to the soil surface, where they would be adversely affected by drought. The layering of the spoil by bulldozer grading is paralleled by later root-system development.

These types of impact from grading on tree seedling root growth are often not evident in the above-ground growth until years later. Corn, which makes its growth to maturity in one season, may show adverse effects each year. In an USDA Forest Service study black walnut made equal growth on flattened and ungraded sites for 18 years. We measured this stand after 40 years and found huge differences. On the ungraded banks the walnut forest was healthy with continuing good growth. Apparent disaster had struck the trees on the graded site. The leaves were yellowish and the branches had died back to give a stagheaded appearance. Broomsedge and other old-field weeds were growing under the dying trees which had "run out of lunch" with their evidently limited root systems.

If compaction from grading were limiting root growth, then ripping or subsoiling should improve rooting. A test plot had a series of rows ripped to approximately 30-inches depth, and other, unripped, rows. Black walnut seed were spring planted and the seedlings dug in August. The ripped rows had greater top growth, much better root system development, and greater penetration of the wetting front in the soil after rain. Although ripping is an available technology to offset surface compaction problems, we do not know whether it may serve only to give trees a lease on life for vigorous growth for a few years until root growth needs exceed the volume of loosened soil. Corn growth likewise may have only an early-season reprieve.

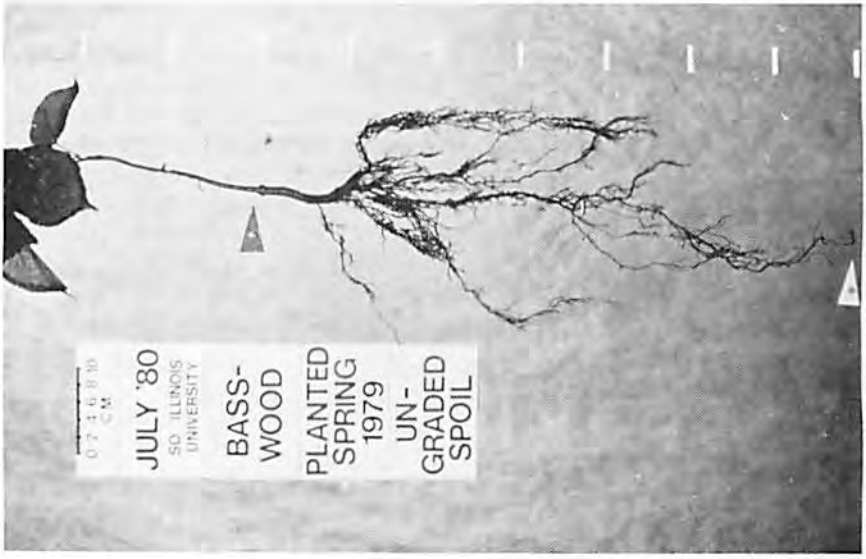
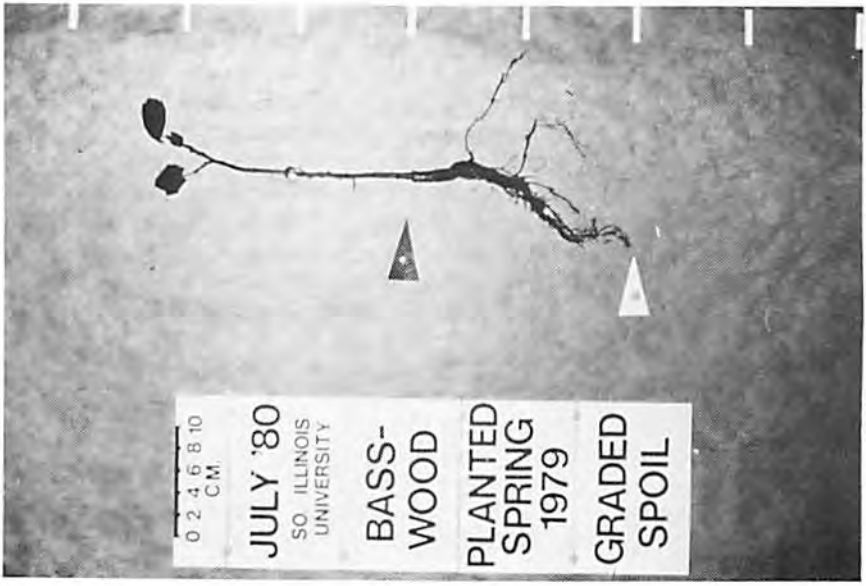


Fig. 3 — Good root-system development is a key to successful reclamation. Basswood responds strongly to favorable soil conditions.
A. (*Top*) On ungraded spoil this seedling developed widespreading roots with good depth to avoid drought stress. The markings along the right margin are 10 cm each.
B. (*Bottom*) Rooting depth and growth were greatly limited on the graded site. Shallow roots followed the soil layering from grading. Some vertical scale.



CONCLUSION

Today development of technology for better reclamation may be constrained by permitting and other regulatory requirements. An example of developing technology at a mine in Indiana uses a hydraulic loader and end-dump trucks for moving the rooting medium. The earth is dumped in a long, high windrow on the graded cast overburden. This material is then bladed off to the sides, with traffic on the deeper materials and very little traffic on the flattened earth. Surface compaction on the deeper materials is eliminated as successive layers are bladed off. The amount of compaction on the final surface can largely be handled with a disc. Although details would have to be worked out, end-dump trucks may have substantial advantages over scrapers in placing surface materials.

Surface mining has focused on the coal seams and tended to ignore the other mineral soil resources in the overburden. The "bad old days" of mining were only true for limited areas, and the unplanned mixing of overburden resources in mine soils gave us the "good old days" with productive tree-covered and pastured slopes. Present-day reclamation regulations should produce results at least as good as pre-law performance. This may some day be possible if experimental practices are allowed in spoil handling. New technology can contribute to offsetting regulation-related problems. Recognition that reclamation offers new opportunities in land use may be the best solution to the root of our reclamation problems.

Linda Dutcher: We have a few minutes if anyone has any questions of Dr. Ashby.

Beverly Herzog: You compared the root growth in ungraded areas to graded areas and graded areas to ripped areas. Did you make any comparisons between ripped areas and graded areas in terms of the root growth?

Clark Ashby: The last two slides showed the same land, part of which was ripped and part not ripped.

Beverly Herzog: Yes, the earlier slides show very good growth where it was ungraded, and I wonder whether the ripped area compared well with the ungraded area.

Clark Ashby: We made plantings this year so that when we dig them up next year we could do that.

Sy Kinane: I live in the northern part of the state, and one of the problems we have up there is getting rid of the sewage treatment materials from sewage treatment plants. I was wondering whether any of the material from these plants has been used in reclamation such as you were talking about today.

Clark Ashby: Not on the land I was talking about. Not far away is the Powser Project where there was a lot of sludge used, and I worked on that

for several years. We put on roughly 260 trimetric tons per acre and created a real transformation. The land turned green in that year. Since then about half of it has reverted back for various reasons. I am not sure whether erosion is part of it, but the sludge is certainly enormously valuable for that type of site. One of the factors that was of concern, is that you might bring in such things as heavy metals. There has been release of these types of things from the rocks because of the acid and pyrite weathering. The last I knew was that the additional metals in the sludge couldn't be picked up against the background of those materials already in the Powser site.

Sy Kinane: Thank you. Do you find that sludge is an economical way to treat the soil or is the cost prohibitive?

*Clark Ashby:*I think it was a little over a million dollars and unless it is worth it to an outfit such as the Chicago Metropolitan District to find disposal, I doubt you could justify it on the basis of improved land values. I think you would have to justify it on the basis of somehow easing Chicago's problems of removal of the material.

President Lucas: Thank you Dr. Ashby. I was suprised that someone did not pick up on Dr. Ashby's implication of Rule 1104 when he was talking about rock particles in the mines soil. I thought that might provide some more discussion. To move along, at first I would like to say that Linda Dutcher had to leave to catch a plane.

Our last and final paper this afternoon is a review of Illinois Mining Subsidence Law by Robert E. Beck, who is a professor at law at SIU. He holds law degrees from both the University of Minnesota and New York University. He has taught at the Univesity of North Dakota for fourteen years and was awarded there the Chester Fritz Distinguished Professorship of 1975. He moved to the SIU law faculty in 1976. Mr. Beck.

REVIEW OF ILLINOIS MINE SUBSIDENCE LAW

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INTRODUCTION

There are four basic aspects to Illinois mine subsidence law. Since this paper is to be a survey, I intend to deal briefly with each. The first aspect is that which has been around the longest, the common law. It imposes liability for damages on those causing subsidence. The second aspect, preventing subsidence damage from old mines, began more or less in 1977 with the passage of the Federal Surface Mining Control and Reclamation Act. The third aspect, that of insuring against damage from subsidence, went into effect on October 1, 1979. The fourth and final aspect, that of implementing the prohibition against causing subsidence from current mining operations contained in the 1977 federal act, has not really begun yet in Illinois. It is a part of the permanent program, rather than the interim program, under the federal act, and the permanent program is not yet operative in Illinois. Hopefully, it will be soon.

THE COMMON LAW

In 1880 the Illinois Supreme Court announced that a mineral estate owner had a duty to the surface estate owner or occupant not to remove minerals "without leaving support sufficient to maintain the surface in its natural state."[1] If there was a violation of this duty and damages resulted, the surface owner or occupant was entitled to collect the damages, and an award of damages was sustained in the 1880 case. This basic rule has never been changed. There are four important questions to ask. First, who is it that owes the duty? Second, what is the scope of the duty? Third, to whom is the duty owed? Fourth, since it is basic to any case that the complainant prove that the event has occurred (here subsidence), that the defendant did it, that the complainant has sustained damage, and that the event caused the damage, how does the complainant prove these elements in the subsidence context? I want to comment on each of these four questions in turn based not only on the 1880 case but on subsequent Illinois court decisions that have amplified considerably on the answers to be given to each question.

WHO OWES THE DUTY?

Although the language of the 1880 case was to the effect that the mineral estate owner owes the duty, this is an oversimplification because in most instances of mining today, the mineral estate owner has leased or otherwise transferred the minerals for development to a mineral developer.

It is in this context that we must ask, does the mineral developer owe the duty, does the mineral estate owner owe the duty or do both owe the duty? Furthermore, suppose that a mineral owner/developer removes some of the coal and then transfers ownership of the remaining coal to another person. Is the latter person responsible when the surface subsides as a result of the previous removal of coal?

On the question of owner versus developer duty, we begin in Illinois with the proposition that it is the mineral estate owner who owes the duty. When the owner transfers an interest for development purposes, does the developer undertake the same duty? The answer from the Illinois courts appears to be yes. When the owner transfers an interest for development purposes, does the owner remove himself from the duty? In the one Illinois case dealing with this issue, the court said no. However, on the facts of that case, the court found that the owner had exercised control over the mining operation so that it was in reality the owner's mining operation. What about a situation where the owner leaves it all up to the developer? The court did say gratuitously that a mineral owner should not be able to escape responsibility by selecting an "irresponsible lessee."[2] However, we cannot give a definite answer to the question until we have a judicial decision.

On the question of successor in interest liability, the Illinois courts have held the successor generally free of liability, although the basic decision to this effect did not come until 1964. The legal reasoning employed by the court was that it is necessary to have either an express or implied assumption of the liability for it to transfer in the deal. Generally where you have an arms-length transaction involving only the sale of the asset (coal) as contrasted with the sale of the business (mining operation), there will be no implied assumption of liability. One would not expect an express assumption of liability to have occurred. Policywise the court said that the rule would not cause any loss to the surface estate owners; however, this ignored the fact that having sold its coal, an entity would be free to go out of existence. Since the coal where mining has occurred often was owned by entitities rather than individuals that is what usually happened. Thus with the successor not acquiring the liability and the predecessor going out of existence, there would be no one for the surface owner to seek recovery from when the subsidence occurs. And subsidence usually occurs long after the mining has taken place. The courts have considered questions of corporate merger and parent-subsidiary liability in this context also, but it is beyond the scope of this paper to develop those aspects of the problem.

What Is The Scope Of The Duty?

The statement that the court made in 1880 was that the duty was to maintain the surface "in its natural state."[3] This would appear to mean that if the surface is no longer in its natural state, such as by having buildings on it, and if the surface subsides because of the weight of those buildings, that is, the surface would not have subsided without the buildings being on it, the mineral operator would not be responsible. Indeed, mineral operators

have made this argument in several Illinois cases, but it has never succeeded. Thus a serious question arises as to the argument's viability. Furthermore, it is clear that once the duty has been violated and liability attaches, the surface owner is not limited to collecting the damages to the surface in its natural state, he may collect for the damages to the buildings and other improvements as well.

To Whom Is The Duty Owed?

There are two issues to be noted in this subtopic. First, to what specific individuals does the duty extend? Second, to what extent may those individuals waive liability for violation of the duty?

In connection with identifying the specific individuals benefiting from the duty, it is obvious that the owner, in the traditional sense, of the surface estate is owed the duty. Others that have been recognized by the Illinois courts as being owed the duty include contract purchasers of the surface when in possession, trustees of the surface estate, surface tenants, and the owner of an underground cement mine situated above the defendant's coal mine.

In connection with the waiver issue, the Illinois courts have recognized a power in the surface estate owner to waive liability not only for himself but for all future surface estate owners and successors in interest. The benefit of this waiver extends to the immediate contracting party and to any successors in interest of that party. The waiver does not extinguish the duty to support the surface estate, but merely waives liability for violation of the duty. This power of waiver was recognized by the Illinois Supreme Court in the 1880 case.

One change has occurred in the law of waiver in Illinois over the years. In the early years from 1880 onward the courts scrutinized purported waiver clauses very closely and demanded clear language indicating waiver of the right to surface support. Thus a clause such as "without any liability for surface subsidence caused by mining out of the coal or other minerals and from not leaving pillars or artificial supports under such land"[4] would be effective. In more recent years, beginning with an appellate court decision in 1923, the courts generally ceased looking for the specific language illustrated above and began holding general language to include waiver of liability for subsidence. The more general the language, the better it was. Thus language "for *any* damage done to the surface of [the] land"[5] and "waiving, releasing and surrendering *any* and *all* claims for damages and *all* liability by reason of damages . . . to . . . [the] property"[6] have been held effective waivers of liability for surface subsidence. However, all of these general language decisions have been by Illinois appellate courts; the Illinois Supreme Court has never considered this change in interpretation approach.

The significant impact of permitting surface owners to waive liability is that it ignores the public interest in maintaining the integrity of the surface. To posit the extreme case, it is clear that Illinois need not sit idly by and

watch 65% of its surface subside as mining progresses underneath. There is a public interest in preventing this from happening, and the public interest extends to situations far short of this extreme. Indeed, it is at least in part because the common law has failed to recognize this public interest that attempts at corrective legislation have been made, legislation which will be discussed later in this paper.

How Prove The Elements?

However the persons damaged proceed, an Illinois statute requires that they proceed within five years of the accrual of their claim, and the Illinois courts have said that the claim accrues at the time that the subsidence occurs and not at the time that the mining occurs. Several other court decisions also have made the proof situation easier for the complainant. First, in its 1880 opinion the Illinois Supreme Court announced that "[t]he act of removing all support from the superincumbent soil is, *prima facie* the cause of its subsequently subsiding."[7] Thus when the complainant shows for example that coal has been removed and that the defendant removed it, the burden shifts to the defendant to show that the cause of the subsidence was something other than the removal of the mineral. Second, complainants have been allowed to use existent maps to show that coal has been removed and that the defendant did the removing. These maps are required by Illinois statute and must be prepared and filed by coal mine operators showing details of underground mines.

In Illinois the measure of damages depends upon the nature of the injury. If the injury is to land, the measure is the difference between the market value of the land before the injury and the market value after the injury. A different measure is used if the injury is to buildings or other improvements on the land. In such cases, the measure is the cost of repair or the cost of restoring the premises to their original condition. This measure is justified on the basis that without it complainants could not recover for minor damages such as broken windows. The complainants' proof obviously must show that the particular alleged damage has occurred and then demonstrate the value thereof based on the appropriate measuring stick. A number of cases have dealt with the sufficiency of the evidence offered, but these cases cannot be analyzed in this brief overview. Although it is theoretically possible to obtain from Illinois courts an injunction ordering a defendant to prevent subsidence, the courts appear reluctant to grant such relief because of difficulty in supervision and their view as to the general sufficiency of the damages remedy.

PREVENTING DAMAGE FROM OLD MINES

The federal Surface Mining Control and Reclamation Act of 1977 created an Abandoned Mine Reclamation Fund from levies collected on mined coal. Monies in this fund would be used to correct problems associated with abandoned mined lands either directly by the federal agency or after being returned to the states. Congress made it clear that this in-

cluded "prevention, abatement, and control of coal mine subsidence."[8] For a project to qualify the land must have been (1) mined for coal or affected by such mining and (2) abandoned or left in inadequate reclamation status (3) prior to August 3, 1977, and (4) be land for which there is no continuing reclamation responsiblity under state or federal laws. Although some questions of scope remain, it appears that such funds can be used to fill mine voids, sinks, and cracks in the surface, repair access, and shore up buildings to prevent damage. On the other hand, funds cannot be used to repair buildings except to the extent necessary to prevent further damage.

Illinois has been working on a program for dealing with abandoned mine lands since 1975, but it was not until the 1979 Abandoned Mined Lands and Waters Reclamation Act which took effect June 1, 1980, that Illinois could be said to include subsidence problems among those to be dealt with from abandoned mined lands. Even then there was no specific reference to subsidence in the Illinois Act similar to that in the federal act just quoted above. However, in the course of preparing guidelines for dealing with abandoned mined lands and identifying thirty or more factors to take into account in deciding whether or not to proceed with a particular project, the Illinois Abandoned Mined Lands Reclamation Council recognized and mentioned subsidence as a factor. Thus within Priority I, there is a reference to "[s]ubsidence damage to water supply, sewage or gas lines"[9] and within Priority V there is reference to "[d]egree of damage to a public facility due to subsidence."[10] However, the Illinois focus always has been on refuse and surface pollution.

Since these corrective measures depend on funding and can be expensive, the scope of the Illinois effort is going to depend largely on the amount of monies available from the federal fund. It is my understanding that Illinois abandoned mined land experts believe that Illinois' guaranteed share over the fifteen year life of the federal fund would approximate only one-third of the Illinois need.

The guaranteed share for a state is one-half of what is collected from the state and as of June 18, 1981, that one-half amounted to about 23.8 million dollars for Illinois. However, a state cannot apply for any of that money until it has an approved abandoned mined lands plan, and it cannot get approval for that plan until it has been given primacy over the active surface mining reclamation program. Illinois does not have primacy yet; therefore, it has received none of the 23.8 million. Fortunately, that money remains in escrow for when Illinois does attain primacy. Much of the remaining one-half that is not guaranteed to individual states remains available to all states in a discretionary pot that the Secretary can dole out. Illinois has been able to share in that pot since such sharing does not depend on primacy, and some of that money has been used in connection with subsidence. The most important subsidence projects involve emergencies created by actual subsidence such as the need to shore up a house in order to prevent further subsidence damage. Here, I understand, there is funding within 24 hours, although no monies are transferred to the state to spend. It is done by direct federal contract.

In order to avoid unjust enrichment to property owners, Illinois law provides that under some circumstances if monies expended by the State for reclamation on privately owned property results in an increase in value of that property, the State may obtain a lien against the property. However, this lien may not exceed the amount of the increase in value.

SUBSIDENCE INSURANCE

As of October 1, 1979, subsidence insurance was to be available in Illinois. The requirement came as a result of legislation which was not fully effective until November 29, 1979. The timing confusion resulted from legislative uncertainty about how to fund the insurance program. The final funding decision consisted of three basic elements. First, the insurance will be provided by private insurance carriers who will also settle claims. They will get commissions for the policies they write and reimbursement from a state fund for claims paid. Second, the state fund will be constituted from premiums to be charged the insureds. The two administrators of the fund, the Director of the Illinois Department of Insurance and the Illinois Industry Placement Facility, set the initial premiums at from $6 to $12 per year depending on amount of coverage and type of construction. Third, the State would lend up to a maximum of $500,000 to the fund to get it started. This loan would have to be paid back over the three-year period 1984-1986. From then onward the insurance program would have to pay for itself.

The statute specifies automatic coverage for all counties except a county with 1 million or more inhabitants and any county contiguous to such county. In addition, the statute gives the Director and Facility authority to exclude further counties from this automatic coverage. It is my understanding that this authority was used to exclude counties with less than one percent of the surface undermined resulting in 34 counties with automatic coverage. What automatic coverage means is that any current or future insurer of a structure must offer its insured subsidence coverage at the set premium. The insured then has the option of rejecting the coverage by signing and returning a statement to that effect. Obviously this is an option that should be exercised in many instances since in some counties relatively few acres are undermined. However, apparently to date there are no statistics on the rate of rejection. In the nonautomatic counties such insurance must be available to all who want it.

The statute places several limitations on program coverage. First, coverage is limited to "structures", and they are defined in the statute as "any dwelling, building or fixture permanently affixed to realty, but . . . not . . . land, trees, plants and crops."[11] Second, coverage is limited to a maximum of $50,000, although insurance companies are free to offer their own insurance for any excess amount. Third, there is a variable deductible ranging from $250 to $500. Finally, an insurer can refuse coverage in certain instances where subsidence has occurred previously.

One important feature of the law is allowing the fund to be subrogated to the insured's claim against those responsible for causing the subsidence.

An individual land owner with a small claim might be reluctant to sue a mine operator because of the expense of such an action. However, in a situation where the fund has to pay out several small claims in an area as a result of subsidence from one mine operation, the fund's action could be more efficient in consolidating the numerous claims in one subrogation suit. It is therefore possible that the program will lead to placing more of the financial responsibility of subsidence on those causing it. This too could help perpetuate the fund without having to rely solely on premiums to do it.

Despite almost two years of program operation there are to the best of my knowledge no published reports of any kind available on how the program is going. Data collected for me by the SIUC Law Library Staff had to be obtained through telephone conversations with persons in-involved in the administration of the program. What I was told indicates that approximately 400 claims have been filed to date, with approximately 200 of these confirmed as legitimate and 100 paid out. Apparently many of the claims have been under $10,000, although they range to the maximum.

PROHIBITING SUBSIDENCE FROM NEW MINES

Both the Illinois Surface Coal Mining Land Conservation and Reclamation Act of 1979 and the Federal Surface Mining Control and Reclamation Act of 1977 contain the following basic subsidence provision:

> Each operator shall adopt measures consistent with known technology in order to prevent subsidence causing material damage to the extent technologically and economically feasible, maximize mine stability, and maintain the value and reasonably forseeable use of surface lands, except in those instances where the mining technology used requires planned subsidence in a predictable and controlled manner. Nothing in this Section shall be construed to prohibit the standard method of room and pillar mining.[12]

Illinois similarly adopted regulations for interpreting this section almost identical to those adopted by the Federal Office of Surface Mining in interpreting the federal act provision.

The primary purpose of this section is to protect the public interest in the continued utility of surface estates in general, the public interest in avoiding expenditures for repairing sunken roads, school houses and other public improvements, and the public interest in avoiding the economic loss of having a large number of surface owners impoverished as a result of subsidence. Thus only secondarily is the interest of the private surface owner to remain whole involved.

Basically the Illinois regulations interpreting this section are divided into two parts, one part setting forth the information that must be submitted at the time of application for a mining permit and the other part establishing basic performance standards for all underground mine permit holders. Since the application regulations reflect the criteria established in the performance standard regulations, the performance standard regula-

tions will be considered first.

There are four subsections to the performance standard regulations, one each on general requirements, notice to the public, surface owner protection, and buffer zones.

The general requirements subsection does little more than restate the statutory language indicating additionally only that the operator must comply with any subsidence control plan that he has submitted as a part of the permit application process. The federal regulation does specify additionally some of the methods that can be used to prevent subsidence. Thus the most important aspect of the federal regulation is in making it clear that there is no one way to prevent subsidence, and, that therefore, local regulatory authorities must consider the particulars of the specific situation involved.

The public notice subsection does not provide for public notice; it merely provides for notice to owners and residents of property overlying or adjacent to the proposed mine area. Even then utility easement owners are not specifically included as property owners although clearly they should be.

The surface owner protection subsection requires a permit holder who conducts a mining operation which results in subsidence that causes material surface damage or diminution in surface use to (1) restore or rehabilitate the surface, or (2) purchase the property at pre-mining fair market value, or (3) secure an indemnity for the surface owner before mining begins such as through the purchase of an insurance policy. However, even when purchase of property or insurance occurs, the permit holder continues under an obligation to restore and rehabilitate the premises to the extent technologically and economically feasible. This is because even though the primary focus of this subsection is on the secondary purpose of preventing wide-spread loss to surface owners and residents, it also reflects the primary public interest in maintaining the integrity of the surface.

The buffer zone subsection limits or prohibits mining beneath or adjacent to certain streams or water impoundments, aquifers, or public buildings. However, the regulatory authority has discretion to allow mining in those areas if it determines that subsidence will not cause material damage to the affected category of property. In addition, these regulations restate the statutory provision which requires the suspension of mining when imminent danger threatens inhabitants of urbanized areas, cities, towns or communities, industrial or commercial buildings, major impoundments, or permanent streams.

The application regulations require submission of a survey showing whether there are any "structures or renewable resource lands" within the proposed mining area. Renewable resource lands are defined to mean "aquifers and areas for the recharge of aquifers and other underground waters, areas for agricultural or silvicultural production of food and fiber, and grazing lands."[13] If such structures or lands exist, the survey must show whether subsidence could cause material damage or diminution of reasonably foreseeable use of the structures or lands. If the survey shows such damage could occur or the regulatory authority believes that it could

occur, the applicant must submit a subsidence control plan which describes (1) the mining methods and other actions of the operator that might affect subsidence and (2) the measures that will be taken to (a) prevent subsidence from causing material damage or diminution of use, (b) mitigate effects of material damage or diminution of use, and (c) determine the degree of material damage or diminution of use. Examples of each are provided in the regulations.

This regulation in its limited definition of renewable resource lands ignores the primary subsidence problem that Illinois has faced. Much of the subsidence that causes substantial damage in Illinois occurs in areas that were not urbanized at the time the mining took place but which subsequently have become urbanized. Since such areas are not necessarily used for agricultural or silvicultural production at the time of mining, the regulation may well not be protecting Illinois areas of future urbanization.

One issue that has not been addressed adequately in either the federal or Illinois regulations relates to a situation that has occurred often in Illinois. In this scenario, after underground coal mining is completed, the operator quits business and goes out of existence. Thereafter subsidence occurs. Of what value is the regulatory provision to the effect that the operator shall restore the surface or purchase the property? Neither the insurance nor the bonding provisions of the statutes or the regulations cover this situation.

The federal bonding regulations on mine subsidence require only that a performance bond be filed to guarantee completion of measures to be taken pursuant to the mine subsidence control plan. Despite the title of the equivalent Illinois regulatory bonding section, "subsidence and mine drainage",[14] the Illinois section contains no bond requirement relating to subsidence.

A September 1981 proposed amendment to the federal regulations would require either that all of the subsidence control plan measures be completed or that a performance bond be filed to guarantee their completion before any underground operations are extended.

CONCLUSION

In 1880, the Illinois Supreme Court established in a surface owner an absolute right to subjacent support, a right inherent in the bundle of rights called ownership and, therefore, entitled to substantial protection in the courts. A period of strict court enforcement of this right followed. Beginning with decisions in 1923 relating to waiver and decisions in 1963 relating to liability of successors in interest to ownership of coal, the Illinois courts started undermining this substantial protection standard. By the mid-1970's enough problems had arisen with the adequacy of the common law that legislative bodies found it necessary to enact laws to deal with subsidence problems. As a result of legislation establishing the subsidence insurance program and the abandoned mined lands program, substantial progress was made toward plugging gaps in protecting against loss from pre-1977 mining.

As a result of the legislation requiring current mine operators to use technologically and economically feasible methods to prevent subsidence and the regulations promulgated pursuant thereto requiring indemnification against loss, substantial progress was made toward protecting against loss from post-1977 mining. However, gaps and problems, many of which have been noted in this paper, exist or will arise in the future.

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Question: Correct me if I am wrong, but that paper has been published or is about to be published?

Robert Beck: An earlier long version of it has been published for lawyers.

President Lucas: We will have a short business meeting prior to the papers in the morning sessions. This meeting is adjourned.

MORNING SESSION

The Friday morning Business and Technical Sessions convened in the Lincoln Room of the Holiday East at 9:00 a.m., October 23, 1981. President Walter S. Lucas presided.

BUSINESS SESSION

President Lucas: I would like to call the business meeting to order this morning so we can get a few pertinent items out of the way before we proceed with our technical session.

We would like to start with the report from our Secretary-Treasurer, Heinz Damberger.

SECRETARY-TREASURER'S REPORT

Heinz Damberger: The financial report was approved by the Auditing Committee. We are about $400 short, but the main reason for that is that some of the advertising income has been deferred to this fiscal year. Actually we would be about $2,000 ahead. So I think for the next year we will be in balance again. Our costs are going up, and somewhere down the road we will have to do something. Income from dues has increased from about $7,000 to $10,800 because we raised the dues to $8.00 from $5.00. Advertising income has been down somewhat because we had fewer pages in advertising. Income from interest has gone up about $1,000 because our cash has been put into a money market fund, and we were getting about 17% interest. Publications expenses are about the same. This is mostly because the book this year was not quite as thick as last year.

It is hard to predict what will happen, but I think that for one or two years we will be in pretty good financial shape. After that we will have to consider an increase in dues again or something else. I think those are the main items for the financial report.

So far we have registered 984 members, about the same as last year. This includes the 27 students who are here.

President Lucas: I am not sure whether we need to get approval for the financial report but maybe you can ask for that. The financial report has been approved by the Auditing Committee. First I will ask if there are any additions from the floor. It is available if anyone wants to see it. And if not, Heinz, it stands approved as reported. The next item of business is a very important one to your Institute and that is the Nominating Committee report for the new directors and the new officers for next year. The Chairman of the committee is Mr. Ralph Banks, if I can call on Ralph Banks now.

NOMINATING COMMITTEE REPORT

Ralph Banks: Mr. Chairman, ladies and gentlemen, the Nominating Committee composed of Richard Rouse, Jack Simon, and myself met several times this summer and we have the following report to submit to you. Continuing on the Executive Board through the year 1982 will be: Douglas Dwosh, Rusty Glen, William Murray, and R. A. Taucher. Continuing on the Executive Board through the year 1983 will be: Brad Evilsizer, Robert Izard, William J. Orlandi, and Ron Siler. In keeping with the policy of this Institute we have to elect four new members to the Executive Board, and the Nominating Committee recommends and moves that the following men be elected to the Executive Board to serve through the year 1984: John C. Bennett of Peabody Coal Company, Erich Egli of Sahara Coal Company, George L. May of Monterey Coal Company, and Dale E. Walker of Freeman United Coal Company. Mr. Chairman, the Nominating Committee moves that these men be elected to the office of Executive Board.

President Lucas: Are there any nominations from the floor? Do I hear a motion from the floor that these directors be elected for a four year term. Second? All in favor? All opposed? The slate has been approved.

Ralph Banks: Mr. Chairman, the Nominating Committee further has selected the following people for the respective offices as follows. We wish to continue our very able and capable Secretary-Treasurer, Heinz H. Damberger; for Second Vice-President, H. Elkins Payne of AMAX; First Vice-President, Wayne E. Haynie of Old Ben Coal Company; and President, Jack A. Simon, Illinois State Geological Survey.

President Lucas: The Chairman of the Nominating Committee recommends that we nominate these people to those respective offices. Again, do we have any further nominations from the floor? Do I hear a motion that these people be elected by acclamation? And a second?

Our new officers for the 90th year of the IMI, will be President, Jack A Simon; First Vice-President, Wayne E. Haynie; Second Vice-President, Elkins Payne; and our Secretary-Treasurer, Heinz H. Damberger.

HONORARY LIFE MEMBERSHIP

Before we get into the Scholarship Committee report I would like to report for the Honorary Life Membership Committee, the Chairman of which was Lou Weber. Our Honorary Life Member this year will be Joe Schonthal, and he will be honored at the luncheon at noon today. I now would like to call upon our Chairman of the Scholarship Committee, Mr. George Eadie.

SCHOLARSHIP COMMITTEE REPORT

George Eadie: Thank you, Mr. President. The Chairman of the Schol-

arship Committee and Lannie Richter have joined the Committee for Scholarships for the Illinois Mining Institute this year. I think it is probably a landmark, since in the time of my memory I don't believe I have heard a scholarship report given by anyone other than Dr. Jack Simon. Since Dr. Simon has moved on to bigger and better things in the Institute, Lannie and I are very pleased to be part of the Scholarship Committee this year. The Illinois Mining Institute continues to be a pace setter, not only in programming, but also in support of students and scholarship programs throughout the Illinois Basin. This year the Institute will provide $5,000 to six institutions for their scholarship programs. I have been in contact with these schools and have asked each of the representatives to be prepared to come to the podium this morning to tell us a little about their program and to introduce their scholarship holders, if they are present. I would like to start this by going to the Illinois Community Colleges. Three of them each will receive $500 towards their scholarship program this year, and I would like to start with Ron Sanderson of Rend Lake College.

Ron Sanderson: First of all I would like to thank you for the opportunity to be here. Rend Lake College is a community college located near Ina, Illinois in the sourthern part of Illinois. I would like to tell you a little about the background of the school in case you are not familiar with it. We have a student population at the college which is both a transfer and vocational technical school. In the mining area we have approximately 400 full time students, and we do work very closely with various coal companies in the area such as Inland, Freeman, and Old Ben. We have 18 full time instructors. I would like to take a minute and have Mr. Bob Mooneyham stand up. He is one of our instructors with me today. Bob is an instructor in the practical mining area. In the back of the room, if you are interested, we have a little brochure about our mining program.

On behalf of our mining program at Rend Lake College we would like to thank the Illinois Mining Institute for the scholarship. We have awarded this year, three $250 scholarships. We had a balance from last year, so what we are doing this year is giving three of our students a $250 scholarship on behalf of the Illinois Mining Institute. This money will then be used to help defray their expenses and transportation. We had an application that each of the students, who were interested, filled out. I was going to take time to read a little about each of the students, but I think that maybe in the interest of time I will pass on that. David Burkitt from Christopher, Illinois is a sophomore in our program at Rend Lake and is planning to transfer to Southern Illinois University upon graduation. Gregory Heck from Tamorora, is also a sophomore. Ted Jennings from Royalton, Illinois is in our program. These students all have classes today, so they are not with us. On behalf of the college and on behalf of the students, we do want to thank you for this opportunity and this scholarship. Thank you.

George Eadie: The Southeastern Illinois College report will be given by Wayne Hemmerick. Wayne is actually a Sahara Coal Company employee and is an adjunct instructor at Southeastern in Harrisburg, Illinois.

Wayne Hemmerick: We have two students this year getting the scholarship. One of them is Bill Crittenden from Carrier Mills; I think he works for Peabody Coal Company part time and goes to school part time too. Another student, Charles Butts, is a sophomore in the program. Both these students have a very high grade point average. They wrote a one page paper which we reviewed. We had approximately 12 students apply for the scholarship. Doug Ramsey, sitting back there, is also a part-time instructor at Southeastern and works at Sahara Coal Company. The mining program this year is a lot bigger than it has been in the past. We are just getting started, and it is growing a little. On behalf of Southeastern and the students, thank you very much.

George Eadie: The Wabash Valley report will be given by Dr. Ed Wallen. Wabash Valley has several campuses that they are operating throughout Illinois. Dr. Wallen is in charge of all of those programs at the various campuses.

Ed Wallen: Wabash Valley College is in Mt. Carmel, Illinois. When the program began there, I believe in 1972, that was the only site, but through a series of cooperative relationships with other community colleges in the state, we now have the five sites. What we do with the one $500 scholarship is make five $100 scholarships so that we can have a person at each of the sites to receive some help and learn something about the Illinois Mining Institute. At our Carterville site, at the John A. Logan campus, our recipient is James Little. He is 18 years old. At our Centralia site, at the Kaskaskia campus, our recipient is Harold Elmore. He is in his second semester. He is 42 years old. At Marissa, where we have a cooperative arrangement with Belleville Area College, our recipient is Chris Akers, a second year student. He is 19 years old. They all have a high grade point average and good attendance. At our home site in Mr. Carmel our recipient is Jerry Alderman, a second year student. He is 26 years old. At our Virden site, where we are on a cooperative arrangement with both Lincoln Land and Louis and Clark, our recipient is Genelle Brast. She is completing her first year.

George Eadie: In addition to these three $500 scholarships that go to the community colleges of Illinois, there are five $750 scholarships that go to the traditional engineering schools in the area. Dr. Ken Tempelmeyer will give the report for Southern Illinois University at Carbondale. Dr. Tempelmeyer is Dean of the College of Engineering and Technology on the Carbondale campus at SIU.

Ken Tempelmeyer: Thank you very much, George. I am happy to report on behalf of SIU and, in particular our students do appreciate the assistance that IMI gives with the scholarships. Before reporting on the scholarships I would like to review our mining related programs very briefly. We have had for some years a program in mining technology. This program is designed to accept students who come from the community colleges and allow them to finish a four-year program in mining technology.

This program continues to grow and has a good flow of students, and more important to those in the mining industry, it has a continual flow of graduates. In addition to that we have had a Master of Science program in mining engineering for several years. Enrollment in this program stays strong; we have had an increasing number of graduates each year. I wish though, I would see more native students in our MS program. We have an easy time interesting foreign nationals in the program, but I think we would benefit by more native students. Two years ago we created a new Department of Mining Engineering and instituted a Bachelor of Science program in mining engineering. This program now has about 70 students in it, and it is also continuing to grow. Last summer we produced the first two graduates from this program. The number of graduates will continue to increase in the coming years. We have increased our faculty in mining engineering by two positions this year. Unfortunately, I have to report to you this has been at the expense of the demise of the Department of Energy and Mining Technology Center. But I guess that in every cloud there is a silver lining, and as DOE found it necessary to close this center down, we were able to obtain two very fine faculty members, who were formerly employed there. We have also made a Committee on Space and Equipment to build the laboratories in our Mining Engineering Department.

We received two $750 scholarships and we sub-divide these into three scholarships. A scholarship this year has been given to Sandy Sherman, who is here with us today. She is a senior, who will graduate in December of 1982. She is in civil engineering technology and from DuBois, Illinois. She is interested in reclamation and mine construction and design. She has formerly worked for Peabody Coal Company and for the Department of Energy, Carbondale Mining Technology Center, and at the present time she is the President of the Student Chapter Society of Women Engineers. Sandy is a very good student, and I am sure will be a credit to IMI. The second award went to Dina Lawrence. Dina is a senior student in engineering. She comes from Country Club Hills, a suburb of South Chicago. She is a senior who will graduate in May of 1982. Her interests are in coal preparation, groundwater hydrology, and reclamation. She has worked several times at different assignments at Commonwealth Edison including in some of their fossil fuel plants. She is a very fine student. Mr. President, I think you will also see she is a credit to IMI. The third award went to Mr. Tim Thompson. Tim is also a very fine student. He is a senior engineering student, and I believe his plans are to continue with the Master's degree in mining engineering. SIU at Carbondale really appreciates the assistance that IMI provides through these scholarships. Thank you very much.

George Eadie: The University of Missouri-Rolla report will be given by Dr. Stuart Gillies.

Stuart Gillies: I'll just give you an update on what has happened at Rolla in the last year. Most of you know Dr. Ernest Spokes; he was acting Dean of Mines and Metallurgy last year. He has relinquished that post. He is back teaching and doing research as a professor. Our dean now is Don

Warner. We have one new faculty member in mining engineering — Paul Wersey. He is in the rock mechanics and explosives area. We presently have as our department chairman, Richard Ash, who is in mining. Before I talk about the scholarships I would like to show my appreciaton to those of you whom I have met out in the field visiting mines. I have taken quite a few student field trips which were possible only because of the opportunities you in the mines give us to take large numbers of students. I know it can be an inconvenience with the numbers we do have, and we really do appreciate the cooperation you have offered. First I acknowledge our appreciation for the $1500 given to Rolla by the Institute. We have our three scholarship recipients here this morning. We have Michael Spengler, who is from South Corning. He is a junior in our mining program. David Wilhide is from Indiana, and Dennis Smith is from Arkansas. Dennis has worked for a couple of summers in the Illinois coal mining area. Rolla thanks the Institute for the $1500.

George Eadie: The University of Wisconsin at Platteville report will be given by Dr. John Krogman.

John Krogman: Thank you very much. The University of Wisconsin at Platteville is located in the southwest corner of the state. We have a small branch at Madison. Next year will be the seventy-fifth anniversary of the Department of Mining Engineering which was established in 1907 as a Wisconsin Mining School. We have evolved from the first 7 students to the present 6 departments of engineering. Mining presently has 115 students. We have 40 new freshmen, our biggest class ever. The College of Engineering has 1360 students. We are doing quite well. We have selected three outstanding seniors in mining engineering as recipients of the IMI scholarships this year. Unfortunately, these students couldn't be with us today, but we do have about a dozen students down for the meeting. The recipients are all from Wisconsin and are all seniors — Russell Meier from LaCrosse, Jeff Rusord from Mumford, and Daniel Goethel from Baraboo. On behalf of them and the University of Wisconsin-Platteville I would like to thank IMI for their continuing support of our scholarship program. Obviously, this makes our recruiting much easier and also enables us to maintain outstanding students at our University. Thank you very much.

George Eadie: Thank you, John. The Illinois Mining Institute does have available for a scholarship of $750 for the University of Illinois. I did talk to Jerry Dobrovolny, who is head of the General Engineering Department of Illinois where the undergraduate degree of mining is taught as a mining option in general engineering. Jerry said that they do have ten students in the mining option program, but there is no scholarship being presented to Illinois this year. On behalf of the Institute we want to thank the students and faculty who have participated in the report this morning. That concludes the report, Mr. President.

President Lucas: Thank you, George. I would like to add that you can see by the length of the reports how important the Scholarship Committee is

and how important the money is that comes from the Institute to the various schools. As a matter of fact, since my tenure on the Board of Directors and since attending meetings, the scholarship has always been of prime importance because it is one of our most important functions. At our Board of Directors meeting this year we discussed the various ways whereby more money could be received by the Institute for distribution to the student and to the various schools. It was decided that in cooperation with the new Scholarship Committee and the new Board of Directors, that next year with the advance registration letters there will be not only a flyer but an extra box for anyone of the individual members wanting to contribute to a special scholarship fund which will be administered through the Illinois Mining Institute. Last year the Institute received $1000 from a donor, who wished to remain anonymous. This could be used possibly as seed money to continue and possibly enlarge the scholarship fund for next year. We'll see how that new program is received by the members next year.

ADVERTISING COMMITTEE REPORT

I would like to say that the Advertising Committee, chaired by Mr. Mike Killman, has apparently done an outstanding job. As you will remember there was still some carry-over in the advertising, and so far as I can find out, the Advertising Committee is ahead of last year. I must not only thank the Advertising Committee, but the various companies who advertised. For those of you who don't know, that is what pays for the *Proceedings* every year. I know we use it around our company for various reasons. It is a very nice publication, and by being a member of the Institute you recieve a copy.

I would like to personally thank all of the committees and especially the chairmen of the committees, who have done just a super job this year. I also want to thank Heinz, who was the Chairman of the Program Committee and put together an outstanding program. I thought the one yesterday was just super, and we have another one coming up, which I think is going to be just as good.

TECHNICAL SESSION

President Lucas: Apparently we have had a response to the scholarship report in that there has been at least the makings of some seed money for a new scholarship. I'll have to talk to Heinz a little about that during this session, then maybe we'll have something to report at the luncheon. Now I would like to at least start the technical session by introducing your chairman, who is Robert M. Izard, Vice-President of Operations for Midland Coal.

Robert Izard: Thank you, Walter. Good morning, ladies and gentlemen. I would like to also welcome our speakers, and on behalf on the Executive Board and members of the Institute, I would like to thank you for

your preparation in putting these papers together. Our opening speaker is Mr. Robert "Red" Robinson, Senior Associate Engineering Geologist with Shannon and Wilson Inc. of Seattle, Washington. Mr. Robinson received his Bachelor of Science degree in geology from UCLA in 1970, and from 1970 to 1974 he did graduate research work at the University of Illinois. Red has considerable experience in slope stability and will speak to us about "Imperical Relations for Predicting the Stability of Surface Mine Spoils". Would you welcome please Mr. Robinson.

Robert Robinson: It is always a pleasure to be back here in the Midwest. I was born and raised in Wisconsin and then went to school in Illinois. The topic of my talk, "Imperical Methods for Predicting the Stability of Surface Coal Mine Spoils", derives from a research project that Shannon Wilson did for the U.S. Bureau of Mines between 1977 and 1979 entitled "Surface Mine Spoil Stability Valuation for the Interior Coal Province". It comes in two large volumes.

EMPIRICAL RELATIONSHIPS FOR PREDICTING SURFACE MINE SPOIL STABILITY

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INTRODUCTION

Spoil failures in surface coal mines may severely affect the economics and feasibility of coal retrieval. Spoil failures may cover valuable coal, damage expensive mining equipment, and pose a hazard to personnel in the mine. Consequently, in evaluating the economics of a potential mine, it is desirable to be able to predict the stability of spoils derived from the highwall, and the need for any preventative or remedial measures necessary to promote stability. Historically, there have been no methods for predicting spoil properties based on the exploration data for use by a mine designer in predicting spoil pile stability. Mine designers have traditionally relied on their experience with nearby mines or mines in similar materials to gain a feel for the stability of spoil piles for an as yet developed mine. What is needed, therefore, is a method for predicting those material properties which control the stability of a spoil pile.

This report presents a number of tentative empirical relationships which may be used to predict spoil material properties and, subsequently, the stability of spoil piles. These empirical relationships require input in the form of easily and inexpensively measured properties of the highwall materials as determined from boring samples, anticipated configurations of the proposed spoil piles, and equipment types or excavation methods proposed for use in excavating and placing spoils. Once derived, these relationships may also be used by a mine designer to assist in:

- Selecting appropriate mining equipment.
- Designing optimal pit configurations and mining sequences.
- Assessing the cost and need for any preventative or remedial methods for enhancing spoil stability.
- Determining the effect of spoil pile instability on the overall cost effectiveness and feasibility of the proposed mine.

These empirical relationships were derived by relating and evaluating spoil failure case histories from 16 surface mines in the Interior Coal Province as part of an investigation for the U.S. Bureau of Mines (Miller, et al., 1979). Failures ranged from shallow surficial slides involving as little as 400 yards of material up to deep-seated failures extending through the pit bottom and covering as much as 10,000 yards of coal, closing the pit and

damaging equipment. These case history evaluations also included a variety of pit configurations and corresponding excavation and placement techniques including small truck-shovel operations, draglines, bucket-wheel excavators, and large shovels.

PRELIMINARY EMPIRICAL RELATIONSHIP

Mine operators have observed that the frequency of spoil pile failures appears to increase with greater highwall height and increasing percentages

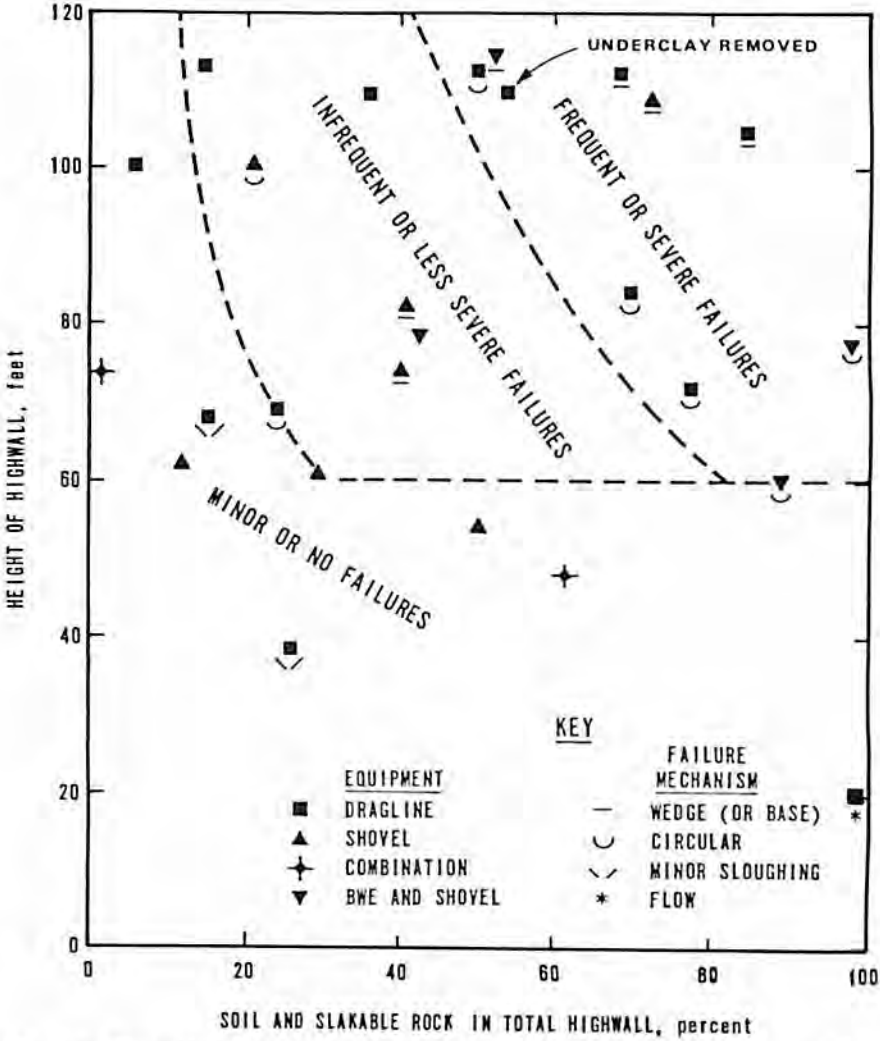


Fig. 1 — Effect of highwall height and percentage of soil and slakable rock in the highwall on spoil stability.

of soil in the highwall materials. This suggests a relationship between highwall height, percentage of soil in the highwall, and the occurrence of spoil pile failures, as shown on Figure 1. This figure indicates that for 20 pits in the Interior Coal Province, spoil pile failures were negligible for highwall heights of less than 60 feet and containing less than 20 percent soil and slakable or degradable rock (slakable is defined as the tendency to crumble or disintegrate when exposed to air and water). When highwall heights exceed 60 feet and contain more than 20 percent soil and slakable rock, then some spoil pile failures were observed. Once the percentage of soil and slakable rock in the highwall exceeds approximately 40 percent, spoil failures were frequent and severe. The one pit which was observed to contain no spoil pile failures, but which had a highwall height greater than 60 feet and more than 40 percent soil and slakable rock, had removed the underclay which had contributed to previous spoil pile failures. Highwalls containing very large percentages of lacustrian sediments may also defy this relationship, resulting in spoil pile failures with pile heights of as little as 20 feet, as shown by the point at the lower right side of Figure 1.

This empirical relationship, while of a fairly general nature, provides a preliminary method for predicting spoil pile failures for planned pits. An advantage to this simple predictive relationship is that it requires only a knowledge of the height of highwall and the percent soil and slakable rock, properties which are easily determined from the exploratory borings. However, this method is not capable of assisting in the assessment of various preventative or remedial measures for enhancing spoil stability such as pullback benches, high-strength buckwall zones, removal of the underclay or the effects of various types of excavation and stacking equipment. Therefore, where the highwall height exceeds 60 feet and contains more than 40 percent soil and slakable rock, it may be desirable to more reliably predict spoil pile instability and to assess preventative and remedial methods, using an analytical method which takes into account the configuration of the spoil pile and the strength properties of the various zones of spoil materials.

FACTORS CONTROLLING SPOIL INSTABILITY

As a refinement to the basic empirical relationship presented above, we should begin by determining the basic parameters which affect the stability of any slope, either natural or manmade. These parameters basically include the configuration of the slope and the strength of the spoil material. Slope configuration parameters include the height and angle of various portions of the slope. For surface mines the spoil pile configuration is a function of the height of the highwall from which the spoil materials are derived and the method of spoil placement which affects the angle or slope of the pile and the need for any intermediate benches. The strength of the spoil material is related to the parent materials in the highwall, the degree of disturbance created by excavation, and the method of spoil placement.

Strengths of the overall pile may be further affected by placement

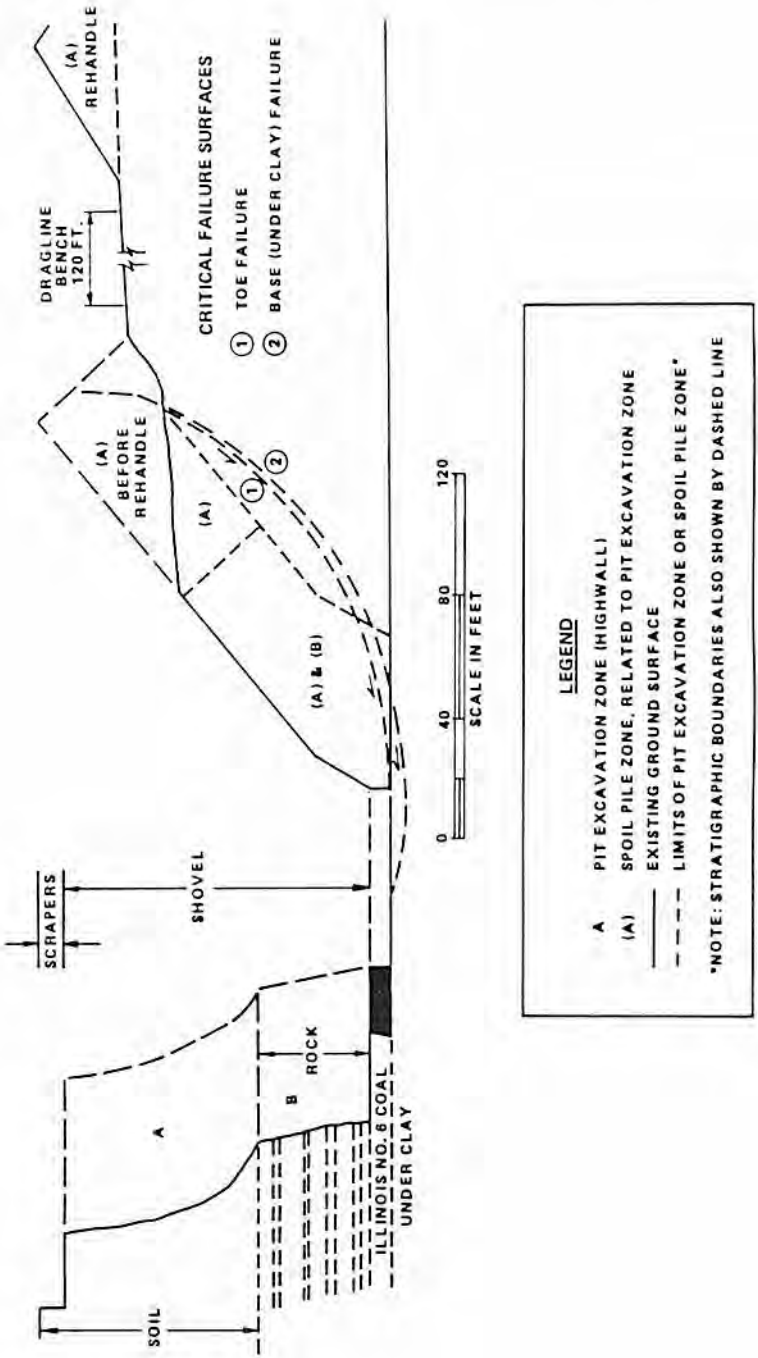
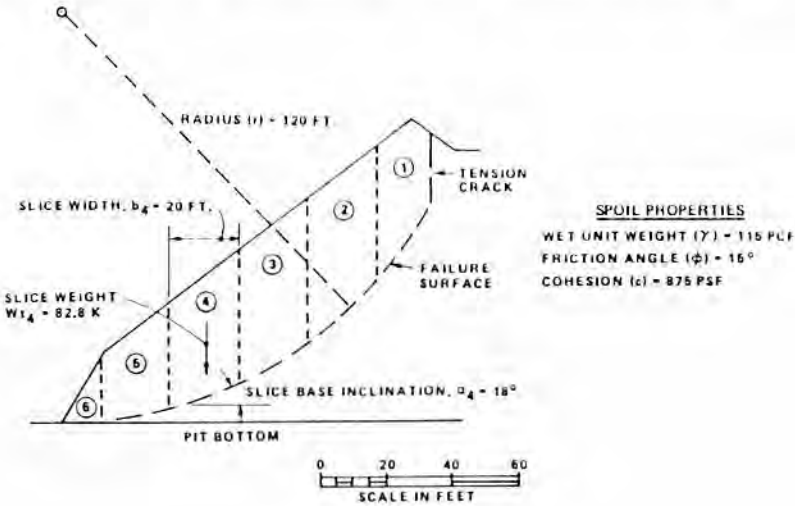


Fig. 2 — Generalized profile of highwall and spoil pile with analyzed critical failure surfaces.

techniques which create zones of high-strength and low-strength spoils in the pile by selectively excavating portions of the highwall and placing these materials in discrete zones in the spoil pile as shown on Figure 2. Failure surfaces in the spoil pile may be controlled by the occurrence of these low and high-strength zones. In many mines relatively high-strength spoils are



COL. / SLICE	(1) Wt. (kips)	(2) b (kips)	(3) α (deg)	(4) c (kips/ft)	(5) φ (deg)	(6) b/Cos α (ft)	(7) (6)·c (kips)	(8) Wt·sin α (kips)	(9) Wt·cos α (kips)	(10) (9)·tan φ (kips)	(11) (10)+(7) (kips)
1	62.1	16	65	0.88	15	27.9	24.6	50.9	35.6	9.5	34.1
2	98.9	20	43	0.88	15	27.3	24.0	67.4	72.3	19.4	43.4
3	98.9	20	30	0.88	15	23.1	20.3	49.5	85.6	22.9	43.2
4	82.8	20	18	0.88	15	21.0	18.5	25.6	78.7	21.1	39.6
5	59.8	20	10	0.88	15	20.3	17.9	10.4	58.9	15.8	33.7
6	13.8	11	2	0.88	15	11.0	9.7	0.5	13.8	3.7	13.4

DRIVING FORCE = Σ (8) = 204.3 RESISTING FORCE = Σ (11) = 207.4

$$F.S. = \frac{\Sigma\left[c\left(\frac{b}{\cos\alpha}\right) + (Wt\cdot\cos\alpha)\tan\phi\right]}{\Sigma\, Wt\cdot\sin\alpha} = \frac{\Sigma\,(11)}{\Sigma\,(8)} = \frac{207.4}{204.3} = 1.02$$

Fig. 3 — Example computation using the ordinary method of slices (Fellenius, 1936).

selectively placed in the toe of the pile as buckwalls with the intent of containing the lower strength spoils and preventing or inhibiting failures through the toe of the pile. Significant low-strength zones may include the interface between successive pile strips which become weathered or saturated in the time interval between placement of the next successive strip; and low-strength underclays along the pit bottom, which may become degraded due to seepage into the pit or disturbance by heavy equipment traveling along the pit bottom. Such weak and strong zones may force non-circular or wedge-shaped failure surfaces.

Other parameters which might be considered to affect spoil pile stability include precipitation, temperature, the occurrence of groundwater, drainage, and blasting vibrations, all of which have been found to exert comparatively minor effects on the short-term stability of spoils considered herein. Consequently, the following paragraphs will only be directed at assessing the more significant parameters affecting spoil pile stability including pile configuration and spoil material strength and weight.

A large variety of mathematical techniques are readily available from the civil engineering field for analyzing the stability of slopes and assessing the importance of the various input parameters. These slope stability analysis techniques range from very simple chart systems requiring minimal input data on slope configuration and material properties on up to very complex and rigorous mathematical and often computerized techniques which allow for considerable complexity in the slope configurations, material properties and groundwater conditions. These various analysis methods have been summarized by Miller, et al. (1979) and their attributes, benefits and deficits compared. All of these techniques require input data in the form of spoil pile height and slope angle, and spoil strength and density properties as shown in the example on Figure 3.

The simple analysis presented on Figure 3 is for an observed failure at the mine diagrammed on Figure 2, and is presented as a basis for assessing the sensitivity of the analyzed factor of safety to the various input parameters. The example was analyzed using actual field data, and therefore, also shows the accuracy with which a slope can be analyzed given even fairly sparse data. A plot showing the sensitivity of the factor of safety of the spoil pile to changes in each of the input parameters over a reasonable range is shown on Figure 4. A factor of safety of 1.0 or less represents a failure condition. As shown on Figure 4, the factor of safety is extremely sensitive to relatively small changes in the cohesion and angle of internal friction of the spoil while being less sensitive to changes in the wet density, slope height and slope angle below a factor of safety of 1. Scrutiny of this plot, therefore, provides insight into the relative effect of small variations in the stability input parameters and indicates those parameters which exercise the greatest control over stability. The plot also may be used to assess the relative effectiveness of various spoil stability enhancement techniques such as decreasing the slope angle, decreasing the slope height, or increasing spoil material strength.

EMPIRICAL RELATIONSHIPS FOR STABILITY ANALYSES

We will present in the next few pages recently developed empirical relationships relating spoil properties and spoil pile configurations to easily and inexpensively determined highwall material properties, and the proposed excavation and placement methods. These relationships may be used by themselves to locate areas of the pit potentially containing low-strength spoil materials which may lead to instability. These materials may also be used as input for stability analyses. Input parameters which are required for any stability analysis technique are:

- Angle of internal friction of spoils (ϕ_s).
- Cohesion of spoils (c).
- Wet unit weight of spoils (γ_{wt}).
- Angle of internal friction of underclay (ϕ_f).
- Height (H_s) of spoil pile (relates to bulking factor).
- Slope inclination (B) of spoil pile (stacking angle).

As will be shown, these stability input parameters may be derived from a number of easily and inexpensively measured highwall properties and a knowledge of the proposed excavation and stacking equipment types, as follows:

- Thickness of individual soil and rock units (h_i).
- Percent of soil and slakable rock in highwall.
- Water content of soil and rock units in highwall (w%).
- Dry unit weight of soil and rock units (γ_{dh}).
- Atterberg limits, or preferably direct shear tests on underclay.

All of these properties can be derived from good quality core or chunk samples obtained during the exploration program for the mine area.

Based on a visual classification, it was possible to separate the spoil materials of the Interior Coal Province into three categories: 1) predominately soil spoil with over 75 percent soil, 2) mixed soil and rock spoil with 10 to 75 percent soil, and 3) predominately rock spoil with less than 10 percent soil. While separation of spoil types into 3 categories is somewhat arbitrary, classification into more detailed groups is not warranted on the basis of the present level of testing. Table 1 presents a summary of the range and median values of various engineering properties derived from spoils from 20 different pits. This table illustrates definite differences between soil spoil and rock spoil, whereas mixed soil and rock spoil tends to overlap with both soil spoil and rock spoil. While Table 1 provides a good indication of the distinct variation in properties between the three categories of spoils, the ranges of these properties are too great to be of value in a stability analysis. Consequently, some alternate and more site-specific relationships are necessary

Figure 5 presents a relationship between water content (w) of the spoil and its angle of internal friction (ϕ_s). Since we are mainly concerned here with the short-term stability of unsaturated surface mine spoils with no established groundwater table, the angle of internal friction presented on Figure 5 is in terms of total strength rather than effective strength. As the

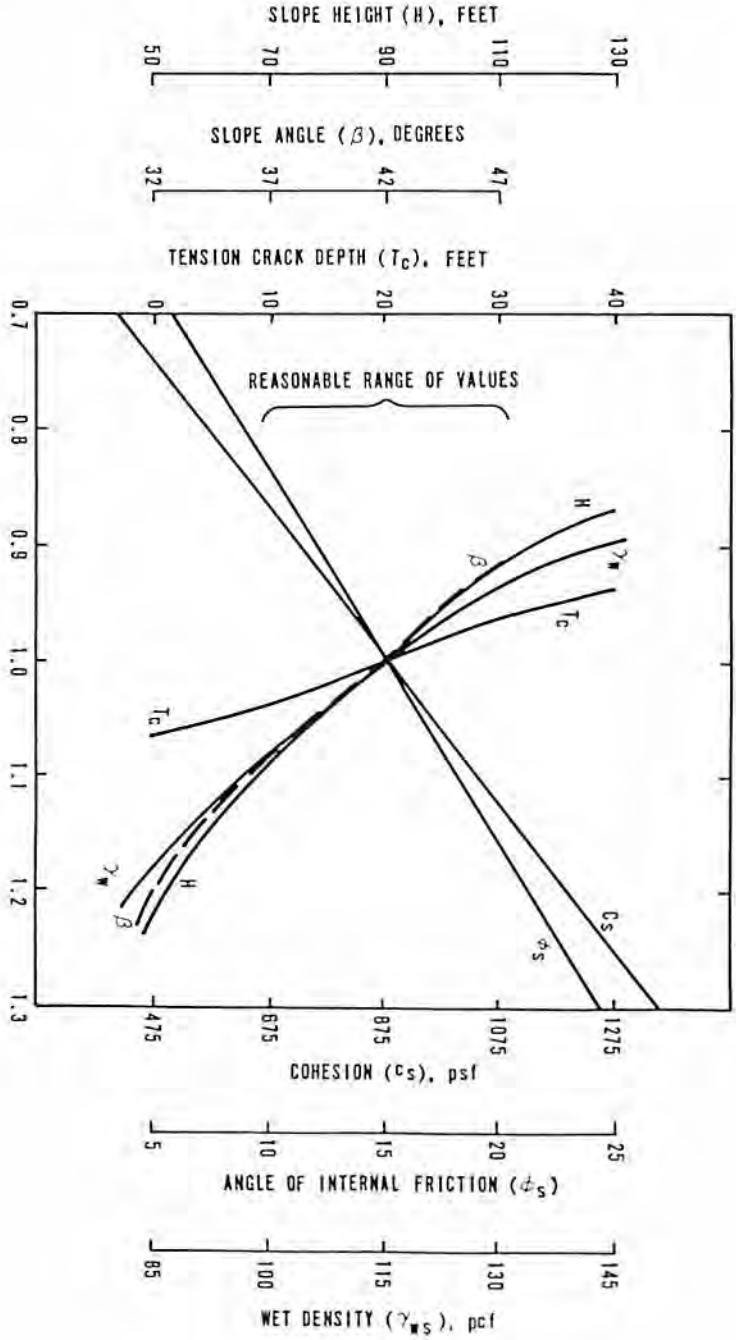


Fig. 4 — Sensitivity plot of circular toe failure (total stress).

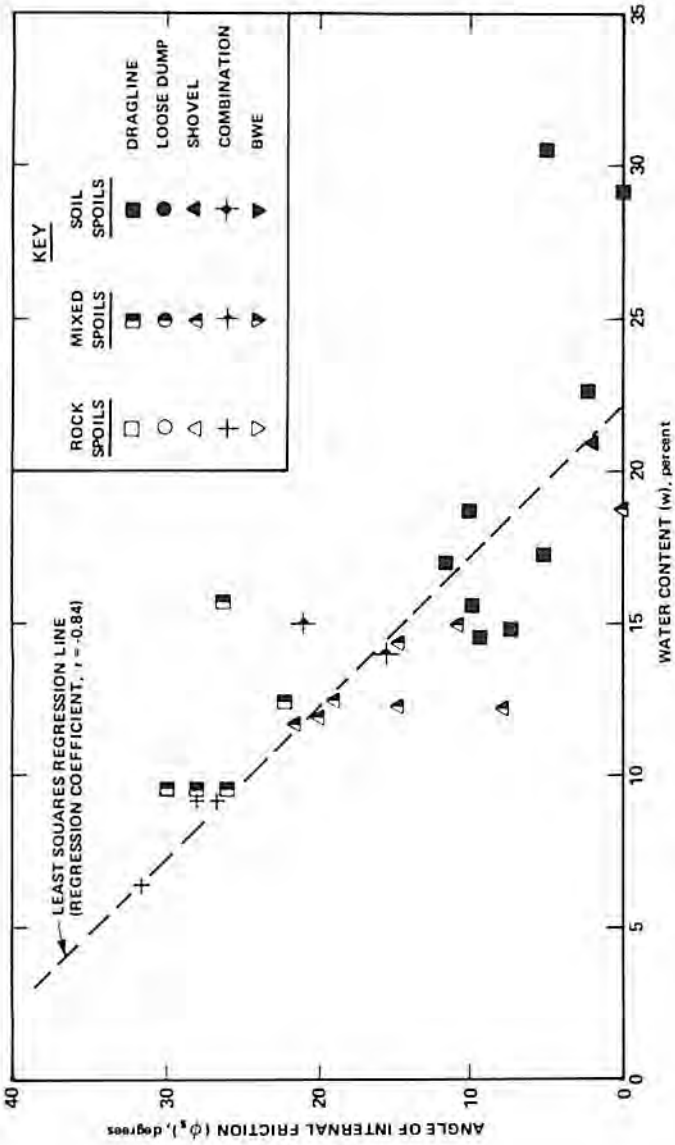


Fig. 5 — Angle of internal friction (total stress) versus water content for spoil.

water content increases, the angle of internal friction decreases with a reasonably linear relationship. Therefore, wet undrained spoils tend to have lower strengths and be less stable than dry or well drained spoils. This relationship may be due to the greater affinity of the weaker fine-grained soils for water and the build up of pore water pressures in these same soils during shearing which tends to reduce the total strength. As on Table 1, the figure also shows a marked relationship between water content, friction angle, and the spoil category.

Table 1 — Engineering Properties of Three Spoil Categories

Spoil Categories	Natural Water Content w percent	Dry Density γ_d pcf	Angle of Internal Friction (Total) ϕ_s Degrees	Cohesion (Total) c_s pcf	Compaction C_s percent	Plasticity Index PI
SOIL	13 to 37	86 to 109	0 to 10	200 to 2000	70 to 95	12 to 30
(>75% to soil)	(21)	(96)	(5)	(1200)	(80)	(19)
No. of Tests	29	29	9	9	30	9
MIXED SOIL & ROCK	9 to 19	82 to 129	4 to 30	400 to 2800	65 to 115	14 to 32
(70% to 75% soil)	(13)	(105)	(20)	(1300)	(95)	(19)
No. of Tests	44	43	14	14	45	16
ROCK	5 to 15	90 to 119	27 to 32	600 to 1000	70 to 110	14 to 20
(<10% of soil)	(9)	(103)	(29)	(800)	(85)	(18)
No. of Tests	21	20	3	3	15	6

Note: Numbers in parentheses are the median defined as the value of a variable below and above which an equal number of variables fall.

Figures 6 and 7 present a relationship between spoil cohesion (c) and spoil dry density (γ_{d_s}) and Standard Proctor compaction, respectively. Standard Proctor compaction is a measurement of the degree to which the soil has been compacted in the field relative to a laboratory determined maximum value. There is considerable scatter on Figure 6 showing a rather poor relationship between cohesion and dry density, however, Figure 7 shows a much better relationship between cohesion and Standard Proctor compaction. Unlike Figure 5, there appears to be no relationship between spoil category and either cohesion, dry density, or Standard Proctor compaction. This lack of relationship is also shown by the range and average cohesions for the various spoil categories on Table 1. Nevertheless, the fairly good relationship between cohesion and Standard Proctor compaction suggests that if compaction can be predicted or easily determined, then cohesion may subsequently be predicted.

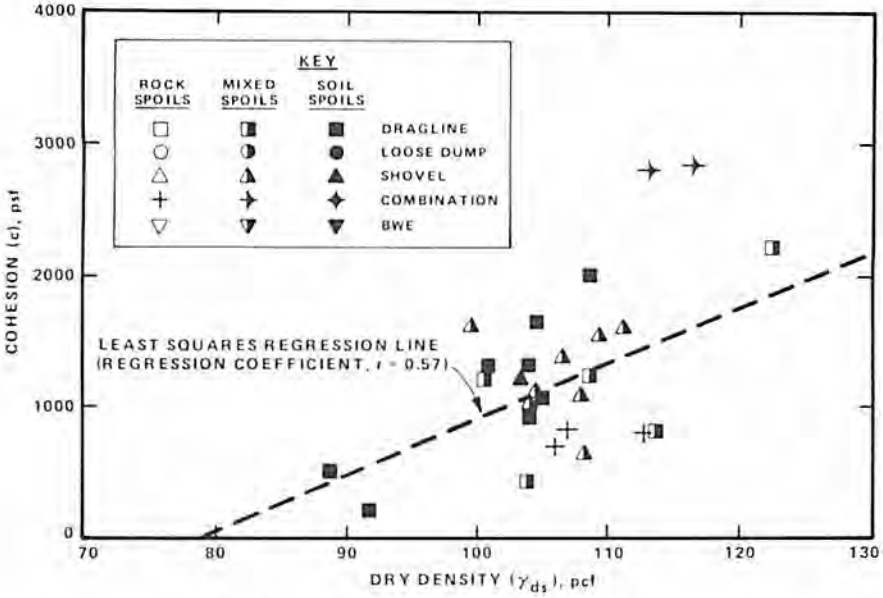


Fig. 6 — Cohesion versus dry density for spoil.

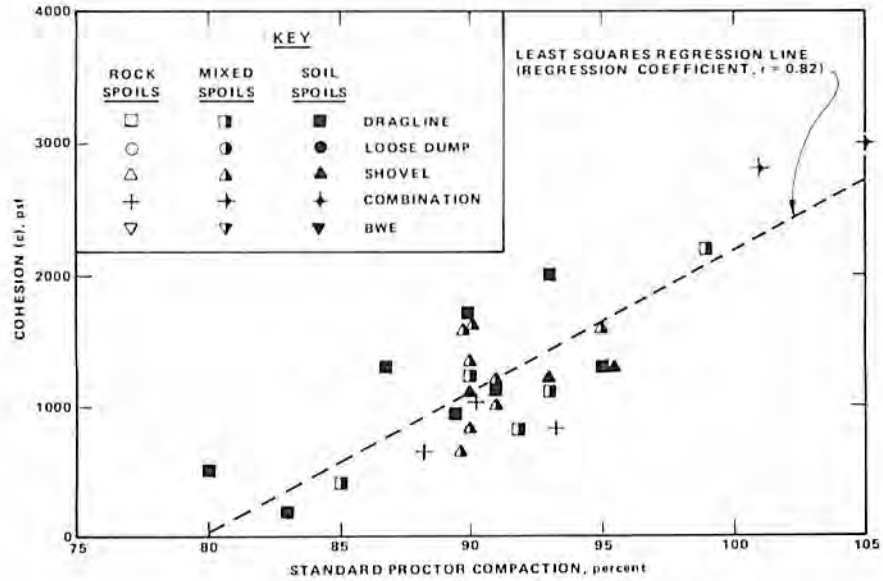
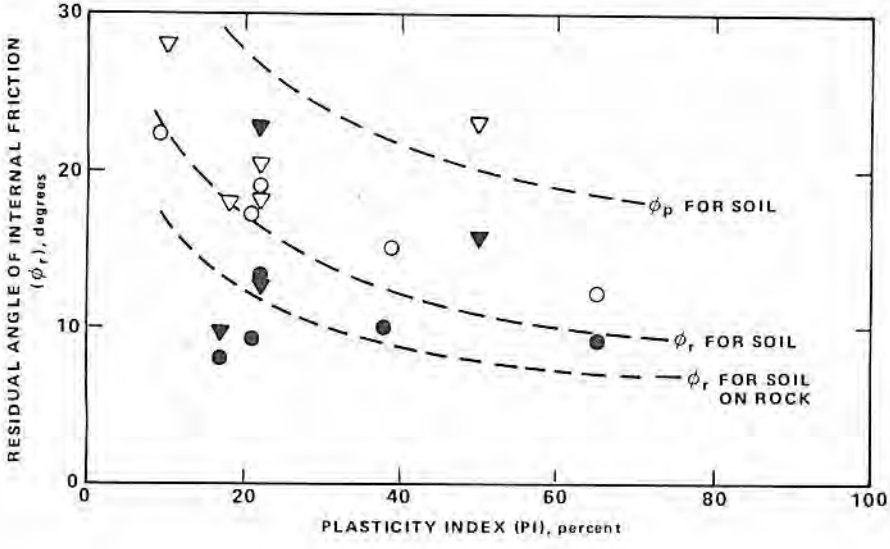


Fig. 7 — Cohesion versus percent compaction for spoil.

Where spoil pile failures may extend into or along the pit bottom due to the presence of a weak underclay, some empirical relationship between shear strength of the underclay and an easily determinable index property would also be desirable. Such an empirical relationship has been determined by Kanji (1974) for relating internal friction angle of clays to the plasticity index as determined from the Atteberg limits. Figure 8 presents this relationship with data points from laboratory direct shear and field torsion shear tests on underclay superimposed on the curves. The top graph shows a somewhat scattered relationship between residual friction angle, which results after considerable remolding or shearing of the underclay, and plasticity index. The lower plot shows the relationship between peak friction angle, the maximum friction angle under small amounts of shear or minimal disturbance, and the plasticity index. The superimposed data points for laboratory peak direct shear tests and field torsion shear tests on underclay samples are also somewhat scattered. A comparison of the data points for the two plots does show a distinct contrast between residual and peak friction angle, with the residual friction angles generally less than 20 degrees and as low as 8 degrees, and the peak underclay friction angles generally greater than 20 degrees. Analysis of several spoil failures involving underclays indicated that at the time of failure the clays were at residual strength, possibly due to seepage into the pit or remolding of clays by equipment operating on the pit bottom. As suggested on Figure 1, pits in which the underclay has been removed may avoid costly spoil pile failures. The Atterberg limits may be determined on remolded core samples of the underclay for a preliminary estimate of residual friction angle. If good quality core samples are available, it is suggested that direct shear tests on these samples would provide more reliable determinations of peak and residual friction angles at only a minor increase in cost. This, of course, requires that the exploration borings extend several feet below the bottom of the coal. In several instances spoil failures have been observed to extend through underclays as far as 20 feet below the pit bottom, showing the need for extending exploration to these depths.

Now that Figures 5 through 8 have been presented for relating spoil and underclay strength properties to index properties, it would be desirable for prediction purposes to relate these index properties to either highwall material properties or excavation and placement techniques. The following paragraphs will present several empirical relationships between spoil properties and properties of highwall materials and spoil placement techniques.

Water content was used as an index property on Figure 5 for determing friction angle of the spoil materials. Figure 9 presents a relationship between water contents of various highwall material zones and water contents of the corresponding spoil zones. Theoretically, this relationship should be perfect, however, minor testing errors and the addition of water from precipitation has resulted in some deterioration of the relationship. Many of the mines used in determining these relationships had been involved in a fairly lengthly strike and a severe winter prior to collection of the samples. It is likely that the water content of at least the upper 5 to 10 feet of the



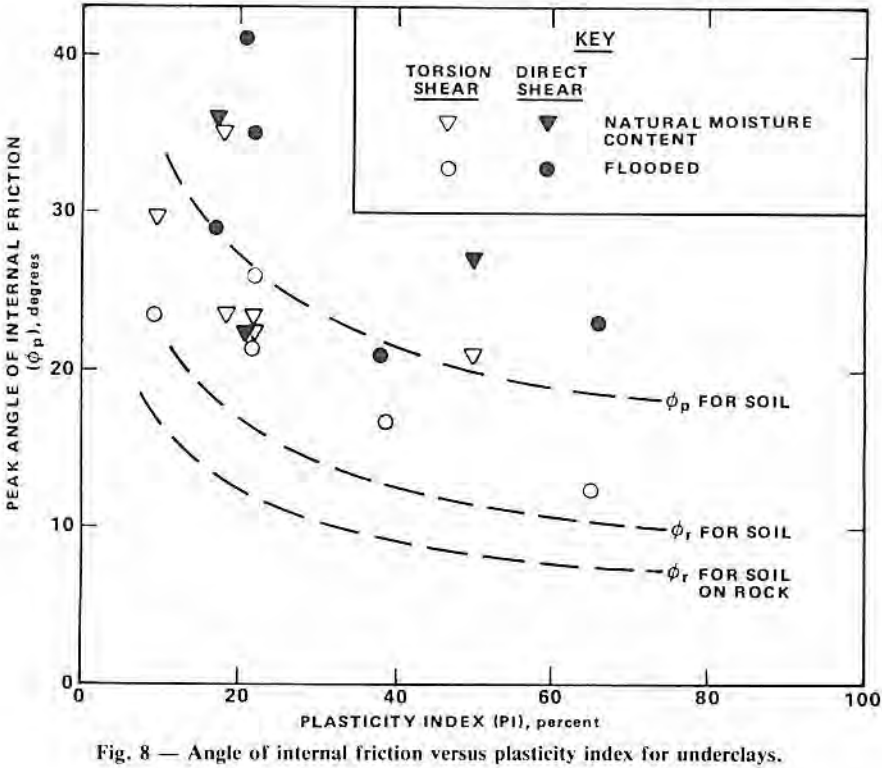


Fig. 8 — Angle of internal friction versus plasticity index for underclays.

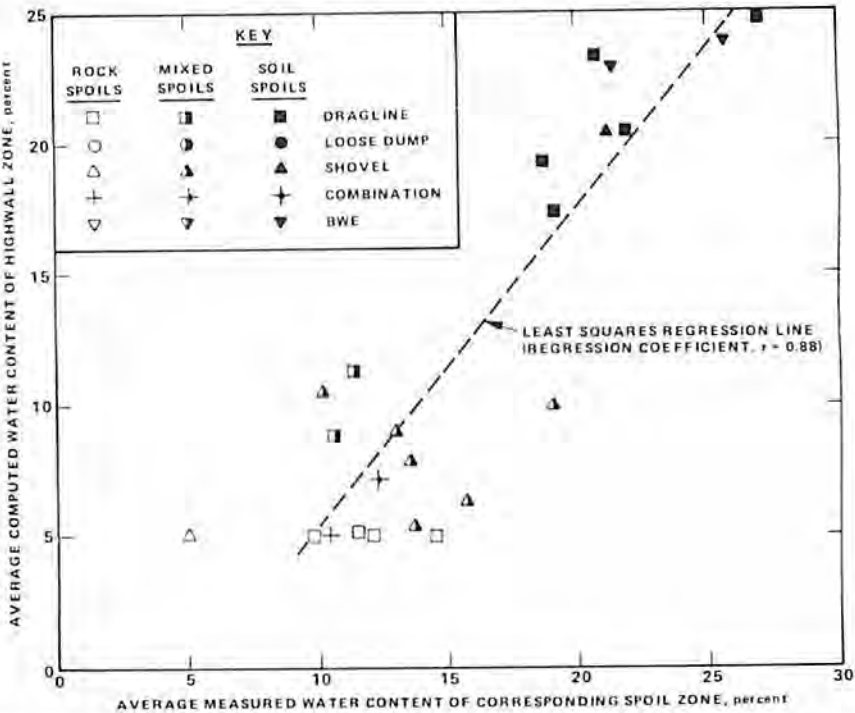


Fig. 9 — Comparison of computed average water content of highwall zone to measured water content of corresponding spoil zone.

spoils had increased somewhat during this period of time. Where mining is active and the spoils are continuously being placed, then less time would be available for the water contents of the spoils to increase above those of the corresponding highwall zones. Nevertheless, Figure 9 indicates that water contents determined for the highwall materials may be projected with reasonable accuracy to the corresponding spoil zones and, subsequently, used for empirically determining the friction angle of the spoils. Water content is a very easy and inexpensive tests which is frequently used as an index property in soil and rock mechanics, and might easily be incorporated in the normal test procedures on overburden samples during exploration. This relationship also emphasizes that wet, undrained highwalls may lead to wet, low-strength failure prone spoils.

Cohesion was found to relate to dry density or Standad Proctor compaction of the spoils, as shown on Figures 6 and 7. On Figure 10 the spoil density distribution has been plotted as a function of placement method. The bucket-wheel excavator (BWE) is primarily used for placing soil spoils and has a relatively small height of drop resulting in densities in the range of 80 to 90 pcf. The shovel placed spoils indicate a very well defined concentration of densities in the 100 to 110 pcf range. Dragline spoils, on the other

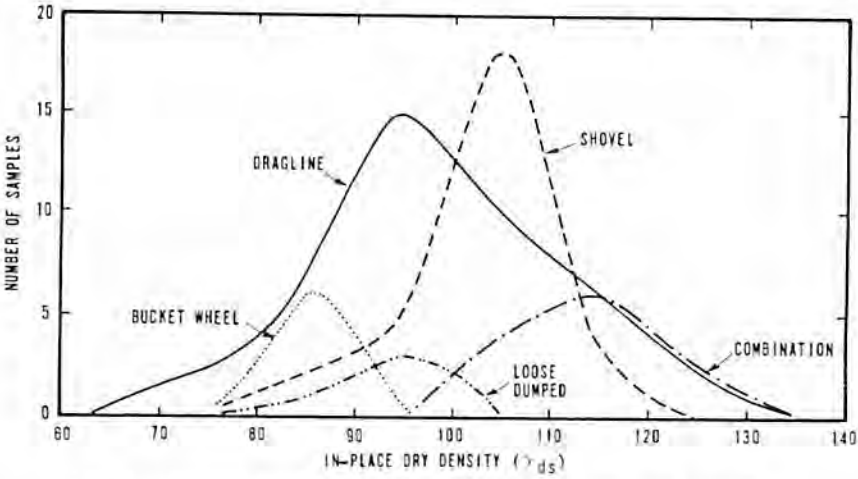


Fig. 10 — In-place dry density of spoil as a function of placement method.

hand, show a very broad range of densities from about 70 to 130 pcf with a smaller peak at 95 pcf, probably due to the wide range of bucket sizes and heights of drop. Combinations of equipment produced generally higher densities than the other methods, with most densities in the range of 110 to 120 pcf, probably as a result of the placement of thin layers of spoil and the compaction afforded by trucks, loaders, or scrapers routed over the spoil as it is placed. The loose dump spoils were placed by pushing rock blocks off the highwall with a dozer into the adjacent pit bottom from a relatively small height which generated little or no compaction of the underlying material.

Although dry density generally provides better correlations, wet density is required as an input parameter for stability calculations. The dry density of a material can be converted to wet density using the natural water content in the following equation:

$$\gamma_{ws} = \gamma_{ds}(1 + w/100) \tag{1}$$

where γ_{ws} is the wet density, γ_{ds} is the dry density, and w is the percent water content of the spoil.

A somewhat better relationship was found between spoil cohesion and Standard Proctor compaction on Figure 7, consequently, Figure 11 relates Standard Proctor compaction to placement method. Results of these comparisons are similar to the density relationships discussed previously. Interestingly, dragline and BWE placed spoils exhibit a peak compaction in the 70 to 90 percent range which is generally considered to be about as loose as granular materials can be dumped. Shovel placed spoils and spoils placed by combinations of truck-shovel equipment had peak compactions ranging from 90 to 100 percent, thus approaching what might be considered satis-

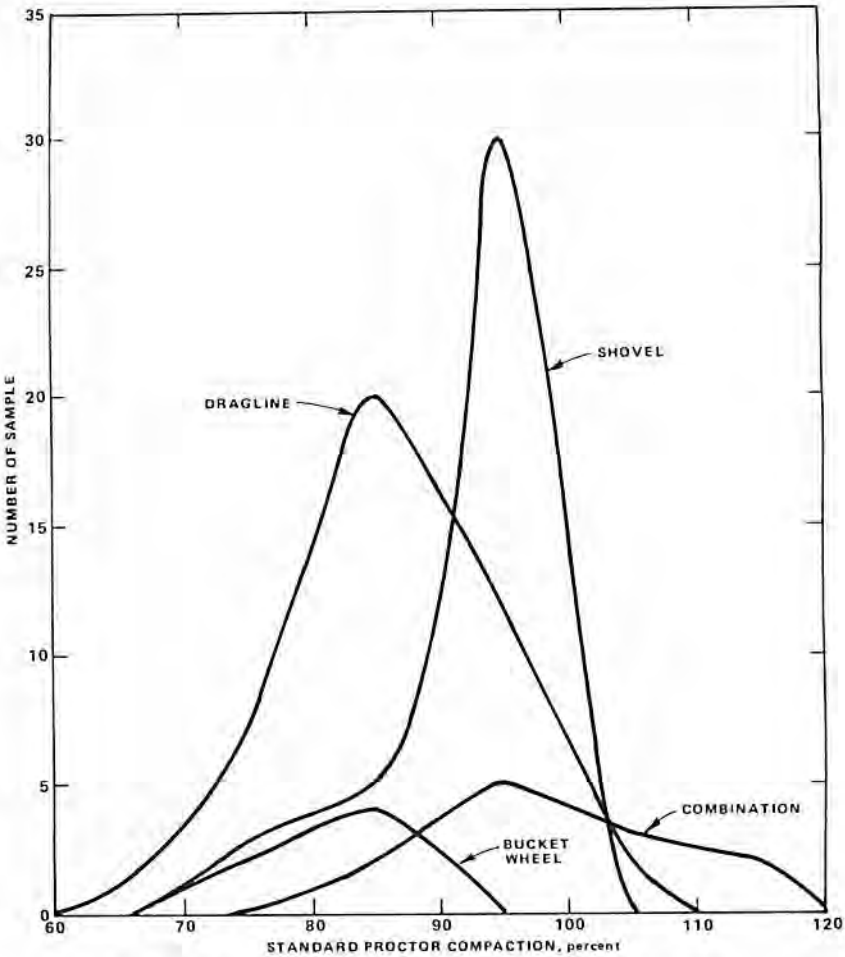


Fig. 11 — Compaction of spoils as a function of placement method.

factorily compacted structural fill on civil construction projects. It should be noted, therefore, that greater compaction, as achieved by shovels and combinations of equipment result in correspondingly higher spoil cohesions as shown on Figure 5 and, therefore, these placement methods tend to result in a stronger, more stable spoil pile.

The configuration of the spoil pile is a function of the volume changes induced on the highwall materials when excavated to produce spoil, the stacking angle or angle of repose of the spoil material, and the spoil placement techniques which may include the use of intermediate benches, depending upon equipment limitations. An empirical relationship is presented on Figure 12 between stacking spoil slope angle (B) and percent soil and slakable rock in the corresponding highwall zone. The various categories of

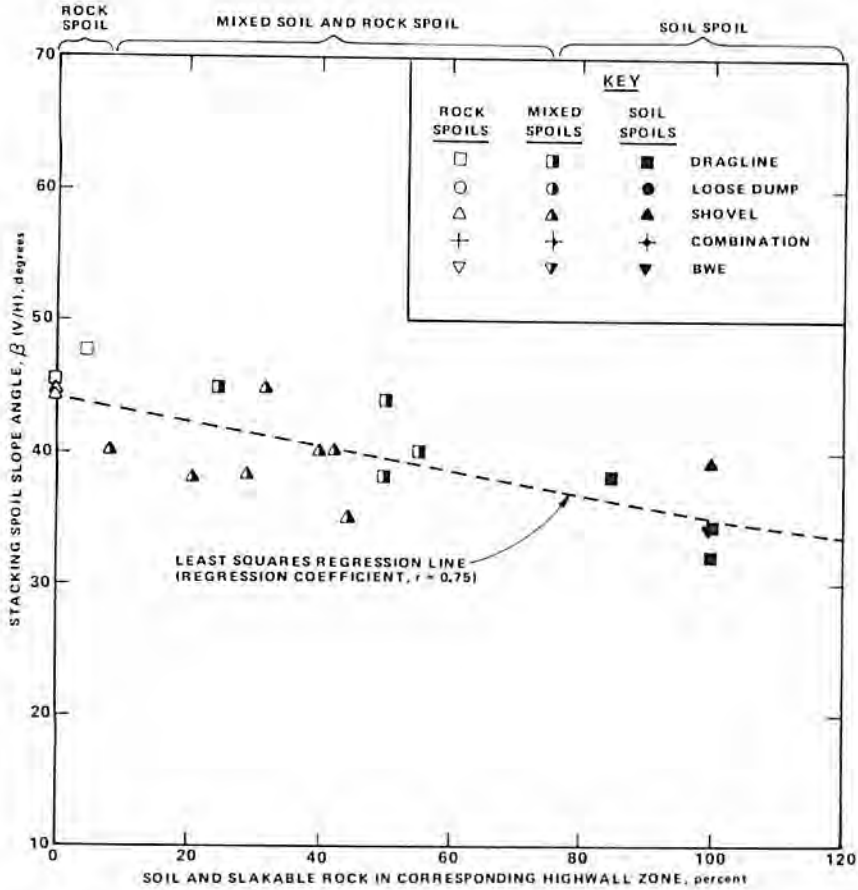


Fig. 12 — Stacking slope angle versus soil and slakable material in corresponding highwall zone.

spoil materials show good correlation with discrete ranges of stacking slope angles. These stacking angle relationships, while of value in a stability analysis, would also be of value in assessing the required reach for spoil placement equipment such as draglines or shovels.

The height of the spoil piles is a function of the stacking angle and the degree to which the spoils have bulked due to excavation from the highwall material. The curves shown on Figure 10 provide a means for assessing spoil densities as a function of placement technique. Consequently, the bulking factor (BF) may be estimated using the following equation:

$$BF = (\gamma_{dh}/\gamma_{ds} - 1)\ 100 \qquad (2)$$

where γ_{dh} is the dry density of the highwall material determined from core samples and γ_{ds} is the dry density of spoil determined from Figure 10.

The height of the spoil pile (H_s) may be calculated as follows:

$$H_s = H_h (\gamma_{dh}/\gamma_{ds}) \tag{3}$$

where H_h is the thickness of the overburden, and γ_{dh} and γ_{ds} are as defined before.

Figure 13, showing an empirical relationship between bulking factor and percent soil in the corresponding highwall zone, may be also used to determine the dry density of spoils derived from the highwall. Again, there appears to be a fairly strong relationship between category of spoil and, in this case, bulking factor. The rock spoils have a bulking factor of around 40 to 50 percent, but extending from 30 to 65 percent, whereas the soil spoils have a bulking factor ranging from 0 to 15 percent. The intermediate mixed spoils have a bulking factor ranging from 10 to 55 percent with a strong concentration point around 20 to 35 percent. These bulking factor relationships may also be of value in predicting final spoil thicknesses for reclamation purposes.

Thus far, we have presented empirical relationships which may be used for deriving various stability input parameters from the highwall materials and construction techniques. Using the aforementioned figures and equations, individual stability input parameters for the spoil may be estimated in accordance with the following list of procedures:

- Estimate γ_{ds} for the spoil from Figure 10, as a function of stacking equipment.
- Where draglines are to be used, estimate the bulking factor from Figure 13, as a function of percent soil and slakable rock, and estimate dry density (γ_{ds}) for the spoil in accordance with equation (2).
- Estimate the height of the spoil pile in accordance with equation (3).
- Estimate the slope angle (B) of the spoil from Figure 12, as a function of percent soil and slakable rock in the highwall.
- Estimate percent compaction for the different stacking equipment combinations, except dragline, from Figure 11.
- Estimate cohesion (c) of the spoil from Figure 6 or 7 as a function of percent compaction.
- Estimate the internal friction angle (ϕ_s) of spoil from Figure 5, as a function of the average water contents in the spoil zones which are equivalent to water contents in the corresponding highwall zones. Calculate the wet unit weight (γ_{ws}) of the spoil in accordance with equation (1).
- Estimate the residual angle of internal friction for the underclay (ϕ_r) from Figure 8, as a function of the Atterberg limits for Kanji's curves for soil sheared against rock, or preferably from laboratory direct shear tests performed on underclay samples obtained from the exploration borings.

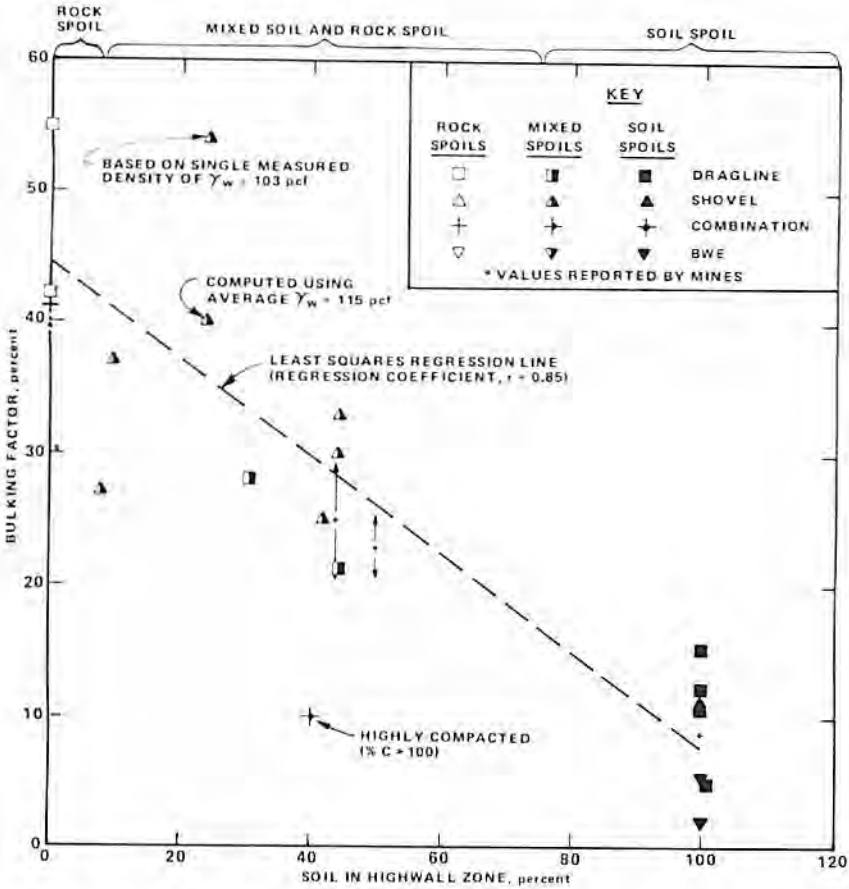


Fig. 13 — Bulking factor versus percent soil in corresponding highwall zone.

Thus, with a few easily and inexpensively determined highwall properties, the quantitative spoil properties required for input into a stability analysis may be estimated, based on the empirical relationships presented in the preceding figures. It should be noted here that these figures are of a preliminary nature, having been based on case histories from only 20 pits. Consequently, the plots show a certain amount of data scatter which, when compared to the sensitivity plot shown on Figure 4, may amount to errors in calculated factor of safety by as much as 30 percent for each parameter. Therefore, preliminary stability input values should be selected using best fit lines or distinct maximum, disregarding the variations of data. Data from additional case histories should aid in reducing this scatter and improving the best fit lines and maximum points; however, until more data are acquired these figures should be considered to be of a preliminary nature.

CONCLUSIONS

The empirical data relationships and the suggested approach to predicting spoil pile stability for proposed mines as presented above, however tentative, should be a useful addition to the intuitive or experiencial approach currently being used by most mine designers. The empirical relationships and predictive method discussed in the preceding pages may also be used for the preliminary evaluation of other aspects of a proposed strip mine operation, such as equipment requirements or various methods of modifying spoil stability. As an example, the bulking factors and stacking angle relationships shown on Figures 12 and 13 might be used to aid in setting minimal requirements for distance of reach for large shovels or draglines. Alternately, low predicted factors of safety resulting from low spoil internal friction angles which correlate with high water contents might provide a basis for implementing preventative measures such as special blending or zonation of the highwall materials to obtain high-strength buckwall zones, predrainage of the highwall materials, or elimination of the low-strength highwall soils from the pit using scrapers or truck-shovel operations.

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1. Kanji, M.A., (1974), "The Relationship Between Drained Friction Angles and Atterberg Limits of Natural Soils", *Geotechnique*, V. 24, No. 4, December, pp 671-673.
2. Miller, R.P.; Douglass, P.M.; Robinson, R.A.; Roberts, D.A.; and Laprade, W.T. (1979), *Surface Mine Spoil Stability Evaluation — Interior Coal Province*, prepared for U.S. Bureau of Mines and published by Nat. Tech. Info. Service, PB80-211113 (Vol. 1) and PB80-211121 (Vol. 2).

Robert Izard: We have a question and answer period.

George Morgan: In your calculations do you have any figures allowing for the New Madrid Fault?

Robert Robinson: We looked briefly at the structural input in the major report. Are you talking in terms of seismic calculations?

George Morgan: Like earthquake tremors.

Robert Robinson: This analysis was aimed primarily at short term stability of spoil piles, that is, strip mine piles. You place one pile, then you place another pile adjacent to it, and so on. So we were not really trying to address long-term instability that might be due to an earthquake.

George Morgan: The reason I am asking is that in the New Madrid Fault area near Madisonville and Evansville, I have heard there are more problems with slate falls in some of the deep underground mines. It seems to me that there is some sort of correlation with the earthquake activity picking up. So perhaps it is more like a short term thing.

Robert Robinson: Yes, I think in general, it would just get prohibitive for a mine designer to attempt to take seismic factors into account when he addresses the short term stability of one of these spoil piles. It would be back to the situation of designing, for example, a retention facility or something like that when you have to address seismic co-efficients. The cost would be prohibitive; these piles would all have to be designed for a standard of 35 to 40 degrees instead of 25 to 30 degrees. You are talking about a one-time event. The chance of one of these major earthquakes occurring and causing a failure is one in a million in the next year or so.

Question: Did you come up with static safety factors for inclines that were left after mining at angle of repose?

Robert Robinson: Again, this would be a long term safety factor, and we would expect that there would be some degradation of the spoil pile. We are trying to evaluate the short term strength of these spoils in terms of what we have in the highwall. The highwall material is fresh and with time you add water to the spoil piles, and you would have to know what that moisture content change is. For the short term failures the only moisture content is the moisture that was inherent in the rock from the highwall. The spoil piles are there for such a short period of time, from weeks to a month, that they don't really have an opportunity to pick up much moisture. When you calculate the moisture change that you get from a one month period or two inches, for a pile a hundred feet high, that change in moisture is almost beyond calculation.

Question: Do you think it is possible to calculate the safety factor after mining activity has taken place and the potential water inpoundment is filled?

Robert Robinson: I think you can calculate that, I just don't think these data is pertinent to that. I think it would be stretching the data too much beyond what is intended. I think that would be another study in itself, and I think what you have to do then is go in and actually measure the changes in moisture content of that spoil as a function of time and come up with your new friction angles.

Questions: How did you run a Proctor test on rock mixtures and high rock and soil mixtures?

Robert Robinson: Our standard Proctor test was run on a standard size mold, and we graded it down to take out everything. We just retained the material less than an inch in diameter. We found fairly good correlation; there were a couple of mines where the mining company or one of the state surveys had gone in and done a large number of in situ density tests where they had taken out several yards of material and made a very large cone of sand. I think they weighed the trucks that carried the material out, and they measured the volume of the hole. They came up with the Proctor density of the material they had taken out. We found very good correlation between those densities and the densities we did with just a standard sand cone den-

sity test. Apparently the large chunks that are in there don't have that much of an influence over the over all density. Now it becomes a little more difficult when you are dealing with the very rocky end of the spectrum, the soil end, or the intermediate blend of soil and rock. Then those large chunks are a minority. When you get up to that very rocky end then it becomes a little more of a problem. That is also the higher friction angle end, so maybe its not as much of a problem in terms of over all stability of the pit.

Question: How do you account for the correlation between density and standard Proctor?

Robert Robinson: As for correlation between density and standard Proctor, I haven't got a good answer for that. It was one of those things that fell out. I think that it just takes into account that difference due to machine operation. One spoil that's placed by a drag line is going to have a density of 95 pounds per cubic foot, and the same spoil placed by a combination of equipment including scrapers where it is placed in shallow piles and then run over, has a much higher compaction. That just provides a better correlation for cohesion.

Robert Izard: It sounds like there is a lot of interest in this. The next subject to be discussed is "High Resolution Seismic Exploration of Peabody Coal Company's Mine 10". The paper was co-authored by John Acker and Dr. Kumamoto, Chief of the Geophysics for Peabody. John is going to present the paper. He received his BA degree in geology and English from the University of Indiana and attended the Texas Instrument School for Digital Field Systems Operations. He joined Peabody on a full time basis in 1980 after working summers during his school years.

John Acker: Thank you Mr. Izard. I'd like to take this opportunity to thank you for inviting us to present a short case history of Peabody's work with high resolution seismic coal exploration. Now when I first inquired about what kind of audience would be here today, I was told I would get people from those who did not know anything about seismic activity at all to those who use it on a daily basis. Obviously, this is a very broad audience, but I have tried to divide my presentation to address three groups. First, to those of you who have never had experience with seismic techniques, I will present an outline of seismic techniques. Secondly, to those of you who have perhaps seen some results at other mines but are a little skeptical, I will present an encouraging case history that will hopefully let you have some faith in seismic work. Finally, those of you who have contracted, perhaps unsuccessfully, seismic work at your own mine and at your own expense, I offer to you a convenient target in order to ask some pointed questions.

HIGH RESOLUTION SEISMIC EXPLORATION AT PEABODY COAL COMPANY MINE #10

J. R. ACKER
Geophysical Party Chie

and

DR. L. H. KUMAMOTO
Chief Geophysicist
Peabody Coal Company
St. Louis, Missouri 63102

INTRODUCTION

Considering the novelty of seismic exploration to the coal industry, it is important to understand those aspects of seismic work which are integral to coal and those which are common to all seismic activities. The aim of this presentation is to take a few moments to explain what takes place in seismic exploration and then go on to show how Peabody Coal Company has applied these things to their own work at Mine #10. Finally, Peabody will present some of the current projects they have underway to help improve the quality of their seismic data.

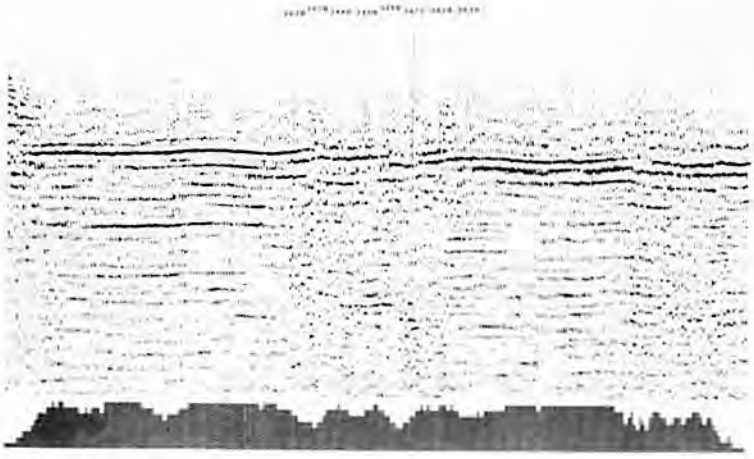

Fig. 1 — Uninterpreted Seismic Section.

EXPLANATION OF SEISMIC PECULARITIES

There are similarities and differences between coal and oil seismic exploration, but just what does set the two apart? Simply there are three things: shallow depth, high resolution, and fast sample rate. Where the oil industry normally is looking at depths of a mile or more for their structures, the coal industry is only concerned with depths of less than 1,000 feet. When working with wave reflections, these shallow depths affect the type of reflections one sees as data. Because of the close proximity to the wave source, a greater percentage of the return energy is seen in high frequency reflections in the range of 250 to 500 Hz. In normal oil operations, frequencies this high tend to be attenuated in favor of the lower frequencies associated with greater depth. Since most of the reflections common to coal exploration fall in the realm of high frequencies or high resolution, the rate at which the data is sampled becomes very important. With the later (that is deeper) low frequency reflections, samples can be taken at intervals of one to eight milliseconds (ms) with no loss of precision. With the higher frequencies, however, the reflections require faster sample rates of between 1 and 1/4th of 1 ms to record frequencies greater than 250 Hz. In other words, to get the most out of the data coming in, very short sample intervals are needed.

Drawing your attention to a sample seismic section in Figure 1, a brief explanation of common areas of misconception would be helpful. First, the vertical scale is deceiving in that it is a time scale rather than a depth scale. What is depicted is two-way time. This is the total time path traveled by the energy from the source to the interface in question and back to the surface. Depth can be estimated, but it must be mathematically translated using

Fig. 2 — Location of Mine #10 Seismic Area.

wave velocities estimated from the time data. Since the time-depth relationship is not 1:1 and since the time variable is the value recorded in the first place, time is the standard for seismic sections. The next common assumption is that the black filled peaks represent the thickness of the stratigraphic layer. What is actually illustrated is the summation of all the reflections at that temporal point. Theoretically this should appear as a set of spikes indicating the upper and lower boundries of a bed, but because the seismic signal originates as a wavelet of finite width, the reflection appears to have width. The magnitude, or amplitude of the peak, represents the difference in physical properties at the boundary between one medium and another, in other words, a different measurement of acoustic impedance (density times velocity) from one medium to the next. The only reason the peaks are darkened is to help the interpreter keep track of one set of peaks from another. Along with these pitfalls, a few other things need to be understood. First is scale. The vertical scale is in time, but the horizontal is in distance, representing the station positions. Next are the reflections themselves. Each one of the vertical traces is actually a summation of 12 different records over the spatial point. So what an interpreter sees is a set of summed data, each wiggle trace representing the acoustic impedance contrasts encountered during a vertical travel path directly beneath its horizontal position.

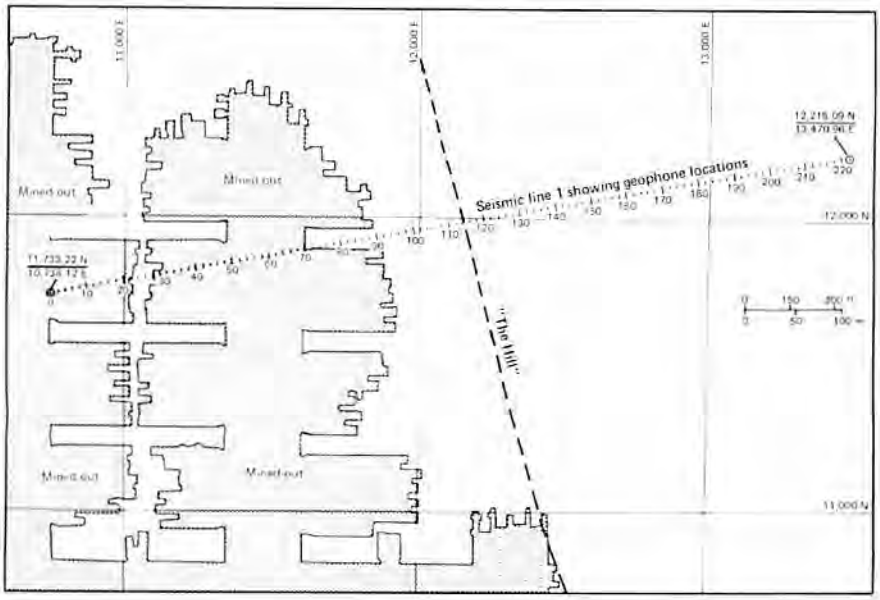

Fig. 3 — Placement of Mine #10 — Line #1.

SEISMIC LINE LOCATIONS

Peabody's work at Mine #10, located in central Illinois (Figure 2), utilized three lines in two separate areas and involved two distinct features. The work in the northern area was occupied in tracing a NW-SE trending fault which mining operations had encountered and initially evaluated with a 5 to 10-foot displacement. The southern area was concerned with tracing the unique Mine #10 structural trough called "The Hill". The third line was placed about a mile south of this trough-like structure, but unfortunately, results here were not as distinctive as the work on Lines 1 and 2.

The first line, shown in Figure 3, which ran roughly through the center of Section 31, Township 14 North, Range 3 West, was intentionally placed over old works and ran close to perpendicular to the estimated "Hill". It was placed over old works to try to pick up this occurrence with the Texas Instruments DFS-V system and get a picture of what to look for in future projects with abandoned mines. Mining operations were halted by "The Hill" at Mine #10 and farther south it caused the abandonment of works in old Mine #8. The estimated strike of N16W was obtained from extrapolation of these two positions.

Line 2 (Figure 4) was placed a mile further north, again perpendicular to the expected fault and close to the center of Section 30, Township 14 North, Range 3 West.

SEISMIC PROCEDURE

Now, to have located a line anywhere, preliminary discussions must have taken place, and it is in these procedures as well as in the recording and processing of a line that coal and oil seismic exploration run parallel paths. Anyone wanting to run a seismic survey must coordinate three separate procedures: preliminary surveying, actual recording of the line, and processing the data.

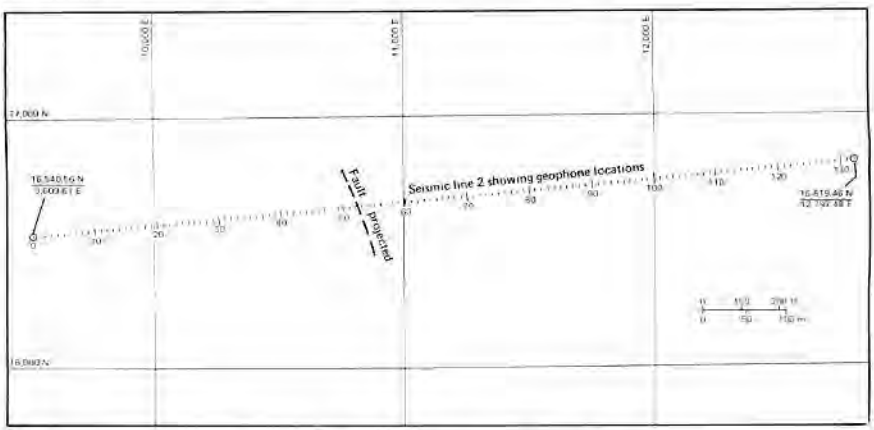

Fig. 4 — Placement of Mine #10 — Line #2.

Fig. 5 — Peabody's Surface Drill with Auger and Kelly Bars.

RECONNAISSANCE

During the preliminary survey, the people planning a seismic line must first determine the objective of the line and then consider the feasibility of retrieving useful data. Is the target too shallow? Is there any structure or strata present that might dissipate the energy prior to reaching the target? Does surface topography even allow access to the target area? These are all questions which must be answered as a reconnaissance is made of the site. Once the project feasibility is affirmed, line planning can begin. As can be expected, each line has a unique set of parameters in its plan. In the case of Line 1 (Figure 3), it was mentioned that the line was placed not only to en-

counter "The Hill" but old works as well. To help facilitate a strong view of these old works, geophone spacing was set at 12.5 feet with an average depth of 4.5 feet. With Line 2 (Figure 4), geophone spacing was every 25 feet at a depth of 12 feet. The geophones, or jugs as they are commonly referred to, were placed along a single line, with one jug per cable take out (T.O.). The geophones were also placed downhole to avoid surface noise and bypass the highly attenuative surface weathering layer. After reviewing the preliminary data from Line 1, it was also decided to add water to each hole to create better coupling for both the explosion and jugs. Once the spacing had been set, the mine engineers could then survey and flag the line.

Fig. 6 — Geophysical Equipment Ready for Placement Along Line.

RECORDING

After the preliminary surveys are finished, recording can begin. At Peabody, recording takes place in three phases. First the crew drills out the entire line. Then the crew returns with the recording equipment, sets out the line and records the data. And finally, a line clean-up is conducted.

Peabody used a small, hydraulic surface drill with augers and kelly bars shown in Figure 5. Cutting a 10-foot hole normally takes 7 to 10 minutes, including set-up, drilling and removal off the hole. Each hole is depth sounded, and the depth recorded for future elevation corrections and then covered to await shooting.

In the second phase of recording (Figure 6), the cables and geophones are dropped at specific points and then laid out by the crew. After the cables have been laid out, each geophone is set downhole (Figure 7). At the shotpoint, the geophone is placed at the surface, and the hole is prepared for the seismic source (Figure 8), in this instance a casing for a downhole shotgun. At the shotpoint (Figure 9), the geophone above ground plays a different role. Here the geophone senses what is known as the up-hole time or the interval from the instant the shot goes off until the first wave stimulates the phone. This time is essential for precision statics while processing the data. Once the explosive source is downhole, a series of operations are carried out to safely prime, arm and then fire the explosives (Figure 10). The actual firing command is initiated and issued from the recording van.

To wade through the mire of complex, sequential operations carried out by the DFS-V system, it is easiest to start with a brief description of each component as seen in Figure 11. In the lower left hand corner is the controller module. This unit is the heart of the DFS-V system. It gives all the commands to the other units, monitors switch settings for correct procedure, monitors all units for system error and failure, and synchronizes timing between units. The two boxes to the immediate right are the analog modules. They receive the raw signals which they filter and amplify and then translate from analog to digital signals. On the far right is the tape transport which records the digitized data on nine track magnetic recording tape. These units consititute the basic DFS-V system, but the other peripheral equipment expands the system capabilities. The camera, to the left of the transport, provides visual monitor records of the signals and will indicate problems with the cables or excess noise. The roll-along switch, located between the camera and the analog modules, is a rotary slide which

Fig. 7 — Setting the Geophones Downhole.

Fig. 8 — Preparing the Shot Hole.

give sequential access to any 24 adjacent cable T.O.'s and helps eliminate excessive equipment movement. The patch panel/step calibrator, attached to the top of the roll-along, helps monitor and calibrate individual channels on the oscilloscope, which sits above the controller. And finally, the radio blaster or Synchrafone above the oscilloscope is used for two-day communications and the generation of the fire command.

The data flow then for this system is as follows:

> The controller instructs the Synchrafone to generate a fire command and then allows the tape and camera to get up to speed. After the controller's programmed delay, the explosive source is fired. The geophones translate mechanical vibrations into analog electrical signals which flow through the cable into the patch panel and then the roll-along. Here the setting determines which geophone outputs are recorded, and then the data goes to the analog modules. It is filtered, sent to the controller for formatting, and then transmitted to the tape transport. The transport records the data, reads it, and sends it on the camera which produces monitor records.

After the recording is finished, the crew must go back over the line picking up any trash and plugging the holes (Figure 12). Peabody's crew uses plastic discs which are shoved two to three feet down the hole and then filled in with the cuttings. The only trace left is a few tire tracks and small mounds of dirt which are naturally reclaimed within a year. Larger vibrators or heavier drilling equipment would induce correspondingly greater surface damage.

Fig. 9 — Securing the Seismic Source Downhole.

Fig. 10 — Operation of the Synchafone and Shotgun during Firing Sequence.

Fig. 11 — Peabody DFS-V Recording System.

Fig. 12 — Plastic Plugs Used in Hole Reclamation.

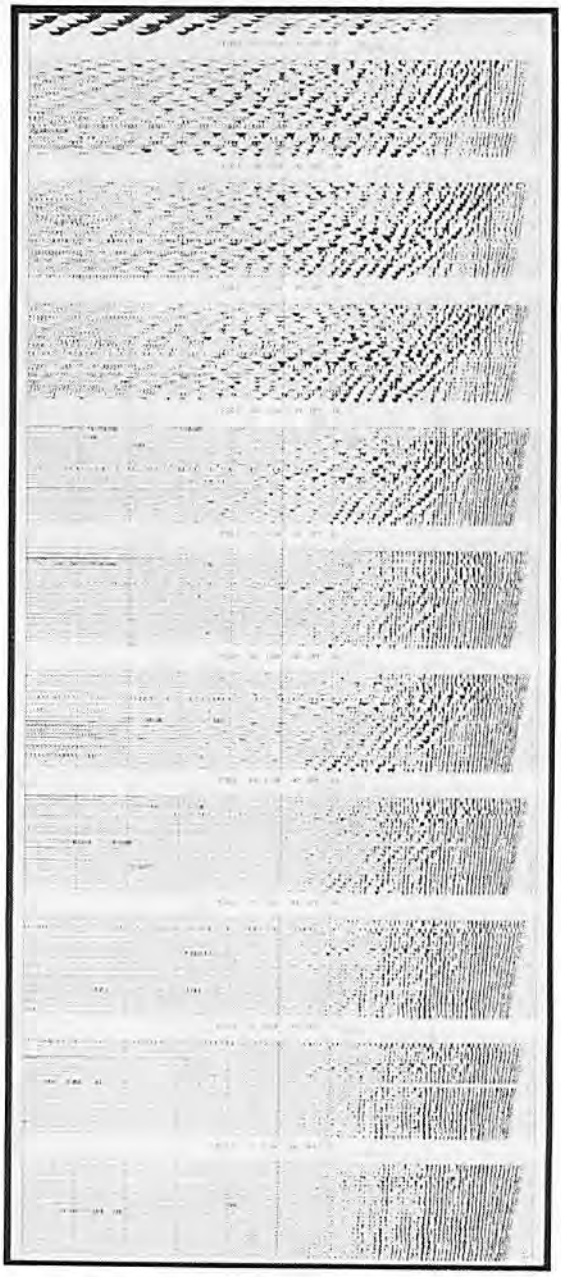

Fig. 13 — Demultiplexed (DMX) Records of Line 1.

PROCESSING

The final procedure in running a seismic survey is the processing. Once the data is collected and brought back to the office, the party chief begins an inventory of the records that should be sent to the processors. Depth of geophones, depth of shots, station elevations, and notes on irregularities in the recording sequence must all be compiled to aid the processing of the data. When the processors get the data, the first thing they do is run a DMX or "dump". They make a paper record of what is on tape separating the data into single traces which correspond to single geophone stations. This gives them a preliminary look at the quality of the recordings. Figure 13 shows a portion of the dump of Line 1. This section gives some good examples of raw data and a chance to see what the processors look for. First, each of the columns are records of individual shots showing the data on all 24 channels. The vertical scale is time, the horizontal is the distance from the shotpoint. The reflection data can be seen in the nearly horizontal alignment near the top of the record. The slight slope in the data is actually hyperbolic with the concave side down. This slope is produced from the time delay in a signal reaching the nearest geophone sooner than the farthest. The reflection data themselves are very good. Strong coherent alignment of peaks with a frequency content around 250 Hz can be seen. Some lower frequency noise is present in the steep slope alignment, especially in the first four columns. This can be due to ground roll and air wave shocks from the explosion, but in the first four bad shot coupling is also a reason. In these, some of the energy escaped to the surface so a greater percentage of low frequencies was returned with the data.

Another necessary correction to the data is statics. This process corrects each trace for elevation deviations and the time offsets caused by variations of the weathering layer. Move-out, or the hyperbolic slope, which is very small for our shallow data, and the static corrections are two of the biggest problems with processing seismic data.

Fig. 14 — Depth Section of Line 1.

INTERPRETATION

It was mentioned before that depth sections can be constructed; the time to depth conversion, however, can produce areas of distortion in the section. This distortion can be explained if one understands the role of velocity and spatial orientation in seismic processing. A time to depth conversion presumes an exact knowledge of the velocity distribution in three dimensions around the seismic line. A time scale presumes only a close approximation of that velocity distribution in only two dimensions. The first problem in a depth section, then, is the assumption that spatial relationships and temporal relationships are in 1:1 correspondence. In other words, the placement of the line over the exact three-dimensional geometry of the stratigraphic section assumes a perfectly normal orientation to the strike and dip of the beds and therefore, arrival times derived from purely planar relationships. Local abnormalities will invalidate this assumption thereby causing distortion in the theorized depth section. The second problem occurs in assumptions about velocity in individual media. When move-out corrections are made, adjusting the hyperbolic slope to remove the effect of varying shotpoint geometries, stacking velocities are estimated for specific depth intervals. If a depth section is made, the processor must assume these estimated velocities vary smoothly between the specific points of velocity analysis along the line. It is from this assumption that the distortion may result. If the actual stratigraphic medium contains a zone of greater velocity, the horizons under this zone will appear antiformal, while a locality with lesser velocity will produce synformal features.

In the depth section from Line 1, shown in Figure 14, note that the structure near the middle looks like a very distinct, domed graben. In Figure 15 however, the final time section of Line 1, that structure is nowhere near as pronounced. Taking the first darkened reflection to represent the No. 6 Coal horizon, the areas over old works have a very ragged continuity of peaks.

Fig. 15 — Seismic Section of Line 1 With Data Interpretations and Corresponding Drill Hole Locations.

A greater percentage of low frequency signals is also seen, which could be caused by the roof/coal interval absorbing the high frequency waves. Although the old works are there, it is difficult to interpret specific areas of chambers, roof fall and general roof weakness because these specific situations all affect the reflections similarly. The first obvious discontinuity is probably the fault; and subsequent drilling placed an offset exactly at this position. The second discontinuity appears as a small anticline-like structure possibly associated with a minor fault.

On Line 2, shown in Figure 16, the number of interruptions within the interpreted coal seam, again the first dark reflection, indicate a very fragmented area. The corresponding drill holes though, showed a good conformance to the interpreted section. The location of the displacements and the absence of the No. 6 Coal where there appears to be a channel, show the high degree of success with the system.

INTERPRETATION PROBLEMS

Admittedly, there were a few problems with the Mine #10 data, the most obvious being the time offset on the major fault. Where expected and later confirmed, ten-foot displacements were found, the seismic data showed offsets of 20 to 25 feet. Also the faults appeared as reverse on the section, but normal when drilled out. The excessive offsets might be explained by compositional changes in the roof strata around the fault zone and the apparent reverse sense of the faults explained in that, under certain

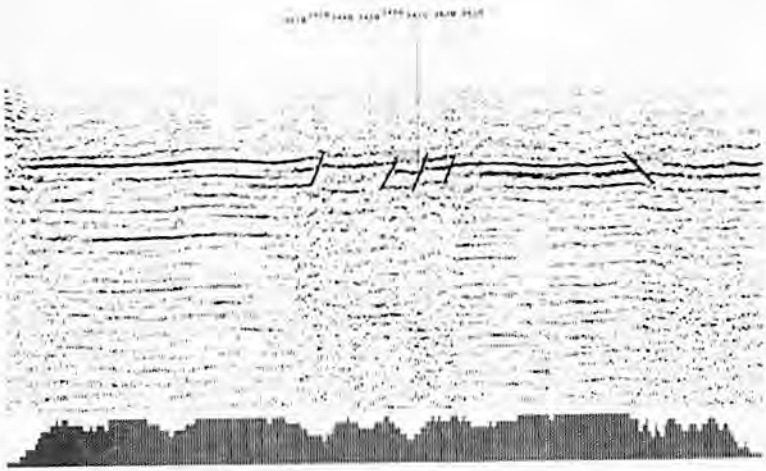

Fig. 16 — Seismic Section of Line 2 With Data Interpretations and Corresponding Drill Hole Locations.

conditions a strike/slip fault can show up as an apparent reverse fault. One must also consider that under the coal horizon very little of the data line up in coherent strata and without distinct offsets it is very difficult to extrapolate the direction of such small faults. Although the data did show some frequencies in the range of 250 to 275 Hz in the field records, the frequencies in the stacked records were around 125 to 150 Hz. These low frequencies consequently made the resolution of the data coarser. The Mine #10 data were useful and accurate. The fault was correctly located and additional geologic features were evident. The subsequent drilling program enhanced the credibility of the seismic data as well as established accurate measurements of structure positions and fault offsets.

Fig. 17 — Complete Set-Up of the Experimental Downhole Shotgun.

PRESENT PROJECTS

CALIBRATOR

The question can now be asked, what is Peabody currently doing with its system? In an effort to improve techniques, several projects were launched to help increase the reliability of the system. The first of these projects was the patch panel/step calibrator described earlier. It was designed to monitor the entire system's response to a single electrical impulse. With it, a technician can determine the response variability in each geophone or observe any change between the response of individual channels. This is extremely useful in providing our processors with an accurate base from which they can make data attenuations.

SHOTGUN

The second project was the downhole shotgun, shown in Figures 17 and 18. After the work on Line 2, Peabody began to look at the possibility of a repeatable seismic source. An economical, repeatable, low-energy impulsive source was found in the shotgun. Its repeatable firing permits summing of successive shots to enhance signal to noise ratios. The shotgun shells are a low-energy source which will minimize ground roll and air wave disturbances and prevent hole deformation, and at the same time, the impulsive nature of the shell detonation gives the high frequency content needed for Peabody's work. To top it all off, the availability of standard shotgun shells eliminates the limitations and cost of handling explosives.

To operate the gun, it is charged from its own battery source and fired automatically through the Synchrafone system. The shotgun time break (or the moment of blast) and the up-hole time are registered, combined and transmitted through the cable to the van for recording on tape. An additional separate unit which allows manual operations of the shotgun was designed for safety in the event of a misfire. The system does work, but it still has a few bugs to work out.

MAGNETOMETER

In response to Peabody's request to test another kind of low-cost, geophysical technique, the Illinois State Geological Survey loaned personnel and a fluxgate magnetometer for a ground vertical component profile over a buried, basic igneous dike at Peabody's Equality Mine. Drilling had disclosed igneous material and coked coal at about 30-foot depths occurring at the positon of the coal. These thin dikes seemed to branch laterally into

Fig. 18 — Close-Up of Dismantled Shotgun.

the coal interval. The experiment found the technique very useful and pinpointed the dike locations within a single 20-foot station interval. This enabled single dikes to be projected for several thousand feet. The ability to calculate dike thickness and geometry, using two-dimensional dike interpretations and independent magnetic susceptibility measurements, is now being developed. The technique to locate and map the dikes was so successful that Peabody has already purchased its own magnetometer (Figure 19). Peabody also plans to use this instrument to map burned coal outcrop areas in their western coal fields. Peabody Coal would like to take this opportunity to formally thank the Survey for its valuable assistance.

Fig. 19 — Peabody Magnetometer.

CONCLUSION

Going back to the topic of the work at Mine #10, it would be best to stress a few points that were important to Peabody's endeavors. Considering the unique properties of seismic coal exploration; shallow depth, high resolution, and fast sample rate; Peabody's crew was able to select field parameters, following the procedures first developed by the oil industry, to obtain good quality field data. The data were used to create interpretable record sections, and the interpretations showed a fair to good correspondence to drill data. It is the processing of field data that remains problematic. Present processing methods cannot always rectify statics, velocity, and frequency degradation to comply with specific needs, but it is to this end that Peabody is developing instrumentation which will help the reliability of Peabody's DFS-V system. Peabody's recent experience suggests it is most beneficial to conduct seismic surveys prior to mine development, or at least as soon as a particlar problem is encountered. Although some confirmation drilling will always be necessary, continued experience with data acquisition will increase the reliability of the data as well as the credibility of seismic method, thus permitting more efficient, less costly drilling programs.

Chris Ledvina: What is the practical limit of length for a geophone survey?

John Acker: With our system, we have worked on the scale of 2,000 feet to around 5,000 feet, a mile, or even a mile and a half. We cannot use our particular system on large scale work because of the geophone spacing which we have in our cables. It's a logistical limitation of our work.

Jim Palmer: One of the big problems with the high resolution seismicgraph is that very commonly the coal companies have tried it and have found it very expensive or have been unable to get good records in a certain area. While I think you have given a good description of the basic techniques, I don't think you have addressed the practicality of this method and the cost involved as far as mine development and mine exploration is concerned. Could you give us something more on the actual cost and how far this method is from practicality?

John Acker: We have calculated that the cost for an individual line runs at about $40,000 per line.* Now this includes the time for the people, all the equipment, the explosives, the recording tape, and camera records that we need to use. Larry do you want to include something?

Larry Kumamoto: I must mention that with our particular lines we did suffer some time setbacks, and this is why a lot of the salary data increases

*The amount, $40,000, given by the speaker refers to a group of three lines. The actual cost for each line ran about $13,000.

the cost of the lines. As far as the practicality of it, the line itself can be done rather shortly in the order of a month to two months. The turn-around time on the processing, however, can take as long as six months and that has happened for us. However, right now we are using processors that seem to be turning out our data in 3 to 4 months.

To the point of the general practicality, in central Illinois it is a special situation where high frequencies are obtainable largely because of shallow water tables. Other people have started to use hydrophones to increase their frequency response even further. But trying to extend this type of high--frequency work toward the east, toward West Virginia or Kentucky, (areas of very high topography where there is no ground water), you would have to take a different approach. It is my understanding that Consolidation Coal Company is operating a more conventional vibratory type source and has had success at finding channels in that type of terrain. This particular approach in getting high frequency is costly, but I think the cost John has mentioned here has been largely due to the experimental nature of getting in and out and doing just about everything we have done with a very small crew. The actual field work does not take long once we have access, and as John said,the greatest time interval is spent with the processors.

Earl Widel: Would there be any technical advantage to drilling holes in the coal face itself and firing the shots there and taking it up on the surface.

Larry Kumamoto: Well, there are several other approaches to coal seismic work that have been taken. I think that particular method that you are talking about has not been looked at very much. There is hole to hole work where a shot down one hole and a receiver in another is used to estimate the continuity of the seams between those two holes. There is underground work where geophones are positioned on one side of the longwall face and shooting is done on the other side straight through the coal, which is analagous to surface seismic technique. There is some other two dimensional work with coal seams in which seam waves are generated and frequencies of the guided waves are interpreted. As for shooting underground in coal and receiving at the surface, I really don't think there are any practical uses for this other than as a means of measuring attenuation.

Robert Izard: Thank you John and Larry for your interesting paper. The next paper we are about to hear is from Colin Treworgy of the Illinois State Geological Survey. Colin received his Bachelors degree in geology from Principia College and has been with the Survey since 1975. His major responsibility has been mapping and evaluating coal deposits throughout the state and has mapped more than 15 billion tons of coal resources during this time. Mr. Treworgy.

A NEW LOOK AT DEEP — MINABLE COAL RESOURCES OF ILLINOIS

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INTRODUCTION

The United States has vast coal resources that have been widely touted as an answer to our future energy needs. However, very little is known about the minability of these deposits. For instance, how do the characteristics of these resources (such as thickness, depth, and quality) compare with the characteristics of deposits currently being mined? How much of this coal can be mined at today's prices? How soon will the most easily mined deposits be depleted?

Answers to these questions are of great importance to the coal industry, coal users, government, and private landowners. Coal companies and landowners would like to know how the deposits they own or are planning to lease compare with the entire body of coal resources. Government agencies and companies responsible for providing services connnected with mining (such as transportation or housing) would like to know where new mines are most likely to be opened. Consumers of large quantities of coal, such as utilities, need information about the quantity and quality of the easily minable coal available.

This article, describing recent work done at the Illinois State Geological Survey (ISGS) to evaluate the minability of coal, provides an important new perspective on the coal resources of the state. A more detailed presentation of this work will be published by the Survey in 1982 (Treworgy and Bargh).

Illinois has about 181 billion tons of identified coal resources spread over more than 50 counties. Figure 1 shows the amount of deep-minable coal in each county; however, it does not give any indication of the minability of these coal resources. Minability of these coal resources can vary greatly from county to county, as will be shown for two counties — Crawford and Madison Counties (fig. 2). This article discusses the evaluation of deep-minable coal resources only, but the general method described could be applied to surface-minable coal as well. Deep-minable coal refers to coal thicker than 28 inches and deeper than 150 feet that would generally be mined by underground methods.

EVALUATION OF DEVELOPMENT POTENTIAL — AN EXAMPLE FOR TWO COUNTIES

Crawford County in southeastern Illinois contains 7 billion tons of coal in seams 28 inches or more thick; this tonnage is roughly equivalent to the total coal resources of Oklahoma. Considering this statistic, one would ex-

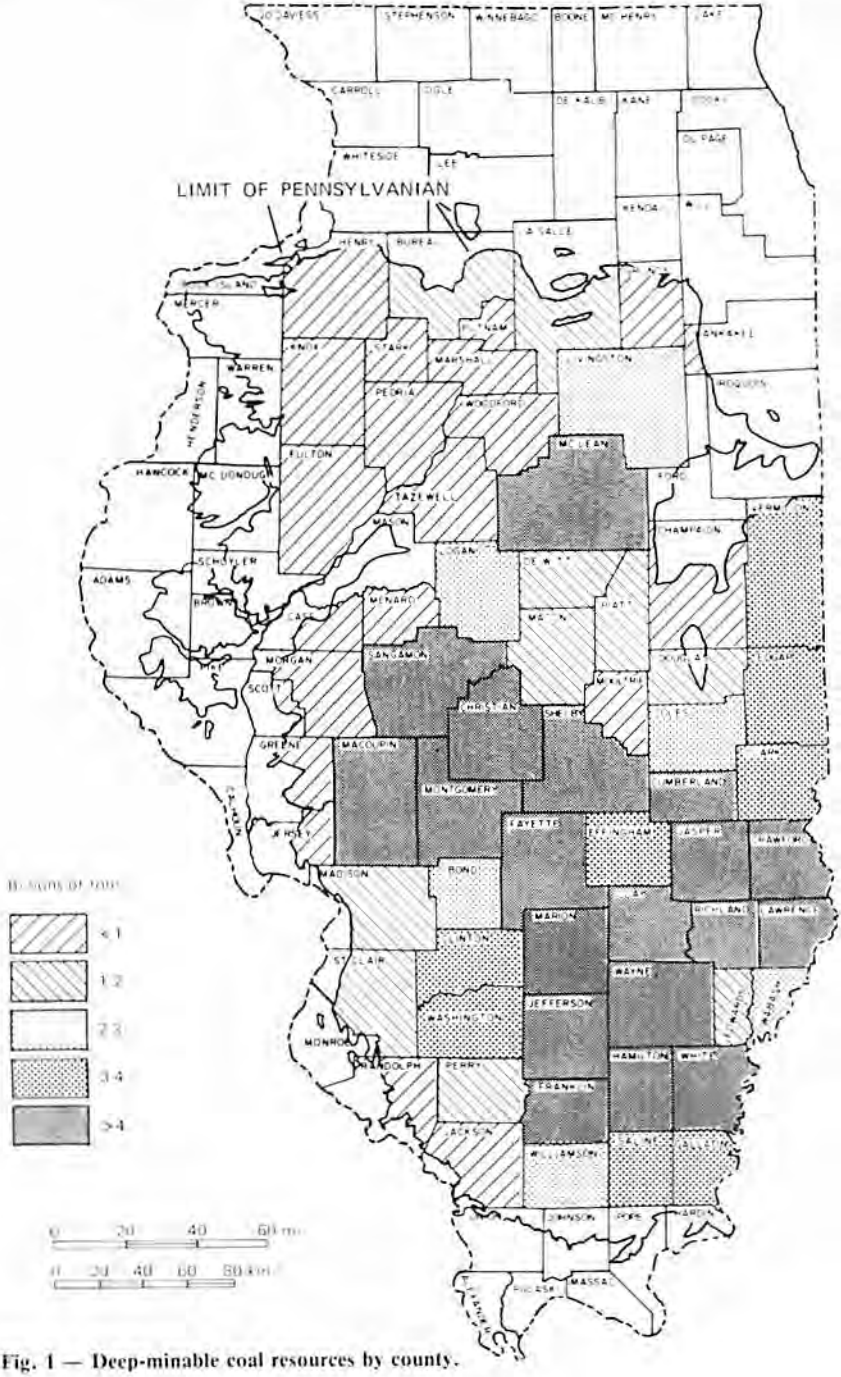

Fig. 1 — Deep-minable coal resources by county.

Fig. 2 — Index map showing Crawford and Madison Counties.

pect Crawford County to be an important coal producer. However, no mines are currently operating in that county, and no significant mining activity has ever occurred there. Why have these resources not been developed?

In Figure 3 the coal resources of Crawford County are shown divided into two categories: minable and restricted. The restricted coal consists of 2.5 billion tons within areas densely drilled for oil and 0.2 billion tons under towns, interstate highways, and other surface development. The oil fields are large areas where oil wells have been drilled on a spacing of one well every 10 to 20 acres. Because federal and state laws require that barriers of unmined coal be left around oil wells (unless they are properly plugged), it is difficult and uneconomical to develop a mine where wells are closely spaced. Although it is possible to mine coal in oil fields, it is not likely to be done on a large scale in the foreseeable future because of the very high cost involved. The coal under towns, interstates, and other surface developments will probably not be extensively mined because of the risk of subsidence.

Estimates of "minable" coal (as in fig. 3), typically include coals with a wide range of thickness, depth, and quality. Although technically minable, much of this coal cannot be mined at a price competitive with that of currently mined deposits. To make the resource estimates more useful to persons associated with the coal industry, the potential for development of the deposits should be evaluated.

Two of the most important factors to be considered in evaluating a deposit are the thickness and depth of the seam. The potential for development of a coal deposit can be evaluated on the basis of these two factors. In-

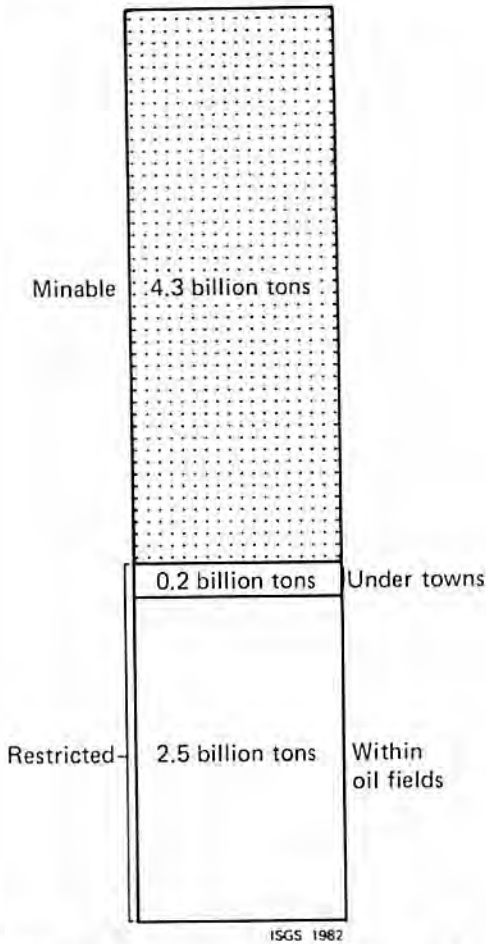

Fig. 3 — Deep-minable coal resources of Crawford County.

formation on thickness and depth of seams currently being mined and leased (fig. 4) and information obtained through interviews with seven coal companies and consultants were used in this study to define three categories of potential for coal development:

1. *Coal with the highest potential for development:* coal with a thickness and depth equivalent to deposits now being mined. Currently, this category consists of coal greater than 4½ feet thick and less than 400 feet deep, or greater than 5½ feet and less than 1000 feet deep (fig. 4).

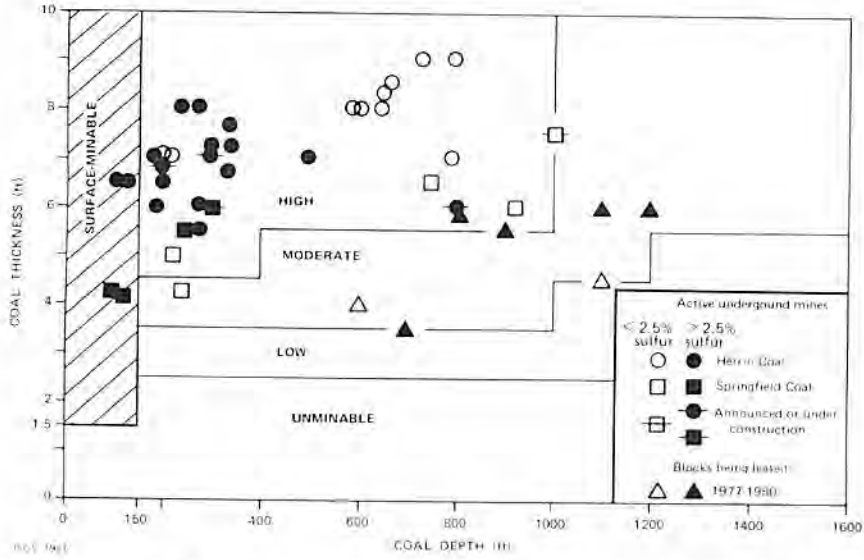

Fig. 4 — Classification of developmental potential of deep-minable coal in Illinois, based on the thickness and depth of coal currently being mined or leased. Solid symbols indicate that coal has a sulfur content greater than 2.5 percent. Stippled symbols indicate a sulfur content of less than 2.5 percent.

2. *Coal with a moderate potential for development:* coal seams being actively leased, but slightly thinner and/or deeper than deposits currently mined. This coal is excluded from the high potential category, but is greater than 3½ feet thick and less than 1000 feet deep; greater than 4½ feet thick and less than 1200 feet deep; or greater than 5½ feet thick with no limit on depth.
3. *Coal with a low potential for development:* coal significantly thinner (but over 28 inches) and deeper than deposits currently mined. This coal has been traditionally included in our resource estimates as minable because technically it is minable (Cady, 1952).

Coal less than about 2½ feet thick is considered unminable (fig. 4).

As shallow, thick depostis are mined out and the price for coal increases, mining and leasing activities will be extended to thinner and deeper seams, and the limits of the high and moderate development potential categories will change.

When these definitions of development potential are applied to the coal in Crawford County now classified as minable, only 9 percent (0.6 billion tons) of the original 7 billion tons has a high potential for development and only 21 percent has a moderate potential (fig. 5). The remaining minable coal is too thin or too deep to be of immediate interest.

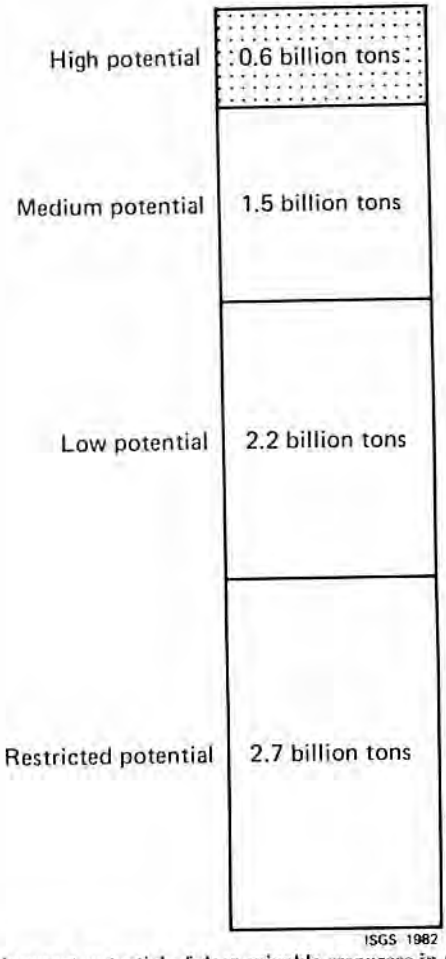

Fig. 5 — Development potential of deep-minable resources in Crawford County.

COAL QUALITY

The quality of the coal also influences the minability of a deposit. Although little is actually known about the quality of coal in Crawford County, some comments can be made about its sulfur and chlorine content. The sulfur content of most of the coal in Crawford County is probably high (3 to 5 percent); however, because most Illinois coal has a similar sulfur content, coal in Crawford County is no less desirable than much of the coal produced in the state.

The chlorine content influences the development potential of some Illinois coals. Although no coal is currently considered unusable because of chlorine content, high-chlorine coals are less desirable. Coals with high chlorine may cause corrosion and fouling in boilers. All Crawford County

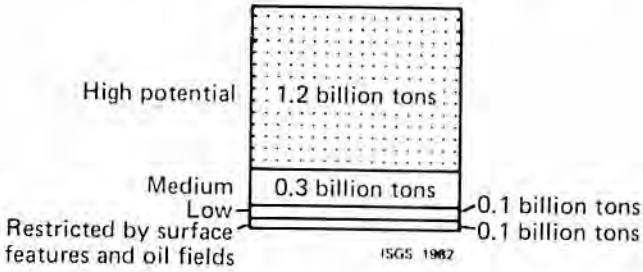

Fig. 6 — Development potential of deep-minable resources in Madison County.

coal probably has a chlorine content of 0.3 percent or greater; about 55 percent of the coal with a high development potential may have a chlorine content of 0.4 percent or more. In comparison, most coal currently mined in Illinois has chlorine content of less than 0.4 percent.

Size of Mining Blocks

Another parameter that must be considered is the size of the blocks of minable coal. The coal in Crawford County is found in three different seams. The contiguous blocks of coal with high potential are not large; many blocks do have sufficient tonnage to support a modern mine. Therefore, although Crawford County has 7 billion tons of coal resources, there may be no more than a few good mine sites with coal similar to deposits currently being mined.

Madison County provides an interesting contrast to Crawford County. Madison County has only 1.7 billion tons of deep minable coal — about one quarter of the resources of Crawford County (fig. 6). About 70 percent of the coal (1.2 billion tons) has a high potential for development. Only a small amount of coal has a low or restricted potential for development. Most of the coal in Madison County has a chlorine content of less than 0.3 percent; some has a medium-to-low sulfur content (less than 2.5% sulfur). In addition, this coal occurs in large blocks with many good mine sites. Madison County, with just one-fourth of the coal resources of Crawford County, has twice as much deep minable coal with high potential for development.

The evaluations of minability of coal in Crawford and Madison Counties show that estimates of the coal resources in the ground are not reliable indicators of where, when, and how much mining is likely to take place in the future.

DEVELOPMENT POTENTIAL OF DEEP — MINABLE COAL IN ILLINOIS

Illinois has 161 billion tons of deep-minable coal. Approximately 26 percent (44 billion tons) has a high development potential; 33 percent (54 billion tons) has a moderate development potential; and 28 percent (45

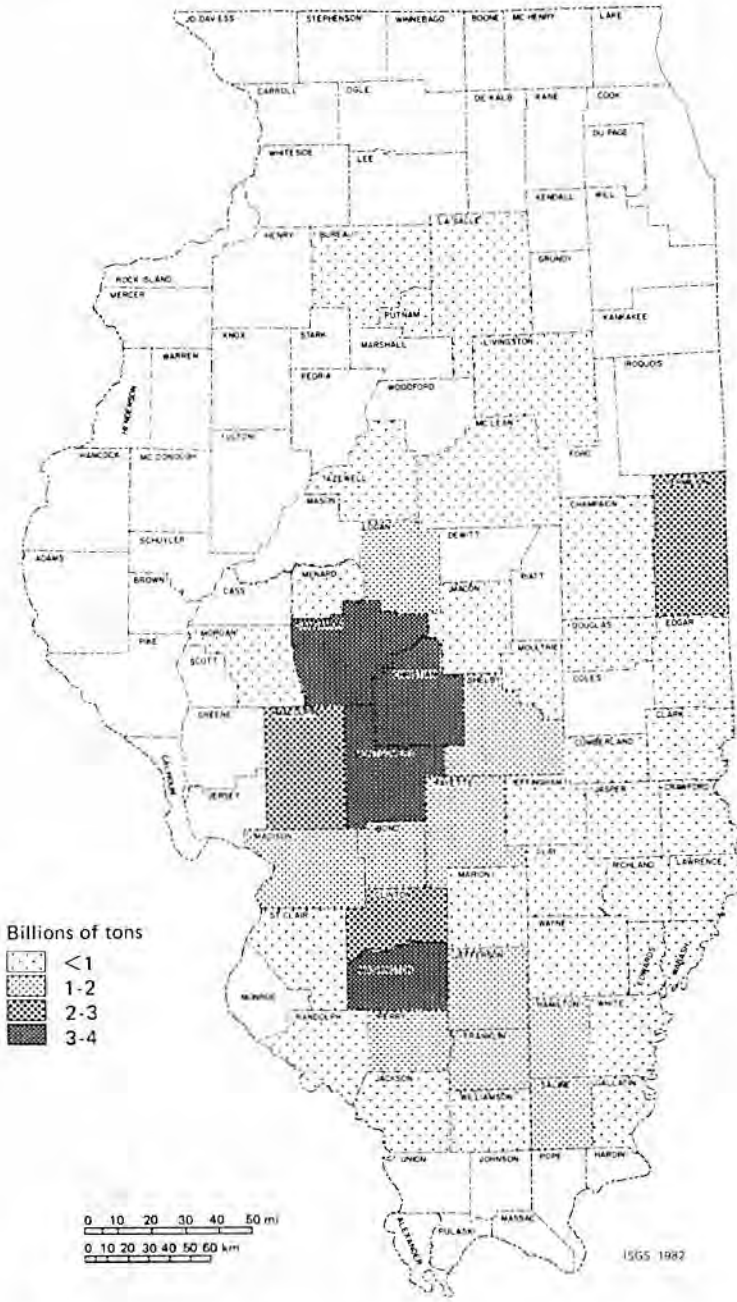

Fig. 7 — Deep-minable coal resources with high potential for development.

billion tons) has a low development potential. About 11 percent (17 billion tons) underlies surface development or public lands, or is within oil fields; this coal is considered to have a restricted development potential.

Total deep-minable coal resources are distributed more-or-less evenly over a large area of the coal field. However, the distribution of resources by category of development potential is quite uneven (figs. 7-9) and helps to explain the location of current mining and leasing activity and to indicate the general future trend of mining activity.

Resources with a high development potential are concentrated in the west-central, southwestern, and southern parts of the coalfield (fig. 7). These have been and are the major areas of underground mining in the state. More than 80 percent of current production from underground mines is from these areas, and underground mining is expected to be concentrated in these areas for many years.

Most of these resources are believed to be controlled by coal companies. Furture exploration and leasing activities in this areas will be conducted primarily by companies trying to consolidate their holdings.

Resources with moderate potential for development are concentrated in the southeastern and east-central parts of the coalfield (fig. 8). Although there has been relatively little underground mining in these areas, a considerable amount of leasing activity has occurred over the last five years. As deposits with a high development potential are mined out or committed to markets, mining activity will gradually shift to deposits that now have a moderate potential for development. The ratio of recoverable resources (50 percent recovery assumed) with a high development potential to current annual production is more than 350:1. Therefore, it will probably be many years before there is a significant amount of mining of the resources with moderate potential.

Deep-minable resources with low potential for development are concentrated in the central, east-central, and northern parts of the coalfield (fig. 9). Because the ratio of recoverable resources with a high or moderate development potential to current annual production is more than 800:1 it is unlikely that resources with a low development potential will be mined in the foreseeable future.

Size of Mining Blocks

In addition to having favorable thickness and depth, a coal deposit must be in a contiguous block of sufficient size to justify the investment in mine construction and equipment. A block of deep-minable coal must have 25 to 50 million tons of recoverable coal, which is roughly equivalent to 50 to 100 million tons of in-place coal.

Figure 10 shows the general location of large mining blocks with a high potential for development. Townships that have more than 100 million tons of coal with a high development potential probably have one or more blocks that could support a large underground mine (2 million tons per year for 25 years). Townships with 50 to 100 million tons of coal with a high develop-

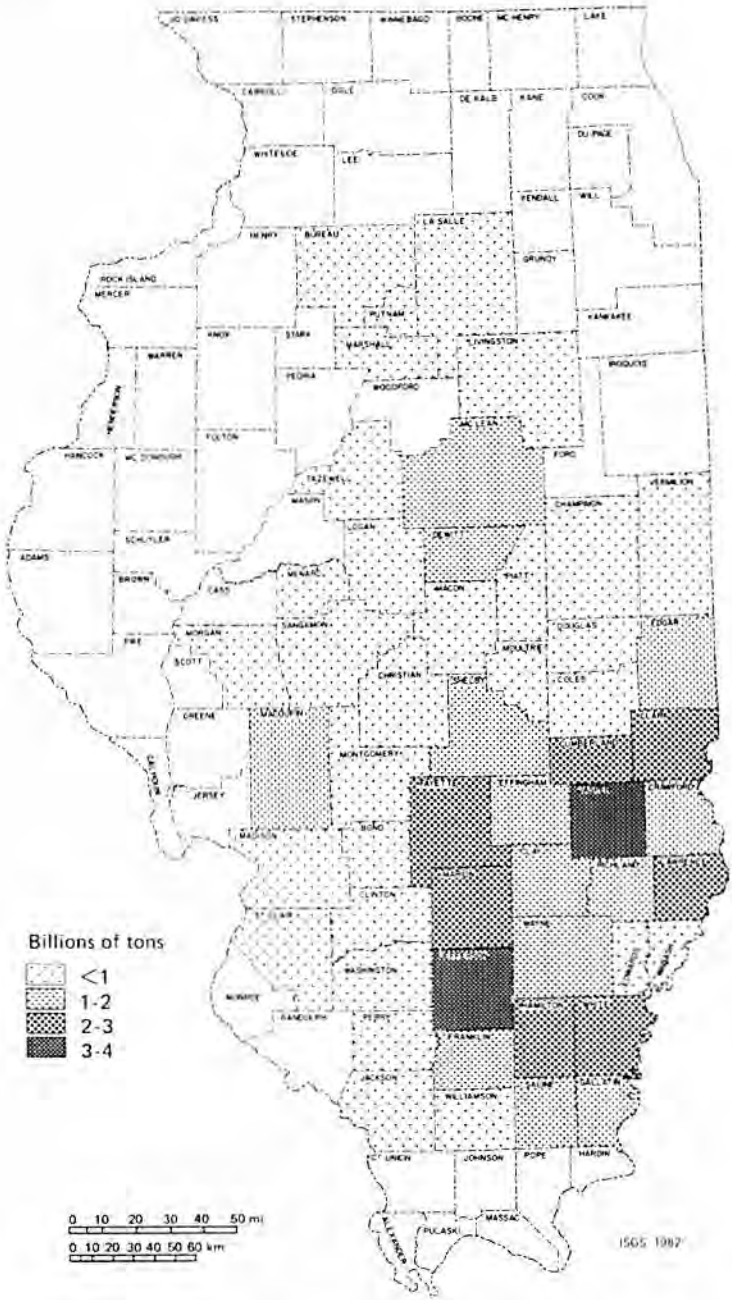

Fig. 8 — Deep-minable coal resources with moderate potential for development.

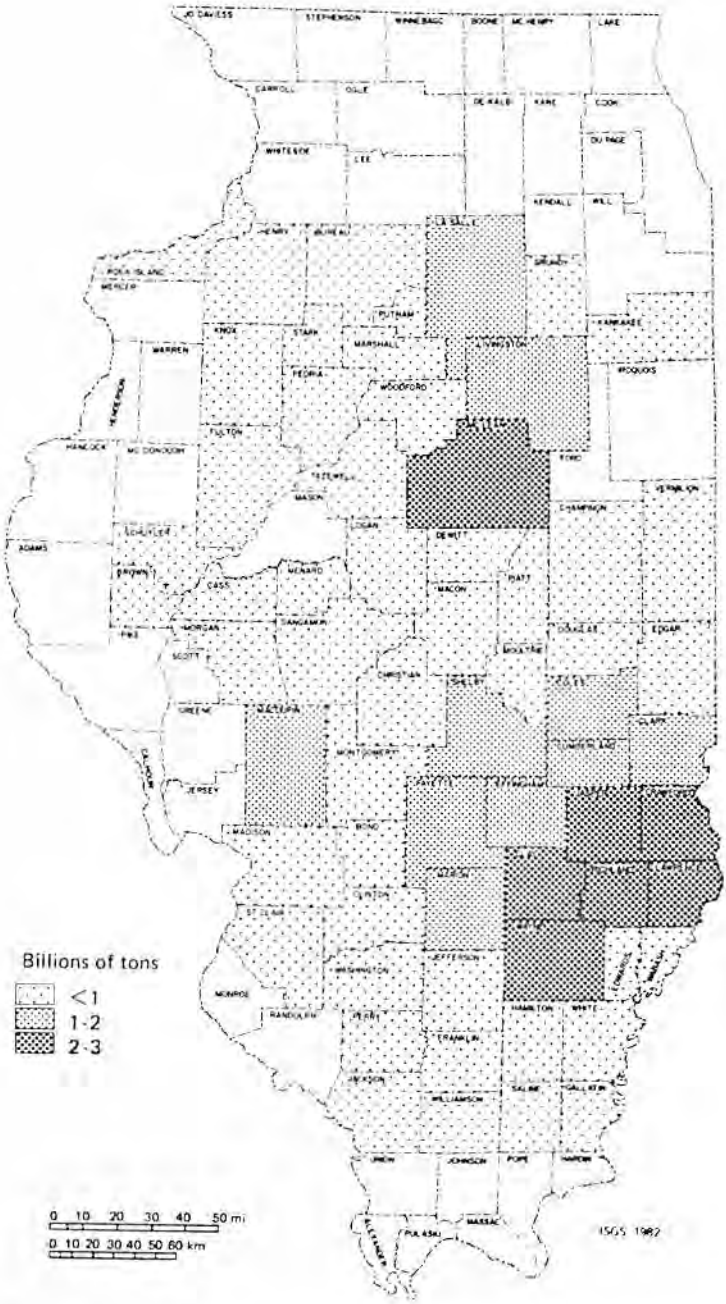

Fig. 9 — Deep-minable coal resources with low potential for development.

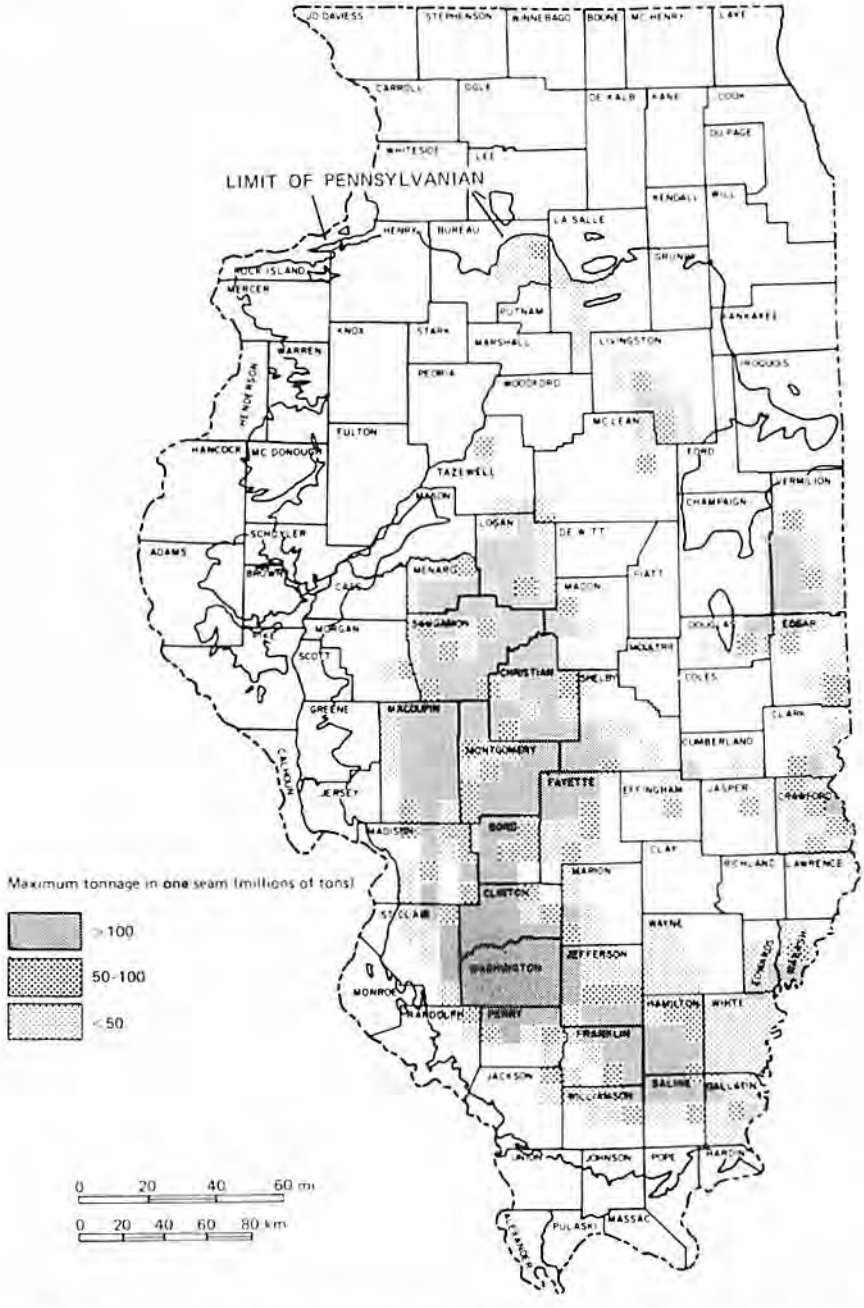

Fig. 10 — Townships containing deep-minable coal resources with high development potential.

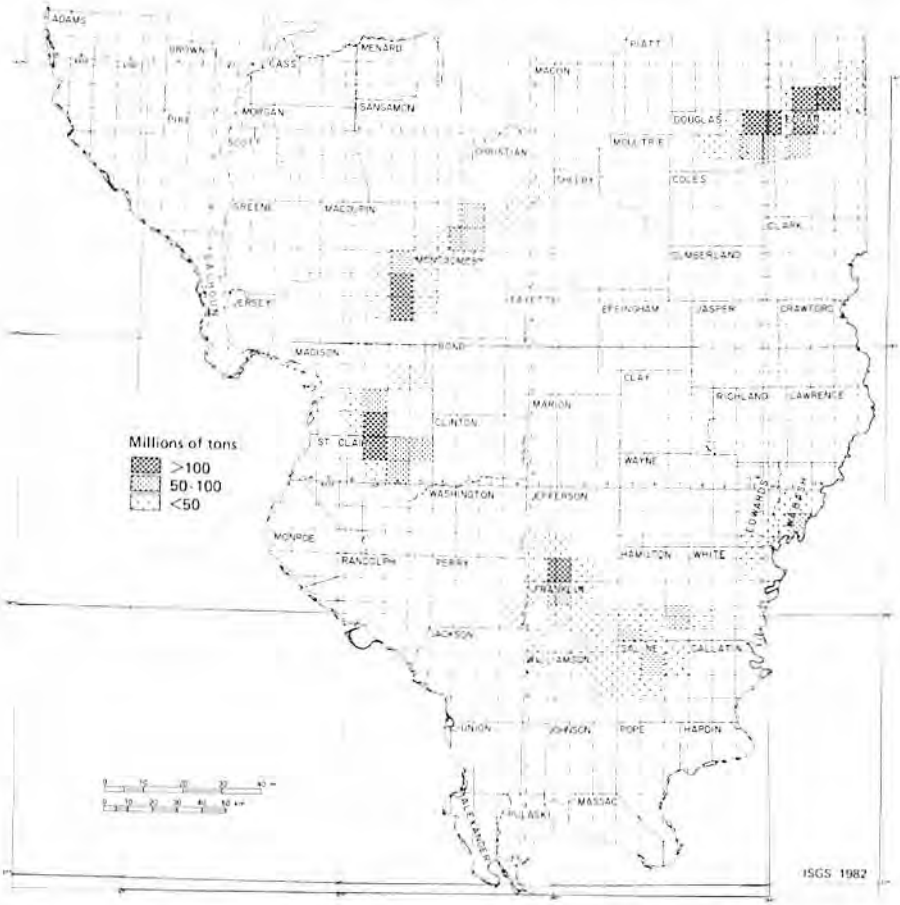

Fig. 11 — Deep-minable coal resources with less than 2.5 percent sulfur and high development potential.

ment potential probably have at least one block that could support a medium-sized mine (1 million tons per year for 25 years). Depending on its position within the township, the block could be combined with coal in an adjacent township to support a large mine. Townships with less than 50 million tons of coal with high development potential probably could not, by themselves, support a modern underground mine; however, if the coal is contiguous to coal with high development potential in an adjacent township, there may be sufficient tonnage to support a mine.

Figure 11 shows the location of large mining "blocks" with a medium- to low-sulfur content (less than 2.5%) and a high potential for development. Because of the scarcity of these blocks and the relatively strong demand for coal with a lower sulfur content it is possible that even deposits with moderate potential may be attractive for mining at this time. Figure 12

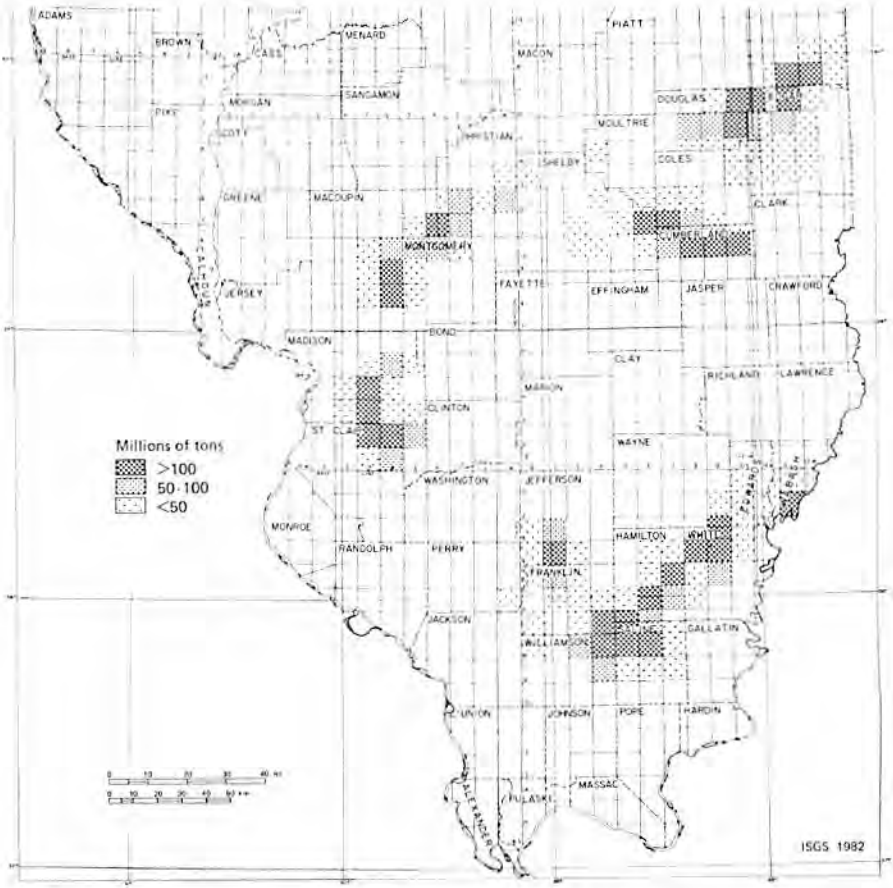

Fig. 12 — Deep-minable coal resources with less than 2.5 percent sulfur and high and moderate development potential.

shows the location of mining blocks of medium- to low-sulfur coal with a high or moderate potential for development. Nearly all of these blocks are controlled by mining companies.

Chlorine Content

The chlorine content of coal in Illinois ranges from less than 0.1 percent to slightly more than 0.7 percent (Chou, in preparation). Although the distribution of coal resources in each category of chlorine content is fairly even, much of the coal with a high development potential is in the lower chlorine categories (fig. 13). Seventy-seven percent of the high potential coal has an average chlorine content of 0.4 percent or less.

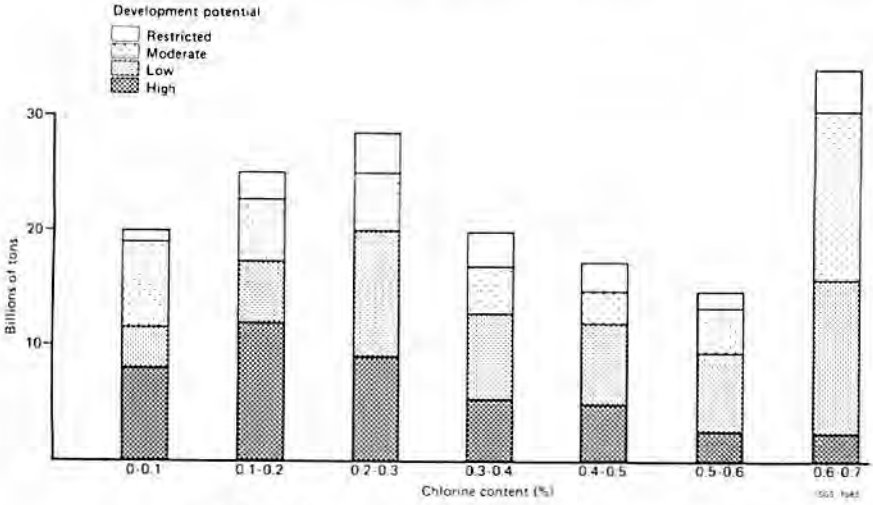

Fig. 13 — Chlorine content of deep-minable coal.

Additional Influences on Minability

Other influences on minability of coal being examined by the Illinois State Geological Survey are: the heating value of resources, and the location of resources relative to features such as cities, dams, public lands, interstate highways, and areas densely drilled for oil. The evaluation of development potential will be updated periodically as new laws, changes in markets, or technology breakthroughs influence the development potential of Illinois coal. Additional factors that might be considered in future evaluations of minability are: the type of rock overlying the coal, ratio of the thickness of the bedrock overburden to the unconsolidated materials overburden, and additional coal quality parameters.

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2. Chou, C. — L., in preparation, Distribution of sodium and chlorine in the Springfield (No. 5) and Herrin (No. 6) Coals of the Illinois Basin, Illinois State Geological Survey Circular.
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Robert Izard: Thank you Colin. Mr. Earl Antonson, Senior Vice President, Engineering, of Roberts and Schaefer will deliver our final paper. Mr. Antonsons' subject is the "Xinglongzhuang Mine: A New Coal Preparation Plant for the Peoples Republic of China". Earl has 30 years experience in material handling and processing with 21 of those years with Roberts and Schaefer. He received his education at the Chicago City College and the Illinois Institute of Technology. He was also one of the chief negotiators for the contract for the mine preparation plant. I would like to present Mr. Antonson.

Earl Antonson: Since we have such a diversified group, a comment about Roberts and Schaefer Company is warranted. We are an engineering and contracting firm, primarily specializing in coal preparation and materials handling. Included in the Roberts and Schaefer family, besides our main engineering offices in Chicago, is a branch in Salt Lake City. The family includes the group from West Virginia, ENI Engineering from Pittsburg, Pennsylvania and also includes the familiar names of CME in St. Louis, and Paper Machine from Bloomfield, West Virginia.

The name of the plant that we are going to be talking about is Xinglonzhuang, and I have as much trouble pronouncing it as the Chairman. One of the dirtiest tricks the Chinese pulled on us was the changing of this name right at the end of the project. By the time I learned the previous name they changed it, and I had to learn it all over again. This was supposed to have been basically a technical presentation on the preparation plant, but I think there has been an interest expressed to broaden this to a little of an overview of just what it is like to do business with the Republic of China.

XINGLONGZHUANG MINE: A NEW COAL PREPARATION PLANT for THE PEOPLE'S REPUBLIC OF CHINA

EARL C. ANTONSON
Senior Vice-President, Roberts & Schaefer Company
Chicago, Illinois

INTRODUCTION

This is to be a technical description of the Xinglongzhuang Coal Preparation Plant, but it is intended to also present a broad overview of what it is like to do business with the People's Republic of China.

In order to establish the realization of the enormity of this country, we will start with a brief review of Chinese geography and history:

- The People's Republic of China is the third largest country of the world in area: It extends 3,000 miles from the Pacific Coast in the east, westward into Central Asia, and more than 2,500 miles from north to south.

Fig. 1 — Location of Xinglongzhuang Mine.

- Its population was estimated at 975 million in 1978. (About ¼ of the world's population).
- Only about 11% of the land in under systematic cultivation.
- This tremendous population and the cultivated land is generally concentrated in the eastern area of the country. In our travels away from Peking, we noted that every available piece of flat land was under cultivation.
- The origins of the Chinese State can be traced back to the second millennium before Christ; documentary records are available back to 1100 BC. Foundations for the Chinese Republic were laid in 1911 when the Manchu Dynasty and its imperial system were overthrown. From the 1920's until 1949, sporadic civil war marked the rivalry between the Nationalists and Communists, who finally carried off a victory under the leadership of Mao Tse-tung, one of the most influential personalities to ever affect the destiny of a nation. Beginning in 1949, the United States and some of its allies boycotted the People's Republic of China until 1972 when state relations were reestablished and ultimately culminated to full diplomatic relations in January, 1979.
- The Cultural Revolution which virtually halted China's economic growth occurred from the mid-60's to mid-70's. The notorious Gang of Four was blamed for this economic stagnation, which culminated in the now historic trials of December, 1980.
- The current strong man in China, Deng Hsio-ping emerged in 1978 with his four modernization programs which are the basis of the current atmosphere that our trade relationships now operate.

FACTS AND STATISTICS ABOUT CHINA COAL INDUSTRY

- Currently ranked as the world's third largest producer of coal with an annual production of 635 million tons per year (1979).
- Estimated reserves of 600 billion tons:
  - 70% Bituminous
  - 17% Anthracite
  - 13% Sub-bituminous and Lignite
- The Chinese coal consumption in 1979 is broken down as follows:

Electric Utility	18%
Metallurgical Industry	17%
Railroad	5%
Chemical, Construction Industries and Others	39%
Household Heating	21%
	100%

Approximately 18% of the coal is being washed. They recognize the need and desirability to substantially increase this amount.

Virtually all the production is used domestically. In the near future, China should not be a major factor in the world market because of

the lack of adequate inland transportation and deep water ports. Once these problems are solved, look for them to use this tremendous natural resource to acquire the foreign exchange they so greatly need.

ROBERT & SCHAEFER'S CONTACT WITH PEOPLE'S REPUBLIC OF CHINA

Our first contact was from the Ministry of Coal in 1976. At that time, we prepared a preliminary flowsheet for an unknown coal preparation plant. We had no further contact as a result of this first encounter. An invitation from the forerunner of the Foreign Trade Corporation now known as Macimpex, came in early 1978, to give a seminar to present our company's credentials. A second invitation was received shortly before our departure for Peking from Techimport, which was representing the Ministry of Coal, and our visit was extended to present a second seminar.

A delegation of Chinese visited the United States during June and July, 1978, and we escorted them on tours of various plants that Roberts & Schaefer had designed, and in our Chicago offices. During this visit, we received the information to prepare the initial flowsheet for the Xinglongzhuang Preparation Plant. In August, we returned to Peking with a proposal for limited engineering and equipment supply, only to find that their requirements were for a completely engineered U.S. facility. All equipment and material including structural steel, piping, wiring materials, etc., were to be furnished from the U.S. All labor, of course, was to be furnished from a Chinese source. During this visit, we travelled to the proposed job site (Fig. 1) which, at this time, was somewhat unusual. We were the first Americans to visit this area since 1949.

With this new information, we returned to Chicago and prepared a proposal to satisfy the new requirements. This proposal was presented the first of December, 1978, at which time we held technical discussions which led to some changes to our proposal. Preliminary commercial discussions were held at this time. We returned home shortly before Christmas with the intent of going back in mid-January, 1979, with our final proposition.

Our return to China was delayed and then indefinitely postponed while they reevaluated their financial position. The project laid dormant for approximately a year. In March, 1980, we were asked to return; this time by the First Ministry of Machine Building (FMMB) to discuss possible technology transfer of our proprietary equipment. While in Peking, at this time, we were given a revised scope of the preparation facilities. This time the emphasis was on providing as much material and equipment from China as possible. The project was discussed and the interface of supply was determined.

Again, we returned to the United States to revise our proposal. We were told that our success in receiving their business would be predicated on an acceptable combination of our plant proposition and a technology transfer agreement. In May, 1980, we returned to Peking with our revised

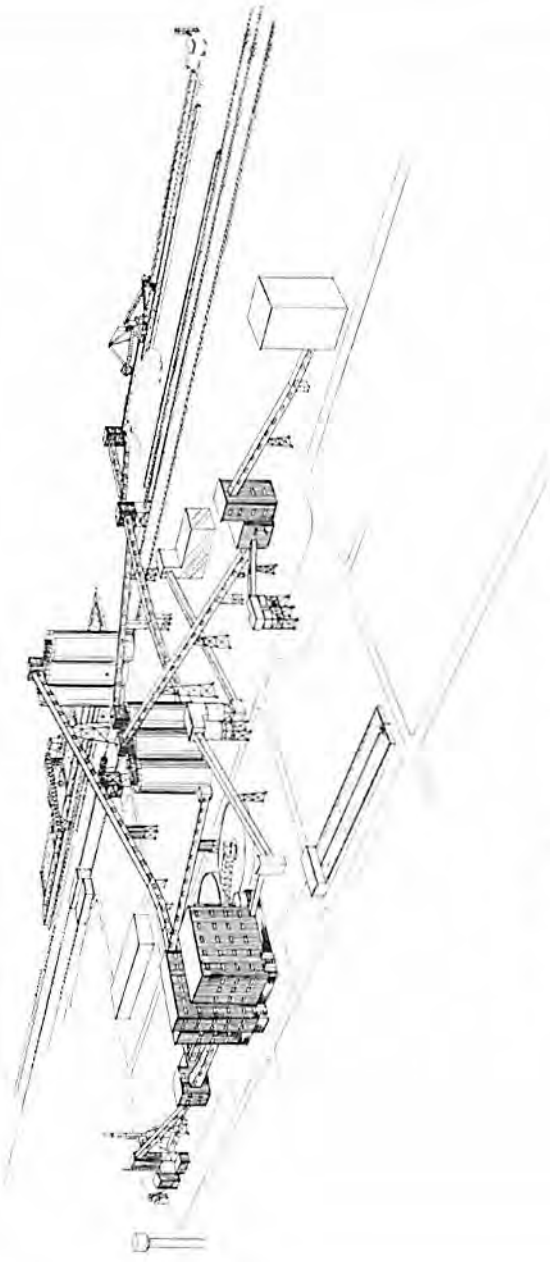


Fig. 2 — Sketch of preparation plant for the Xinglongzhuang Mine.

plant proposal and a licensing agreement for Roberts & Schaefer proprietary equipment.

The first several weeks were spent describing our proprietary equipment in considerable detail to the engineers from the various divisions of the First Ministry of Machine Building. These groups sometimes numbered as many as 30 people. During this time, we had specialists from our subsidiary companies, Tabor and CMI, to assist us with the very technical presentations we had to make. We visited the locations where they anticipated manufacturing our equipment.

Technical discussions on the preparation plant and technology transfer proceeded through early July. The question of supply of some equipment was left unanswered for sometime while the Coal Ministry and FMMB debated. This situation created an interesting power struggle. Since the directive to utilize Chinese products apparently had been made, the end user (Coal Ministry) had to put up a good position to have their way, which was to have all major equipment furnished from a U.S. source.

Once the division of supply had been determined, the meeting settled down to discussions on the commercial terms of the contract. These discussions continued until mid-September when an agreement for the preparation plant contract was concluded. The finalization of the licensing agreement was completed at the end of September.

DESCRIPTION OF THE XINGLONGZHUANG COAL PREPARATION PLANT

The contract Roberts & Schaefer received was for a 940 MTPH preparation plant and related facilities. (Fig. 2) The facilities include: a rotary breaker station, raw coal silos, preparation plant, thermal dryer, clean coal silos with rapid train loading, and a magnetite grinding circuit.

The preparation plant feed belt is equipped with an electronic belt scale, which controls the raw coal feeders and delivers at a constant rate to dual surge bins (Fig. 3). The surge bins are mounted on load cells, which control the trimming action of feeders ahead of two 5-meter Batac Jigs. The Batac Jigs handle the full 940 MTPH of 50mm x 0 raw coal; producing a refuse from the primary elevator (the only reject material from the entire plant) a middlings product from the second elevator, and 50mm x 0 clean coal. The jig clean coal is screened to produce a 50 x 37mm No. 2 clean coal, 37 x 0.5mm, and minus 0.5mm fractions.

The 37 x 0.5mm coal is treated in two parallel heavy medium cyclone circuits, producing a No. 1 clean coal and a middlings.

The 0.5mm x 0 coal is pumped to classifying cyclones producing recirculating water for the Batac Jigs, and feed to 2-stage froth flotation. The froth concentrate is a No. 2 clean coal, and the tailing is thickened and filtered resulting in a middlings filter cake.

The No. 2 clean coal is dried in an E.N.I. No. 5 Coal-Flo Thermal Dryer. The dryer is furnished with a high energy scrubber in order to produce an emission comparable to U.S. standards.

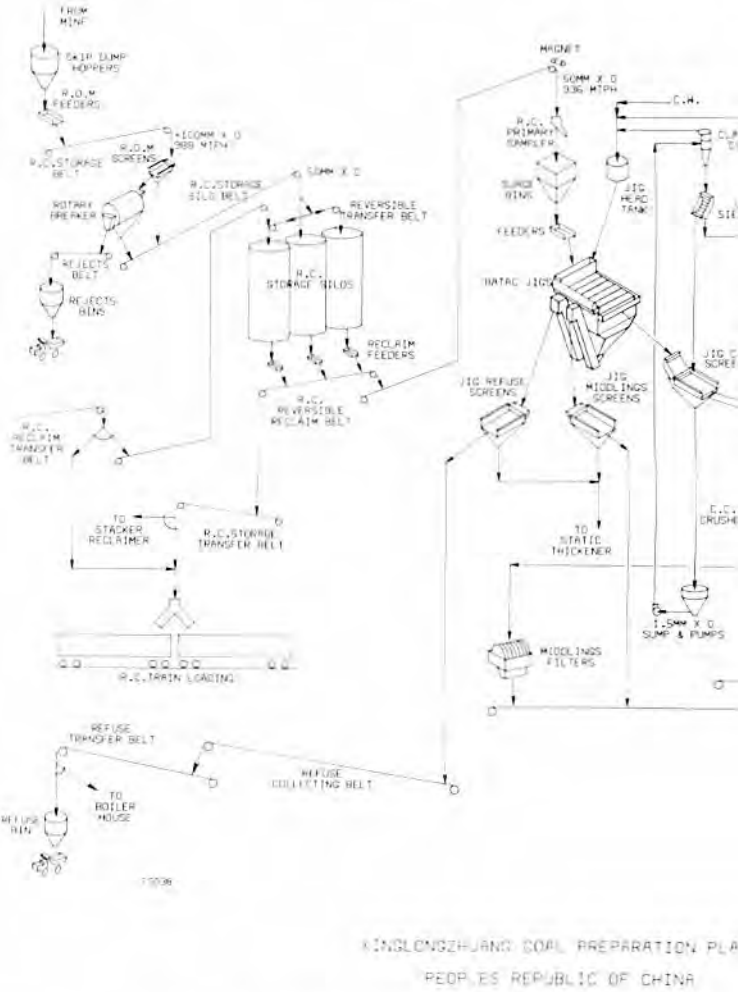
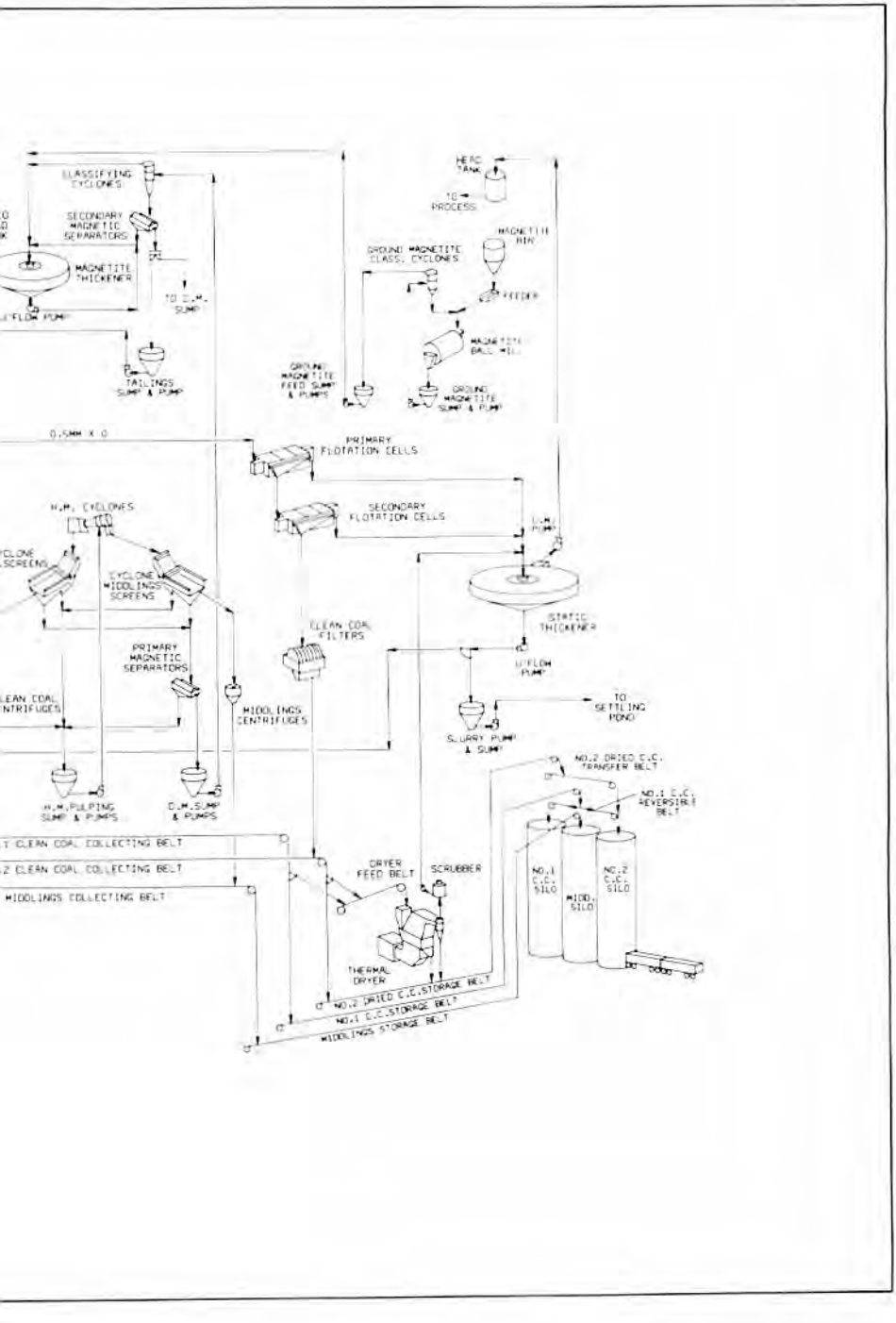


Fig. 3 — Flow diagram of Xinglongzhuang Preparation Plan


CLASSIFYING CYCLONES
SECONDARY MAGNETIC SEPARATORS
MAGNETITE THICKENER
TO D.M. SUMP
TAILINGS SUMP & PUMP
HEAD TANK
TO PROCESS
MAGNETITE BIN
GROUND MAGNETITE CLASS. CYCLONES
FEEDER
GROUND MAGNETITE FEED SUMP & PUMPS
GROUND MAGNETITE SUMP & PUMP
PRIMARY FLOTATION CELLS
SECONDARY FLOTATION CELLS
H.M. CYCLONES
CYCLONE MIDDLINGS SCREENS
CLEAN COAL FILTERS
STATIC THICKENER
PRIMARY MAGNETIC SEPARATORS
MIDDLINGS CENTRIFUGES
TO SETTLING POND
SLURRY PUMP & SUMP
NO.2 DRIED C.C. TRANSFER BELT
NO.1 C.C. REVERSIBLE BELT
H.M. PULPING SUMP & PUMPS
D.M. SUMP & PUMPS
CLEAN COAL COLLECTING BELT
MIDDLINGS COLLECTING BELT
DRYER FEED BELT
SCRUBBER
NO.1 C.C. SILO
MIDD. SILO
NO.2 C.C. SILO
THERMAL DRYER
NO.2 DRIED C.C. STORAGE BELT
NO.1 C.C. STORAGE BELT
MIDDLINGS STORAGE BELT

All three products are conveyed on separate belts in a common conveyor gallery to their own loading silo. The silos are fitted with flood-loading gates.

Magnetite is recovered from the heavy medium cyclone circuit in an improved DSM recovery circuit. Make-up magnetite is produced in a closed grinding circuit, capable of making an ultra-fine product.

XINGLONGZHUANG COAL CHARACTERISTICS

The raw coal fed to the Xinglongzhuang Preparation Plant is mined from an 8-meter thick seam of Permian Age that is flat lying and approximately 300 meters below the ground. The approximate analysis of the raw coal is as follows:

Volatile Matter	37.43%
Fixed Carbon	48.79%
Ash	13.78%
Sulfur, Total	0.41%
Sulfur, Pyritic	0.14%
Sulfar, Organic	0.26%
Sulfur, Sulfate	0.01%

If would be classified as a high-volatile a bituminous coal according to ASTM standard. This coal is similar to US coals such as Pittsburgh No. 8 in the Appalachian Coal Field and Illinois No. 6 in the Eastern Interior Coal Field, with average HGI values of 60-65.

Desired specifications for the products are:

No. 1 clean coal — 7% ash — 8% moisture.
No. 2 clean coal — 10% ash — 8% moisture.
Middlings — 30% ash — 14.5% moisture.

Obtaining the quality of the two clean coal products is reasonable. Obviously, the middlings will be what is left over.

CURRENT STATUS OF THE PROJECT

Engineering is now virtually completed. Three engineering meetings have been held to date. The first in China during November and December 1980, the second during March, April, May, 1981 in Chicago, and third in Chicago from July 1, thru early August. All necessary drawing approvals were obtained.

The relationship of the engineers from both sides has been extremely cordial, and mutual respect was apparent throughout all of the sessions. The technical competency of our Chinese counterparts is extremely high.

The first shipment of equipment left Philadelphia on September 28. The second shipment is being assembled in San Francisco for shipment on November 15.

Our construction advisory team has been put together and the first contingent is scheduled to leave for the job site in mid-November.

CONCLUSION

In conclusion, we would like to quote from a business publication which is giving advice to potential Chinese traders. We did not have this advice prior to our negotiations, but based on our experience find it to be extremely accurate.

"Before endeavoring to penetrate the Chinese market, firms must ensure that they are prepared to make the necessary commitment in executive time, effort and expense, since trading with China requires perseverance and patience".

The tape of the remainder of the meeting was inaudible. Mr. Robert Izard thanked all the speakers who presented papers during the Technical Session and adjourned the meeting.

LUNCHEON MEETING

The Annual Luncheon Meeting convened at 12:15 p.m. in the Ford Room of the Holiday Inn East. Approximately 198 members and guests were in attendance. President Walter S. Lucas presided. Due to a malfunction of the tape recorder, the proceedings of part of the meeting is not available.

President Lucas introduced the individuals seated at the head table. Representatives from the universities and colleges that are receiving Illinois Mining Institute scholarships introduced their students who were attending the meeting. The names of members who had passed away during the year were read by President Lucas. These were: Mat Anderson, Bob Bade, Richard Baldwin, George Lindsay, Sr., Hardy Rush, Wyatt Timmons, and William P. Young.

President Lucas was pleased to bring to the attention of those present that Clascenna Harvey, who has served for many years as organist at the annual meetings of the IMI, was the winner of the 1981 Copley First Citizen of Greater Springfield Award. She was honored on October 15th at a meeting attended by Governor James Thompson and Mayor Mike Houston for her dedicated work as the long-time Director and Chairwoman of the Springfield Commission on International Visitors and as official organist for the Illinois State Fair.

John P. Weir was introduced so that he could present a certificate of Honorary Life Membership in the Illinois Mining Institute to Joseph Schonthal (figure 1).

Fig. 1 — John P. Weir (right) presents certificate of Honorary Life Membership to Joseph Schonthal.

John P. Weir: It is a great pleasure to present a certificate of Honorary Life Membership to my good friend Joe Schonthal. I say good friend — our fathers were good friends also since the early Twenties when Paul Weir and Bela Schonthal came to Illinois. Joe Schonthal and his son, Spike, are well known in the Midwest coal area because of their excellent representation of manufacturers of mining equipment and supplies. What is not so well known is the tremendous contribution Joe has made to the Illinois Mining Institute. Joe Schonthal has been coming to these meetings for a very long time — the first time was 50 years ago. His father Bela Schonthal was Secretary-Treasurer of the Institute from 1929 to 1954. Since that time, Joe has made it his personal responsibility — officially and unofficially — to help the Institute. He has served tirelessly on the Advertising Committee and also on the Institute Board from 1957 to 1979.

Joe is one fine gentleman who can always be counted on to do the kindest thing in the kindest way. That is why he has so many friends. He richly deserves this award, and I am happy to have the honor of presenting it.

Joseph Schonthal: Thank you, Jack. I appreciate your presentation, and considering our longevity of friendship, I was quite relieved that you were very restrained in your comments. On the other hand — come to think about it — the dignity of your presentation typifys your own demeanor.

This award is of special meaning to me because my father, along with Jack Weir's father, and several other gentlemen revived this Institute back in the Twenties, and helped to make it a nationally recognized organization in the coal industry. I therefore have a vital interest and a warm spot in my heart for the IMI.

Thank you again, Jack, and many others for this honor.

President Lucas introduced the luncheon speaker, Kenneth E. Tempelmeyer, who presented the following paper (figure 2).

Fig. 2 — Luncheon speaker, Kenneth E. Tempelmeyer.

THE ROLE OF COAL IN OUR ENERGY FUTURE

KENNETH E. TEMPELMEYER
Dean, College of Engineering and Technology
Southern Illinois University at Carbondale
Carbondale, Illinois

INTRODUCTION

The United States became an industrial power by replacing men and women with machines which now produce a staggering array of products and goods. The use of energy to drive our industry represents a tremendous extension of our ability to do work, but has made us very dependent upon energy of all types. Our use of energy over the last hundred years has grown geometrically doubling about every 20 to 25 years. We use so much energy now that we have coined a new word to describe the amount — the "Quad."

The quad (Table 1) is equal to one quadrillion Btu or 1,000,000,000,000,000 Btu. Most of us have an idea about the unit Btu-the British Thermal Unit. It takes about 200 Btu to bring a small pan of water to boil in order to make tea and a pound of coal contains about 10,000 Btu. However, a quadrillion Btu boggles the mind. I can understand numbers as large as about ten million because I have a responsiblity for managing budgets which are in the range of a few million dollars. I have less appreciation of the magnitude of budgets the size of the federal budget — hundreds of billions of dollars, and even less appreciation yet for something as large as a quadrillion. However, to try to make it easy for you, one quad or one quadrillion Btu, expressed in terms of coal, is represented by a unit coal train that would stretch from Seattle to New York and back. One quad is also equal to the amount of energy from all sources consumed by a city the size of St. Louis in about a three-year period.

QUAD	= 1 Quadrillion Btu
	= 10^{15} Btu
1 lb. Coal	= 10,000 Btu
1 Quad	= 46 Million Tons of Coal

A COAL TRAIN FROM SEATTLE TO NEW YORK AND BACK

1 Quad	= Gasoline for 10 million automobiles per year

Table 1 — Definition of a quad.

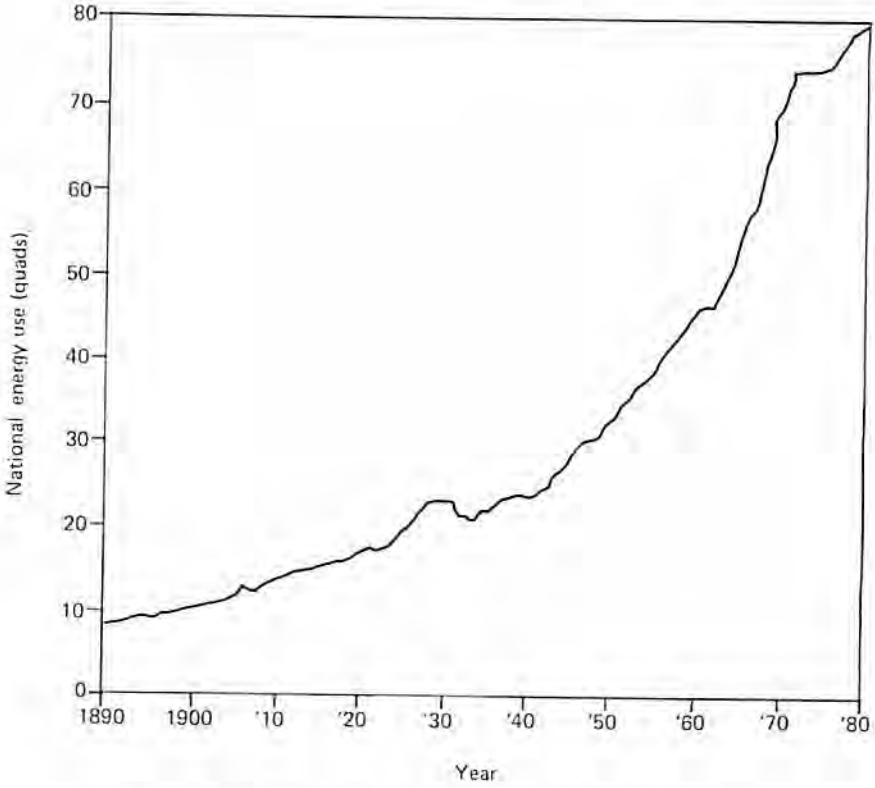


Fig. 1 — Consumption of energy in the United States since 1890.

GROWTH OF ENERGY CONSUMPTION

Our energy use, since the turn of the century, is shown in Figure 1 in terms of quads. At the turn of the century, our country was using approximately 8 quads of energy of all kinds. By doubling about every 20 years, last year our energy consumption reached almost 80 quads. This increase corresponds to a growth rate of 3 to 3½% per year since the turn of the century except for two brief periods when we experienced a decrease or leveling off. The first of these was a decrease in energy consumption during the depression years. The second may surprise you if you are not aware of it, but we experienced a leveling off of energy use in 1972-1973 as a result of the first Arab oil embargo. Other than these periods, we have continued to consume tremendous amounts of energy at a steadlily growing rate.

Our energy use in different sectors is shown in Table 2 for 1978 and 1980. While our growing consumption of energy a few decades ago was used to drive our industry, you will note at the present time about 30 quads are used for residential and commercial purposes and another 20 quads is consumed in transportation uses. Because the price of energy was low,

1978 Energy Use

Industrial Uses	28 Quads
Residential Uses	13 Quads
Commercial Uses	17 Quads
Transportation Uses	20 Quads
Total	78 Quads

1980 Energy Use

Industrial Uses	29 Quads
Residential Uses	12 Quads
Commercial Uses	18 Quads
Transportation Uses	20 Quads
Total	79 Quads

Source: DOE Review

Table 2 — Use of energy by different sectors between 1978 and 1980.

much of this energy was used in making our lives more pleasant and interesting. Currently, about 40% of the energy we consume is used in manufacturing or industrial processes.

It's clear that the cheap and readily available energy of the past is not likely to continue, and we should have a growing conern about projecting our energy needs and supplies for the coming years. After decades of rather constant growth, it's obvious now that the international competition, economics, and politics of energy supply are going to significantly alter our usage pattern in the future.

Figure 2 shows the growth of electrical consumption in the U.S. over the past two decades. This growth has been remarkably steady over the past 30 to 40 years at a rate of about 7% per year which corresponds to doubling our electrical generation capacity every 10 years. At the present time, electical consumption has diminished markedly and is now growing at the rate of only 3½% to 5½% per year depending upon the region of the country. As a consequence, many utilities, building for their 7% growth rate, now have over-installed capacities and a breathing period of a decade or so before they need to decide how they should next plan the future expansion of their system.

FUTURE GROWTH OF ENERGY USE

Projecting the future growth of all energy use is much more complex

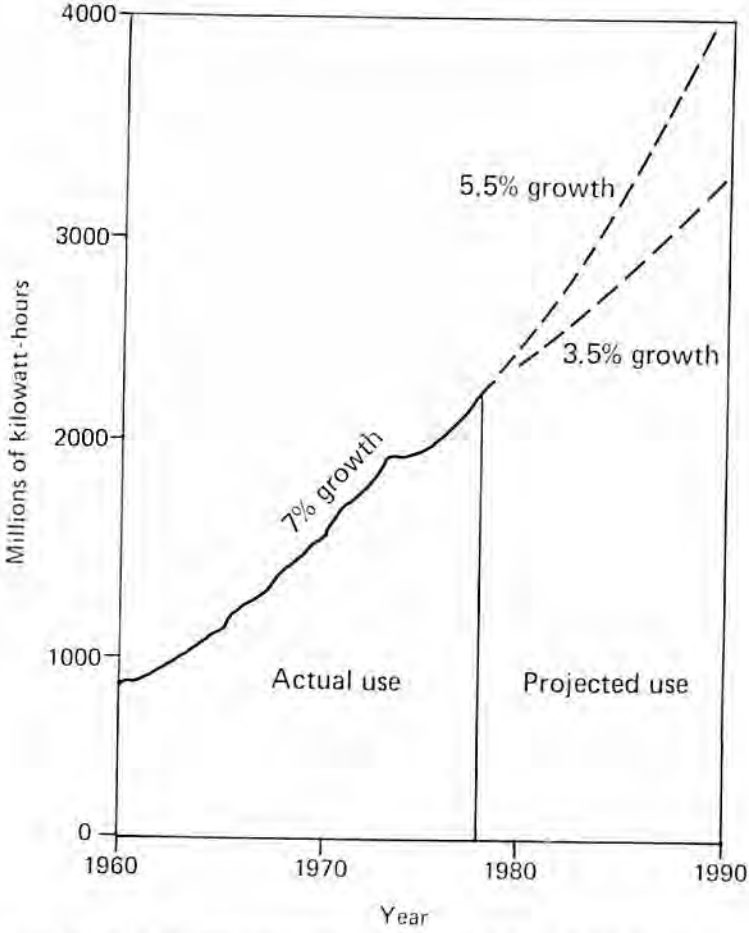


Fig. 2 — Growth of electrical consumption in the United States during last two decades.

because of the wide diverse uses of energy. However, Figure 3 extrapolates our total energy comsumption since shortly after World War II. Since that time, except for a brief leveling off during the 1972 Arab oil embargo, we have grown steadily at the rate of 3½% per year. If we were to continue at the historic growth rate, by the year 2000, we would use roughly double our present consumption rate or about 160 quads per year. Over the past two years in particular, increases of energy consumption have been very modest and it is evident that we may not continue to grow at this traditional rate of 3½% per year. Many estimates have been made concerning our probable energy consumption by the year 2000; they vary greatly but downward from a "business-as-usual" projection of 160 quads. The Department of Energy has estimated that our "most probable" need in the year 2000 will be about

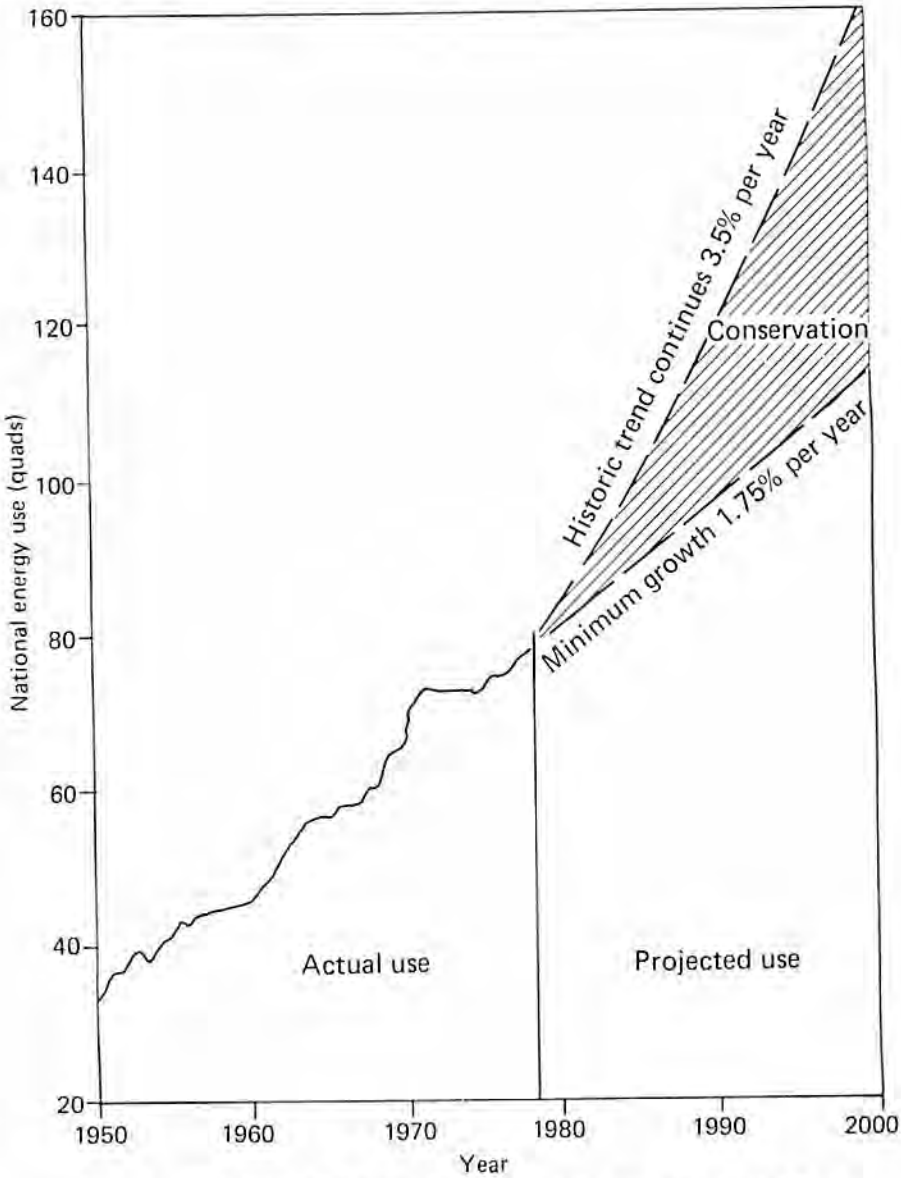


Fig. 3 — Projected growth of energy consumption since shortly after World War II.

140 quads and our minimum requirement by that time would be about 110 quads. A year ago, Exxon Corporation carried out an extensive energy projection study and arrived at about the same number, 105 quads. As another projection approach, if we reduce our total use of energy as we

have reduced our use of electricity over the past few years — that is, the growth rate is reduced by a factor of 2 — our total energy use would increase at the rate of 1.75% per year. This growth rate also leads to a prediction of 110 quads by the year 2000.

Since we have been increasing our energy consumption by 3½% per year, which would lead to a need for 160 quads in the year 2000, what must happen to reduce our use by 50 quads — to a level of 110 quads? The answer, of course, is that we must do this through conservation and change a great many of our present energy habits.

CONSERVATION OF ENERGY

Conservation of energy can come in a great many ways, and Table 3 summarizes only one scenerio to save 50 quads. If we effect a 15% reduction of present heating, cooling, and lighting use in all residences and commercial buildings, and couple that with a 40% reduction of heating, cooling, and lighting use in all new construction between now and the year 2000, we will reduce our residential and commercial energy needs by 20 quads. Industrial conservation can be achieved in many ways; it is difficult to speculate how. Many industries have found, however, that they can reduce their energy consumption by 25% basically by eliminating waste. A 25% reduction would result in about a 10 quad saving. Additionally, if we achieve a 27.5 mile per gallon level for automotive fleets by 1985 and maintain it thereafter, and if we couple that with an 85% load capability by airlines, increase our use of rail transport, and promote more widespread use of automotive pooling, we can reduce our transportation usage by about 20 quads. All of these activities taken together would result in the conservation of about 50 quads which would be needed to get us to the minimum level of 110 quads by the year 2000.

1. Residential & Commercial	20 Quads
A. 15% Reduction of present heating, cooling and lighting use	
B. 40% Reduction of heating, cooling and lighting of all new construction — 1980 to 2000	
2. Industrial	10 Quads
3. Transportation	20 Quads
A. 27.5 mpg for automotive fleets by 1985 and thereafter	
B. 85% Load capacity by airlines	
C. Increased rail transport	
D. Widespread automotive pooling	
SAVING	50 Quads

Table 3 — Possible conservation of energy to save 50 quads.

Oil	38 Quads
Natural Gas	20 Quads
Coal	14 Quads
Nuclear	3 Quads
Hydro	3 Quads
Other	1 Quads
Solar	
Wood/Biomass	
Wind	
Misc.	
	79 Quads

Table 4 — Sources of energy consumed in 1980.

Business as Usual	160 Quads
Continued Widespread Conservation	-50 Quads
PROBABLE MINIMUM NEED	110 Quads
Current Consumption	≈80 Quads

AT MINIMUM
WE NEED BY YEAR 2000 TO OBTAIN
30 QUADS
ABOVE CURRENT USE

Table 5 — Projected energy requirements by the year 2000.

SOURCES OF ENERGY

Table 4 summarizes the various sources of the energy consumed in 1980. At the minimum, we will probably add 30 quads to this total by 2000 (Table 5). Where are we likely to obtain the additional energy we need? Let's review the possible future use of each energy source.

Oil And Gas

Table 6 summarizes some estimates of the future supplies of oil and gas made by the Department of Energy. This particular source indicated an expectation of about 35 quads in oil by the year 2000 and maintaining about the same level of 20 quads of natural gas. If you have little confidence in the estimates made by the Department of Energy, and some people do, the bot-

tom portion of the slide shows estimates made by EXXON Corporation. They indicate about the same level of consumption in 1980 and also projected about the same estimate of 35 quads of oil energy used in the year 2000 and 19 quads of energy to be provided by natural gas. From these estimates, it would appear that we cannot expect to obtain our needed increased energy supplies from oil and gas, but rather these supplies will be decreased by 2 to 3 quads. So, actually we need to identify the sources of 32 to 33 additional quads rather than 30 by the end of the century.

DOE ESTIMATES*

	1980	2000
Oil	38 Quads	35 Quads
Natural Gas	20 Quads	20 Quads

EXXON ESTIMATES**

	1980	2000
Oil	37 Quads	35 Quads
Natural Gas	20 Quads	19 Quads

CHANGE BY 2000 — 2 or 3 QUADS

* DOE Energy Review
** USA's Energy Outlook, Exxon Corp.

Table 6 — Estimates of future supplies of oil and gas.

NUCLEAR

Nuclear energy has been the promise of the future. What can we expect from it? As shown in Table 7, at the present time we have installed about 3 quads of electrical generation capacity in nuclear plants from coast to coast. Presently there are in planning or licensing approximately 20 plants that would have an installed capacity when completed of about 7 quads. While the design, construction, and licensing process of a nuclear plant is painfully slow and a real problem to the utilities, the expectation is that a majority of these plants will be completed and placed into operation. However, it is interesting to note that over about the last 4 years there have not been any new "starts" of nuclear plants because (1) many utilities do not have the need to expand their capacity for the reasons outlined above, and (2) there are a great many headaches in putting a nuclear plant into operation.

Another interesting question is: What is the aftermath of the incident at Three Mile Island? It would appear that the effect of Three Mile Island has been to produce a wait-and-see attitude before there is significant further expansion of nuclear capacity. This attitude may prevail for a decade or so and we may not see significant plans to expand nuclear facilities until the 1990s. As a result, we may expect to produce perhaps an additional 7 quads from the nuclear plants that are presently being designed or constructed.

Expectation from Nuclear

1980 Installed Capacity	3 Quads
Capacity in Planning or Licensing	7 Quads
New Ventures in Last 4 Years	0

CHANGE BY 2000 + 7 QUADS

Expectation from Hydro

1980 Installed Capacity	3 Quads
New Installations	1 Quad

CHANGE BY 2000 + 1 Quad

Table 7 — Estimates of future supplies of nuclear and hydroelectric power.

HYDROELECTRIC

Currently we produce about 3 quads from hydroelectric plants. For the most part, hydroplants are viewed as desirable since they are quiet, scenic, and create many recreational opportunities. The widely held opinion is that we will not be able to achieve significantly increased production of electrical power by this means. Most of the good sites have already been used in producing about 3 quads or 4% of our total power usage at the present time (Table 7). We might expect to get no more than 1 additional quad from this means.

SOLAR

We hear a lot about the potential of solar energy. When we utilize oil, gas, or coal, we are using solar energy which was intercepted by the earth hundreds of thousands of years ago. The advocates of solar energy present it as the best energy supply of the future. About a year and a half ago, I built a passive solar home in southern Illinois and I've been quite pleased with it. Over the past winter, on sunny days, our house cycled between about 65 °F early in the morning to 75 °F in mid-afternoon without auxiliary heating. Our total heating expense for the 1980-1981 winter was $135; we

have neighbors who spent considerably more than that each month. While this was a particularly good winter for solar heating and you can't expect to do as well on the average, I believe that individual solar applications, like in residences, may be very beneficial. However, when I hear the advocates of solar energy claiming that by the year 2000 we can achieve 20 to 25 quads from this source, I'm somewhat skeptical. Our house collected less than 10^{-7} quads.

Table 8 provides one scenerio with respect to what would have to happen to generate 20 quads by solar means. For example, if we converted 15% of all of the 150,000,000 existing houses in the U.S. with active or passive solar and if, beginning in 1980, 75% of the 45,000,000 new houses were constructed with active and passive solar, we would in effect be producing about 7.5 quads. If 10% of all commercial buildings were converted to solar heating, we would achieve an additional 5.5 quads. If 4% of the material now being used in automotive production were put into the construction of wind machines, we would generate about 4 quads. And, if we more than tripled our biomass use, either through alcohol fuels or the direct burning of vegetation, we would generate 3 more quads. All of this totals to some 20 quads; the achievement of this is optimistic to say the least.

One of the problems that will delay widespread use of solar energy is cost. In my home, which is a relatively simple passive system, I'll need about 7 years to pay for the added construction costs including the federal tax credit. Active systems have, in general, a much longer payback period.

1. Convert 15% of the existing 150 million houses to passive/active solar Build 75% of the needed 45 million new houses with passive/active solar	7.5 Quads
2. Convert 30% of all commercial building to solar heating	5.5 Quads
3. Devote 4% of material now used in automotive production to wind machines	4 Quads
4. Increase biomass use	3 Quads
TOTAL	20 Quads

Table 8 — Possible sources for supplying 20 quads of solar energy.

Table 9 summarizes the cost of active systems. In the top portion of this figure, we see the cost per square foot of collector area at which solar heating would be competitive with other heating fuels. In most instances, the current cost of the collector is 2 to 3 times greater than the cost of other heating methods. For electrical power generation, the current cost of photoelectric cells is approximately 10 times higher than that of providing a fossil energy or nuclear plant. Thus, our expectation for solar energy may not be as great as the 20 quads suggested by solar advocates. By expanded use of

biomass, by use of active and passive systems, and by growing installation of wind energy systems, I believe we might expect a contribution of about 4 quads by the turn of the century from solar resources (Table 10).

Oil Shale

Another area that has shown future promise but has not developed rapidly, is the production of oil from shale. Shale oil comes from a solid fossil substance called kerogen. Kerogen is found imbedded in various kinds of rocks and clays. The kerogen got into the rock some fifty million years ago when decaying plant and animal remains settled to the bottom of a prehistoric lake and were covered by layers of lakebed sediments. Over time the organic matter became kerogen and the sediments hardened to become the rock holding it together. Kerogen is a heavy hydrocarbon that will not flow out of the rock at ordinary temperatures, nor can it be extracted simply with solvents. The kerogen is separated by a process called retorting in which it breaks down into a liquid, some combustible hydrocarbon gases, and a black carbon residue. Roughly there are about 1 to 1½ barrels of oil in a ton of oil-shale rock. The generation of oil from shale depends upon (1) effectively getting it out through the retorting process, (2) dealing with the mining of large amounts of shale rock to produce each barrel of oil, and (3) with environmental factors attendant to the mining and waste disposal in areas that tend to be arrid. There are a number of oil shale projects in the Colorado region. Eastern shale, found not far from here, unfortunately has smaller portions of kerogen than the western shale.

1. Residential Thermal Systems	**Break-even Collector**
Location	**Cost**
Los Angeles	$20/sq. ft.
Boston, Minneapolis	6/sq. ft.
Washington, D.C.	10/sq. ft.
Carbondale	10-15/sq. ft.
Current Cost of Collectors	$25-30/sq. ft.

2. Direct Conversion to Electrical Power (Photovoltaic Cells)	
Conversion Method	**Capital Cost**
Nuclear	$1000/kw
Coal-fired	800/kw
Hydro Dam	300-1200/kw
Solar	10,000/kw

Table 9 — Cost of active systems of solar energy generation.

In 1972, I was a member of a panel discussing alternatives to imported oil during the oil embargo by the Arab nations. At that time, the world price of oil was about $2.10 a barrel. I confidently predicted that the foreign oil producers could not drive the price up beyond about $6 to $8 a barrel because that was the cost at which we could obtain oil from oil shale. Presently, the world price of oil is about $30 to $35 a barrel — 4 times the maximum level I predicted in 1972. But, the current estimated cost of getting oil out of shale is about $60 to $70 a barrel or twice the current price of petroleum. While I'm sure progress is being made in the development of our shale oil resources in the West, unless there are some dramatic breakthroughs, the expectation is that we will have little impact of oil derived from shale by the year 2000. The Electric Power Research Institute has made a study of the impact of shale oil (Table 11) and they estimate that by the year 2000, we may be producing 500,000 to 1,000,000 barrels per day. This corresponds to an equivalent of about 1 quad.

1980 Capacity (Biomass)	1 Quad
Expanded Biomass	1 Quad
Active & Passive Solar Heating	2 Quads
Wind	1 Quad

CHANGE BY 2000 + 4 QUADS

Table 10 — Realistic estimate of energy provided by solar energy by the year 2000.

1980 Capacity NIL

Current Activity

Presently in research & development stage

Problems:

A. Effective Retorting

B. Environmental Concerns

C. Water Usage

Projections

Optimistic — 3,000,000 bbl/day by 2000

Most Likely — 500,000 to 1,000,000 bbl/day by 2000

OIL SHALE — 1 QUAD

*EPRI

Table 11 — Impact of oil shale on energy production.

DOE ESTIMATES

1980	**2000**
14 Quads	20 Quads

EXXON ESTIMATES

1980	**2000**
15 Quads	36 Quads

Table 12 — Estimates of amount of coal to be used by the year 2000.

Oil	35 Quads
Natural Gas	20 Quads
Nuclear	7 Quads
Hydro	4 Quads
Solar	5 Quads
Oil Shale	1 Quad
Coal	38 Quads
	TOTAL 110 Quads

Table 13 — Projected sources of energy supply by the year 2000.

1. Sulfur Content
2. Myriad of Regulations
3. Transportation

Table 14 — Problems confronting coal use.

COAL

A summary of the expected contribution to our future energy needs from oil, natural gas, nuclear, hydro, solar, and oil shale indicates that by the year 2000 we may fall 20 quads short of our energy requirements unless there is a significant increase in the use of coal. Other energy sources appear unable to fill the need and coal may represent the only alternative to supplying the 20 quads.

Table 12 summarizes some estimates of expected coal use by the turn of the century. Exxon's estimate of a growth of coal use of about 20 quads

by 2000 is similar to that suggested here, by looking at the reasonable prospects of other supplies. Thus, our energy supply mix in the year 2000 as outlined in Table 13 suggests we need to more than double our current production. There are several road blocks to increasing the use of coal (Table 14). However, the failure of the alternatives will force increasing use of coal in the coming years.

The greatest current barrier to the use of Illinois coal is its sulfur content and the emission regulations of the Clean Air Act. Some are advocating changes in the Clean Air Act and this topic will be considered by the Congress this Spring. However, certain changes which would establish a specified SO_2 emmission limit from the combustion of any coal could push the expanded use of western coal and decrease the use of eastern coal unless its sulfur problem can be handled. While most IMI members are concerned about the problems of more effectively mining coal, in my judgment, we must focus greater attention on finding the means to use high-sulfur coals. If we can't sell it and use it, we won't be mining it. The newly created Illinois Coal Research Board would hopefully give its highest priority to support imaginative and promising activities in finding the ways to remove sulfur in coal processing or removing the sulfur in the conversion of coal to some other convenient fuel form. A number of innnovative ideas are available in converting coal to more useful lower-sulfur fuels. Our College is working on three of them. Also, we need to give attention to characterizing coal to identify which types are best suited for specific uses such as gasification, liquefaction, fluid-bed combustion and so forth. The SIU-C Coal Research Center has called attention to this need some time ago. As we find better and acceptable ways to use coal in our view we may have to revolutionize coal transportation if we are to nearly triple our coal usage in the next 20 years.

The alternative energy sources appear incapable of satisfying minimum energy requirements at the turn of the century. Supplying an additional 20 quads per year by coal at the end of the century will create a variety of problems. We are going to have to solve these problems if we want the energy and we may we well begin now.

President Lucas thanked Mr. Tempelmeyer for his presentation, then he introduced President-Elect Jack A. Simon, who presided over the remainder of the meeting. President-Elect Jack Simon presented a souvenir gavel to Walter Lucas for recognition of his service as President of the Illinois Mining Institute (figure 3).

President-Elect Simon adjourned the meeting.

Fig. 3 — President-elect Jack Simon (left) presents souvenir gavel to President Walter Lucas.

CONSTITUTION AND BY-LAWS

Adopted June 24, 1913

Amended November 12, 1926
Amended November 8, 1929
Amended November 8, 1935
Amended October 21, 1938
Amended October 23, 1964
Amended October 23, 1970
Amended October 22, 1971
Amended October 3, 1975
Amended October 16, 1980

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 the current year's dues as established by the Executive Board. 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 determined by action of the Executive Board, on 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 $100.00 and shall be exempt from further payment of dues during his lifetime.

ARTICLE III.

Officers

Section 1. The officers shall consist of a President, First Vice-President, Second 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 President at least thirty days before the annual 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, First Vice-President, Second Vice-President, and Secretary-Treasurer shall be elected by ballot, annually, at the regular meeting and shall hold office for the ensuing year.

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

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 First Vice President.

Section 5. The Executive Board shall consist of the officers, the 12 elected Board members, and, as an ex-officio member, the current active Director of the State of Illinois, Department of Mines and Minerals.

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 First Vice-President shall preside in the absence of the President and perform all the duties of the President in his absence. The Second Vice-President shall perform all duties of the First Vice-President in the absence of First Vice-President.

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 newspaper 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 annual 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. The annual meeting shall be held in the fall 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 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) Adjournent.

ARTICLE VIII.

Dissolution

In the event of complete dissolution of the Institute, the cash assets of the Institute will be distributed to the University of Illinois at Urbana and the University of Missouri School of Mines, Rolla, Missouri, in a ratio of four to one respectively, for support of scholarships in Mining Engineering. Equipment will be donated to any not-for-profit organization that the Executive Board may determine to be worthy recipients.

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Designed to fit every job, ADS pipe is available in sizes ranging from 3”diameter tubing to 24” diameter. Strong as well as durable, ADS pipe is available perforated (3” through 15”) or non-perforated (all sizes).

And, this pipe is easily off-loaded and handled, allowing you to significantly reduce costs. With lighter machinery and less labor time required, total installation costs can be reduced up to two-thirds.

SPECIFICATIONS

ASTM F-405 Standard Specification for Corrugated Polyethylene Tubing and Fittings (3”-8” diameters). ASTM F-667 Standard Specification for 10”, 12” and 15” Corrugated Polyethylene Tubing. AASHTO M-252 Standard Specification for Corrugated Polyethylene Drainage Tubing.

Look for the ADS green stripe

It’s your sign of quality — 24 in the land.

ADS

ADVANCED DRAINAGE SYSTEMS, INC.

ADS Corporate Headquarters
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Columbus, Ohio 43221
(614) 457-3051

Replace belt fasteners less often in less time.

Your underground belting will require less fastener replacement with the long-life FLEXCO® SR™ rivet hinged system.

It's the longest lasting, most trouble-free hinged conveyor belt splice available for today's straight warp and other high tension mechanically rated belts.

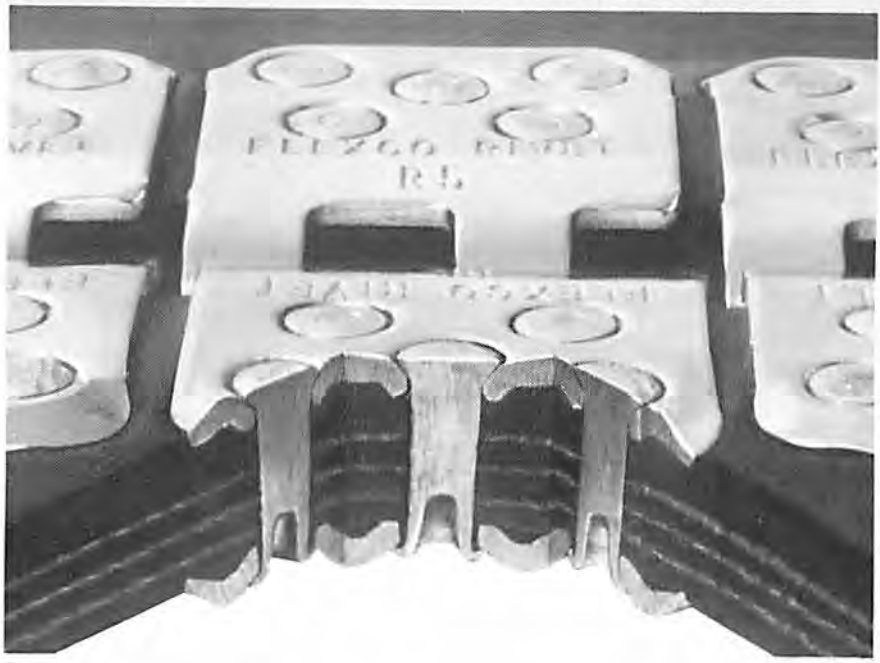
Splicing is fast and easy. All you need is a hammer and installation tool to drive and set the rivets. It's an easy one-step job. With no complicated machinery to maintain and haul throughout the mine.

The SR system uses patented self-setting rivets (see cutaway) easily applied in a secure five-point pattern. No hooks to pull out. No zippering open at belt edges.

The proof is in the use. For a no-obligation demonstration in your mine phone 312/971-0150 or write 2525 Wisconsin Ave., Downers Grove, IL 60515-9961.

FLEXCO®

FLEXIBLE STEEL LACING CO.



"Like my new LN-800?

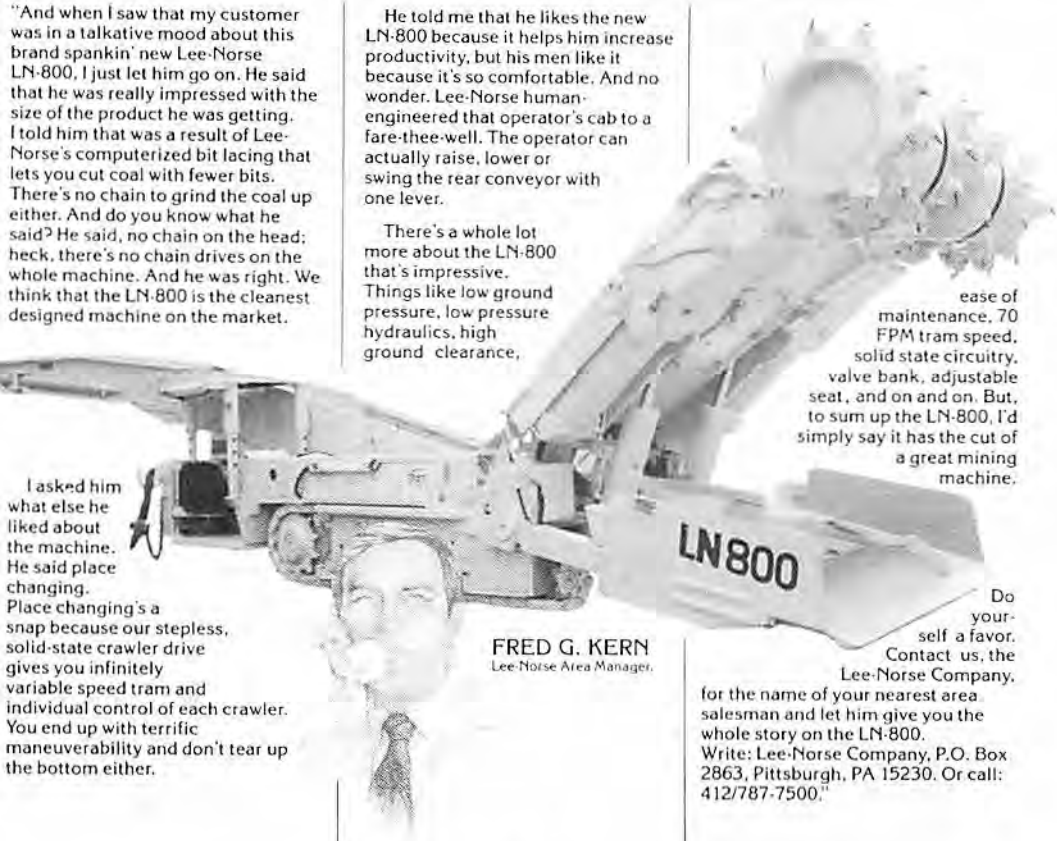
Why Fred," my customer said, "we've gotten up to 2,000 tons in 8 foot coal on a single 10-hour shift. I love it."

At Lee-Norse We're Doin' it.

"And when I saw that my customer was in a talkative mood about this brand spankin' new Lee-Norse LN-800, I just let him go on. He said that he was really impressed with the size of the product he was getting. I told him that was a result of Lee-Norse's computerized bit lacing that lets you cut coal with fewer bits. There's no chain to grind the coal up either. And do you know what he said? He said, no chain on the head; heck, there's no chain drives on the whole machine. And he was right. We think that the LN-800 is the cleanest designed machine on the market.

He told me that he likes the new LN-800 because it helps him increase productivity, but his men like it because it's so comfortable. And no wonder. Lee-Norse human-engineered that operator's cab to a fare-thee-well. The operator can actually raise, lower or swing the rear conveyor with one lever.

There's a whole lot more about the LN-800 that's impressive. Things like low ground pressure, low pressure hydraulics, high ground clearance, ease of maintenance, 70 FPM tram speed, solid state circuitry, valve bank, adjustable seat, and on and on. But, to sum up the LN-800, I'd simply say it has the cut of a great mining machine.



I asked him what else he liked about the machine. He said place changing. Place changing's a snap because our stepless, solid-state crawler drive gives you infinitely variable speed tram and individual control of each crawler. You end up with terrific maneuverability and don't tear up the bottom either.

FRED G. KERN
Lee-Norse Area Manager.

Do yourself a favor. Contact us, the Lee-Norse Company, for the name of your nearest area salesman and let him give you the whole story on the LN-800. Write: Lee-Norse Company, P.O. Box 2863, Pittsburgh, PA 15230. Or call: 412/787-7500."

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ANYTHING LESS WILL COST YOU MORE.

ESCO's original 2-piece design speeds tip changes and reduces throw-away metal.

Argon Oxygen Decarburization (AOD) purifies our steel alloys for greater strength.

Stabilizing ears provide greater strength and holding power.

ESCO's new AOD 12K alloy for greater hardness, wear resistance.

7 different tip shapes for different digging conditions.

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ESCO's AOD 12H alloy for superior toughness and impact resistance.

ESCO's Kwik-Tip® for dragline buckets and shovel dippers is the most imitated tooth system in the world.

For good reason.

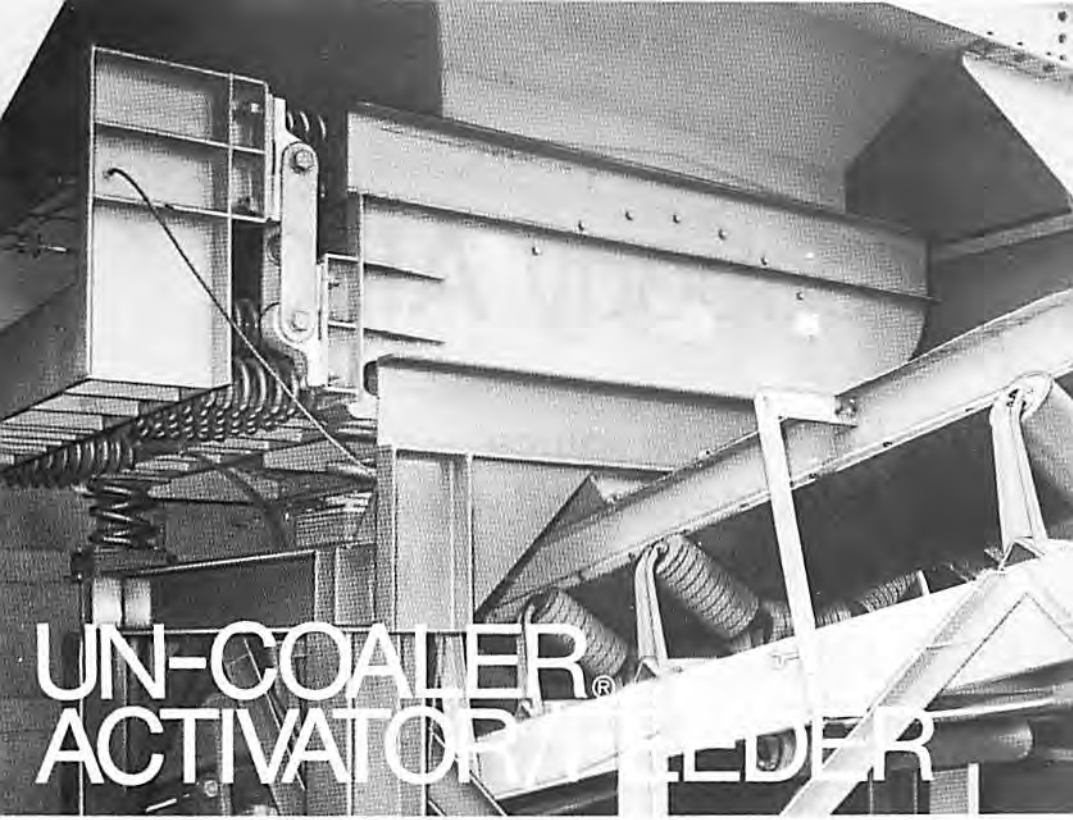
The ingenious design and superior alloys set the standards for strength, durability and value.

You won't change Kwik-Tips often, but when you do it's a simple one-man job.

Now look closely at the other unique features, then call your nearby ESCO dealer today. Because in the long run, anything less will cost you more.

ESCO®

YOU CAN'T AFFORD ANYTHING LESS.



The better idea in bulk reclaim systems.

The General Kinematics Uncoaler combines a bin activator function with two adjustable rate vibrating feeders . . . all in a single, low profile unit that can reduce costs and operating problems substantially.

Unique drive reliability

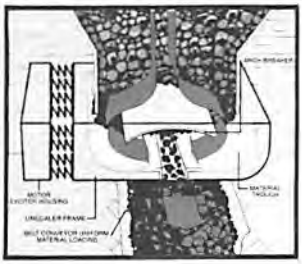
Like our Para-Mount II feeder, The Uncoaler is powered by a rugged, natural frequency vibratory drive system. Exciter force automatically compensates for change in material head load, and material discharge is fully adjustable to maintain optimum, uniform feed rates.

Uncoaler is available in a variety of sizes, including this 12'x12' unit.

Stands on its own

Uncoaler needs no special suspension or roof construction. Entire unit stands on its own, directly above conveyor. Its few moving parts are readily serviced from the tunnel.

Get full information from your Man in Motion, the General Kinematics representative nearest you. Or contact us directly.



Vertical, center discharge produces uniform loading without belt tracking problems.

GENERAL KINEMATICS

The Force in vibratory equipment

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Mining's muscle.

It takes a lot of muscle to dig deep and carry out millions of tons of raw materials every year. And mining's muscle comes from electricity.

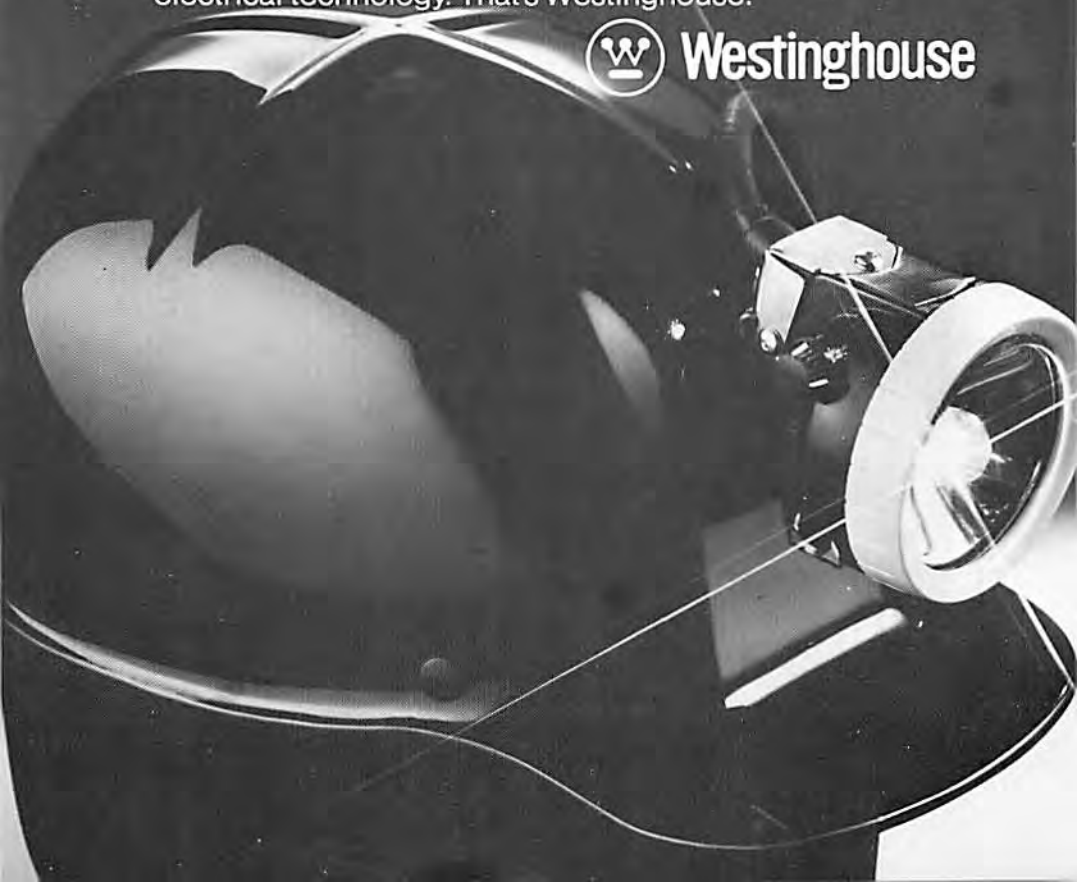
For over 80 years, Westinghouse has helped put electricity to work in America's mines. Our motors, controls, contactors and circuit breakers have increased productivity, reliability and safety. And cut operating costs at the same time.

Yet we're constantly searching for new and better ways to help mining operators spend less and produce more.

One good example is our solid-state Numa-Logic® Programmable Controller. Installed on mining machinery, it can automatically locate electrical problems that may occur, and identify them immediately. As a result, costly downtime can be reduced by as much as 50 percent.

Giving more muscle to America's mines through electrical technology. That's Westinghouse.

Westinghouse



Go all the way with Sanford-Day Line of Products.

With over three-quarters of a century of experience in the manufacturing of mining equipment, the Sanford-Day haulage team is delivering its efficiency at the source, to mines all over America. Whether you need to transport men, equipment, coal, ore, refuse—Sanford-Day will move them fast and safely.

Every piece of equipment we build is reinforced for extra strength, longer lasting life, and has more safety features—to ensure your mining crews safety. The sturdiness and durability of our equipment means added efficiency, higher productivity, and operating economy, while reducing downtime.

Like our 8-wheel 6-Brake Brakeman Car, the only completely certified car of its kind—guarding against runaway trips at slope mines due to rope breakage or hoist failure.

Or our Rubber/Rail Car with a capacity of up to 16 tons on rail, and the car can be operated by one individual, who can lift and lock each wheel all in one motion.

Our 8-wheel Ballast Car has an 8-10 ton capacity. The car has 3 doors and they operate manually, with the ballast levelled in both directions. Also featured are automatic couplers and twin 4-wheel trucks.

Or the 4-wheel Ballast Car having a capacity of 9 to 15 tons, depending on the height of the car and featuring 4 doors that level the ballast in either direction.

Along with our Longwall Roof Support Transport Car, Hoist Retarders, and all other related mining equipment—all are designed with Sanford-Day practicality to stay on the job.

8-Wheel Brakeman Car

Hoist Retarder

Rubber/Rail Car

Longwall Roof Support Transport Car

Ballast Car

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Illinois Power Company and Illinois coal mines have enjoyed a mutual relationship for over half a century. We supply the electric energy that powers modern mining operations at many coal companies. The majority of the electricity we produce is generated with Illinois coal.

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Fairmont Supply Company is the largest and most progressive mining products distributor in the nation.

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Illinois' *only* Full Line Mining Products Distributor.

Fairmont's facility in **MT. VERNON** has rapidly geared-up over the past several years to meet the growing needs of the midwestern coal industry. We are now stocking over 350 lines of quality mining and industrial products — **the most complete selection available from one supplier.** Our **multimillion dollar inventory** is tailored to the mining industry's requirements. We provide **technical assistance** in the application of our product lines through our highly qualified Engineered Products Group. Fairmont's modern **systems contracting** capability can reduce your paper, procurement and handling costs in addition to reducing your inventory investment. Our own truck fleet assures you of **reliable delivery service** as you need it.

The Fairmont Supply team has been serving the mining industry for over 55 years. Call us at **MT. VERNON** and find out what over five decades of mining experience can do for you!

FMC payload savings plan

Vibrating Feeders

Belt Conveyor Idlers

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Between the digging and the burning, you need to move coal efficiently to keep your operation profitable.

That's why FMC Corporation's Syntron® and Link-Belt® feeders, belt conveyor idlers and screens are built to withstand the most grueling conditions. They can save you money on installation and maintenance. And improve your bottom line.

Make the move today. Reliable equipment from FMC Corporation can move your operation toward better output, better profits.

For information contact our Material Handling Equipment Division, Regional Sales Office, 125 Windsor Drive, Suite 128, Oak Brook, IL 60521 (312) 325-3250.

FMC

When you need OXYGEN to solve a problem, recommend CAIROX

Cairox brand potassium permanganate ($KMnO_4$) is really nothing more than oxygen in a solid form. It is widely used as an oxidant in municipal and industrial wastewaters, and can be used in mine wastewaters; or for cleaning up nuisance odors and gases from a wide variety of sources.

Drinking water

Cairox precipitates iron and manganese and destroys taste and odor-producing compounds. It may extend activated carbon filter life, reduce or eliminate prechlorination, and may reduce trihalomethane formation in finished water. WRITE FOR BULLETIN M-1050

Municipal, industrial wastewater

Cairox destroys H_2S and other odors in sewage plants and gathering systems. It removes a wide range of pollutants from industrial wastewaters and is specific for phenol. Plus, it may also assist in dewatering of municipal and industrial sludge. Cairox reacts synergistically with standard conditioning chemicals to improve their effectiveness. It oxidizes organic and inorganic compounds forming manganese dioxide, for better coagulation and flocculation. Thus, use of other chemicals, and overall chemical costs, can be reduced. WRITE FOR BULLETIN M-6001

Acid mine drainage

Cairox precipitates manganese at all pH's, but between 6 and 9 it's well within EPA standards for discharge to receiving streams. In tests at a West Virginia mine, manganese in the wastewater was reduced from 19 mg/l to less than 1 mg/l for about 13¢ per 1,000 gal at a pH of 7.5. WRITE FOR BULLETIN M-8001

Air pollution

Cairox used in wet scrubbers reduces or eliminates nuisance odors, or toxic emissions from many processes. Our new Carus Oxidation Catalyst cleans up stack gas by converting hydrocarbons to carbon dioxide and water at temperatures below 700°F. WRITE FOR BULLETINS M-2022 AND M-4012

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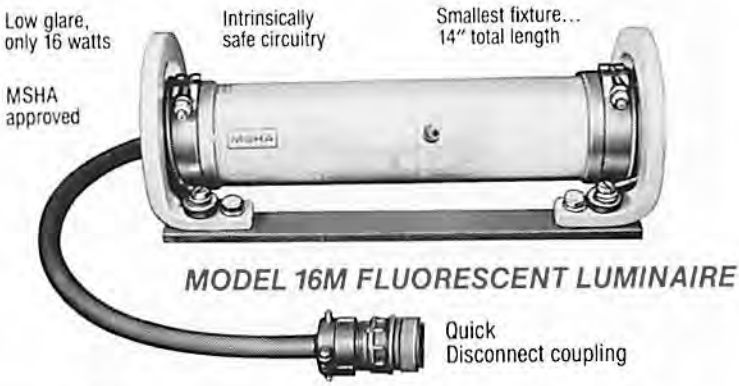

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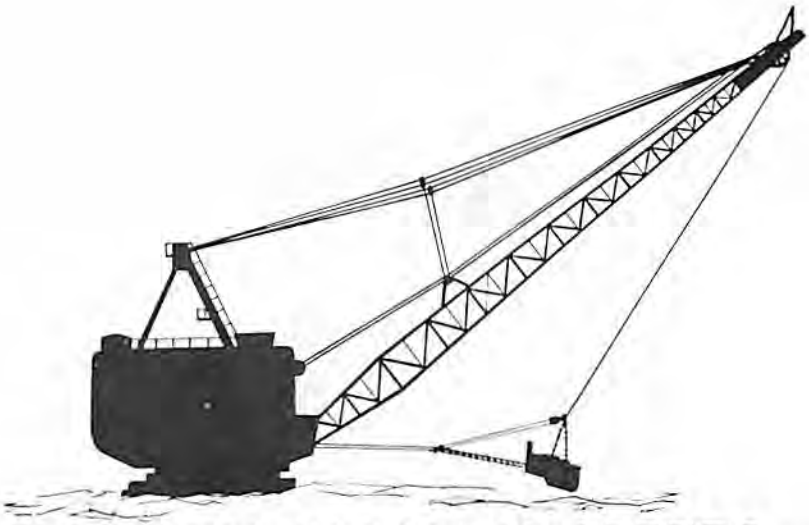

GENERAL ELECTRIC OFFERS COMPLETE DC DRIVE SYSTEMS FOR THE MINING INDUSTRY

- EXCAVATORS
- DRILLS
- LOADERS

ADVANTAGES OF DC EXCAVATOR DRIVES

1. Control of speed with instant torque to match all loads means better bucket fill per pass.
2. High speeds at light loads and fast power reversal mean more passes per hour.
3. High torque at low speeds and heavy loads reduces maintenance, means more working hours per shift.
4. Effortless, responsive control means less operator fatigue, better performance, more end-of-shift production.
5. Drive versatility means broad application of shovel in heavy bailing, rock handling, bench cleaning, road building.
6. Lowest power loss means more power to the bucket throughout the digging cycle.
7. Return of power to the line, when lowering or stopping, reduces waste heat, means lower pit power cost.

General Electric means experienced application and service engineering, fast renewal parts service and fully equipped service shops.

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
DIRECT CURRENT MOTOR AND GENERATOR DEPARTMENT
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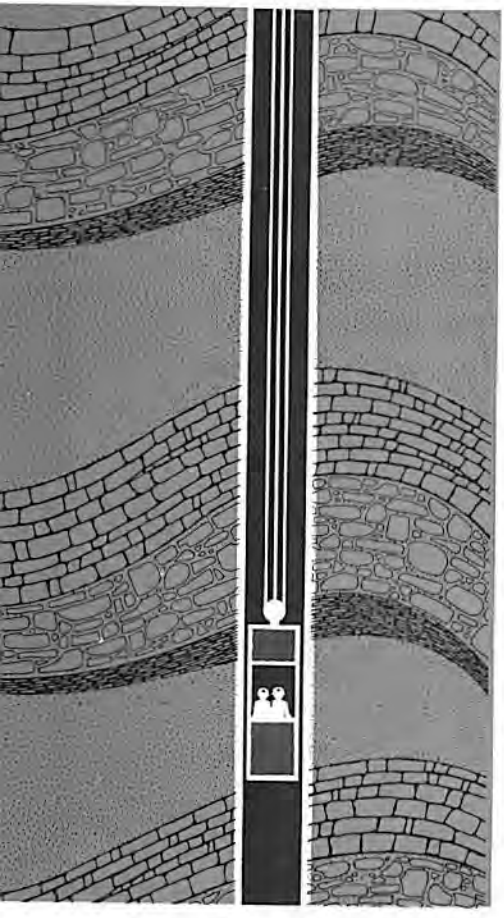
who knows?



GENERAL ELECTRIC'S DIGITAL PROGRAMMED HOIST DRIVE SYSTEM KNOWS

General Electric digital-programmed mine-hoist drive knows where the cage is, always . . . knows when to start its landing slowdown and when to creep. GE drive automatically corrects for new rope stretch and re-zeros each time at end of travel. Digital programming minimizes creep-in time and saves seconds on every trip.

General Electric industry-proved digital programming means fast set-up at installation and eliminates the maintenance of a mechanical program switch.

The first General Electric digital programmed mine hoist drive was delivered in 1961. Others followed as mine operators recognized the accuracy and reliability of solid-state programmed control. *Today, General Electric digital programmed hoist control is offered as standard equipment through leading suppliers of mine hoists.*

For more information call your nearest General Electric sales engineer or hoist supplier today, or write General Electric Company, Drive Systems Department, 1501 Roanoke Blvd., Salem, VA 24153

GENERAL ELECTRIC

HICKS oils

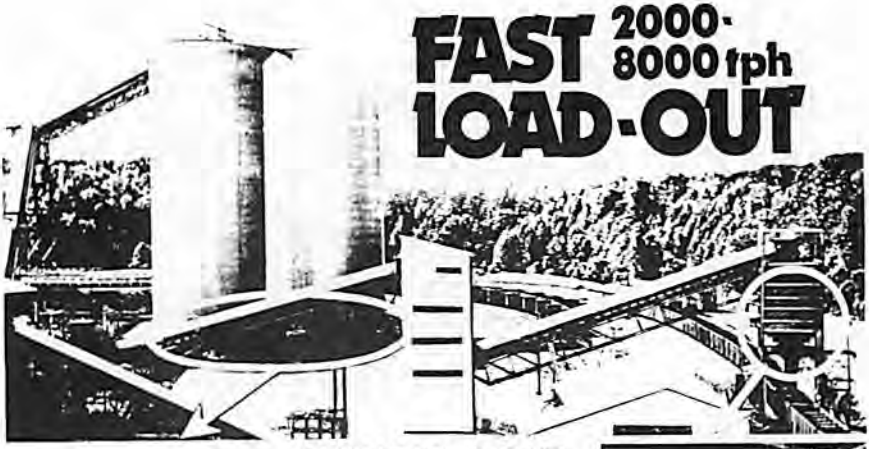
Bulk Oil Handling Equipment for Underground Mines is now offered by HICKS OILS, DU QUOIN, ILLINOIS 62832. Phone: 618-542-5431.

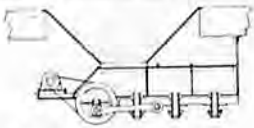
The above pictures feature two types: The square unit is our Scoop Service Unit. This unit has two oil tanks and a service station type grease pump, all operated by hydraulic power. This unit fits in a scoop bucket, using the scoop hydraulic system as a power source.

The Double Pressure Type Tank Unit will transfer oil with it's own air head pressure. No pump or power required.

Contact: HICKS OILS, DU QUOIN, ILLINOIS 62832 for more information.

FAST 2000-8000 tph LOAD-OUT





RECIPROCATING FEEDERS

Field proven as a dependable and economical unit for feeding various materials in controlled quantities, and for unloading bins, hoppers, storage silos and storage piles.

Kanawha Feeders are custom tailored to the application in width, length, height and capacity. Available in widths of 2 to 8 feet and lengths of 5 to 20 feet. Single feeder installations unload at 50 to 2,000 TPH. Multiple feeders will handle loading rate up to 8,000 TPH.

SPECIAL FEATURES:

- All antifriction — including drive arms and drive shaft bearings.
- Floating feed plate rollers require no lubrication.
- Roller shoes and brackets cast from 400 brinell Almanite for long wear and life.
- Flywheels on each end of drive shaft provide inertia for smooth operation.
- Adjustable stroke on all feeders by use of a manual, easily adjustable clamp device.
- Driven sprocket ring assembly — bolted on flywheel and easily maintained.
- Seal strips on sides and back.

RAPID LOADING GATE

The Kanawha Rapid Load System has been the standard of the industry since the advent of unit train loading. Both the standard 4'x4' and the large 5'x5' system provide the same fast, dependable loading capability.

The only physical work involved in unit train loading is operating the control levers to open and close the gate and raising and lowering the chute. Operation is easy since the gate can be powered pneumatically, hydraulically or electrically. The rollaway chute movement is actuated by an electric or hydraulic motor.

SILO LOAD-OUT...

Seven Kanawha Reciprocating Feeders under one silo is a proven, low cost system for the most efficient silo unloading . . . an arrangement that has become an industry standard.

...to unit train loading

Kanawha Reciprocating Feeders combined with a Kanawha Rapid Loading Gate create a positive efficient system for fast unit train loading.

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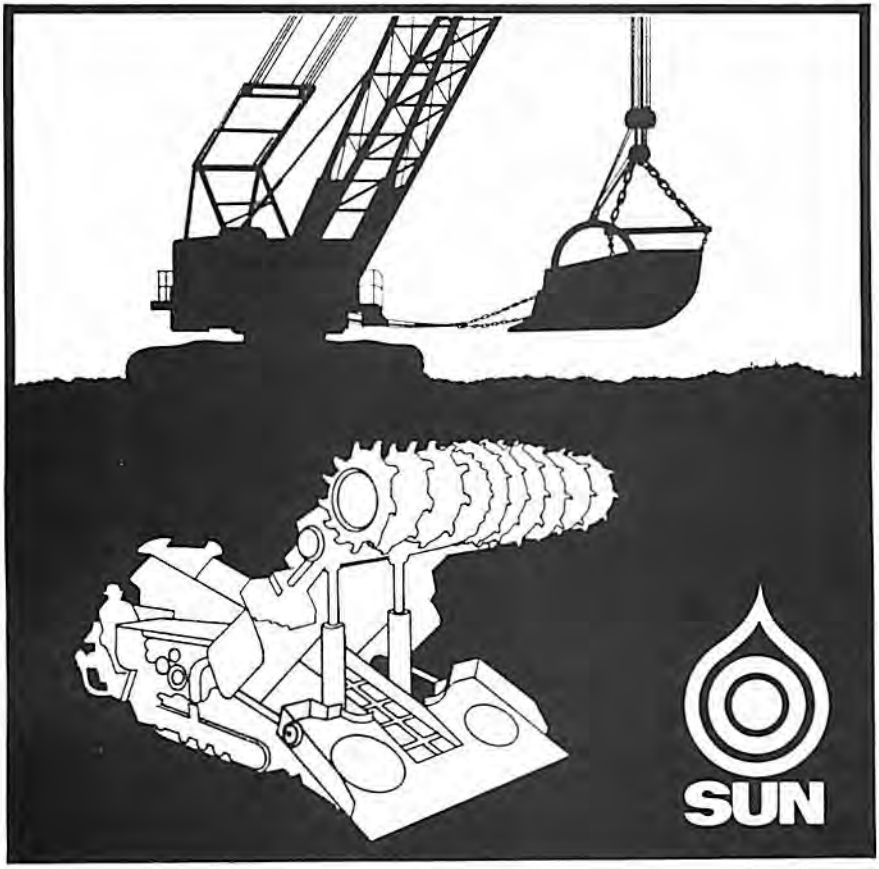
HIGH PERFORMANCE SUN LUBES PAY OFF IN LOWER OPERATING COSTS

Sun high performance lubricants are available for just about every mining application you can think of — above ground or below. Grease, gear oils, engine oils, transmission fluids, specialty lubes — you name it.

Sun lubes are paying off for big operators all across the country. Check with your Sun mining specialist. He can save you plenty on reduced paper work, simplified inventory ... and put SunScope oil analysis to work for you.

Call your local rep, or write direct to Sun, P.O. Box 141, Tulsa, OK 74102.



GIW Hydraulic Lab Aids in Pump and Pipeline Performance Testing on Water and Slurries

- The computerized GIW hydraulic lab was built four years ago to aid GIW in further development of pumps best suited for the demands of the decades ahead.
- The data collected has led to the development of a series of pumps with efficiencies of up to 87%, to a range of vertical pumps, and a group of high pressure pumps to add to our family of LSA pumps.
- By continually expanding the lab to enable testing in 3", 4", 6", 8", and 18" diameter pipelines, we are well equipped to carry out tests on your material and to help you design the most energy efficient slurry pipeline.

GIW

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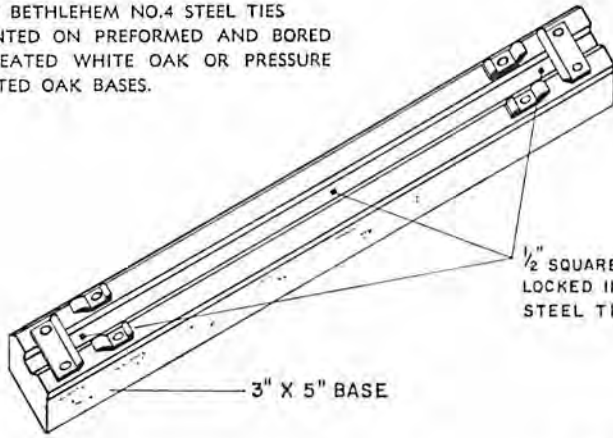
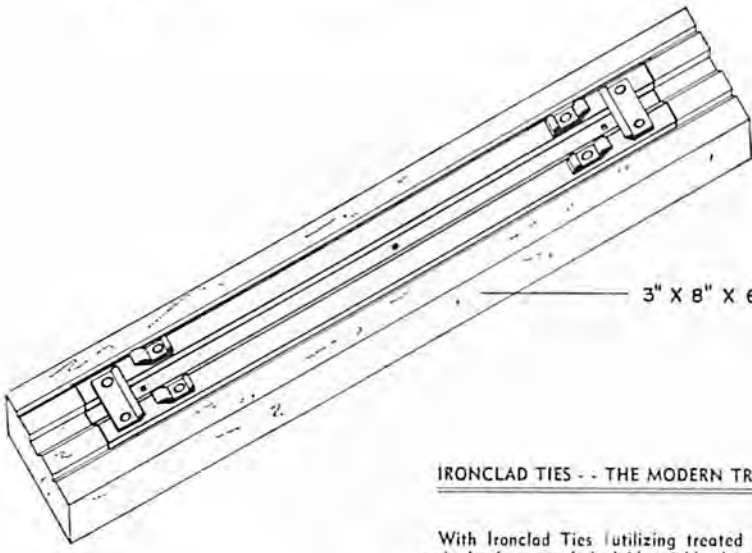
IRONCLAD TIES

WITH BETHLEHEM NO.4 STEEL TIES MOUNTED ON PREFORMED AND BORED UNTREATED WHITE OAK OR PRESSURE TREATED OAK BASES.





IRONCLAD TIES - - THE MODERN TRACK TOOL

With Ironclad Ties (utilizing treated oak bases), main haulage track is laid quickly, less expensively and true-to-gauge, providing a ballastable, stable, long-life, high-speed haulage road. The secondary haulage system using Ironclad Ties with untreated white oak bases will add the re-use feature without spike-killing and true-gauge loss attributable to loose spikes in wood ties or bent and clip-sprung steel ties. Untreated, mountain-grown white oak has an average life expectancy of ten years. Ironclad cross ties and turnout ties are available for all gauges and rail sections.

SEMCOR

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  Flexible Metal Hose—Teflon Hose—Expansion Joints
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  Paint Spray Equipment
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  Teflon, Kynar, Polypropylene Lined Pipe and Fittings
- ☐ **REXNORD**
  Rex Chainbelt — Chain — Sprockets — Conveyor Components — Shaft Couplings — Idlers — Pulleys
- ☐ **UNIROYAL, INC.**
  Conveyor and Elevator Belting — Power Transmission ("V" Belts, "Timing" Belts, and Variable Speed Belts) — Hose — Sheet and Sponge Rubber — Molded Goods — Footwear and Clothing — Matting — Expansion Joints — Skirt Board Rubber

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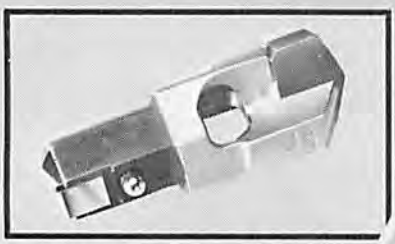
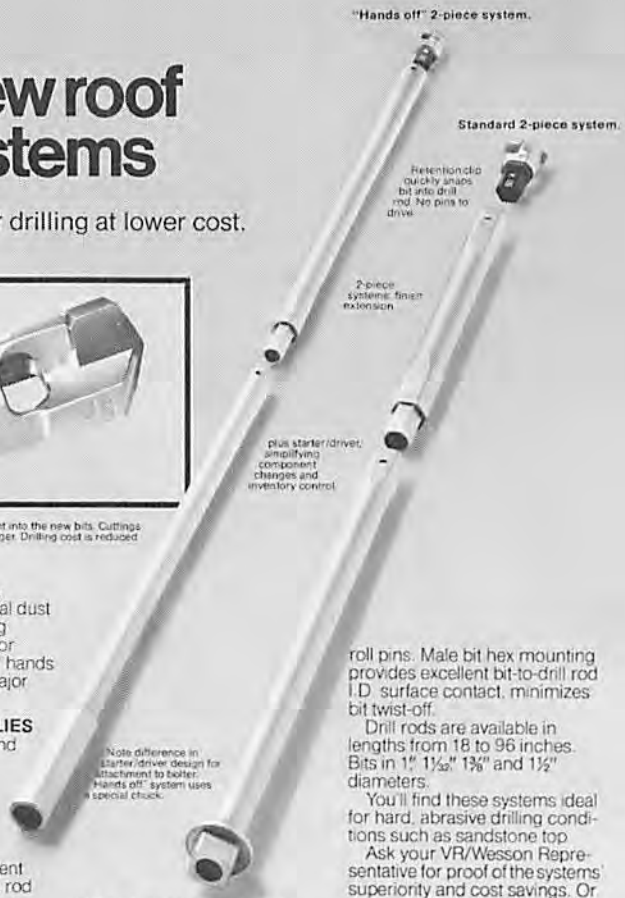
Two new roof drill systems

for faster, cleaner drilling at lower cost.



Dust collection holes are designed right into the new bits. Cuttings removal is fast. Bits run cooler, last longer. Drilling cost is reduced.



VR/Wesson announces a needed advance in internal dust collection type roof drilling systems for resin or anchor bolting. A standard and a "hands off" system feature two major improvements.

NEW 2-PIECE ASSEMBLIES do the work of 3-piece and do it better, faster and easier. In both systems, you have just two parts to handle: a starter/driver and a middle/finish extension. Fewer time-consuming component changes are needed. Drill rod inventory control is made simple.

NEW, IMPROVED ROOF BITS have built-in dust collection holes for fast, positive cuttings removal. Because cuttings are not recut, the bit runs cooler, lasts longer. Penetration is faster, too. The pay-off is more holes per bit, cleaner holes and faster drilling. Overall, lower drilling cost.

MORE ADVANTAGES OF THESE NEW SYSTEMS. Drill steel is fabricated using unitized joints, not welded. This adds strength, minimizes breakage. A constant I.D. is maintained throughout the drill rod (½" for the 1" system and ¾" for the 1⅜" system). There are no constrictions at coupling joints.

The new bits have sturdy retention clips that make bit changing faster. No fumbling for roll pins. Male bit hex mounting provides excellent bit-to-drill rod I.D. surface contact, minimizes bit twist-off.

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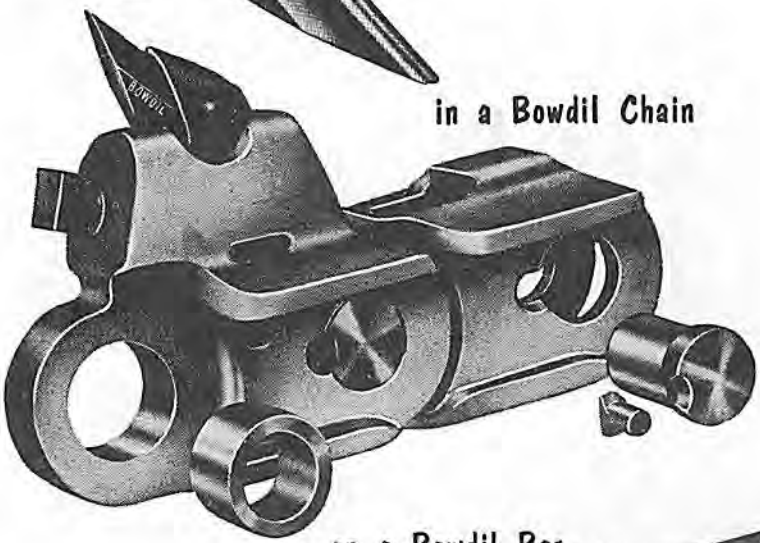

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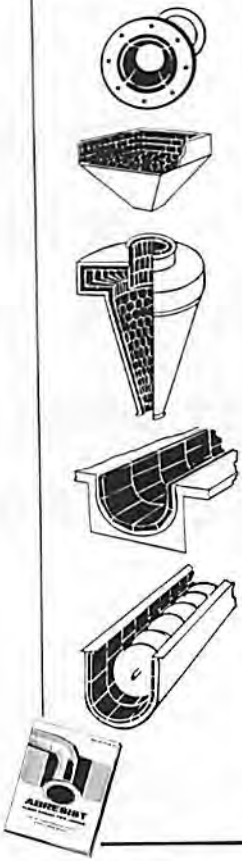

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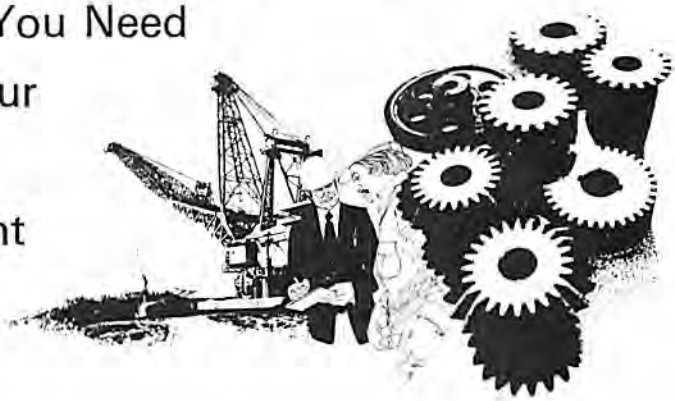

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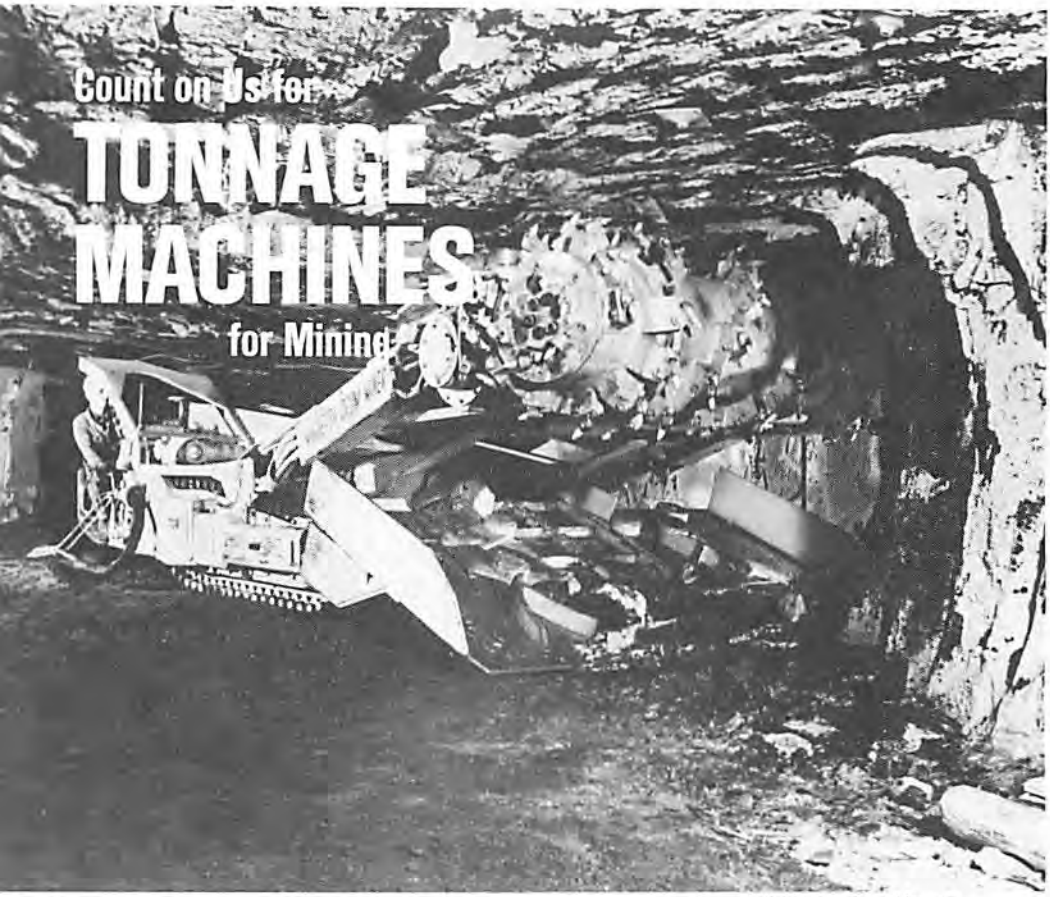

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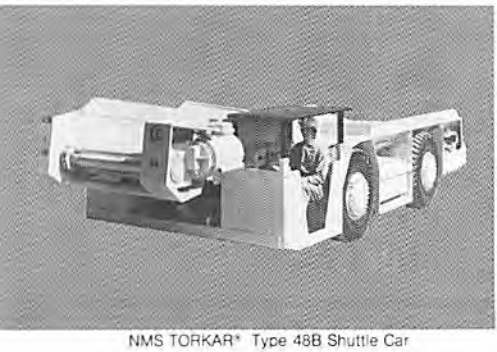

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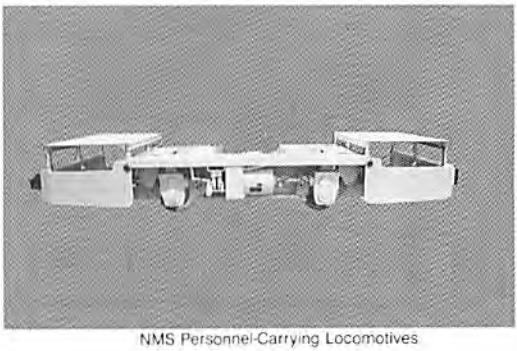

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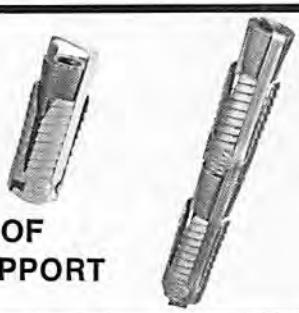

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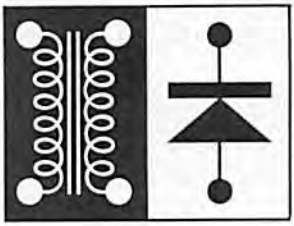

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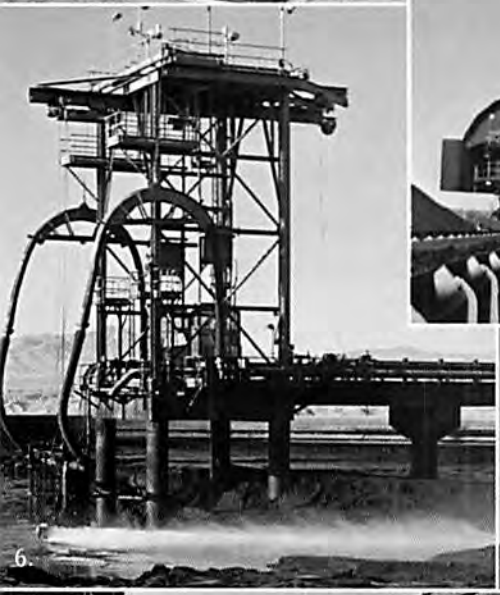

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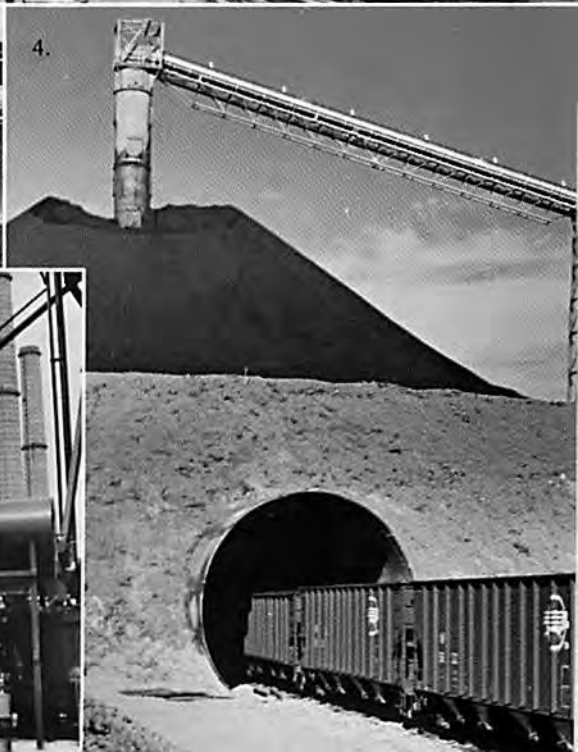

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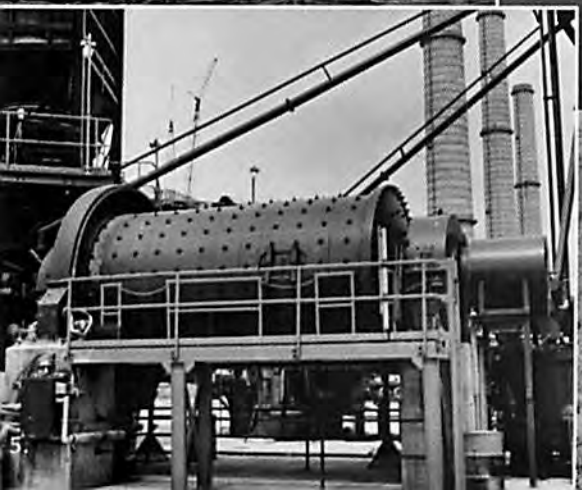

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Coal's future is now. And so is McNally's help in securing it.

America's coal industry is being challenged as never before. By today's cost squeeze, troubled economy, environmental concerns and increasing need for quality control.

But the world needs coal now. And that calls for fast, effective solutions to these problems.

Such as the equipment you see here, all designed and engineered by the McNally Group of companies.

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Problem-solving experience and expertise. It's put the McNally Group out front in service to the coal industry. It gives each McNally company the strength of all McNally companies.

Photos at left: 1. modular coal preparation plant; 2. large heavy media preparation plant; 3. stacker/reclaimer; 4. unit train loading system; 5. limestone grinding system for stack scrubbers; 6. Marconaflo slurry system.

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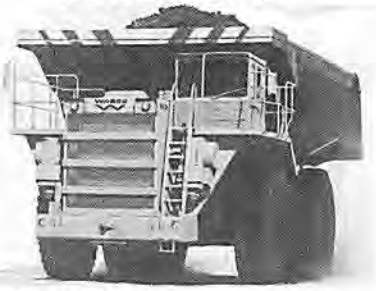

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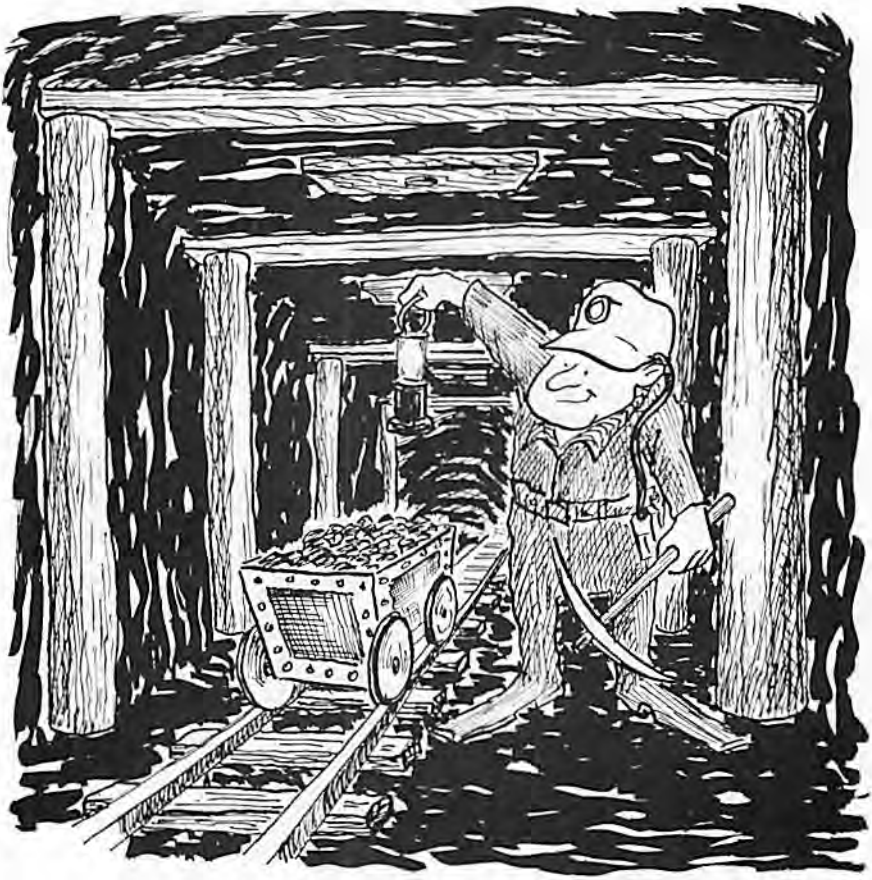

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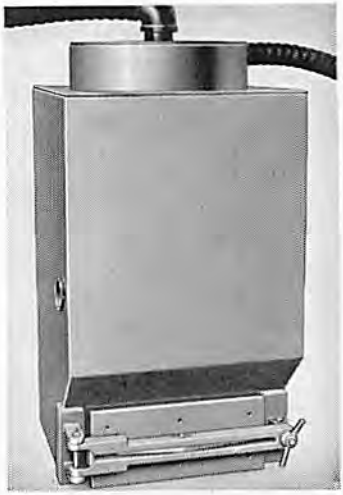

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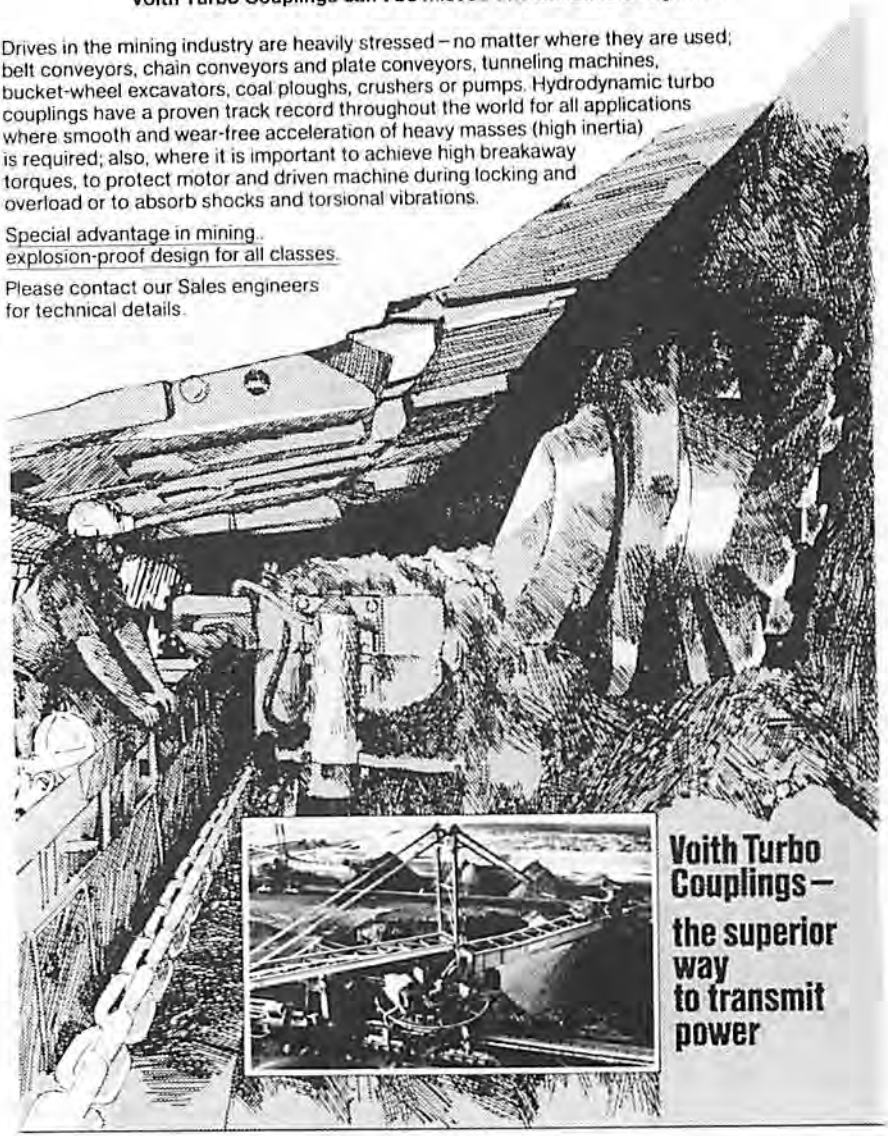

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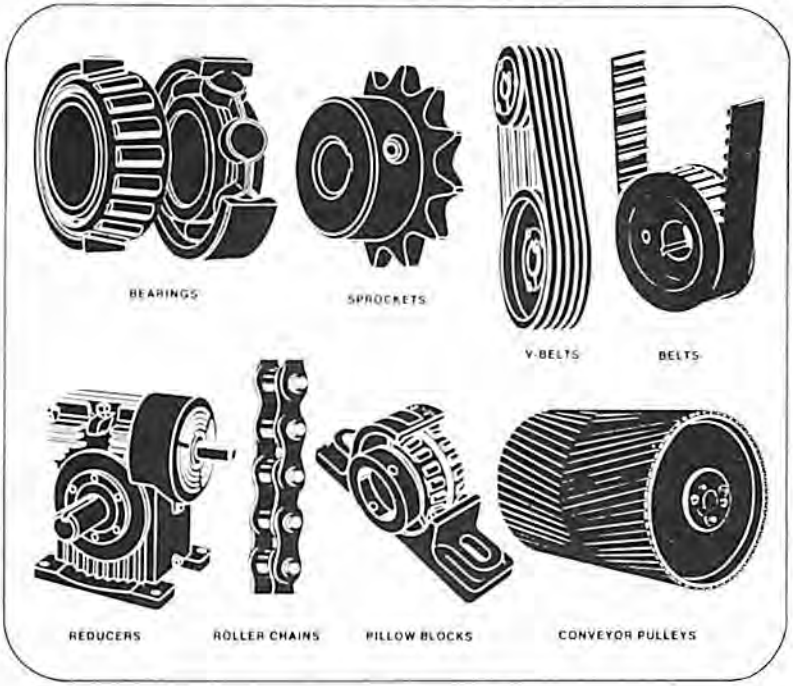

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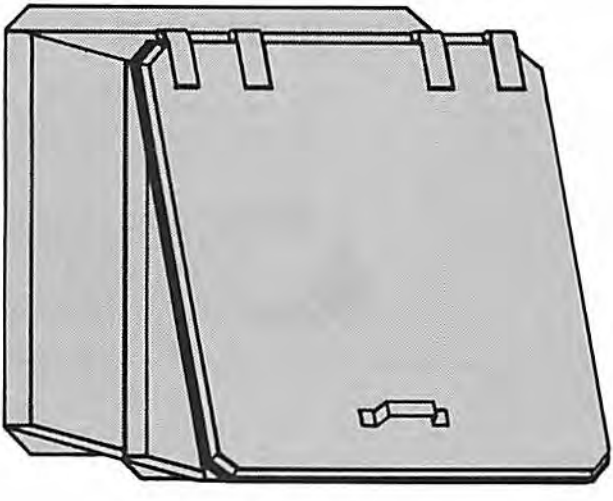

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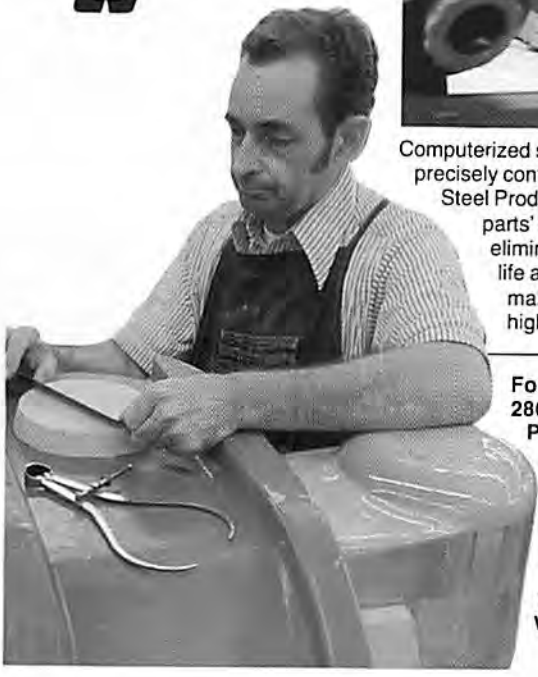

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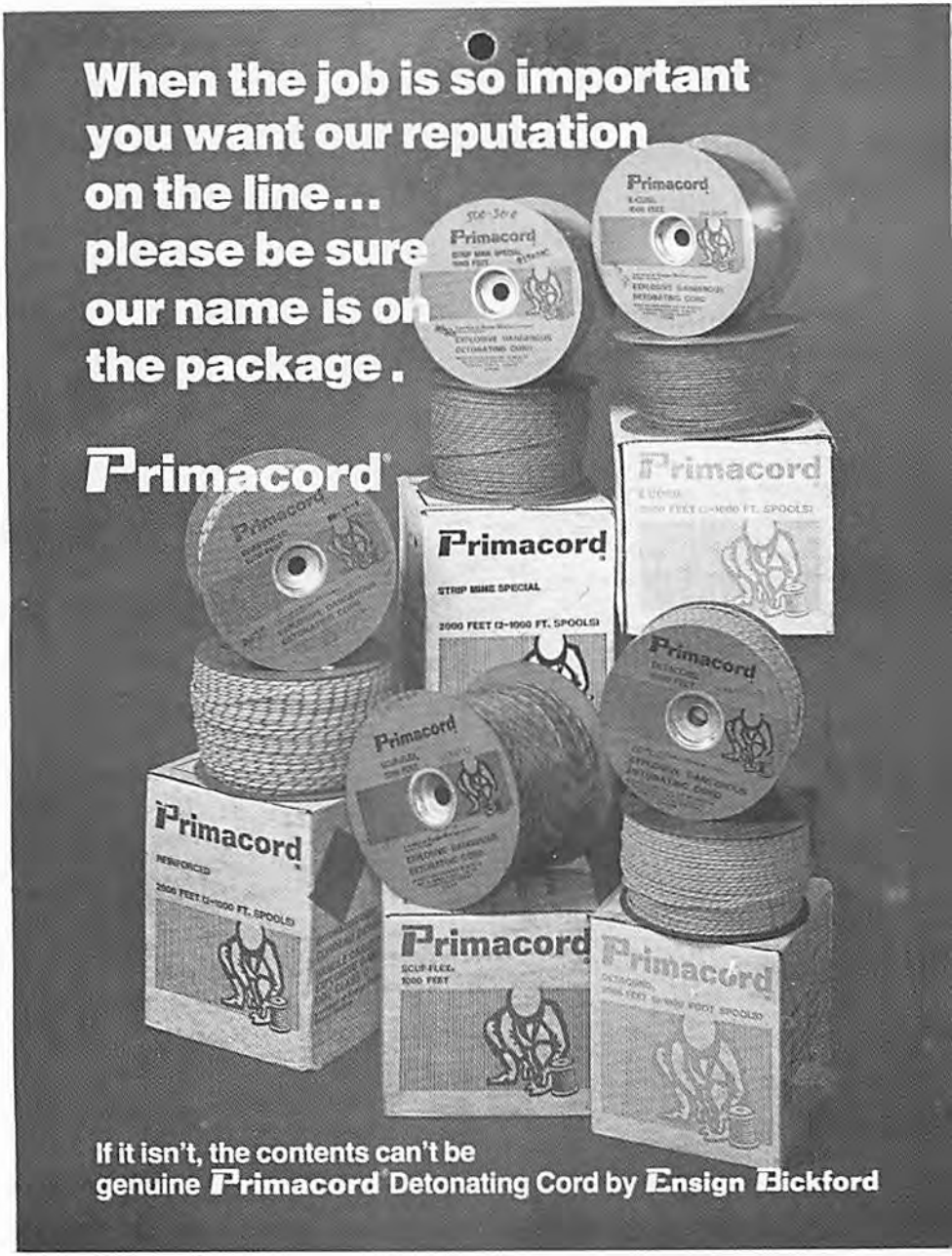
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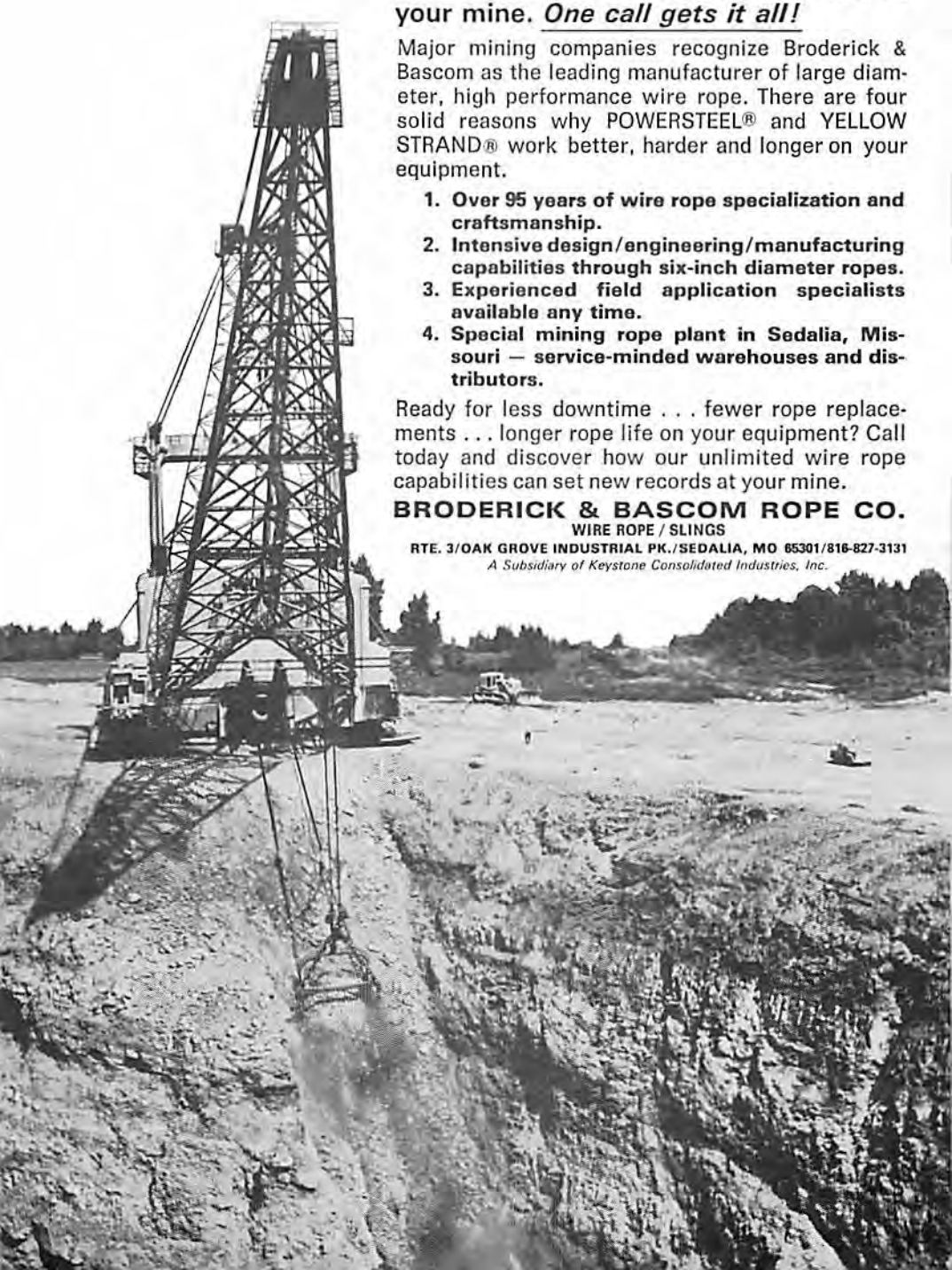

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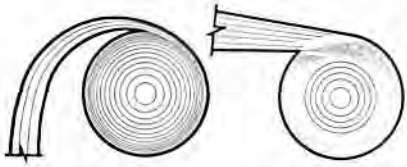

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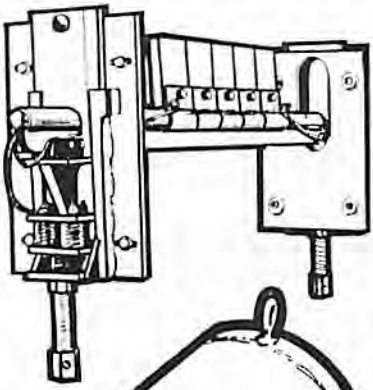
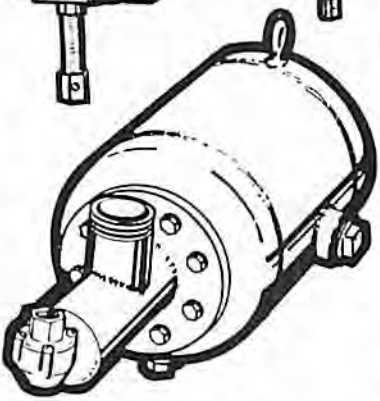
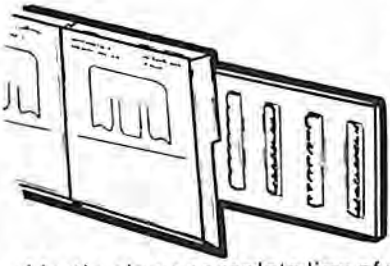


Martin's two-stage TRAC-MOUNT®belt cleaner system, keeps belts clean with one man maintenance. The Trac-Mount system uses a Doctor blade to remove 90% of the carryback material. A second cleaner with multibladed Torsion Arms skims off even the stickiest material. This means a more productive conveyor and no downtime for maintenance.



Martin's BIG BLASTER® air cannons break up and aerate stubborn material that is bridged, ratholed or clinging to the container walls. Cleans material build-up under screens, in chutes, and at conveyor transfer points. Sudden powerful release of air directly into the material causes it to flow freely.



Martin TRAC-MOUNT® skirtboard eliminates material spillage from conveyor transfer points. Individual 6" rubber blocks adjust with the tap of a hammer. Dove tailed ends provide a continuous seal no matter how long the installation. State of the Art in sealing systems for belt conveyors.

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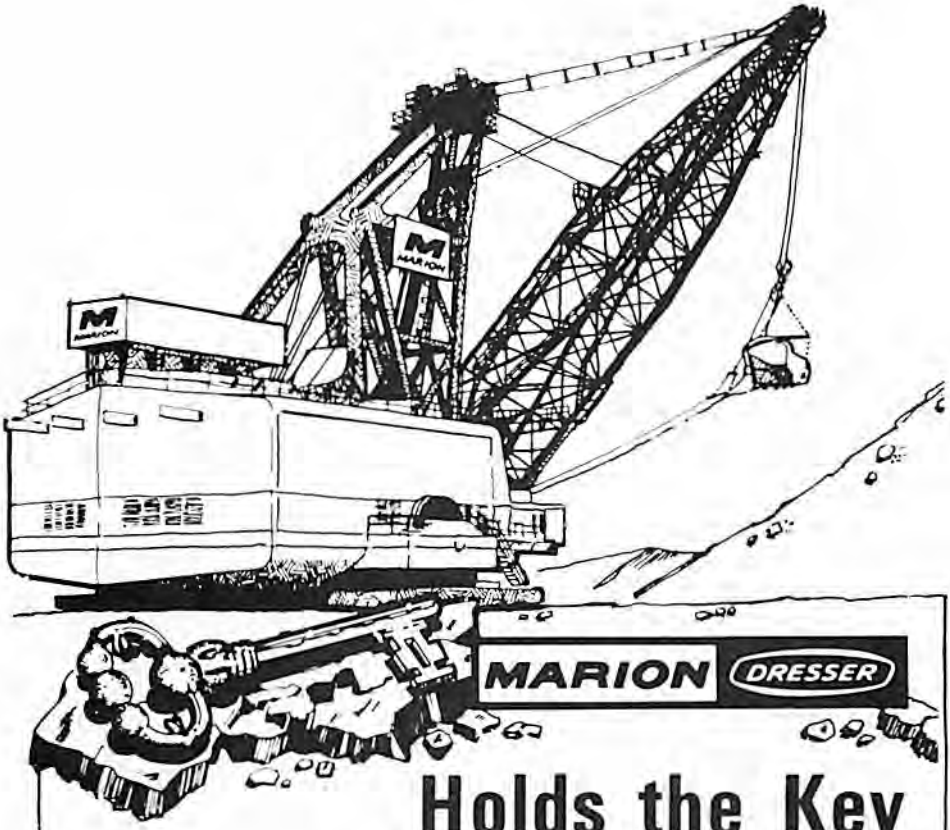

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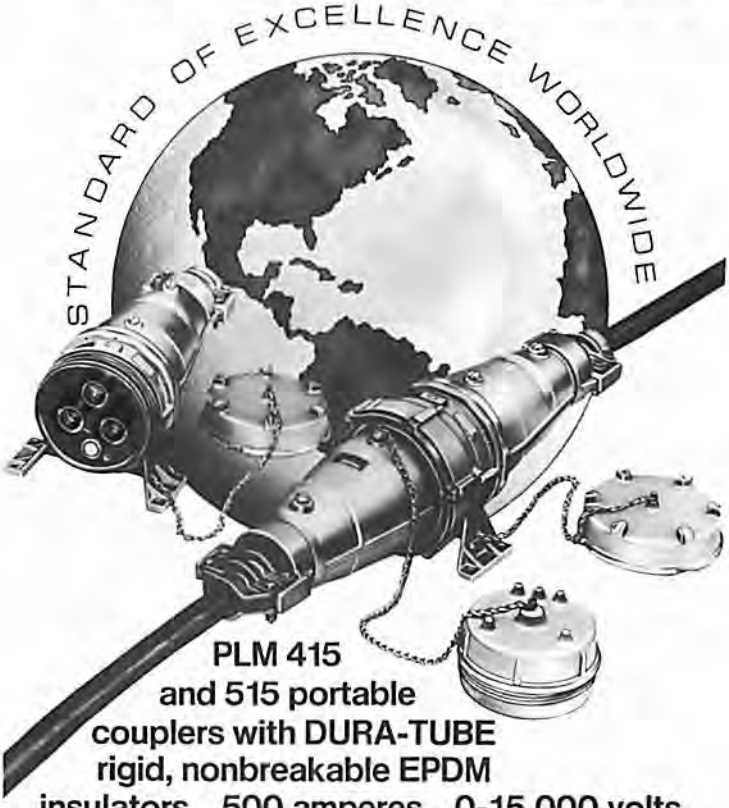

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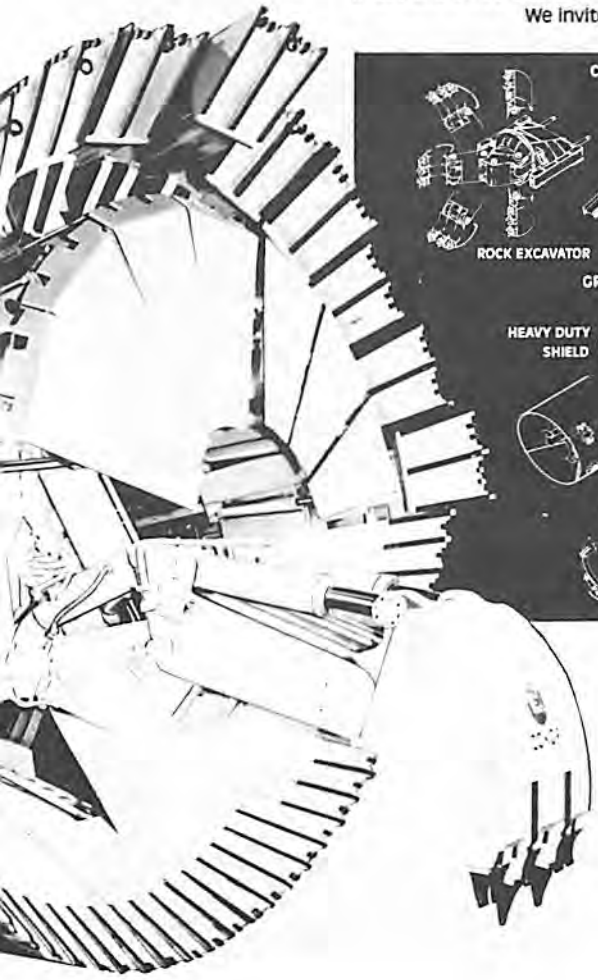

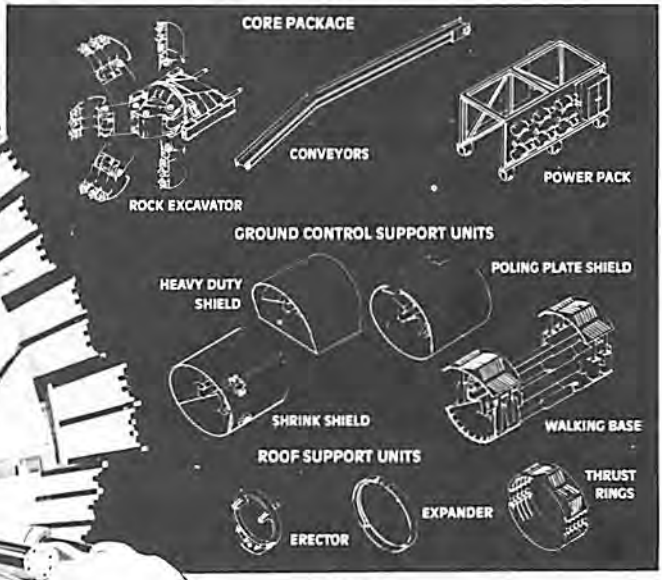

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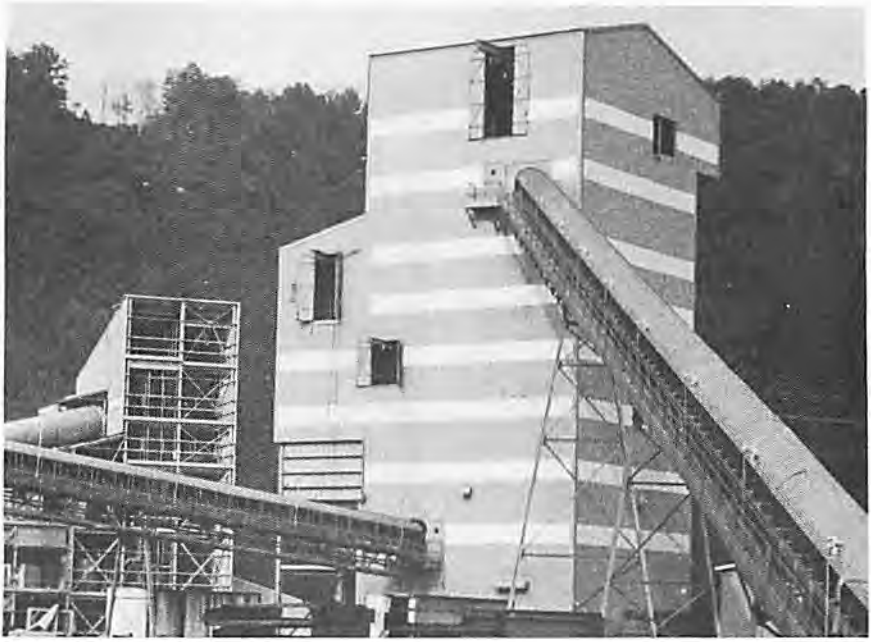
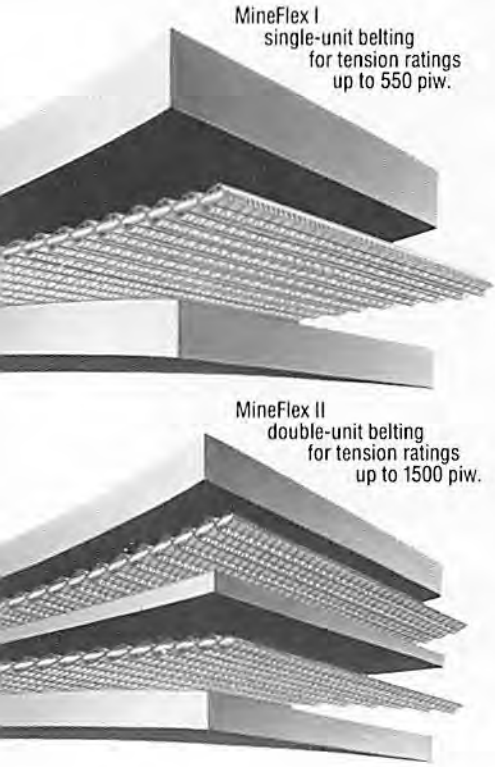


For belting and hose that meet



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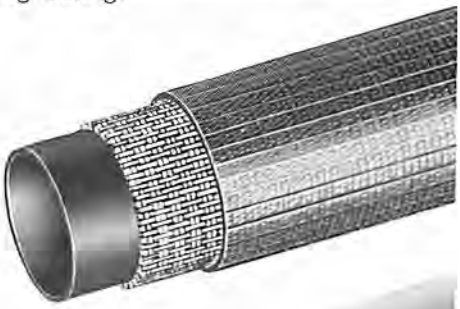

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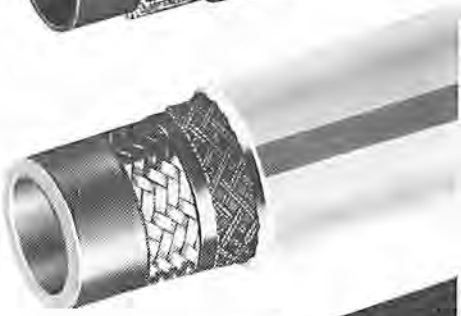

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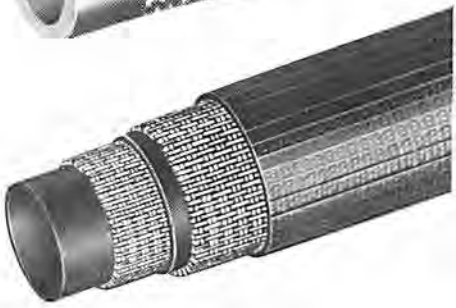

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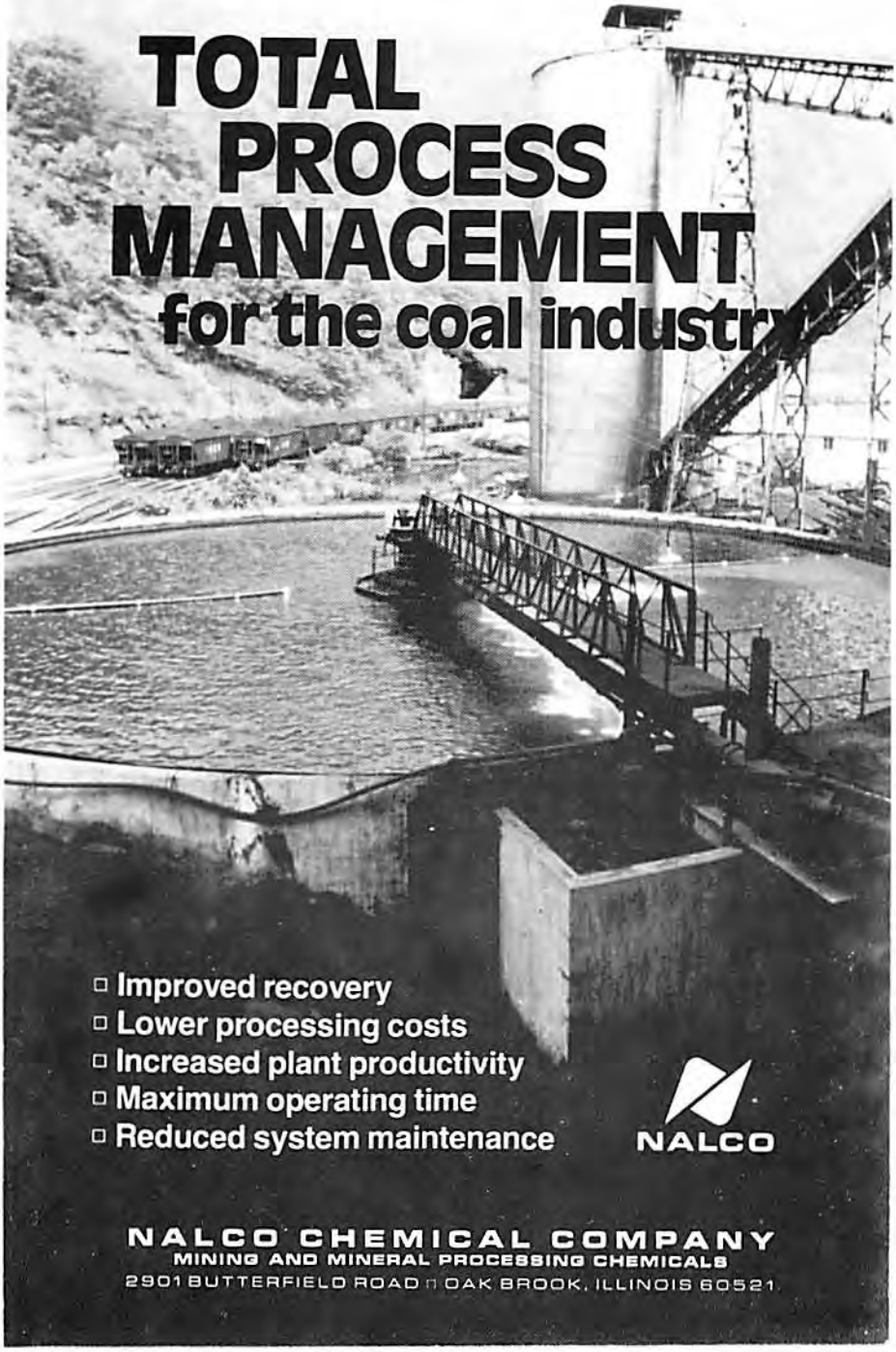
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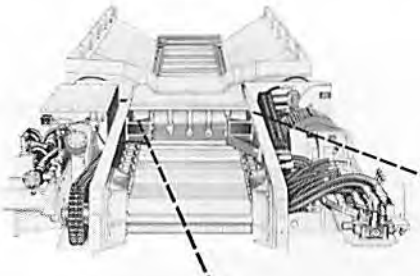

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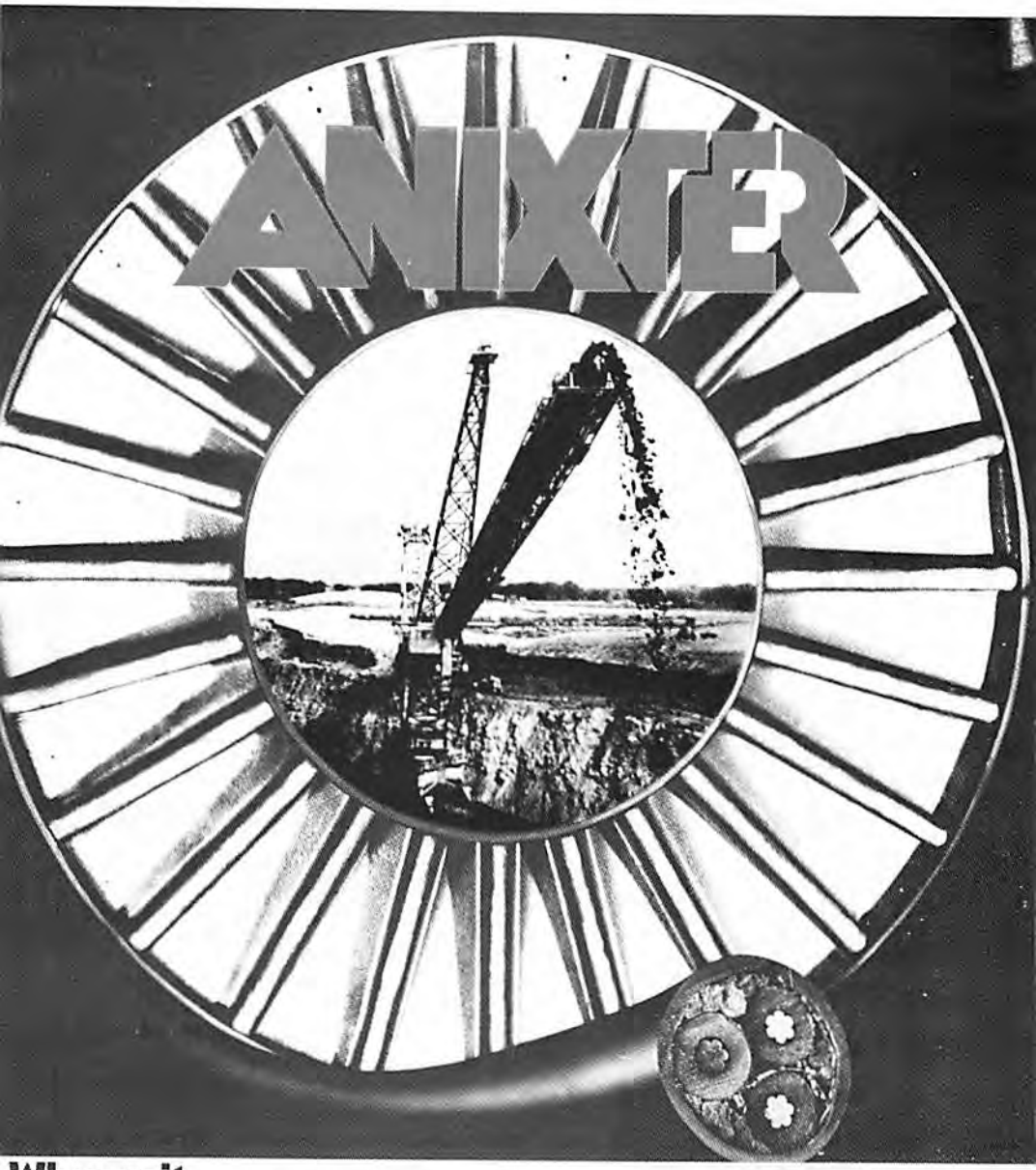

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