



## REPORT

## TECHNOLOGY OF AUGER MINING

PREPARED FOR

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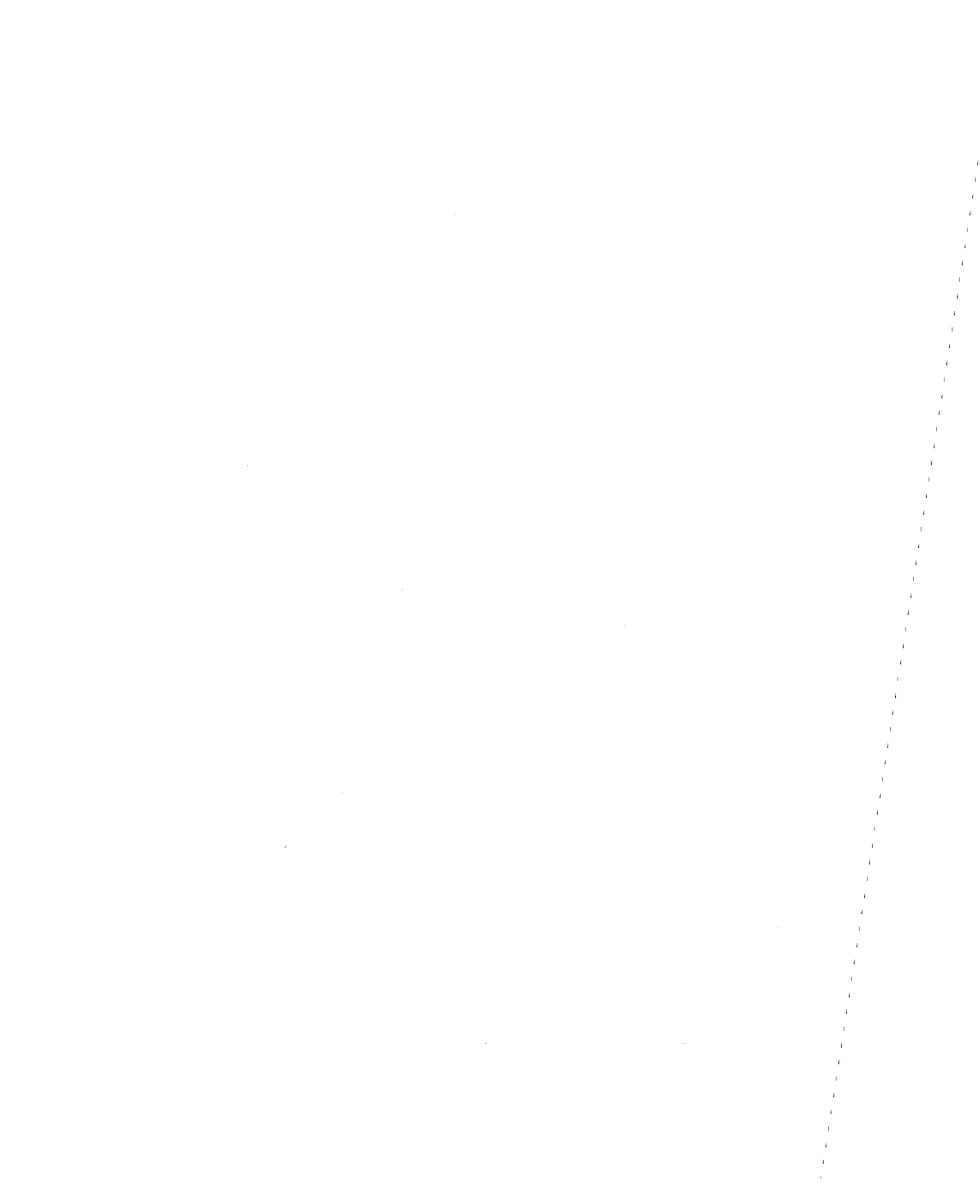
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## FOREWORD

This report was prepared by Ford, Bacon & Davis, Inc. N.Y., N.Y. under USBM Contract No. S0241050. The contract is authorized by law and executed pursuant to Public Law 89-672 (80 Stat. 951) and the Fiscal Year 1974 Appropriations Act for the U.S. Department of the Interior (P.L. 93-120; 87 Stat. 429). It was administered under the technical direction of the Spokane Mining Research Center with Mr. John Goris acting as the technical project officer. Mr. B.G. Horton was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period October 1974 to June 1975. This report was submitted by the authors on October 1975.



Subject Inventions

This is to certify that, to the best of my knowledge and belief, there were no Subject Inventions made or have resulted from the performance of this contract.

October 1975

  
W.J. Habeck  
Project Director

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## SUMMARY

### Coal Reserves and Project Independence

Studies of coal reserves have shown that the total augerable reserve base for the United States is estimated to be five billion tons under the current state of mining technology; the potential reserve base at 850-ft penetration is estimated at 20 billion tons.

It is with the idea of improving coal recovery, a basic objective of Project Independence, that new concepts, such as modifications and improvements in current machines and development of ways to recover pillars left by current augering, are required. Unless recovery is improved, these potential reserves amount to lost coal.

### State-of-the-Art

The auger mining industry, although relatively small as compared to the surface or underground mining industry, has, since its initial development in 1951, continued to grow and provide a supplemental supply of high-quality coal. Approximately 15,554,000 tons were produced by 574 mines in 1972.

Although there are approximately 139 companies engaged in auger mining practices, only six are rated among the top 50 major producers of coal. The balance are smaller independent producers who, in many cases, combine auger operations with their other activities in surface mining. In addition to this group, there are also a number of independent auger contractors who are called upon in many instances by major surface mine producers to auger supplemental tonnages of coal to meet corporate contractual commitments.

According to Keystone Manual, the 1973 individual company annual production ranged from a reported minimum of 218 tons to a maximum of 335,334 tons.

Most of the auger mines are located in the Eastern Region of Appalachia, with the greatest number in Kentucky and West Virginia. Although there are a few auger mines in the Central Region, augering has not gained any appreciable degree of acceptance in the Western Region.

Auger mining activities require low capital investments and produce more tons per manday than surface or underground operations, but irrespective of these economic advantages, the industry is still extremely sensitive to fluctuations in the price of auger coal. This is brought about by the fact that the smaller independent operator, with a relatively low volume of annual production, and limited capital cannot compete with the keen competition of both auger and surface miners when coal prices decline. 2

### Economics

The capital costs for augering equipment range between \$95,000 and \$500,000 depending on type and size of the individual machines and desired accessories. In general, auger machines with single cutting heads are less costly to purchase than dual or triple head units due to the increased power, transmission, flight and cutting head costs. Accessories are relatively few in number and include such items as lights and flight storage racks, if desired.

Operating cost estimates of typical 36-in. single-head auger producing 125,000 tons per year of auger coal amount to \$6.62 per ton. This total mining cost includes direct charges for labor, fuel, materials and supplies, as well as indirect charges for the acquisition, owning and depreciation of the auger equipment. A corresponding estimate of a 27-in. dual-head unit producing 156,000 tons, amounts to \$6.58 per ton as the total mining cost.

### Impact of Laws

A study of the state reclamation laws regarding augering reveals that only two states, Ohio and Kentucky, refer specifically to auger mining. The effect of these state laws on auger mining per se is minimal, requiring only such items as plugging of auger holes and reclaiming auger haul roads and benches created by the auger miner. However, all states regard auger mining as a form of surface mining, and each state has stringent laws with respect to surface mining, slopes and highwall reduction. Time limits are established in many cases between overburden removal and reclamation. The impact of these surface mining reclamation laws is to institute reclamation measures within the specified time limit, thereby covering the highwall as well as the residual coal reserve, irrespective of the extent of augerable coal which remains. The potential coal reserve is thereby lost as a result of the surface reclamation laws.

There is, therefore, a need for more effective augering operations and a closer coordination between surface and auger mining in order to obtain maximum coal recovery, before reclamation prohibits the economic recovery of the reserve by either form.

## Alternatives to Auger Mining

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The alternatives to auger mining are all modifications of underground mining methods which require large reserves, three to five years to develop and major investments of capital. In any and all of the underground methods including room and pillar, longwall, bridgewall, shortwall and punch mining, the hazards and safety associated with underground operations, the maintenance of adequate protection for the miners, and ventilation systems, entry openings, the need for roof bolting and surface support facilities all apply and are of paramount importance. The time and capital expenditures to insure the satisfactory establishment of these facilities is large. By today's criteria, the necessary facilities for a two million ton annual capacity underground mine may range from \$20,000,000 to \$65,000,000. A sufficient reserve of coal must therefore be available to justify the large capital investment.

In contrast to these values of time and capital outlay, augering operations can be instituted in less than a year at a cost of the order of 1,000,000 to 2,000,000 dollars.

Additionally a substantially smaller coal reserve is necessary for augering operations.

### Auger Reserves and Recovery

Although recoveries of 50% at depths of 150 ft are common, average recovery ranges between 25% and 35% at these depths. With due allowance for increased depths to 200 ft and recoveries of 25%, more than 1-1/4 billion tons of coal could be recovered by current auger mining methodology. With the development of auger technology permitting extensions to depths of 850 ft, the estimated recoverable coal at the same 25% rate, increases to 5 billion tons. More than 50% of the augerable coal which can be recovered lies in the Eastern Region where contour and auger mining operations have the highest degree of concentration.

### Machine Modification

Currently-designed augers are simple machines without any degree of elaborate controls. Power requirements are a function of head diameter, length and weight of the scroll, friction factors, speed and tons of material conveyed. Bit diameter is fixed in each case but the friction factor, weight of conveyor scroll, speed and material conveyed are all variable.

Power requirements are cumulative with each additional conveyor flight. Additionally, sag due to weight factors limit the ultimate depth of penetration. Several modifications to existing auger machines are possible.

1. The use of lightweight flights with replaceable shoes similar to that used on spiral classifiers would tend to reduce weight and permit greater depths of penetration.
2. Auger bit redesign to provide not only more flexibility with respect to variations in individual seams, but also to allow for increased recoveries via side cutters. This would produce square holes with higher recovery rather than the conventional circular hole.
3. Screw-thread-type flight connections similar to oil well drill pipe to reduce deflection.
4. Develop oil motor to obtain greater torque with diesel power units for hydraulic line located away from the auger machine.
5. Adaptive control devices to exert constant pressure for uniform loading on cutting edge.
6. Guidance systems at the cutting head, telling what lies ahead of cutting edge.
7. Fail-safe systems for greater protection to operators required to work in highwall area.

These devices would all tend to improve the effectiveness of current augering operations.

#### Advantages and Disadvantages

The advantages of the auger mining method are as follows:

1. It provides more tons per manday than any other form of mining.
2. It is low cost as related to capital expenditures.
3. It produces less environmental disturbance per acre than surface mining.
4. While the volumes of coal that are produced as a result of augering are comparatively small when compared to surface or underground methodology, the quality of the coal produced commands a relatively high price.

5. Auger mining is a relatively safe form of mining when compared to underground mining.
6. Auger mining can be activated quickly and used for recovery of smaller coal deposits as compared to surface or underground methods of mining which requires large reserves and substantial capital and time to develop.

The disadvantages of auger mining are:

1. Low coal recoveries;
2. Inflexibility of auger machines and the lack of versatility in auger components;
3. Limited number of accessories available;
4. Inadequate guidance system;
5. Inadequate control of drill pressure and cutting speeds;
6. Insufficient knowledge of geology of the individual coal seams with wide variation in operator's technological approach and reliance on the ingenuity of operator's talents;
7. Lack of uniformity among operators as to the approach to operating methods;
8. Multiplicity of small, low-volume producers;

### New Concepts

The relatively low recoveries of coal from auger mining suggest the development of alternative methods to recover those additional quantities of coal located in the pillar section between auger holes. Among the methods suggested have been the use of lightweight pipe casing around the auger stems and the design of metal guides to permit the auger to remain in the pillar section, the use of underground cutting chains or plows, and even the potential modification of the underground continuous miner.

The current concepts of removing by augering the pillar areas remaining between two auger holes with the use of dual- or multi-head augers has a certain degree of merit, but it would appear, that without some form of support in the adjacent holes, it would be only a matter of time before subsidence would occur and the cutting head and conveyor flights would be frozen under the highwall. Because of the relative instability of the initial face of the highwall, subsidence would occur before any appreciable depths of penetration could be made, and the total pillar length of coal would be unrecovered.

One of the current techniques used by the operator in determining his initial pillar spacing before augering the second hole is to place a wooden prop in the previously completed hole and start augering the second as close as possible to the first hole. If, during the initial drilling of the second hole, the wooden prop snaps, as a result of excessive rock pressure or subsidence in the first hole, the auger operator uses this as a guide to tell him that he needs a greater pillar thickness.

### Pillar Robbing

The concept wherein a side cutting auger train is introduced to the full depth of an auger hole and retreats at a uniform rate in the pillar between holes would appear to offer some interesting possibilities. Subsidence should follow the cutting head much as it does in longwall mining when the jacks and chocks are advanced. However, much would depend upon the integrity of the roof structure since, according to the analysis of rock structure, the greatest rock structure is usually encountered at depths rather than at the highwall face. There is, currently, no way to readily anticipate seam undulation or geologic fault zones within a given area. Since subsidence would take place from the inside toward the highwall at relatively uniform rates, there would be minimum risk associated with a major highwall collapse. The concept, as set forth, visualizes that all personnel would be at a safe distance from the highwall area where the pillars were being removed and that all machinery would be operated by remote control systems.

### Potential of Auger Mining at 850-ft Depth Penetration

No machine has been developed which will penetrate from the highwall into the coal seams for distances of 850 ft. As far back as 1955, Union Carbon and Carbide created a machine called the "Ground Mole" to provide access to underground coal seams for the purpose of in-place underground gasification. Subsequent to this effort, Peabody Coal Company and Kentucky Oaks Coal Company had two "pushbutton miners" constructed as prototypes. Discussions with the former operator of the "pushbutton miner" at Kentucky Oaks indicated that this unit had actually achieved depths of penetration in excess of 700 ft from the highwall. Additionally, the gyroscopic control system provided such a high degree of accuracy that pillar thicknesses of six in. could be maintained for the entire depth of penetration.

As already noted, the analysis of the current state-of-the-art of auger mining technology determined a capability of penetrating to a maximum of 200 ft, with a probable 150 ft average under good conditions.

Previous discussions on current auger mining technology have all indicated that augering is a highly specialized skill dependent on the operator's sense of touch and feel. Once the auger bit enters the highwall, the operator cannot see what is happening at the cutting face or know of deviations occurring from the cutting and conveying process. Before starting the cutting process, the operator makes absolutely certain the machine is aligned by the spirit-level graduations. As the head enters the highwall face, any faulty alignment of the auger tends to magnify any deflections with penetration into the auger hole. At 150-ft depths, fractional deflections graduate to about two to four in. below the initially established centerline. It is reasonable to assume, therefore, that unless a more effective auger flight system can be developed, maintaining true direction over greater distances, penetration to 850 ft would produce fivefold deflections. The use of existing equipment without modification would result in cutting of more rock and fire clay than coal.



## CHAPTER 1

### SCOPE AND PROCEDURE

#### Scope

The long-term effectiveness of coal surface mining in the United States is directly related to the capability of the equipment and the people who design, manufacture, use and maintain such equipment. The current energy situation has emphasized the importance of surface coal reserves and has caused us to examine not only current practices with respect to reclamation but also the methods employed for the extraction of coal. Ways are now being studied to improve our recovery of coal by surface and underground mining operations. The position of auger mining and its role in the production of coal is but one of the many forms of surface coal mining now being examined.

The purpose of this study is: (1) to determine the current practice and technology of auger mining in U. S. coal mines, (2) to determine the needs of the auger mining industry and (3) to determine ways to improve the effectiveness of auger mining.

#### Procedure

The investigation of the state-of-the-art of auger mining began with a search of the various periodicals and literature. The Offices of the U.S. Bureau of Mines in Arlington, Va., and USGS in Reston, Va., were visited to establish the potential locations, topography and availability of thin seam coal reserves which could be mined by auger methodology.

In the study of coal reserves, the Engineers investigated those seams which had the potential for current state-of-the-art auger mining, namely, seams ranging in thickness from 2 ft to 8 ft. Consideration was given to all of the potential coal seams that might fall into this particular category for the Eastern, Central and Western United States coal regions. An investigation of the recovery factors, the safety features and the economics of alternative methods, as well as those of auger mining, was also made along with a preliminary study of regulations and laws governing reclamation in those states where auger mining is practiced and their impact upon the auger mining industry.

Three manufacturers of auger equipment, namely Salem Tool Co., Advanced Mining and Equipment Co. and Long-Airdox Co. were visited to obtain current equipment design, specifications, capital and operating costs and potential modifications to auger equipment.

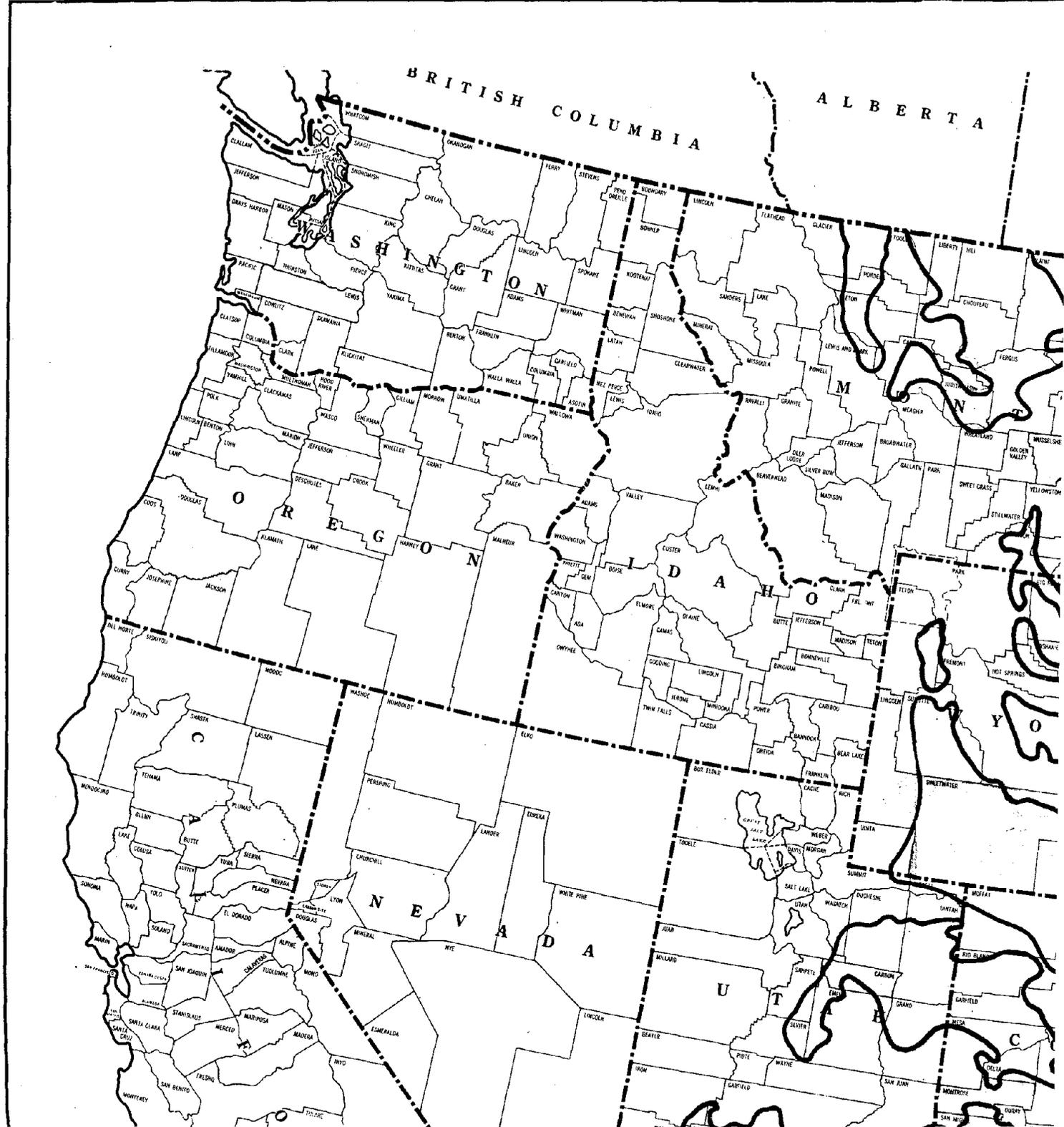
The Engineers visited five auger mines to find out their techniques, learn their thinking on existing equipment, their needs and the abilities of these small operators and small shops to modify, custom-tailor and improve on the manufacturers' designs on augering equipment.

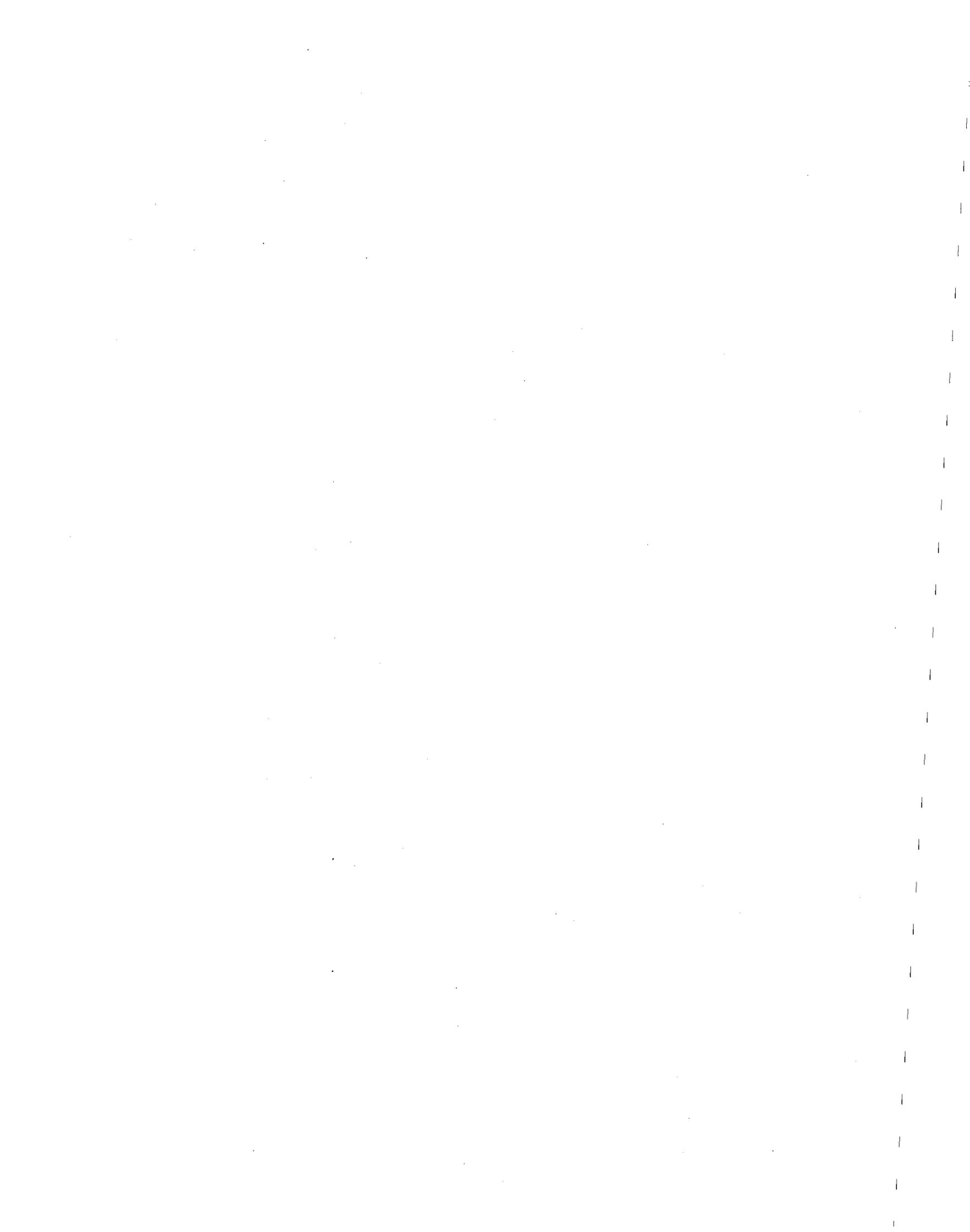
Major producers of coal were also contacted to discover their views on augering in the relatively flat-land states, such as Indiana and Illinois, and to elicit their opinions as to auger coal recovery potential beyond 200 ft. The Engineers also reviewed alternative methods which have been tried or tested for mining thin seam coal.

At the conclusion of the field investigations, the data were analyzed and summaries of the Engineers' findings prepared for the state-of-the-art, augerable coal reserves, economics and impact of law, alternative methods and potential improvements of auger mining. These are discussed in the following chapters of this report.

a-A

aa-B





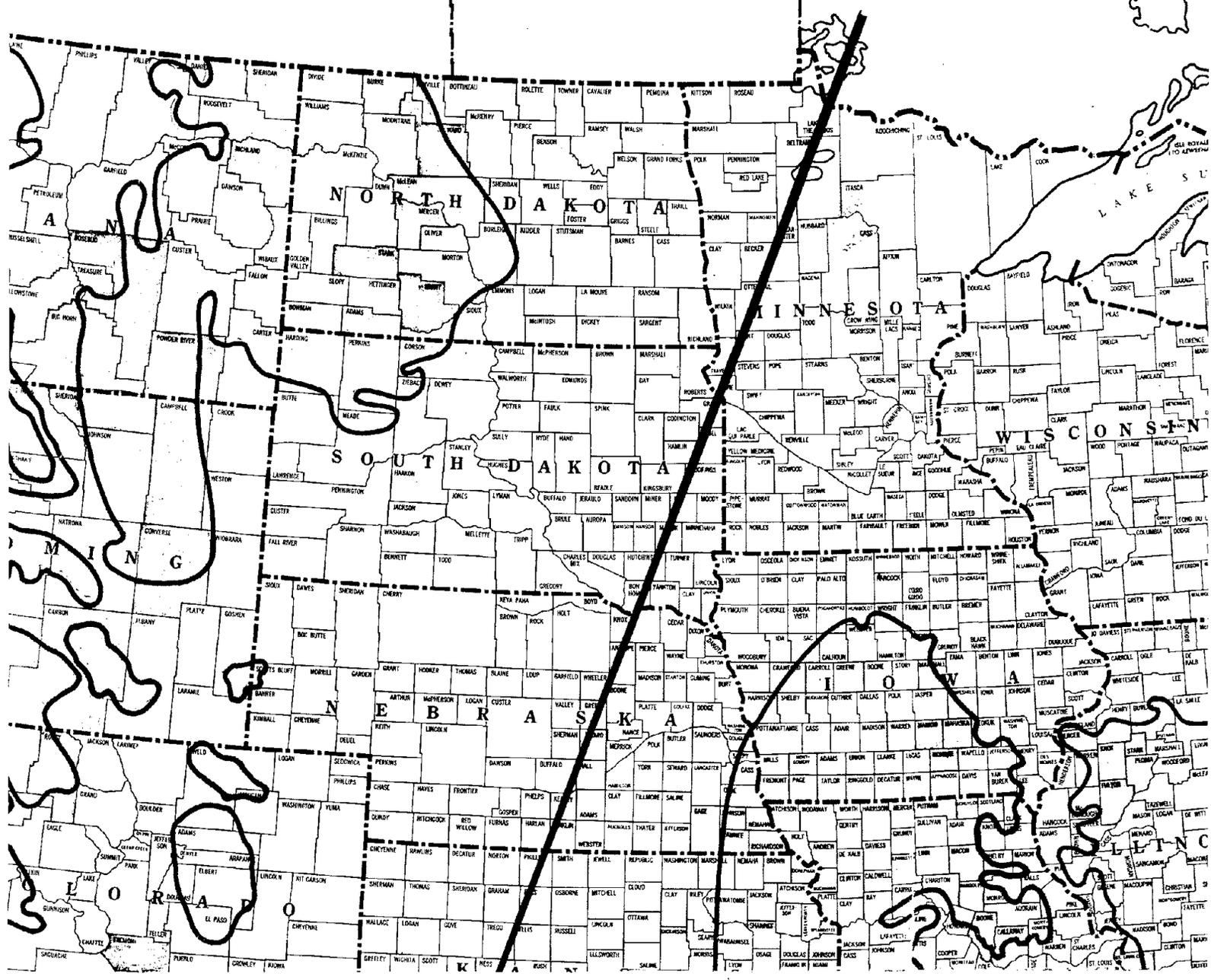
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9a-C

SASKATCHEWAN

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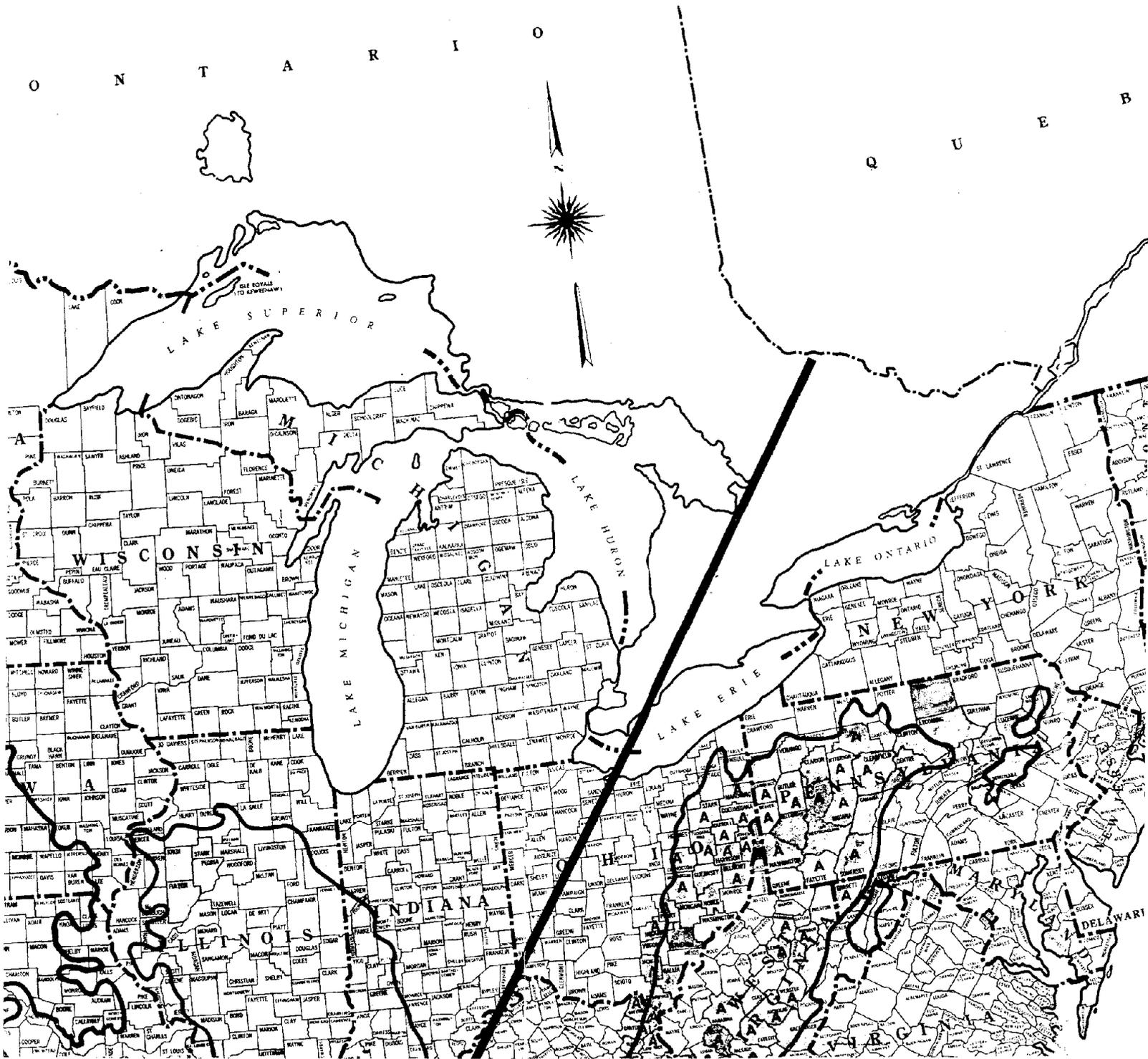
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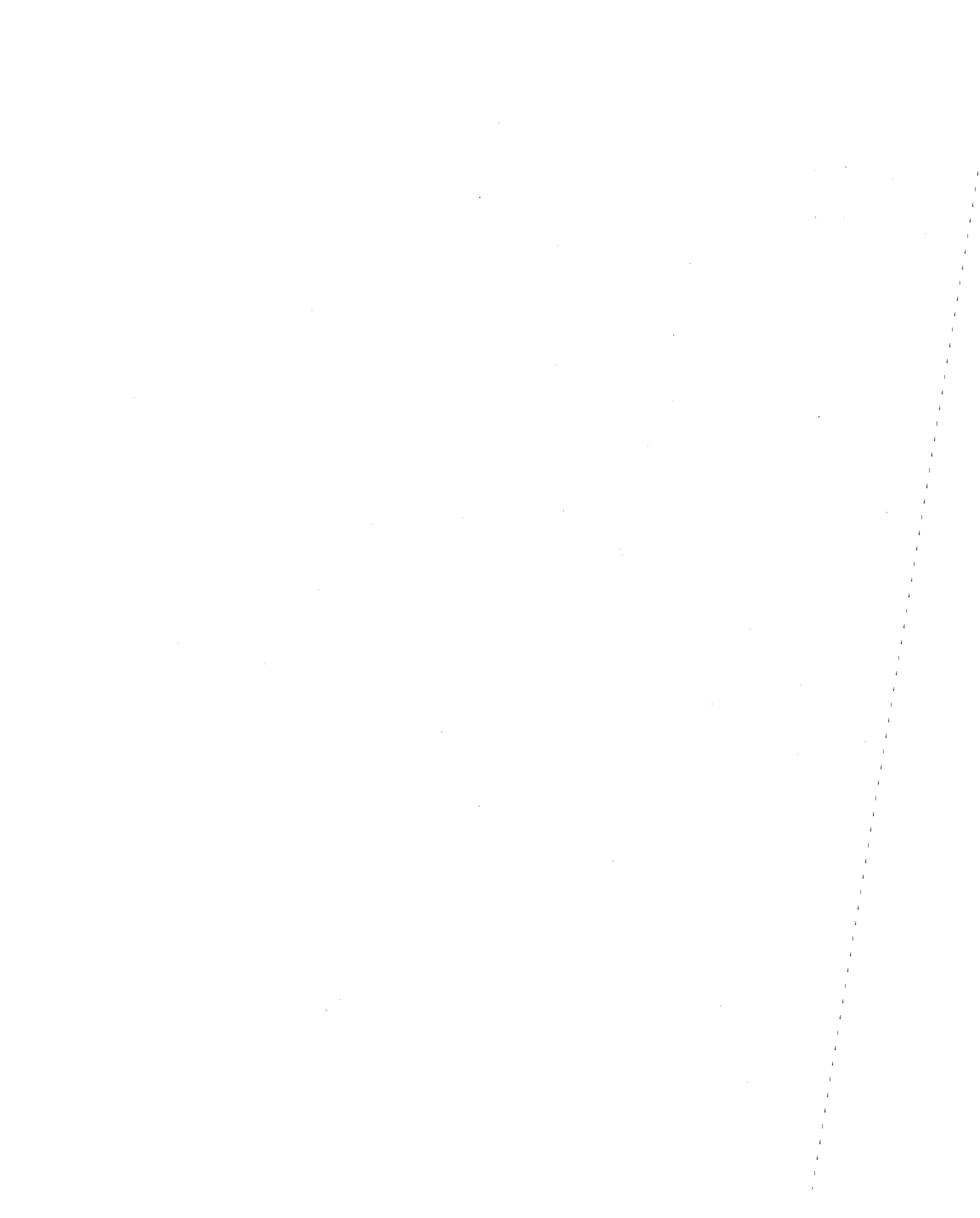




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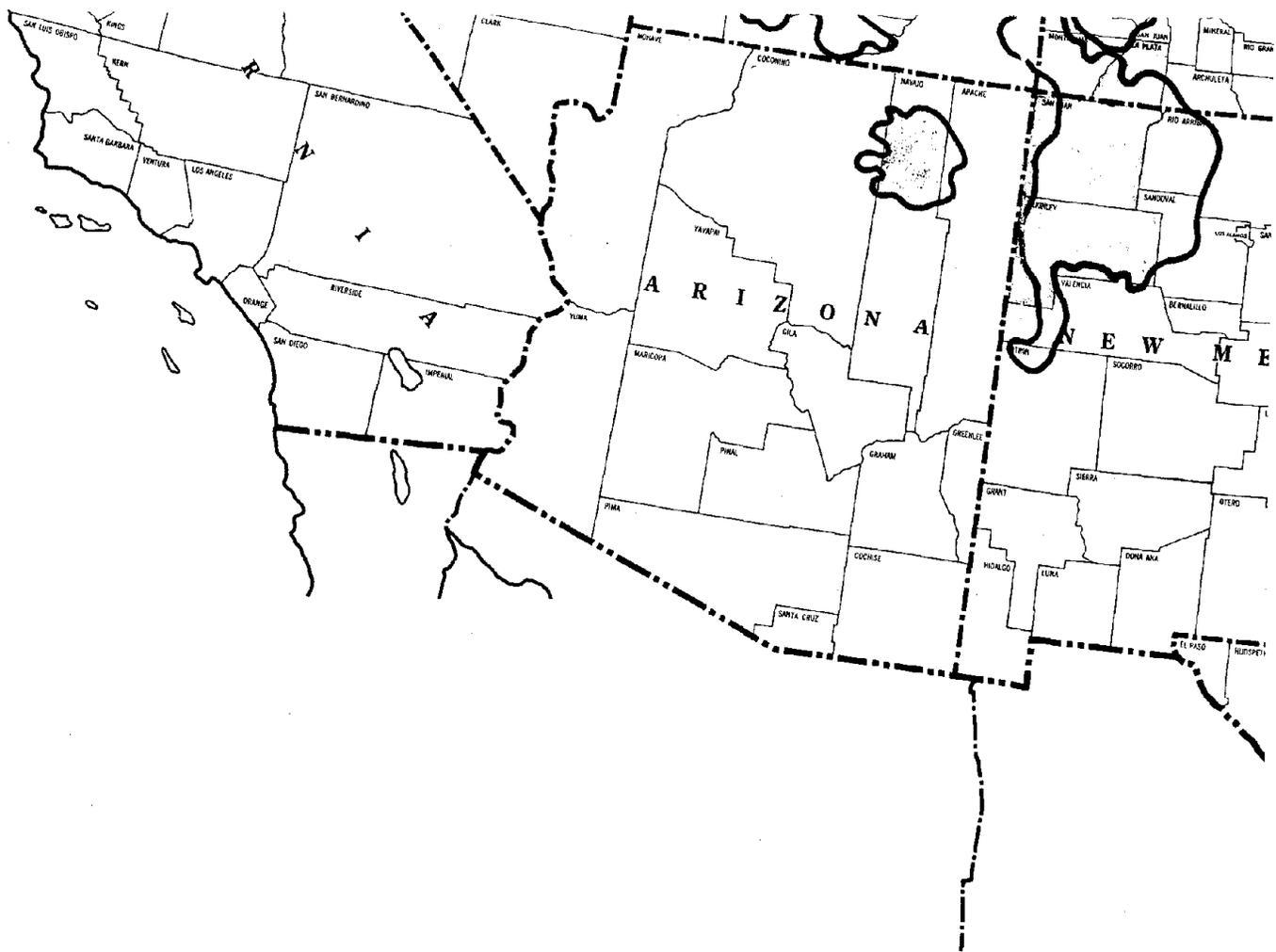
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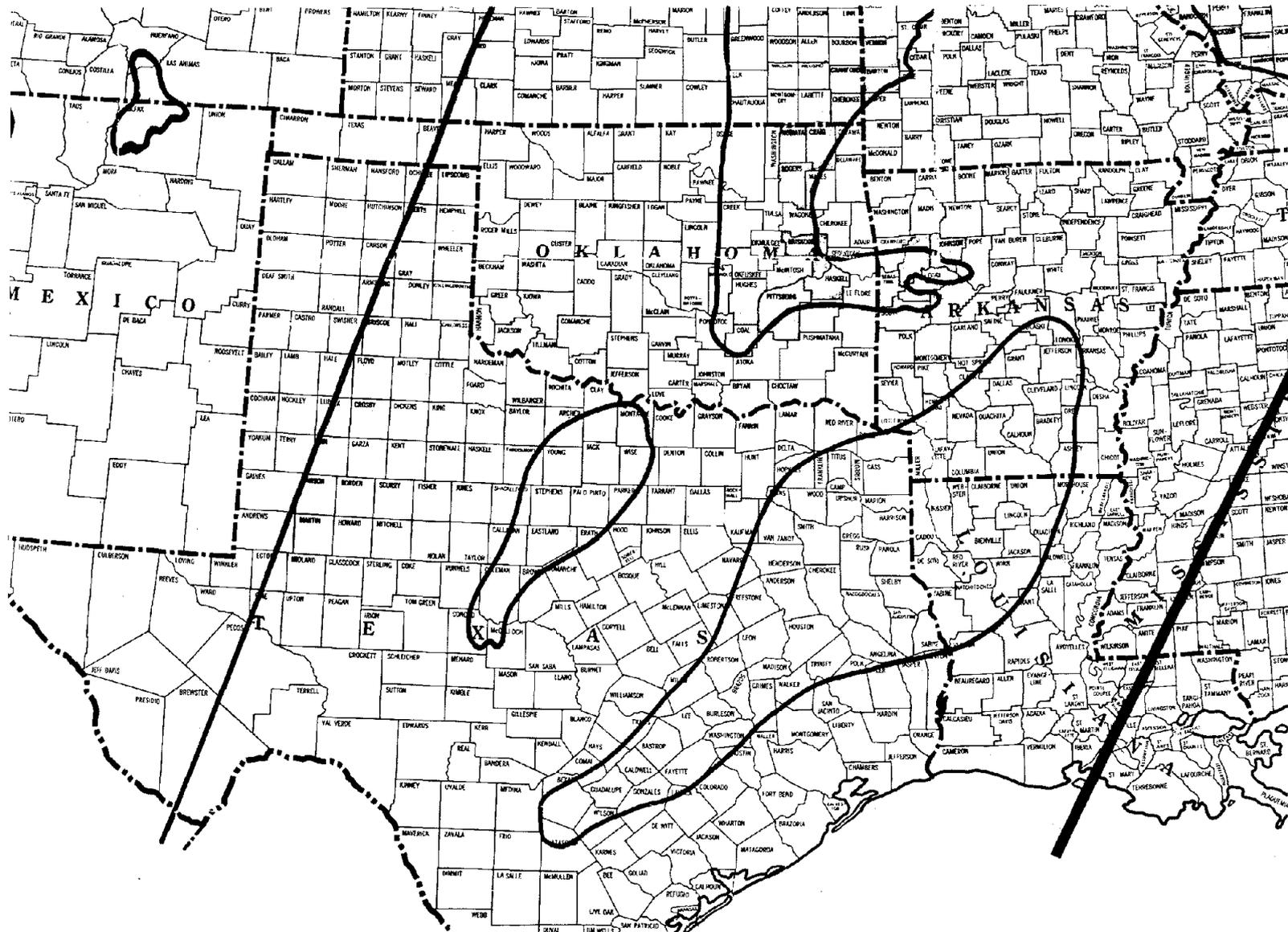


# WESTERN REGION

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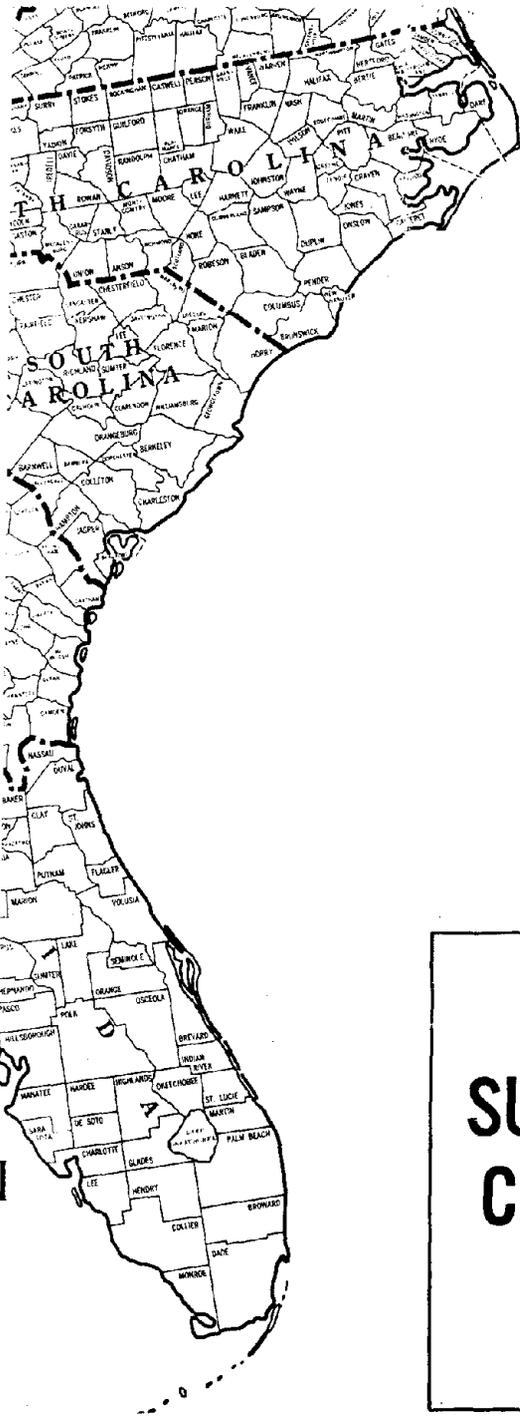
CENTRAL REGION

E



9a-b





**LEGEND**

- SURFACE MINING
- △ AUGER MINING
- ☞ COAL FIELD AREA

Source 1974 Keystone Coal Industry Manual

U.S. Dept. of the Interior  
Bureau of Mines

# SURFACE AND AUGER COAL MINING COUNTIES OF THE UNITED STATES

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Figure 1 9

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## CHAPTER 2

## CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The auger mining industry is a small division of the surface coal mining industry supplying approximately 15,000,000 tons per year or 2 1/2% of the total U.S. coal production of about 600,000,000 tons per year.

This supplemental supply of coal is obtained by a transitional method of mining from coal reserves which are beyond the current economic limits of surface or underground mining methodology.

The auger mining industry, located primarily in the Eastern coal mining region, due to its size and state-of-the-art, is extremely sensitive to fluctuations in price of coal and changes in economics.

Only five of the top 50 bituminous coal producing companies are directly engaged in auger mining. A large portion of the industry carries out augering on a contractual basis, while most of the smaller independent producers combine augering with other types of mining.

Auger mines require relatively low capital investments as compared to other forms of mining, produce more tons per man-day, and can be developed in a shorter period of time than either of the other two major mining methods.

Auger mining is conducted on the basis of an individual mine operator's skill and his assessment of the geologic characteristics of the augerable seam. As a result, there is a wide variation in techniques of augering individual coal seams. There is a need for more geological data and mapping to assist individual auger miners to carry out more effective auger mining operations.

Coal recoveries on an industry basis are variable and have been reported to average between 25 and 35%. Reports from individual mine operators and manufacturers suggest that these relatively low recoveries are improving.

Depths of penetration into the highwall are also extremely variable, with industry averages of 150 ft. With recent trends towards increased power, a few isolated instances of 200 ft depths have been reported.

A comparison of auger- and surface-mined coal from the same seams reveals that auger-mined coal contained less ash than surface-mined coal. Augered coal is sold at premium prices. On this basis, the Engineers conclude that augered coal is of higher quality than comparable mined coal.

The simplicity of machine design and its relatively low cost leaves little room for costly or elaborate modifications. Neither manufacturers nor mine operators are inclined to spend appreciable sums of money for research and development of sophisticated controls, oil motor drive systems or computerized drilling system.

Auger mining exposes fewer men to the hazards of underground mining and is accordingly, safer.

Auger mining disturbs less land area than surface mining and, therefore, the environmental impact of state laws on auger mining per se is minimal. As a form of surface mining, however, the effect of backfilling highwalls and mine benches eliminates the possibility of auger mining to recover additional coal from sources currently uneconomic to exploit. As a consequence, the Engineers conclude that the environmental impact is a major factor. There is a greater need for increased augering activities in closer coordination with surface mining operations prior to reclamation as a result of this environmental impact if these additional coal reserves are to be recovered.

Estimates of the augerable coal reserve base using current technology and a penetration to 200 ft indicate that five billion tons of coal are available for recovery throughout the United States at the 25-35% recovery rate.

Estimates of the potential coal reserve base at penetration depths of 850 ft indicate that approximately 20 billion tons are available.

A large portion of the potential augerable coal reserve is located in the Western Region but very few, if any, auger mines are to be found in this region. Additionally, there is very little geological data available with respect to the augering characteristics of these deposits. There is a need for new technology to be developed and more geologic mapping if these potential coal reserves are to be recovered.

The alternatives to auger mining methods of recovery of coal from under the highwall are deep, open-pit surface mines or underground mining methodology, along with all their associated factors of safety. It is concluded that, in view of the wide variations in economics, neither of these methods could be justified under the present economic structure of mining.

As a result of the evaluation of the current state-of-the-art of auger mining, the Engineers conclude that there is room for improvement in the design of the auger machine, but that it is designed to meet the current demands of the industry. Considering the economic structure of the industry, there is little incentive to improve machine design. Irrespective of the lack of incentive, there are also short-term and long-term improvements in machine design and auger mining methodology and practices which can and should be made if increased coal with optimum recovery of our resources is to be effected.

There is a need for hydraulic oil motors, improved safety with the use of fail-safe devices, remote control systems, constant pressure devices, shaft and flight redesign to reduce deflection of the conveyor, auger heads with more flexibility, and improved guidance systems to increase coal recovery.

This study has also indicated that while pop-up cutters and reamers may have some future merit there has been little demand by the auger mining industry to develop these tools.

With more than five billion tons of augerable reserves available for recovery by the current technology and relatively inefficient machinery, and 20 billion tons potentially available, it becomes mandatory to improve current methodology in order to increase auger industry averages of coal recovery to the levels currently attainable by surface mining methods of 80-90%.

The currently designed auger machine would require extensive modification for use in depths exceeding 200 ft.

With increased recoveries as a result of short-term improvements, the necessity for the long-term development of methodology and remote control machines penetrating to depths of 1,000 ft becomes even more acute.

Long-term development of methodology which will recover residual coal from auger pillars, along with potential gasification of augered-out or orphaned lands, presents some interesting research projects to effect maximum conservation and effective use of the augerable coal base.

The literature research investigations revealed that very little data are available on auger mining and that the need for training of new mining engineers applies to auger mining to a greater extent than to conventional surface or underground mining.

## Recommendations

There is a need for more effective use of our existing coal reserves. Auger mining has been contributing in a small and relatively efficient way to satisfy the need to recover coal that is beyond the current economic limits of surface or underground methods. The Bureau, manufacturers and the coal mining industry must join forces in a cooperative effort to increase efficiency of the auger, its productivity, and its depth of penetration. Also, a closer coordination of effort towards the end result of greater coal production and recovery, with improved reclamation practices is needed by the surface, auger, and underground mining industry, state agencies and federal agencies.

Recommendations for action and implementation by the various groups are as follows:

### The Bureau of Mines

1. Develop better geologic data relative to coal seam characteristics, location, mapping and potential augerable deposits.
2. Conduct a pilot program using 7-ft diameter or larger auger or mining machines to determine recovery from thick seam deposits that do not lend themselves to underground or surface mining methods in the Western Region.
3. Undertake a R&D program in conjunction with manufacturers and operators to develop remote controlled mining machines that will penetrate to depths of 850 ft with no men underground.
4. Develop the methodology to recover residual coal from auger pillars.
5. Develop a guidance system for mining machines which will enable them to remotely operate at 850 ft and follow the coal seam.
6. Study the potential of coal gasification of previously augered or orphaned lands.

### Manufacturers

1. Improve existing machine designs to improve recovery such as adaptive controls, mobility and power trains.
2. Improve and expand safety controls of auger machines.
3. Modify auger bit and scroll designs to increase productivity.

4. Develop a variable size auger head.
5. Develop an auger head to recover auger pillars.
6. Develop machine controls that would be adaptive to remote control operations.

#### Mining Industry

1. Advise manufacturers of auger machine modifications to aid in new designs and improvement of old.
2. Institute better practices of augering to increase recovery.
3. Expand maintenance practices to increase machine availability.
4. Develop a more selective use of the auger to properly size cutting head to seam thickness.
5. Update job training of machine operators to increase productivity.



## CHAPTER 3

## THE ECONOMICS OF AUGER MINING

The Economic Feasibility of Mining

The economic feasibility of a mining operation is dependent upon many variable factors, including the selling price of coal, operational expenses for labor fuel, power, materials, and supplies, administrative and other direct and indirect charges, production capacity, the equipment available to the operator as well as geologic conditions.

Geology exerts an economic impact on the feasibility of mining. The quantity of overburden which must be removed in order to obtain a ton of coal is of particular importance to surface mining economics. Economic stripping ratios are established for each mine to serve as a guide to the surface mine operator.

As a follow-up of a surface operation, auger miners are usually required to handle less overburden than the area or contour mine operator. Frequently, augering is carried out after the surface mining has removed coal and prior to reclamation of the area.

The economic feasibility of an underground mine is also influenced by the geologic conditions. The quality of the roof structure and expenses for roof supports, shafts, ventilation, mine safety and development all affect the economic feasibility of underground operations.

Auger mining is carried out from the surface within the coal seam with reliance on the coal pillars to provide support and protection against roof fall. Since no men are underground and only equipment is involved in the penetration of the highwall the economic impact of rock structure on the auger miner is less severe than it is on the underground operator.

While the quantity and quality of overburden of the rock structure limit the feasibility of both surface and underground mining the impact of these factors is less critical to auger mining economics than it is to surface or underground mining.

Additionally, auger mining also required little or no drilling or blasting to be carried out as is the case with both surface and underground operations. The auger concept is in itself a drilling operation. These geologic advantages are all reflected in the economic feasibility of auger mining as compared to surface or underground mining.

Auger mining provides an economic and often the only pragmatic means of extracting coal. The conditions which favor the feasibility of auger mining fall into three broad categories:

- 1) When surface mining has reached its economic limit and a high-

wall with an augerable coal seam remain accessible. (2) When the auger may be used for the initial mining of an outcrop of coal and (3) The selective mining of coal which cannot be mined by other means. Conditions which favor auger mining in preference to the establishment of an underground mine are (1) inadequate coal reserves to support the development of an underground mine, (2) inadequate rock structure, and (3) thin seam coal.

#### Inadequate Coal Reserves

In many cases after surface mining, there is not sufficient coal left in a leased or owned area to justify the expense of an underground mine. Because capital costs are higher for an underground operation than other methods of mining, there must be enough reserve in the remaining deposit to amortize the capital investment and return a profit to the investor. These reserves must be sufficient to provide for a payout period necessary for an economic exploitation (20 years is often used). The auger method enables the operator to recover a portion of this coal that would otherwise be lost to recovery, because of inadequate reserves to justify an underground mine.

#### Inadequate Rock Structure

There are cases where the overburden is too deep to justify the continued stripping of a coal deposit but is not of sufficient depth or rigidity to provide for a strong enough roof for the economic and safe extraction of the remaining coal by underground methods. The auger can be used effectively to extract a significant percentage of this coal, due to the better stress distribution that results around the openings of the auger holes. Three reasons account for this: (1) there are no shatter cracks from use of explosives to decrease the effective area of pillars and cause points of excess stress concentration; (2) spacings between pillars are comparatively small; and (3) beam action of the roof is reduced because of the arching effect of a circular cut.

#### Thin Seams

Although some thin coal seams can be economically stripped by surface methods, the underground mining of thin seams which remain after surface mining has reached its economic limit may be economically prohibitive. With the present state-of-the-art, it is usually uneconomical to surface or underground mine coal in formations that are less than 24" thick. By use of the auger, a percentage of this resource can be recovered that would not normally be economically extracted.

#### Augering for Thin-Seam Outcrop Coal

When coal seams are too thin to mine by surface methods, the multi-head auger may provide an economical tool for recovery of an otherwise uneconomic coal deposit. The multi-head auger, specifi-

cally the tri-head, has proven effective in mining coal seams as thin as 18 in. In the Appalachian region, where slopes tend to be steep, and the overburden increases rapidly from the outcrop, surface mining of seams thinner than 24 in. usually prove to be uneconomical, and auger mining provides the only economically attractive method of mining these coal deposits.

#### Selective Mining of Coal Seams

Selective mining of coal seams can be effectively accomplished with the auger. This is especially important for decreased production cost and good quality control. By augering the coal seams and leaving the partings the materials handling cost is reduced by not having to remove the parting as would be required in surface and underground operations. When a coal seam is erratic in continuity because of washouts, faulting, or pinching out, sufficient coal cannot be found to justify stripping and an auger can be effectively utilized for mining this coal.

#### Economic Recovery Factors

The auger mining recovery of in-place coal is not as large as either underground or surface mining on a percentage basis. Although recoveries have reached as high as 50 to 60% of coal in-place for penetration depth of 150 to 200 ft, the average for augering is in the range of 25 to 35%. Compared with underground mining, which usually yields about 50% recovery, or surface mining, which yields close to 90%, the auger is an inefficient method of mining in terms of coal recovery. It may also be uneconomic in the long term if the auger operator owns the land and mining rights. Even though the tons mined per manday may be greater than either underground or stripping, the total recovery of coal will be less than the other two methods, and thus he will not realize the full potential return on the property. This recovery factor from an economic standpoint is not as important to a mining contractor who leases land for augering; his objective and emphasis is on tons of coal produced. His income is derived only from the tonnage produced and not on the percentage of the coal recovered. This situation has in the past led many auger operators to drill shallower holes in order to increase the tons per manday produced at the expense of higher recovery of coal resources. Because of the lower recovery from auger mining and past wasteful practices of certain auger operators, many lessors are now stipulating in their leases that auger mining is not to be allowed.

Auger mining economics is extremely sensitive to changes in the price of coal. When the price of coal is stable, augering will be conducted on the basis of mining coal as usual. As the price increases, auger mining operators will work longer days and buy more equipment to create greater production and to obtain the maximum financial advantage before the price of coal decreases.

As a comparatively small producer of a supplemental supply of coal, the economic advantages usually obtainable through large volumes of production are limited when applied to an auger mining operation.

Additionally, since auger mining is a transitional form of mining and, as such, enjoys certain economic advantages when compared to surface or underground methods, the auger miner is required to operate within a limited period of time.

As a follow-up of surface mining, the auger miner is dependent upon the surface miner to provide a highwall which becomes available only when the economic limit of the surface mine has been reached. Auger mining begins when surface mining ends. Reclamation law requires backfilling of that highwall within a given period of time. The auger miner must complete his operation within the framework of that time span if a supplemental supply of coal is to be obtained. His economic structure reflects this factor.

The reason for the extreme cost sensitivity of auger mining is that the small independent operator with limited capital cannot compete at low selling prices for coal and drops out of the market.

The operator of one of the mines visited indicated that while they were willing to auger mine in certain states, in other states the additional reclamation costs would make his operations economically prohibitive. In some cases, labor costs and productivity create sufficient differences in the economic structure as to make auger mining a marginal operation. In addition to the foregoing factors, there are variations among the individual auger operators as to type and size of equipment used, the coal seam thickness augered, depth of penetration, and emphasis on coal recovery.

In terms of capital costs there are equally wide variations. In some cases, only the augering equipment is actually owned and operated, while the ownership of associated loaders and dozers equipment is charged to the adjacent contour or strip-mining operations. In other cases, where auger mining is carried out on a large contractual basis, several auger machines, dozers, wheel loaders, haulage trucks, and supporting ancillaries may be owned by the auger contractor.

In view of these wider variations in individual augering operations, only estimates of potential costs of auger mining can be developed.

Estimates of typical owning and operating costs as well as the capital costs of auger equipment as secured from manufacturers are shown as follows:

Examples of Owning and Operating Costs

Figs 3a and 3b show typical 1974 costs for a 36 in.-diameter single-head auger and a 27 in. diameter dual-head auger operating in conjunction with a 6 yd. loader and a D9-dozer.

ANNUAL OPERATING COST FOR A  
36 IN.-DIAMETER AUGER

*Auger Owning Cost	\$ 47,500	
Finance Charges	21,000	
Insurance	2,500	\$ 78,500
Auger Flights	7,500	
Operating Costs: (assumed 2,000 Operating Hours/Year)		
Fuel 40,000 gal. @ \$ .36	\$ 14,400	
Bits 4/hr. @ \$1.50	12,000	
Repair and Maintenance @ \$2.50/hr.	5,000	
Lub and Grease @ \$2.50/hr.	5,000	\$ 127,600
Labor 3 men @ \$9.50/hr.	57,000	
(Benefits) 60% of labor	34,200	
6 yd. front-end loader with Operator		75,680
D9 Dozer with Operator \$43.47/hr.		86,940
	Total Cost/Yr	<u>\$ 368,720</u>
Production of 125,000 TPY	$\frac{368,720}{125,000}$	= 2.94/ton
125% Overhead and Profit		= $\frac{3.68/\text{ton}}{\$ 6.62 \text{ FOB Mine}}$

\*Six-year depreciation - straight line

Fig 3a

ANNUAL OPERATING COSTS FOR A DUAL-HEAD  
27 IN.-DIAMETER AUGER

*Auger Owing Cost	\$ 79,167	
Finance Charges	35,000	
Insurance	4,166	
Auger Flights	11,250	\$ 129,583
Operating Costs (assumed 2,000 Operating Hours/Years)		
Fuel 40,000 gal @ \$0.36	14,400	
Bits 6/hr. @ \$1.50	18,000	
Repair and Maintenance @ \$2.50/hr.	5,000	
Lub. and Grease @ \$2.50/hr.	5,000	\$ 164,000
Labor 4 men @ \$9.50	76,000	
(Benefits) 60% of Labor	45,600	
6 yd. front-end loader/Operator @ \$37.84/hr.		\$ 75,680
D9 Dozer/Operator @ \$43.47/hr.		86,940
	Total Cost	<u>\$ 456,203</u>
Production of 156,000 TPY	$\frac{456,203}{156,000}$	= 2.92/ton
125% Overhead and Profit		= $\frac{3.66}{\text{ton}}$ \$ 6.58/ton

\*Six-year depreciation - straight line

Fig 3b

Capital Costs

As shown in Fig 3c, the cost for an auger machine ranges from \$95,000 to \$500,000.

1974 Capital Costs for Current Models of  
Auger Machines

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Salem	
Model 1500 -	\$ 150,000
1600	300,000
Mul-T	500,000
Compton	
Model 28	\$ 250,000
36	300,000
Long-Airdox	
Model 155-H	95,000

Fig 3c

The components are simple, straightforward and the machine is without complication, sophisticated attachments, accessories or control systems. Unlike the large surface mine machinery manufacturers with labor forces ranging from a few hundred to more than a thousand, the auger machinery manufacturers have a complement of less than 200 persons. Two of the three manufacturers sell other types of mine machinery, while the third restricts production to a single line for guaranteed orders, closing down his manufacturing facilities when the order has been fulfilled. The ability of these manufacturers to finance research and development projects or modifications to auger equipment is much less than that of machinery manufacturers having multi-million-dollar sales with large organizational technology upon which to draw. While they would like to develop new modifications and improvements, their market will not permit or accept the increased costs of incorporation of these modifications into machine design. Their financial structure and needs demand that their equipment be manufactured without computerized control systems, expandable cutting heads, oil motors, or other equally desirable features, without specific commitments from their customers.

Their customers, on the other hand, with the exception of the major corporations are, for the most part, in a similar financial situation with respect to funds for R&D. "Coal Age" statistics show that the maximum production that can be expected from a single auger is now of the order of 350,000 tons a year. The economic structure, sales revenue, and cash available for R&D from this volume of production is minimal. Many of the major corporations subcontract their augering in order to permit them to devote their entire attention to their primary sources of income, which are usually derived from surface or underground mining. Nevertheless, they expect their augering operations to be conducted on an economic basis, which would be completely independent of sales of coal derived from other sources. With this type of financial structure, there is very little incentive for the funding of auger mining research and development.

For the long-term research and development effort therefore, there is a need for financial assistance to develop this mining industry.

## CHAPTER 4

## AUGERABLE COAL RESERVE BASE

Methodology

Estimates were made of the coal reserves available for auger mining, using the present state-of-the-art technology. Also, the reserve data were analyzed to determine the potential recoverability of coal if auger equipment capabilities were improved by extending penetration ability from the current 200 ft to 850 ft.

Data were analyzed from the following sources: The U. S. Bureau of Mines, the U. S. Geological Survey, various state geological surveys, private companies, private sources and the files of Ford, Bacon & Davis, Inc. Considerable information was found covering surface and underground coal resources, but no data, published or otherwise, were obtainable on the required nationwide scale covering augerable reserves, per se. It was necessary to devise a number of techniques to arrive at an estimate of current and potentially available augerable coal reserves. These techniques are discussed in the report under the section "Reserve Estimate by State".

Since the amount of coal in the United States physically available to augering machines is not a fixed quantity but a variable depending on definitions and other factors, a number of limiting definitions and assumptions were established.

The precise definition of the terms used in preparing reserve estimates can vary widely with different investigators. As a result of these differences in definitions, any new estimate can have meaning only in relation to the methods used in obtaining it.

The U. S. Bureau of Mines <sup>1</sup> and the U. S. Geological Survey agreed on a definition of reserve in April 1974 which states that the reserve is "that portion of the identified coal resource that can be economically and legally mined at the time of determination." The reserve is also referred to as recoverable reserve. The reserve is derived by recoverability calculations from that part of the identified coal resource designated as the reserve base.

Under this definition, as modified for the case of augerable coal, the term reserve means the quantity of coal that is producible by auger mining methods as currently practiced. This is assumed to mean an auger penetration depth of 200 ft and a recovery of 25%.

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<sup>1</sup> Staff, Bureau of Mines. The Reserve Base of Bituminous Coal and Anthracite for Underground Mining in the Eastern United States. Bureau of Mines Information Circular IC 8655, 1974, 428 pp.

The reserve base is the quantity of in-place coals calculated under specified depth and thickness criteria. The coal that would be available, if augering technology was improved to penetrate 850 ft into the mine face, would be termed "potential reserve base." Since this stage of technology has not yet been attained, it is not possible to make a reasonable estimate of the recovery factor to be applied to this potential reserve base in order to arrive at potential recoverable reserves.

The augerable reserve base is taken to include coal beds 2 to 8 ft thick. This thickness range appears quite reasonable in view of the present day limitations affecting the state-of-the-art of auger mining. Beds dipping from horizontal to approximately  $10^\circ$  were assumed to be augerable, and those with steeper dips were excluded. No attempt was made to subdivide the reserves by category according to rank of coal, sulphur content, or class of reserves, such as measured, inferred and the like. Only bituminous and sub-bituminous coals were considered. Owing to the relatively poor recoveries and adverse economics that would be encountered in augering any coals that can be mined by strip-mining methods, the strippable coal reserves were not included in the estimates.

Where coal beds have been classed as strippable reserves, the associated augerable reserves have been taken to be those coals that will remain accessible to augering after strip mining has reached its economic limit of overburden. These remaining augerable coals would only be available after stripping has ceased and before starting reclamation at the highwall. Where reclamation has already been done, a new cut would have to be opened. The current state of reclamation of existing surface mining areas was not determined.

The coal fields of all the coal-producing states were investigated. Those with identifiable augerable reserves are listed in the accompanying tables. Other states are known to have coal deposits, including Alaska, Idaho, Michigan, Nebraska, North Carolina, Oregon, Texas, and Washington; but these have been omitted from the tables of estimates because either the data will not allow identification and measurement of the augerable reserves, or those augerable reserves appear to be too small to affect the significant figures used in the tables.

Legal and political restraints on mining are not separately considered in preparing the accompanying estimates. They were considered in the preparation of some of the literature consulted, and to that extent their effects are included herein.

Heavy use was made of the data supplied by the Information Circular 8531 (1971) of the U. S. Bureau of Mines, particularly the average figures for coal-bed thicknesses and the state-wide average economic stripping ratios, or ratios of overburden thickness to coal seam thickness, as determined by economic and geographic considerations. These calculations gave reserves as of January 1, 1968. Deducting auger production for succeeding years results in the tabulated figures for the remaining reserves as of January 1, 1974.

The methods of utilizing the basic information are summarized by region as follows:

### Appalachian Region

For the eastern states, the lengths of the coal outcrops and the average slope angles of the hillsides at surface mining areas were derived by analysis of detailed topographic and geologic maps.

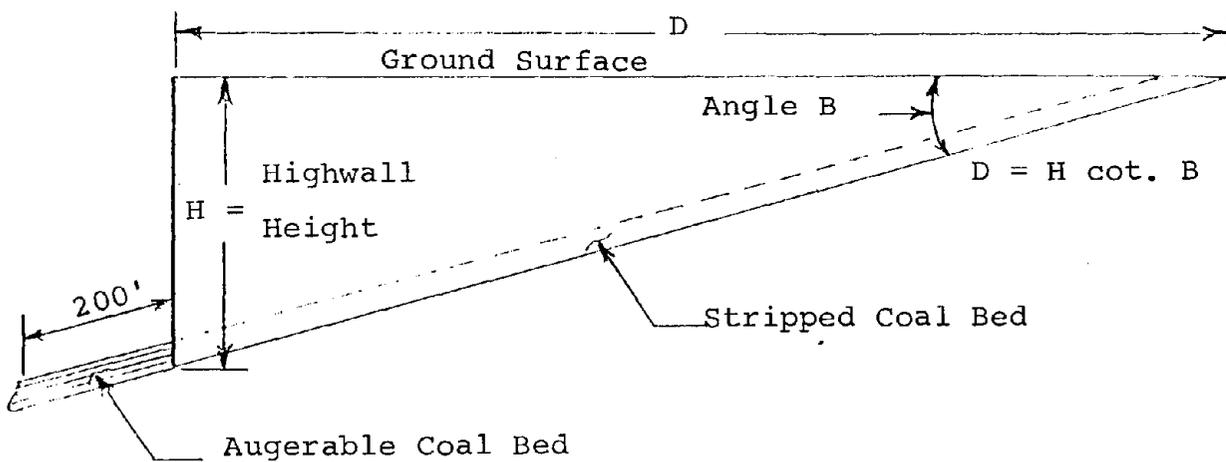
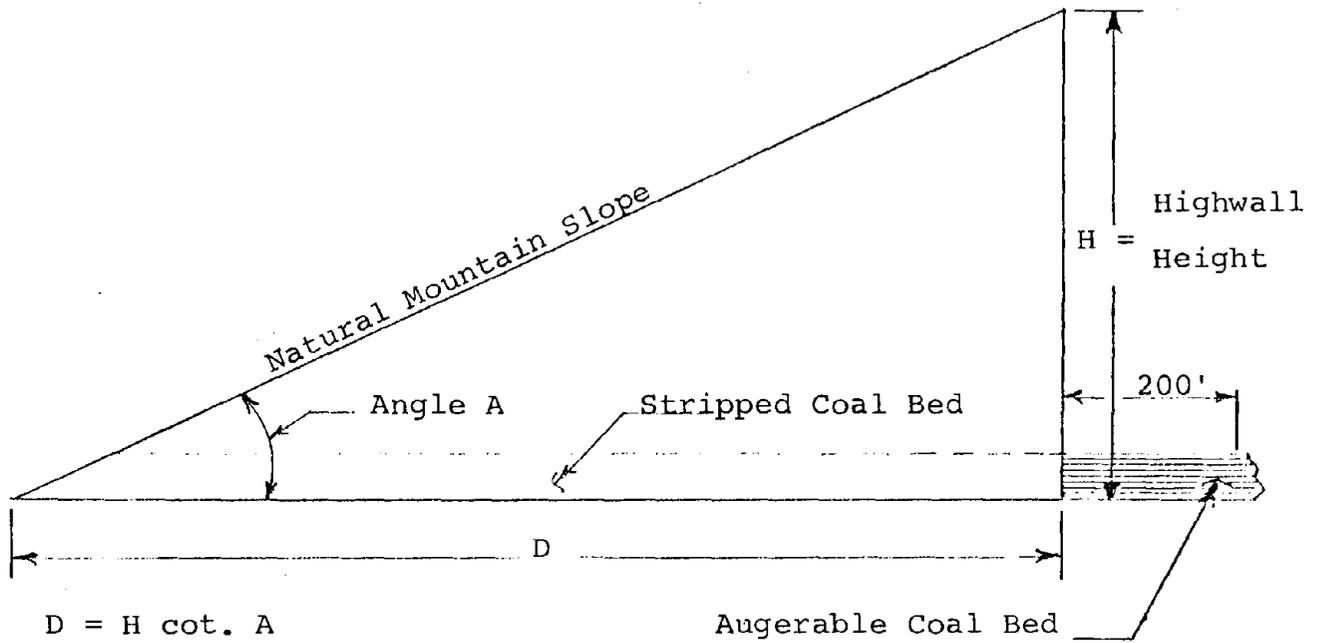
Given these elements, the general procedure was to calculate the distance  $D$  (see Fig 4a) into the hill from the outcrop, to which strip mining will proceed before the highwall height  $H$  reaches the economic limit for overburden. This height  $H$  is a simple function of the coal bed thickness and the stripping ratio. The distance  $D$  is a function of the slope angle  $A$ , which is the average angle between the natural slope of the hillside and the horizontal, at present and future mine sites: Specifically,  $D$  is equal to  $H \cotangent A$ .

By simple geometric relations, a ratio was established between strippable reserves, which are proportional to  $D$ , and the augerable reserves, which are proportional to the depth of auger penetration.

The resulting figures for augerable reserves are reduced by judgmental factors to allow for loss of recovery on inside curves of the mine face and for certain areas where no augering will be possible because of mountaintop removal by the stripping process, which will leave no reserves to be augered. This factor is normally about 25%.

### Central Region

In the central United States, essentially the same kinds of data are given but here the spatial relations are such that topographical relief is relatively unimportant and the regional dip of the coal-beds is a major limiting influence on strip mining. In a simplified typical case, the topography is flat, and the regional dip of the coal-bed is a few tens of feet per mile. Stripping will proceed until the highwall height reaches the overburden limit (see Fig 4b) specified by the stripping ratio.



The width of the stripped area D is here a function of the dip of the coal-bed (angle B), and highwall height H. Specifically,  $D = H \cotangent B$ .

Here also a ratio can be set up between strippable and augerable reserves, and again a factor of about 25% is used to allow for extra losses of recovery due to extreme curvature of the highwall, small areas that will be totally stripped, and related causes.

### Western States

In the western states, the geologic and topographic information is generally not detailed enough to permit the kind of approach that was used in the eastern and central region, although a fairly detailed analysis was locally possible, as noted in the state-by-state remarks.

Most of the coal in the Rocky Mountain states is contained in lagoonal deposits associated with widely shifting shorelines of ancient (Cretaceous and Early Tertiary) seas. The coals have been mined in a few places, but large areas are relatively unexplored. Geological descriptions of the basins frequently stress the difficulty in correlating coal-beds from one locality to the next. The coals commonly show variations and irregularities, pinching and swelling or disappearing along the outcrops. This is often true even where the coal-beds are unusually thick, as in the Wasatch Plateau of Utah. Even the massive sandstone beds, which have received formation names and have been regarded as important "marker" beds, have been shown to be lenticular and to wander up and down through the geologic section. As a result, such beds are unreliable as markers.

In connection with exploration for oil and gas accumulations, an intensive study was made of the correlation problems within this part of the geologic column in the San Juan basin of northwestern New Mexico and southwestern Colorado. In parts of this basin many hundreds of wells have been drilled on close spacing. All were logged by electrical, nuclear, or acoustic logging methods.

The resulting well logs contain a wealth of detailed data on the subsurface formations. From them can be derived or inferred the main physical parameters needed in evaluating the lithology, porosity, hydrocarbon saturation, thickness of permeable and impermeable beds, and permeability. Certain special rock types, such as coals, show up clearly on some types of logs.

Hundreds of well logs were analyzed in detail, bed by bed, in the search for reliable and consistent marker beds. It was found that the best markers were of three types: (1) a fresh-water limestone; (2) bentonite beds recording extensive falls of volcanic ash; and (3) characteristic groups of coal lenses. These were correlated over distances of several miles by statistical analysis.

Groups of coal-beds could be followed across a basin by relating them to the other characteristic markers. The accuracy of the correlations was verified by closing correlation traverses upon themselves in the same way as land surveying traverses are closed.

In this way a large amount of information was gathered on the thickness, distribution, and extent of the coal-beds of the San Juan basin. Concurrently with these subsurface studies, extensive surface studies were conducted on the same facies of rocks at the outcrop.

Field work carried out in several other western states showed that very similar conditions of deposition attended the formation of other coal-bearing rocks of the same ages throughout the Rocky Mountain region and the adjoining basins.

This work from private sources together with the available published information served as basis for the estimates presented in this report for western Colorado, the Denver basin, Arizona, Montana, and Wyoming. From the estimates for the San Juan basin, orders of magnitude of coal reserves per square mile were calculated and were extrapolated into other areas of equivalent rocks where very little detailed information is available. In each case, modifications were introduced according to local variations in the aggregate thickness and areal extent of the coal-bearing, strata, the type of topographic relief, and the intensity of folding and faulting. With these modifications, the available coal reserve base is a fairly uniform function of the outcrop area and volume of the coal-measure facies.

#### Estimated Reserves

The total augerable reserve base for the United States is estimated to be five billion tons under the current state of mining technology. This is a conservative figure for coal in place, and must be reduced by an appropriate recovery factor to arrive at recoverable reserves.

The recovery factor of current augering practice ranges from about 25 to 50%, and more in a few instances. Equipment manufacturers contend that 50% recovery is practicable, and isolated cases of this high recovery at 200-ft penetration depth are reported. However, in many other studies a depth of 175 ft, and 35% recoveries were noted. For present practice, 25% and 200 ft penetration are assumed to be a realistic overall average including both existing mines and future mines in areas that have no prior recorded experience.

Fig 4c shows the estimates of the current augerable reserve base by region and by state, assuming the current state-of-the-art, and the potential reserve base at 850-ft penetration. Fig 4d summarizes the reserve base by region and shows recoverability or actual reserves.

ESTIMATED  
CURRENT AND POTENTIAL AUGERABLE RESERVE BASE, January 1, 1974  
Short Tons  
(Millions)

	Reserve Base	
	Current	Potential
	<u>200 Ft Penetration</u>	<u>850 Ft Penetration</u>
<u>Eastern States</u>		
Alabama	31	132
Kentucky (Eastern)	756	3,214
Maryland	13	57
Pennsylvania	322	1,368
Tennessee	37	156
Virginia	148	630
West Virginia	<u>1,036</u>	<u>4,402</u>
Eastern Subtotals	2,343	9,959
<u>Central States</u>		
Arkansas	1	5
Illinois	36	151
Indiana	11	45
Iowa	2	10
Kansas	5	20
Kentucky (Western)	12	51
Missouri	12	51
Ohio	254	1,079
Oklahoma	<u>1</u>	<u>3</u>
Central Subtotals	334	1,415
<u>Western States</u>		
Arizona	59	250
Colorado	1,176	5,000
Montana	471	2,000
New Mexico	235	1,000
Utah	120	510
Wyoming	<u>35</u>	<u>150</u>
Western Subtotals	2,096	8,910

Fig 4c

SUMMARY TABLE  
ESTIMATED RESERVE BASE AND RECOVERABILITY  
Short Tons  
(Millions)

<u>Region</u>	<u>Reserve Base</u>		<u>25% Recovery</u>
	<u>850 Ft Penetration</u>	<u>200 Ft Penetration</u>	<u>200 Ft Current Technology</u>
Eastern	9,959	2,343	586
Central	1,415	334	84
Western	<u>8,910</u>	<u>2,096</u>	<u>524</u>
Totals	20,284	4,773	1,194
	<u>Use: 20 Billion</u>	<u>Use: 5 Billion</u>	<u>Use: 1-1/4 Billion</u>

Fig 4d

Reserve Estimate by State

In arriving at the foregoing estimates, the procedures were modified from one state or area to another, in accordance with the type and scale of the available data, differing geological conditions, and the like. A few coal fields were omitted from the estimates because the data were too scanty to permit identification of the augerable portions of the reserves.

It should be noted that the calculated ratios of augerable to strippable reserves would be materially changed in the event of major economic changes affecting the stripping ratios. For example, a large coal price rise that would increase the stripping ratio would at the same time increase the strippable reserve. However, it would in general have little effect on the augerable reserve except in the relatively few cases where additional mountaintop removals would result in a slight decrease in the net augerable reserves.

Detailed procedures by state are described in the following paragraphs. All estimates refer to the reserve base lying within 200 ft auger penetration depth, unless otherwise specified.

Eastern or Appalachian Region

Alabama. The Cahaba and the Coosa coal fields were omitted from the estimates because of strong folding and faulting which have resulted in predominantly steep dips. In the Plateau and Warrior fields, 24 important seams were included, ranging in average thickness from 2 to 5 ft. The average slope of the ground surface in these fields was computed at 12° from horizontal and the economic stripping ratio is 24 to 1. The estimated augerable coal reserve base is 31 million tons.

Eastern Kentucky. The Eastern Kentucky coal field, with an area of 10,000 square miles, is part of the Appalachian coal region. Forty major coal seams, averaging 3.1 ft in thickness, were included in the estimates. The stripping ratio is 14 to 1 with an average ground slope of 19°. The augerable coal reserve base is estimated at 756 million tons.

Maryland. The western tip of Maryland covers 455 square miles of the great Appalachian coal region. The average ground slope in the area is 11°, and the stripping ratio is 15 to 1. The average seam thickness of the augerable coals is 3.3 ft. The augerable reserve base is estimated at 13 million tons.

Pennsylvania (Western). The main (bituminous) coal fields of western Pennsylvania are included, but the four anthracite fields were omitted because of severe folding and faulting, steep dips, and difficult mining problems. Representative ground slopes range from about 7 to 13° and average 9°. Average thickness of the augerable seams analyzed is 3 to 5.7 ft. Economic stripping ratio is taken as 15 to 1. The augerable coal reserve base is estimated at 322 million tons.

Tennessee. The coal fields underlie about 5,000 square miles of the Appalachian belt of eastern Tennessee. The average thickness of the augerable seams ranges from 2.5 to 4.6 ft; stripping ratio is 19 to 1; and the average slope is 12°. The estimated remaining augerable reserve base is 37 million tons.

Virginia. The Virginia portion of the Appalachian coal field showed a stripping ratio of 15 to 1, a coal-bed thickness of 2.3 to 7 ft and an average hillside slope of 12.4°. The estimated augerable coal reserve base is 148 million tons.

West Virginia. The economic stripping ratio of West Virginia was taken as 15 to 1. The coal-bed average thickness ranges from 2.5 to 5.4 ft, and the average hillside slope at the mine sites was found to be 12°. Augerable reserve base for a total of 46 coal-beds is estimated at just one billion tons.

#### Central Region

Arkansas. The average slope of the Arkansas mining area (in the Arkansas Valley) is so slight that the area method was chosen for a more accurate determination than the slope method used in the eastern states. The average seam thickness is 2.3 ft, and the economic stripping ratio is 30 ft of overburden per foot of seam thickness. Augerable reserve base in the state is estimated at one million tons from the lower Hartshorne seam.

Illinois. Thirty-eight counties were included, with average coal thickness ranging from 1.9 ft to 6.8 ft. The average regional dip was computed at 25 ft to the mile, and the stripping ratio was taken as 18 to 1. The estimated augerable reserve base is 36 million tons.

Indiana. Sixteen seams of augerable thickness in Indiana show an average dip of 25 ft to the mile. A stripping ratio of 20 to 1 was used, and the seams average 3.4 ft in thickness. The reserve base was estimated at 11 million tons.

Iowa. The data on Iowa coal, as presented by I.S. 8531, cover about 19 commercial seams but are not given seam by seam. Instead they are presented as a single average seam, 3 ft thick. Stripping ratio is 18 to 1, and the regional dip was computed at 25 ft per mile. The estimated augerable reserve base is two million tons.

Kansas. Only two of the listed strippable coal-beds (Mulberry and Weir-Pittsburgh) of Kansas fall within the augerable category as presently defined. The seams average 2 ft and 3 ft in thickness, and the average dip was measured and computed at 30 ft per mile. Using the stripping ratio of 15 to 1, the augerable reserve base is estimated at five million tons.

Kentucky (Western). Eight coal seams in the western Kentucky coal basin are included. Stripping ratio is 18 to 1; average dip was computed at 30 ft per mile. Augerable reserve base is estimated at 12 million tons.

Michigan. Coal production in Michigan has been very small in recent years. Strippable reserve base was estimated at a conservative one million tons without the benefit of measured data. The estimate of 22,000 tons for the augerable reserve base is derived from this arbitrary figure and thus has relatively low reliability. It is too small to affect the significant figures and is omitted from the tables.

Missouri. Three seams in Missouri, with an average thickness of about 2.5 ft, are included. Stripping ratio was 15 to 1, and the dip of the beds was computed at 25 ft per mile. On this basis the augerable reserve base is estimated at 12 million tons.

Ohio. Nine seams in Ohio range in thickness from 3.1 to 4.8 ft. Stripping ratio is 15 to 1, and the average ground slope is 6°. Estimated remaining augerable reserve base is 254 million tons.

Oklahoma. Coals in the northeast Oklahoma shelf area, where dips are generally very low, were counted in the estimates. Those of the Arkoma basin of east-central Oklahoma were excluded owing to the prevalence of steep dips due to strong folding. Four seams from 2 to 3 ft thick, with an average dip of 1.5° and a stripping ratio of 15 to 1 gave an estimated augerable reserve base of one million tons.

## Western Region

Very large coal reserves in several western states exist in massive seams 20 to 85 ft thick. These are not included in the augerable category, not only because the study is limited to coal-beds 2 to 8 ft thick, but for the further reason that the limitations in the present state-of-the-art auger mining could greatly disturb the thick seams and hinder their mining in the future.

Arizona. Only the Black Mesa basin is considered in Arizona. Most of this basin is still unknown, and data do not allow detailed estimates. Total coal reserves have been variously estimated at 14 billion to 21 billion tons. The estimate of 59 million tons of augerable reserve base is derived from stratigraphic and structural comparison with better known fields. The coal measures are Upper Cretaceous (Dakota and Mesaverde formations) strata deposited under conditions closely resembling those of northwest New Mexico. The potential reserves are assumed to be comparable from one area to another. Reserves at other localities in Arizona are too small so far as known to have commercial interest.

Colorado. Estimates for Colorado are based on data gathered in the San Juan basin coal field in southwestern Colorado and northwestern New Mexico. Topographic relief is greater in the Colorado portion of the basin, and parts of the coal-bearing sequence are too steeply dipping to be minable by auger. The total augerable reserve base estimated for the state is just under 1.2 billion tons.

Montana. Most of the shallow coal of Montana is in the eastern part of the state. Available detailed data on the thin layers are limited to the following two areas:

1. Liscom Creek, Custer County. About ten miles of highwall would remain after stripping, with a coal-bed 8 ft thick. The augerable reserve base is estimated at 14.4 million tons.
2. Carpenter Creek, Mussel Shell County, with about 30 miles of highwall expected to remain after stripping. Coal-bed has average thickness of 6.5 ft (Keystone, 1974). The augerable reserve base for this area is estimated at 35 million tons.

Many other beds have portions that fall within the thickness range of 2 to 8 ft but are much thicker over large areas. The portions that are thin enough to fit the definition of augerable reserves cannot be identified from present data. A study of the available descriptions of the deposits suggests that 471 million tons is a conservative estimate for the augerable reserve base of the entire state.

This compares with a strippable reserve of 42.5 billion tons and a grand total surface and underground coal resource, including expected but unexplored coals, of 378 billion tons (including lignite in eastern Montana).

New Mexico. The sketchy data available in the literature, supplemented by Ford, Bacon & Davis' field experience, allows an estimate of an order of magnitude of augerable reserves. For an area of 3,000 square miles of the western and southern flanks of the San Juan basin (in San Juan and McKinley counties), a 235-million-ton augerable reserve base is conservatively expected to be available in the 200 lenticular beds that pinch and swell but average 5 ft in thickness, six miles in length, and 200 ft in augerable depth. These beds dip 2 to 6° eastward and northward.

On the east flank of the basin (Rio Arriba and Sandoval counties) the dips are mostly 15 to 30° or more. No significant augerable reserves are expected from this area.

The strippable reserve base for the San Juan coal field in New Mexico is estimated at 2.5 billion tons.

Other occurrences of coal in the state are numerous and widespread. Their potential augerable reserve base is probably at least another billion tons, but this quantity cannot be identified from the available information and is therefore not included in the estimates.

Utah. The best information available for the present study on Utah coal is the detailed mapping and cross sections of the Wasatch coal field (Spieker, 1931)<sup>1</sup>. Map gauge measurements on the geological maps (scale 1:62,500) coupled with average thicknesses taken from hundreds of columnar sections give an estimated augerable coal reserve base of 120 million tons.

The 16 other coal fields in Utah will contribute significantly to the reserve, but the available data are too sketchy to permit an estimate. A crude comparison of outcrop areas in these other fields suggests a total reserve several times that of the Wasatch field.

Wyoming. Smith, et al,<sup>2</sup> contains detailed estimates of strippable reserves in Wyoming. Maps show the probable limits of stripping and on these, the lengths of the highwalls expected to remain after stripping were measured. Using average thicknesses given in their report, volumetric calculations result in the tabulated figure of 35 million tons of augerable coal reserve base. This is a minimum figure of higher reliability than others in the table for western states.

<sup>1</sup> Spiecker, E. M., 1931: "The Wasatch Plateau coal field, U.S.G.S. Bull. 819

<sup>2</sup> Smith, J. B., et al, 1972: Strippable Coal reserves of Wyoming, Bur. Mines IC 8538

## CHAPTER 5

## IMPACT OF LAWS ON AUGERING

Before any prospecting can be done it is necessary to secure a permit or license, usually from a State reclamation agency, and most of these laws relative to prospecting and reclamation becoming more stringent and restrictive. While such laws are primarily related to mining, drilling and other associated prospecting methods are also covered. The laws, in some instances, are so loose that even the collection of geologic specimens can be construed as being in violation of the law. In general, however, from the viewpoint of reclamation, the concept is to return the land to its original state by filling the drill holes, re-establishing the erosion checks, and re-vegetation of access roads, disturbed lands, or prospecting trenches.

In general, individual state laws governing surface mining and reclamation are applicable to auger mining. Since auger mining is practiced primarily in the Eastern bituminous coal region as shown on Fig 1, the mining laws of these states were investigated in greater detail to determine the impact of laws governing mined-land reclamation upon auger mining.

A compilation of state laws will be found in the Appendix of this Report.

The first law requiring reclamation of strip-mined land was enacted in West Virginia in 1939. Since then, more than 20 states have enacted similar regulations. Common provisions of these include:

- The need for -- a permit
- posting of bonds
- land descriptions
- progress reports
- restoration standards
- time limits
- water pollution controls
- penalties for violations

In view of the fact that reclamation bonds only cover an end result, the states must have a means of assuring compliance with reclamation laws as the mining progresses. This means of compliance is accomplished by penalties for violations which could be monetary or an order to shut down the mining operations.

As previously stated, auger mining falls under the laws applying to surface mining. These laws differ in many particulars, but they generally take the same approach towards controlling surface mining and reclamation.

Before mining can begin, a permit application must be filed with the appropriate state agency. Mining and reclamation plans are often required with permit applications and include such information as the areas to be mined and reclaimed during certain time periods, any changes to be made in surface and ground water flow patterns, the proposed post-mining land-use and regrading and re-vegetation plans. In addition, a performance bond, based on the acreage of disturbed land, must generally be posted, and this bond is held until the permitted land is reclaimed in accordance with an approved mining and reclamation plan. The state mining laws also include many particulars, such as details of road construction, specifications for siltation dam construction, timing of spoil grading and revegetation, and other specifics that vary from state to state. State inspectors visit the mines periodically during the year, as well as before performance bonds are released to insure compliance with the surface mining laws.

Auger mining disturbs less land per ton of coal produced than other methods of surface coal mining. Under state laws, the mining bench, associated spoil areas, and access roads are defined as disturbed lands but not the land under which the coal has been removed by augering.

Only the Ohio and Kentucky mining laws make specific reference to auger mining separate from other surface mining laws. The Ohio law requires auger holes to be sealed with clay or other impervious material and then covered with compacted clay for at least 3 ft beyond the face of the hole and within 48 hours after removing the auger. The Kentucky law stipulates that a highwall resulting from auger mining must be reduced to a slope of 45° or less, subject to certain exceptions, and that backfilling and grading of an area must be accomplished within 15 days of augering. The Kentucky law also allows auger mining only where the surface slope exceeds 28° and sets maximum bench widths depending on the ground slope. All spoil material must be placed on the solid bench when slopes exceed 33°.

In the investigation of auger mines, the mine operators supported the mining and reclamation laws of their state but complained about the inspection and enforcement procedures. In some reported instances there were conflicts between the purpose of mining laws protecting against environmental degradation and the more specific concerns of the mine operators. For example, a mine may be ordered to shut down due to delays in obtaining a permit, while the abandoned pit fills up with polluted water.

This study has indicated that, for the most part, reclamation laws of individual states do not refer specifically to auger mining. Therefore, any effect on auger mining is minimal. However, all surface mining laws which exist in each of the individual states require the reduction or backfilling of the highwall as a necessary part of the reclamation process. Only one state, Ohio, requires plugging of the holes after augering. This is usually done by the auger miner, but for the most part, highwall reduction is left to the surface mining operator, to be handled as a result of his overall reclamation plan. The impact on auger mining, of state laws concerning reclamation, is minimal when considered in terms of the requirement of plugging the augered holes.

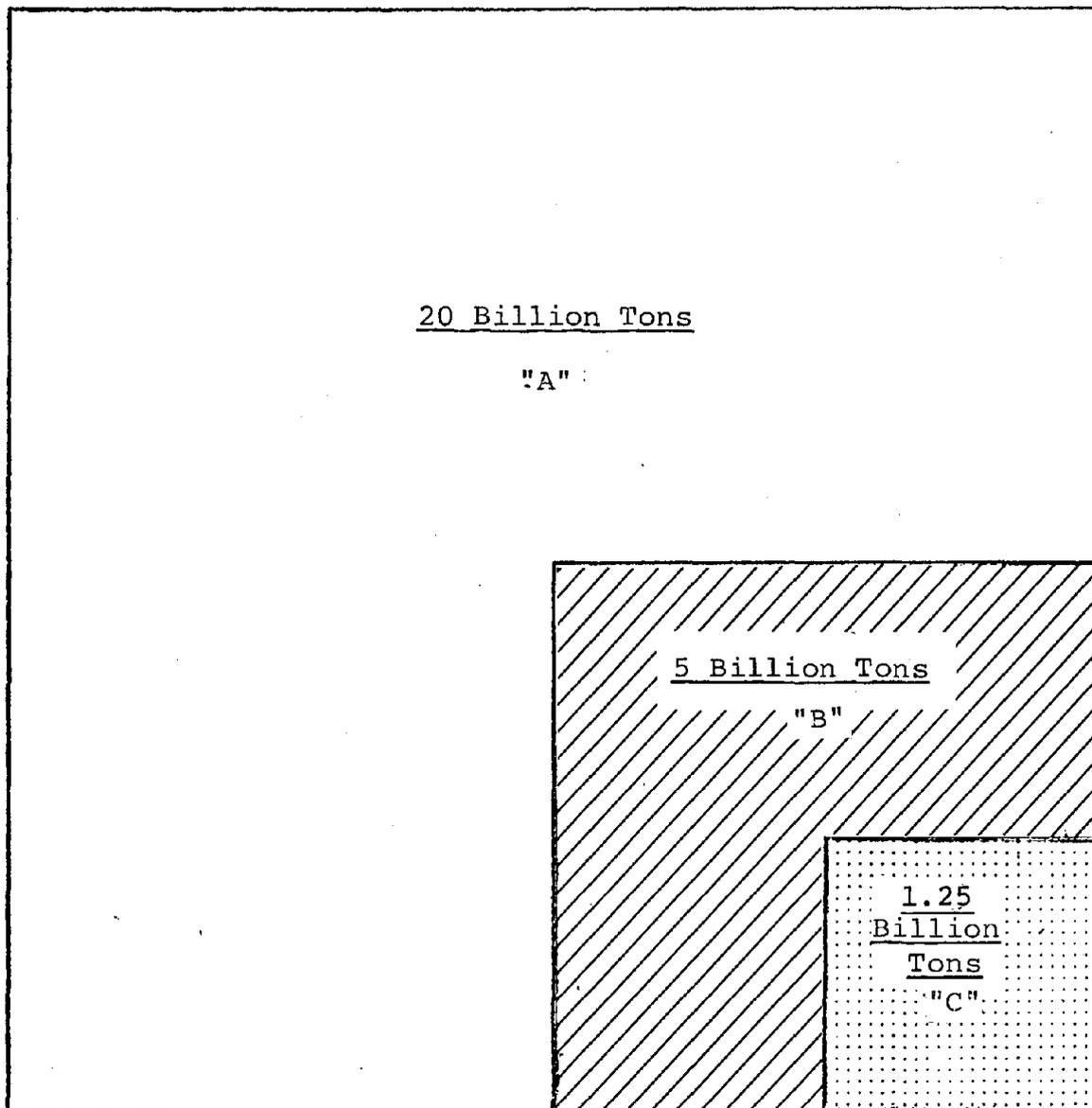
Auger mining is normally conducted in one of two ways. One method is a natural follow-up of surface stripping operations. The other would be as an individual endeavor, with some stripping, to form a bench, and backfilling as required by law. In either case therefore, surface mining reclamation laws do have an impact on auger operations, if only governing the time that should elapse between stopping the stripping operations and starting backfilling and highwall reduction.

Surface mining reclamation laws now require the reduction or backfilling of highwalls, and this is being carried out as part of the normal surface mining process. However, in the course of backfilling and regrading to the initial slopes in order to remove the unsightly mine benches, the coal reserve which remains under the highwall is no longer available for potential recovery. Additionally, such methods may not be permissible under current law, and the economic feasibility of recovering additional coal from previously augered reserves is tantamount to recovering pillars from previously abandoned underground mining operations.

Figure 5a shows augerable coal reserves of 5 billion tons and 20 billion tons to be available for recovery by current or modified augering practices. Assuming the most conservative yield of 25%, 1-1/4 or 5 billion tons could be considered potentially recoverable coal. The remainder 3.75 billion tons or 15 billion tons could be called lost coal.

This lost coal would become the most unobtainable of our national total underground coal reserve as a result of the backfilling and highwall reduction requirements under the various states surface mining and environmental protection laws. There is, therefore, a need for increased production and improved recovery of this augerable coal reserve before backfilling and reclamation.

The impact of surface mining law requiring reduction and backfilling of highwalls of contour mines within a given time period reduces the opportunity for recovery of coal from under the highwall by the auger mining method. In this sense, the impact of environmental law is major.

U. S. Augerable Coal Reserve

- A = Augerable reserve at 850 foot depth of penetration  
B = Augerable reserve at 200 foot depth of penetration  
C = Coal recoverable by current technology

Fig 5a

## CHAPTER 6

## ALTERNATIVES TO AUGER MINING

When the economic limit of normal surface mining is reached, the coal seam still remaining at the base of the last highwall may be recovered either by auger mining or by some method of mining which requires men to work underground.

Auger mining may be the optimum method of coal recovery if:

1. The residual tonnage is insufficient to justify the development of an underground mine,
2. The seam is too thin for an economic underground operation,
3. There are extensive old workings in the coal area,
4. The overburden is not competent.

Auger mining can often recover coal that is physically or economically impossible to recover by any other means. Although auger mining uses equipment which operates exclusively from the surface to extract coal from an underground source and, as such, is a transitional type of mining, it nevertheless is an integral part of surface mining technology.

#### Alternative Underground Methods

In order to establish a basis of comparison with auger mining, several methods of underground mining are described in broad generalities rather than in detail. In any and all of the underground methods, the hazards and safety associated with underground coal mining operations, the maintenance of adequate protection for the miners, the necessity of adequate entry openings or shafts, ventilation systems, the need for surface support facilities, power, roof bolting, mine drainage, and other equally important factors all apply and are of paramount importance. In addition, a sufficient volume of coal reserve must be available to justify the large capital investment required for the long-term operation. All of these factors as well as the economics associated with this type of operation are pre-requisites to establishing an underground mining system. The methods to be described are as follows:

1. Room-and-Pillar,
2. Longwall,
3. Punch,

4. Shortwall,
5. Longwall Stripping,
6. Bridgewall.

#### General Description of Alternative Methods

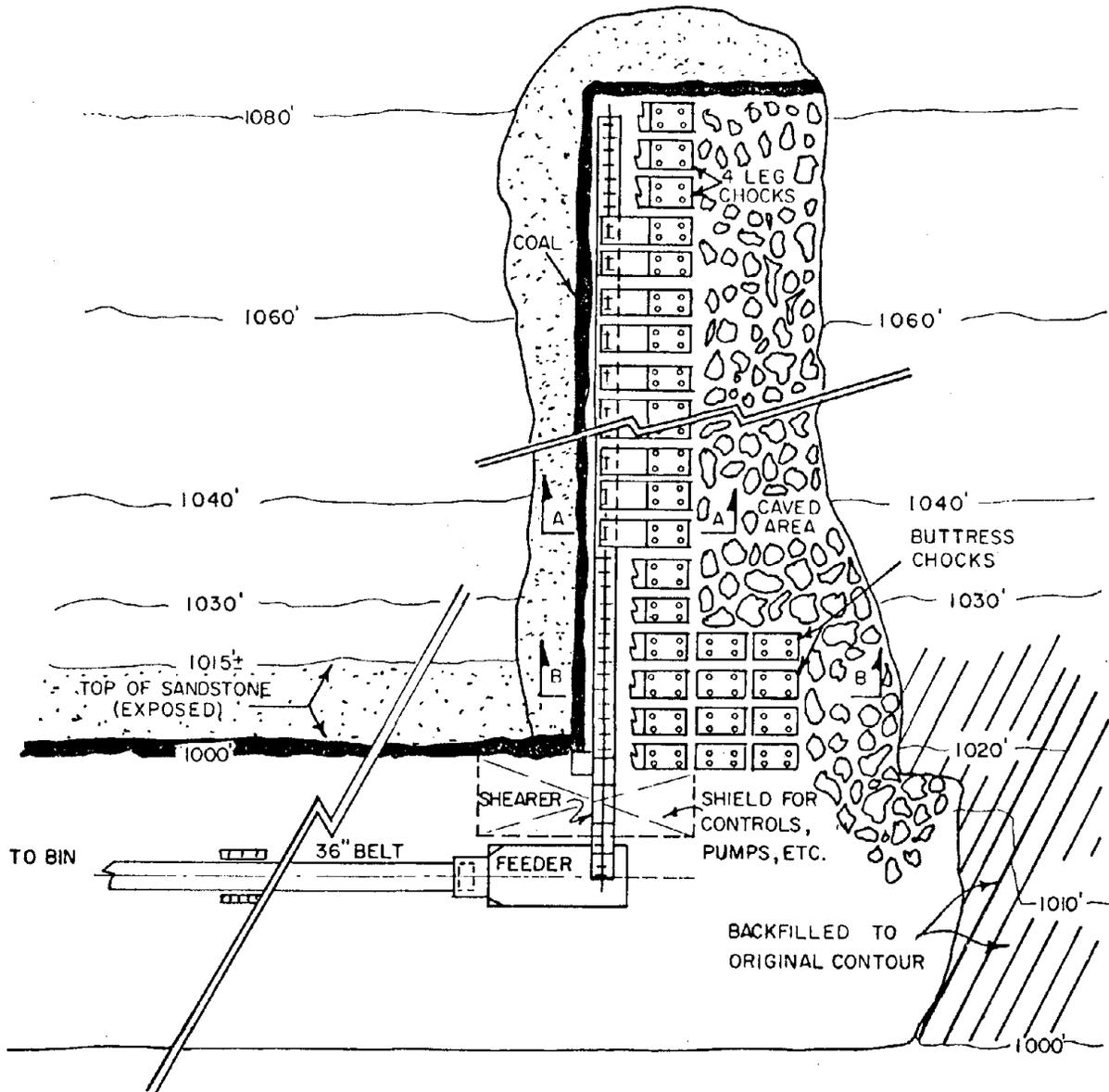
Room-and-Pillar - In this conventional operation, coal is cut and removed with the use of various pieces of mechanical equipment. Room width may range from 14 to 50 ft with an average of 30 ft. Total coal recovery will depend upon the thickness of pillars but generally ranges from 50 to 70%.

Longwall - A method of working coal seams believed to have originated in Shropshire, England, towards the end of the 17th century. The seam is removed in one operation by means of a long working face or wall, thus the name. The underground workings advance (or retreat) in a continuous line which may be several hundred yards in length. The space from which coal has been removed is either allowed to collapse or is filled or stowed with stone and debris. There are now about 50 such operations in the United States used for coal deposits ranging from 3 to 8 ft thick. Coal recovery approaching 100% is possible by using this method. Fig 6a shows a plan view of an adaptation of the underground longwall method.

Punch - Usually is an accompaniment of contoured stripping which is normally employed for the recovery of small, odd-shaped tracts in orphan areas and hilltops where the distance through is sufficient for setting up a gathering belt, meaning as a rule 1,500 ft or more, though shorter panels may be worked with shuttle cars. The method has been used near mountain tops in eastern Kentucky where the outcrop of the coal seam encircles the mountain at nearly the same elevation. On this contour, a bench is made, exposing the coal seam completely around the mountaintop. This bench provides an access road and working bench from which a panel of five to seven parallel tunnels are driven (Punched) simultaneously through mountains by following the coal seam. The entries are each about 16 ft wide, usually spaced on 50 ft centers and as high as the thickness of the coal seam; thus, all excavated material is coal. Crosscuts are made between tunnels, leaving pillars of coal to support the roof of the underground openings. This phase of mining extracts approximately 40% of the coal available in the panel area. Most of the remaining coal is recovered by systematically robbing the pillars between crosscuts, so that the ultimate recovery approximates 90%. The Punch mining method is illustrated in Fig 6b.

Where there are several coal seams at the mountaintop, the commercial seam highest in elevation is mined first, followed by the next highest and so on. The subsidence that accompanies the robbing of pillars at the final phase of Punch mining will otherwise disturb and rupture unmined coal seams. From the viewpoint of natural resources recovery, it is important that the above sequence be followed.

Plan View of Longwall Stripping System



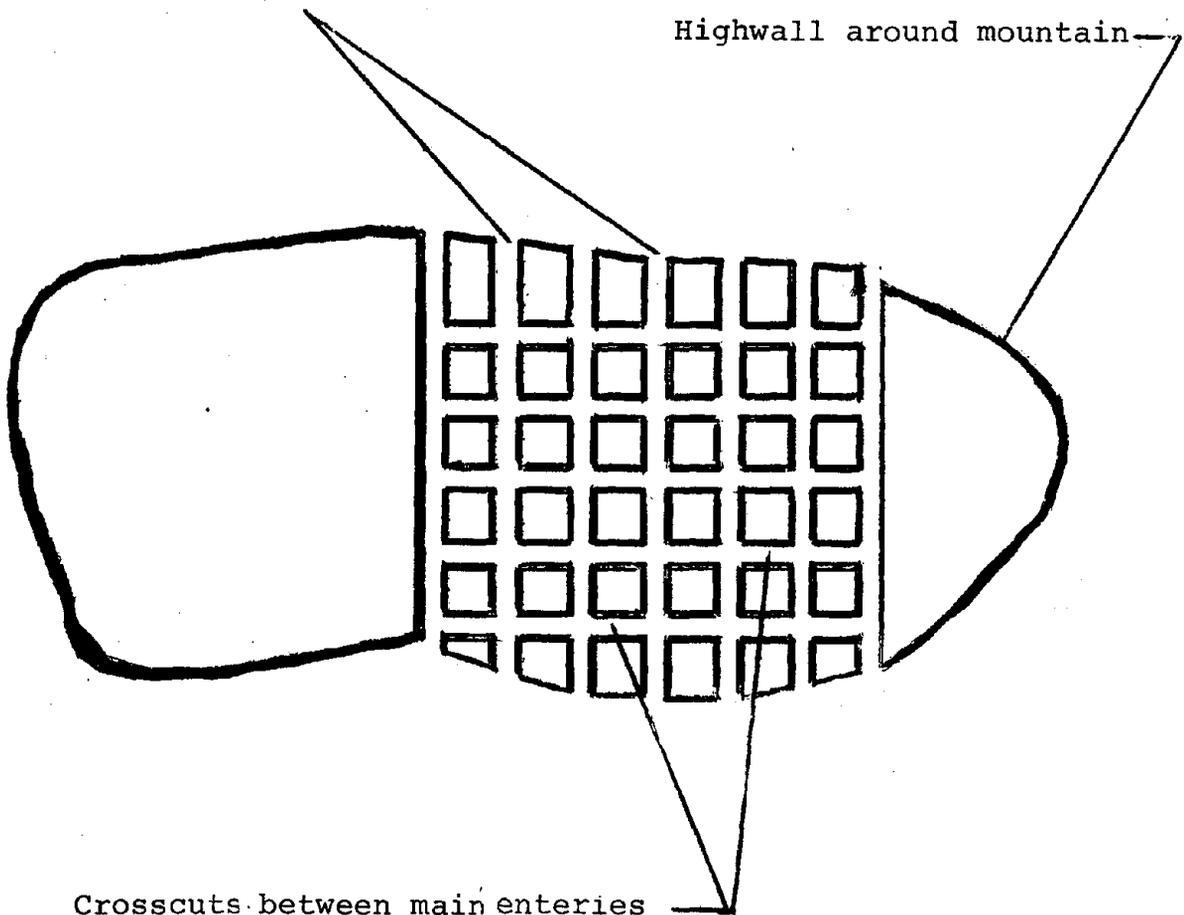
Source: EPA-670/2-74-002

Fig 6a

Plan of Punch Mining Method

Enteries driven through mountain  
from highwall

Highwall around mountain



Crosscuts between main enteries

Fig 6b

The Punch mining method recovers coal from under the mountaintops without removing the mountaintop, and with minimum disturbance of land surface. However, it leaves a highwall rim and bench around the mountaintop which is not esthetically pleasing. After mining, there is little or no land use potential at the highwall rim area.

The miners who go underground for Punch mining face unusually hazardous working conditions since the roof above the coal may be faulty through subsoil alteration common to mountaintops. The cost of maintaining safe working places and relatively high cost of labor limits considerably the potential for Punch mining.

Shortwall - Is quite similar to Longwall, but is mainly used for a regular coal deposit. Again, rock stratigraphy above and below are of vital importance. The primary difference is the length of the working face which is usually limited to about 160 ft, contingent upon safety factors and mining laws. Shortwall mining offers a higher degree of flexibility than Longwall, particularly in bad roof areas.

Bridgewall - A version similar to the Shortwall method uses a mobile bridge system to provide a continuous flow of coal from the continuous miner to the mine car. It also employs roof support units similar to the longwall mining system as the support for an open end pillar recovery system.

Longwall Stripping - Adopts existing underground Longwall mining technology for use in recovering shallow cover coal without the total environmental disturbance associated with surface mining as shown in Fig 6b. This method offers some interesting possibilities as an alternative in the respect that penetration depth of 200 ft is now being tried with a potential of 1,000 ft or more. The method would have application in mountainous areas with thin seams extending from one side of the mountain to the other.

The aforementioned alternative methods are all modifications of underground mining and as such are subject to all the controlling factors which enter in to the establishment and operation of an underground mining system.

#### Limitations of Alternate Methods

The development of an underground mining operation requires three to five years before the mine reaches full production. The necessary facilities for a two million ton annual capacity mine may range from \$20 million to \$65 million by today's criteria. In contrast to these values of time and capital outlay, augering operations can be instituted in less than a year at costs in the order of one to two million dollars.

Auger mining does not need the exterior support facilities of underground mining or the large reserves to justify mining. In comparison, by virtue of economic difficulties, auger mining is conducted on a short-term basis and can extract a portion of that additional quantity of coal which is available neither to surface nor underground methods.

Underground mining is also restricted by the technological problems that limit the coal recoverability. For example, the bulk of underground mining is accomplished by the room and pillar method, with recoveries ranging from 50 to 70%. The longwall and shortwall methods have a potential recovery of nearly all of the coal. However, the recoveries are all based on rock strata and geology of the coal seam. Robbing the pillars to recover more coal greatly increases the hazards. The failure of the roof to cave or the inability to remove chocks in order to advance the coal face in the longwall or shortwall operation not only affects recovery but introduces a risk to man and equipment. It is well known that rock structure is not as safe as one approaches the surface where augering is a potential method of recovery.

Although ground support accidents are encountered by both auger and underground operations, many dangers are unique to underground mining that account for high loss of life and injury. Such hazards as coal dust explosions result in large scale loss of life, and only by expensive monitoring and elimination of explosive gas can this hazard be eliminated from underground operations.

The February, 1975, issue of COAL AGE lists roof falls in underground coal mines as the greatest single cause of accidents during the year 1974. Poor roofing in a mine increases the probability of severe and often fatal accidents. Of the 98 fatalities listed in 1974, 15 were attributed to roof failure.

### Recovery

Underground coal mining will recover more coal per acre than auger mining. Recoveries for punch underground mining, without robbing of pillars, are of the order of about 50% while a well-run room and pillar mine may run to about 60% as compared to an auger recovery of 25 to 30%.

### Quality

A comparison made between auger mined coal and surface mined coal at the same mine shows substantially less percentage of ash in the product which has been auger mined. An operation in the Blue Gem Seam of Kentucky analyzed 2.1% ash for auger mined coal vs. 4% for strip mined coal. Another property on the Sewell seam analyzed 3.5% for auger coal and 5.0% for surface mined coal.

## CHAPTER 7

## DEVELOPMENT OF AUGER MINING

Augering for coal in the United States began in the mid-1940's in the bituminous coal fields of West Virginia. The method later spread to Kentucky, Pennsylvania, Ohio, Tennessee, Alabama and Virginia. The demand for coal during World War II promoted extensive contour mining of the hills which left many miles of coal beds exposed under highwalls of such thickness that further removal of the overburden to reach the coal seam with the equipment then available was uneconomical. Auger mining provided a means of obtaining additional coal at a minimal cost for equipment and labor. The first units were placed in operation in 1945, and after a few years of experimentation, the coal recovery auger developed into an efficient mining tool, production began to grow, and that growth has continued ever since. As of the mid-1970's, all of these States have auger mines in operation, and the method is spreading to Colorado, Idaho, Montana, Wyoming and other western states. The birth and continued growth of the method is based mainly on the economics of recovery.

The earliest augers were adaptations of horizontal rock drills designed to bore into overburden. One of the first recorded experimenters in their use for coal recovery was the Becker County Sand and Gravel Company in Summersville, West Virginia. During World War II, Becker's success with six- and nine-in. rock drills to recover coal led to the later development of drills of larger diameter. Both the Salem Tool Company and the Cardox Company were involved in these early experiments. Mr. R. M. McMillan, of Becker County Sand and Gravel, and Mr. M. M. Lilly, Jr., a duPont technical representative of Charleston, West Virginia, were pioneers in the new process.

In 1958, the United States Bureau of Mines investigated the use of large-diameter augers to drive ventilation connections between coal gangways in an underground anthracite mine. A total of 3,246 ft were driven, the largest single hole being 87 ft augered to a 24-in. diameter. A portion of these holes were reamed to a 48-in. diameter, using the same auger train (which had broken into a larger working chamber) by pulling the reamer towards the drive unit. This unit was powered with an oil motor connected, in turn, by flexible hydraulic hoses to an electric motor-driven pump.

The largest auger was a Compton 84 in., which was built by James Compton around 1960 for the Kelly Sturgill Coal Company; this unit is not in use. In later years, a 51-in. Salem 1800 was manufactured for the Charlotte Coal Company in Steubenville, Ohio; this was replaced by the Salem 1600.

A 4-headed 16-in. auger was also built but was dismantled due to the many operational problems.

Some of the original coal augers were relatively crude homemade pieces of equipment. They were merely modified versions of horizontal drills that, with the addition of a few augers of large diameter, were able to drill into and produce coal. Production was as low as seven tons per hour; the resulting coal was fine ground, and the holes drilled were relatively shallow.

The augers were often owned and operated by individuals who located an augerable property and mined it on a contract basis which provided a high production rate at a low investment cost, regardless of the total potential recovery.

Almost all augering has been confined to bituminous coal because it is easier to drill, and the seams lie sufficiently level for the drill to follow them readily. The mines are concentrated in West Virginia, Kentucky, Pennsylvania, Ohio, Tennessee, Alabama and Virginia.

Most augering operations are a follow-up of surface mining operations and, as such, make use of existing surface mining operational facilities to assist in the recovery of additional coal prior to the reclamation of the area. Thus, the operator incurs little additional expense for haul roads, mine benches or reclamation.

When auger mining follows conventional contour mining, the coal auger salvages coal that probably would be left unmined. It produces coal without any additional stripping of the overburden, drilling coal from the face of highwalls that have reached their maximum economic height; thus, augering makes it possible to bore coal from seams exposed on the highwalls of exhausted strip mines. It may also recover coal that is too close to the surface to be safely mined by underground mining methods.

Since the first recorded production of 205,000 tons of augered coal in 1951, production has steadily increased to 15,554,000 tons in 1972. During this period, the number of auger mines grew to a total of 574. Fig 1 shows the coal deposits and counties throughout the United States where auger mining is practiced.

## CHAPTER 8

## PRESENT AUGERING OPERATIONS

Auger Mining Defined

Auger mining is generally practiced but not restricted to hilly coal bearing regions of the country. This type of mining utilizes a machine designed on the principle of the auger, which bores in to an exposed coal seam, conveying the coal to a storage pile or bin for loading and transporting. Auger mining may be used alone or in combination with conventional surface mining. When used alone, a single cut is made sufficient to expose the coal seam and provide operating space for the machine. When used in combination with surface mining the last cut pit provides the operating space.

Description of Auger Equipment

A typical augering machine shows that the equipment consists of three principal components: (1) a cutting head, (2) a spiral conveyor, and (3) the prime mover with all controls and outside handling equipment. These three components are coupled together so that the three units function as an integral power train.

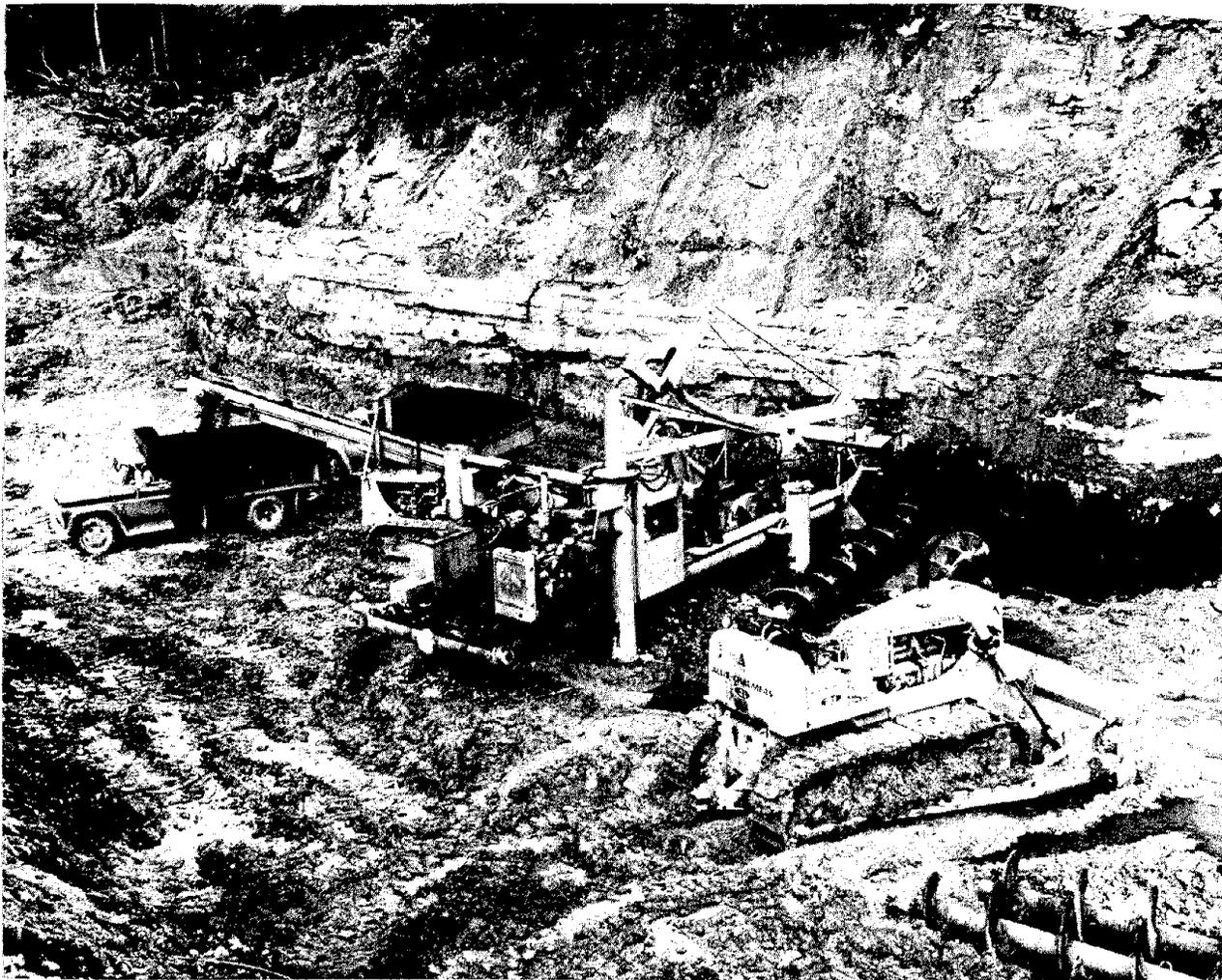
Fig 8a shows a single cutting head which cuts the coal, breaks it into manageable lumps and starts it along the scroll or spiral conveyor to a belt and elevating conveyor outside the highwall. Also shown is a typical operating arrangement where the coal is being directly loaded into a waiting truck.

The coal seam itself acts as a trough or container against which the spiral flights can move the coal.

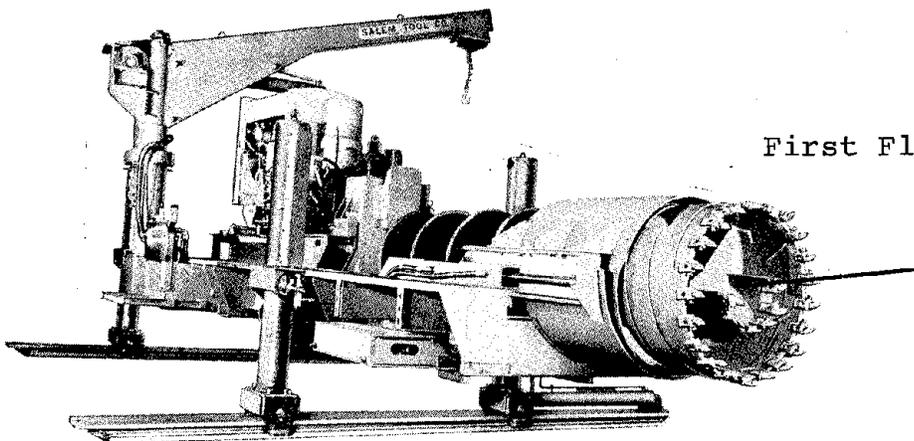
The prime mover is usually skid- or pad-mounted to allow movement over uneven terrain. Figs 8b and 8c show skid and pad mounted machines. Jack-legs are used to provide firm anchorage, as well as leveling the carriage on uneven ground. The carriage including the engine, the drive head and sometimes the operating controls, move towards the highwall in a crowding action to force the rotating cutting teeth into the coal and, then after releasing the auger string, retreat enough to insert another flight to the string.

Description of Augering Operations

The operation of an auger at the face of a coal seam can be described as follows: The first flight, with the cutting head aimed at the coal seam face, is inserted in the machine. The machine is lined up and leveled by means of hydraulic jacks



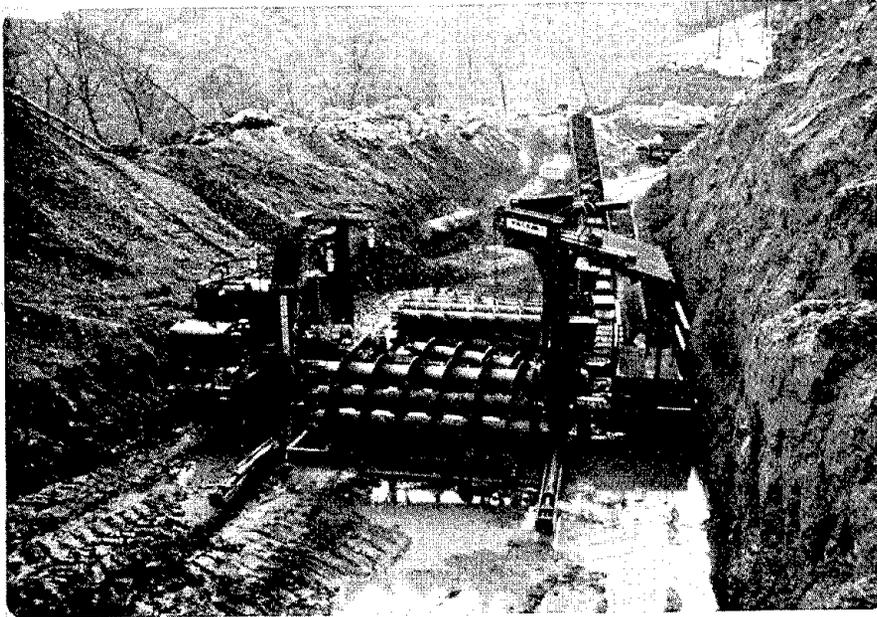
Typical augering operation showing bench maintenance, augering and loading



Cutting Head  
First Flight of Single Auger

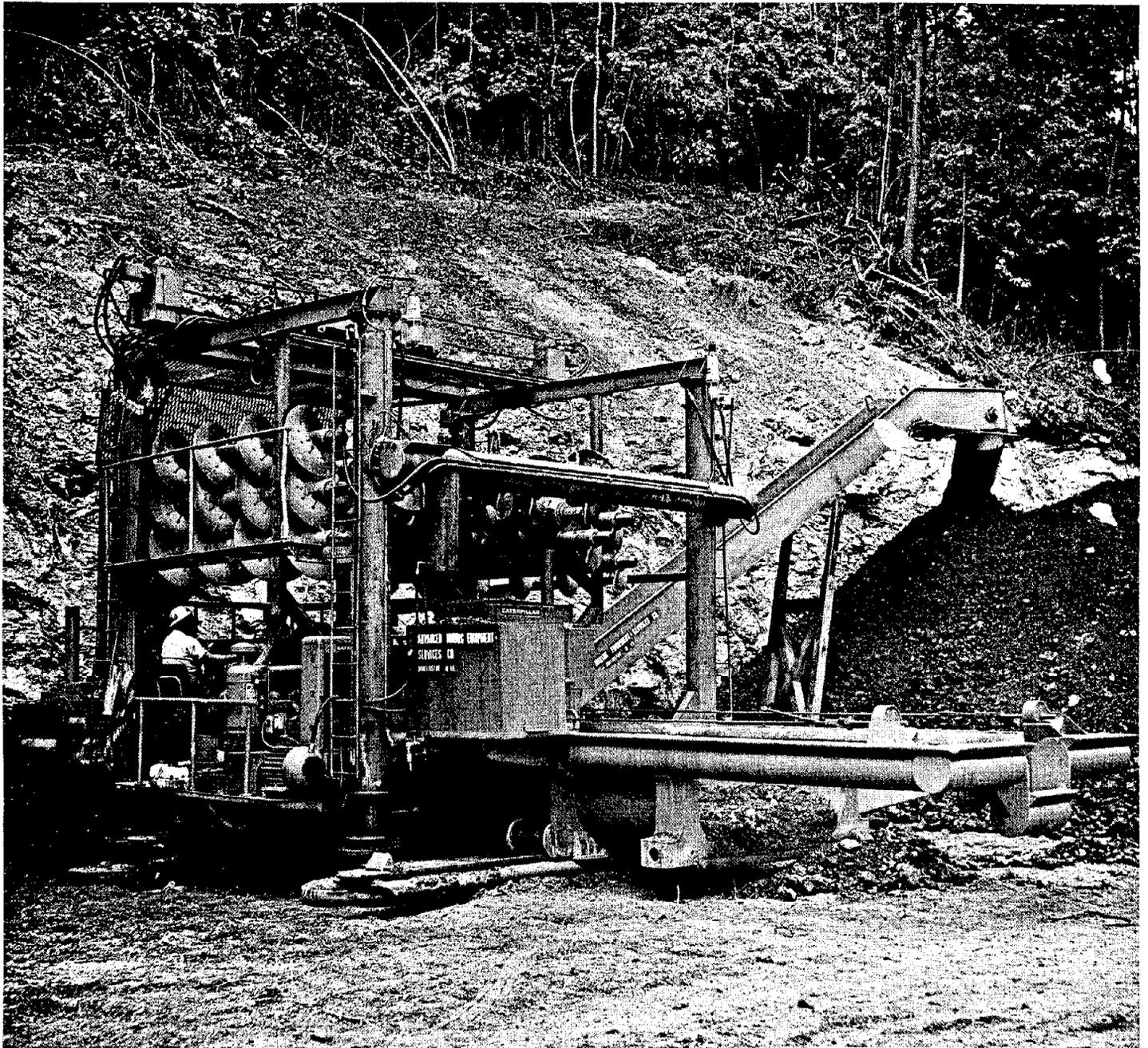
breaker

Fig 8a



Skid mounted auger. Note hydraulic jacks  
to provide lateral movement.

Fig 8b



Pad mounted auger with skids for lateral movement

Fig 8c

in the frame columns (Fig 8d). Lateral movement (parallel to high-wall face) for skid mounted units is provided by hydraulic jacks. Lateral movement for purely pad-mounted machines is provided by a bulldozer or front-end loader.

After the first flight is driven into the coal seam, the pin holding the flight to the drive mechanism is pulled. This operation can be a manual one, but some machines are equipped with an hydraulic pin release. Most machines manufactured today have spring-loaded pins which provide automatic coupling but require manual disengagement for removal of the flight. The drive engine is returned to its position furthest away from the face of the wall and another flight is installed; they are then pinned together.

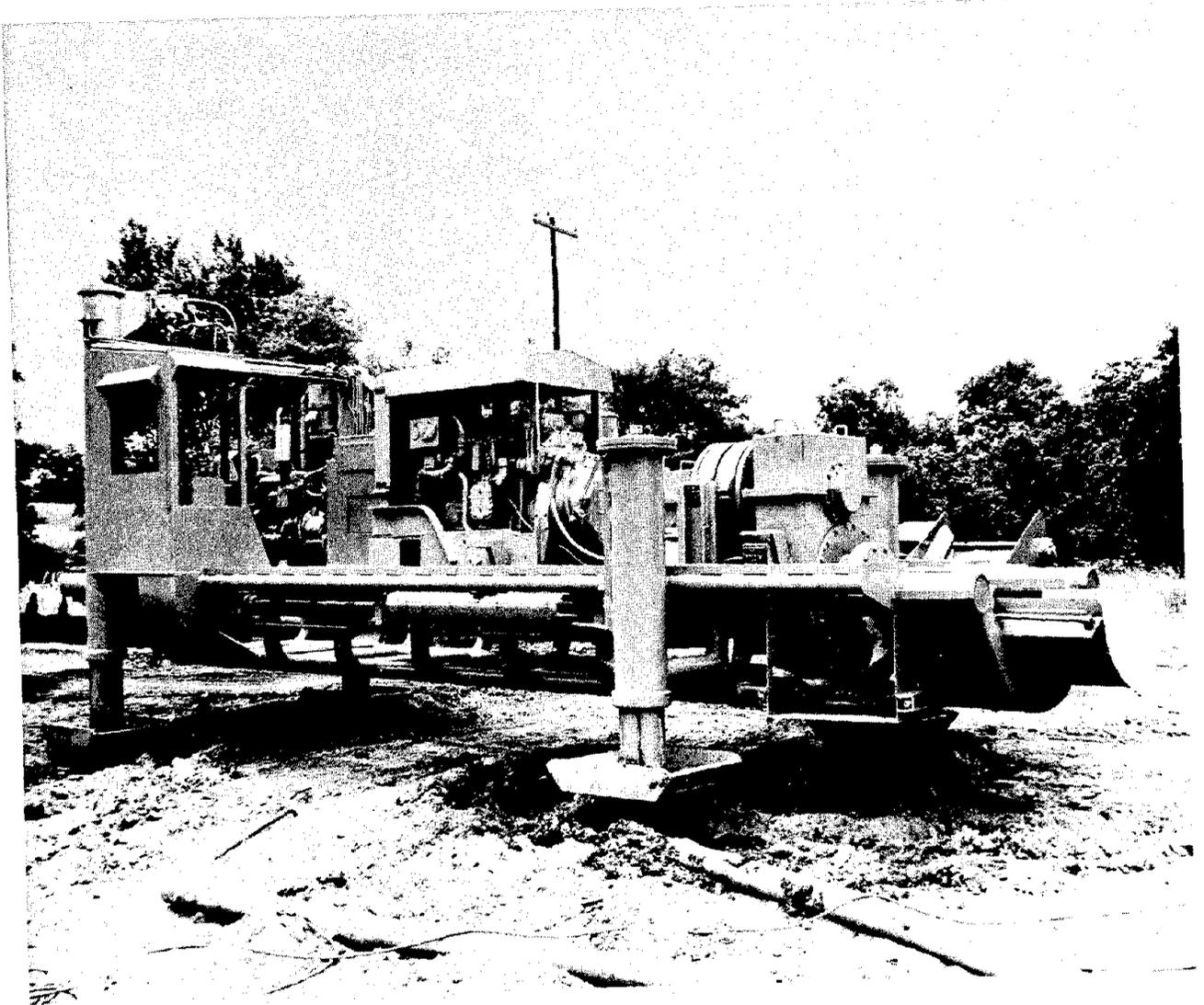
Unused flights, depending upon the individual machine design, are stored in racks on one side of the machine (Figs 8b and 8e), on both sides of the machine, overhead (Fig 8c) or on the ground (Fig 8f). They are handled by hoists attached to the machine frame.

The operator uses his sense of "feel", hydraulic gauges and tachometer, when available, to advise him as to whether the auger is boring coal or drifting out of the seam. Additional "sensing" is secured by means of visual observation of the material being transported back from the cutting head, through the succeeding flights, to the conveyor.

Augering requires much skill and constant alertness in order to avoid damage to the machine, loss of the valuable auger head, or accidents such as breaking into abandoned underground workings which might be full of methane gas or flooded with water-- a sudden easing of the resistance to the crowding pressure and the sound and vibration produced just prior to breaking through will allow an alert operator to stop without damage.

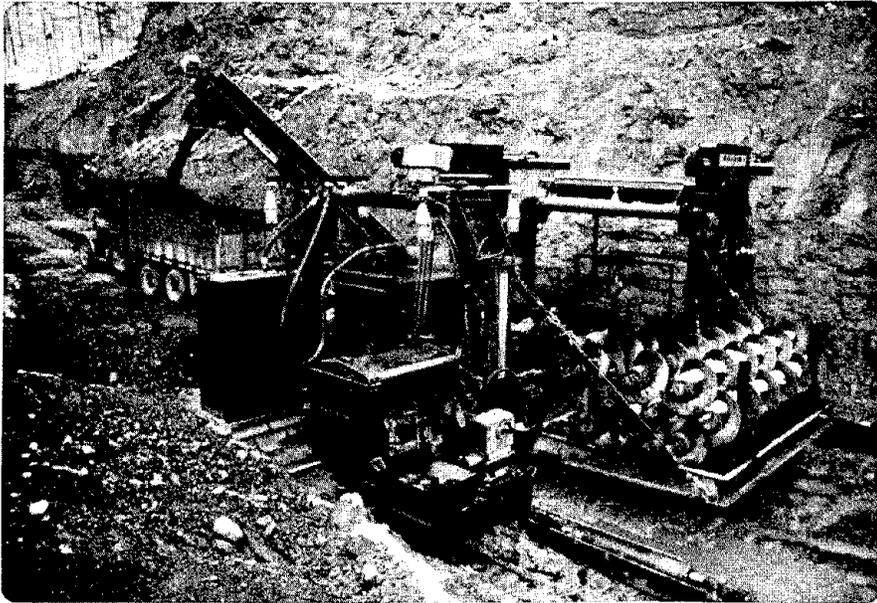
#### Starting the Cut

The coupling of the individual flights together as the cutter advances into the coal is such that there must be enough clearance between the connections to effect a mechanical coupling. These necessary shank clearances together with the incremental increase in weight of the flights result in a sagging or bow effect upon the auger column and drill head. In order to compensate for this effect and prevent the cutter from cutting rock at the base of the seam, the auger operator starts his drill hole at the top of the seam and advances it as long as he is able to produce coal without cutting rock.



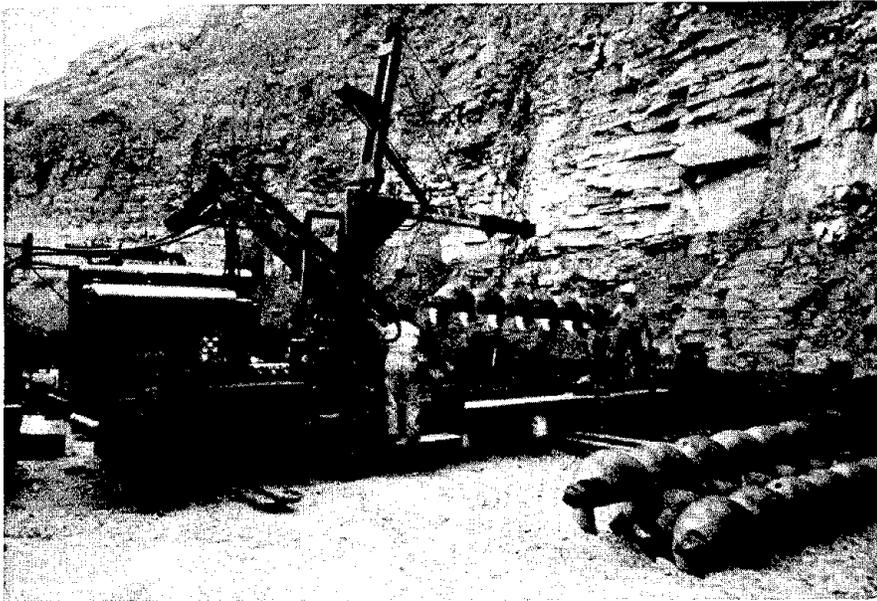
Auger machine using hydraulic  
jacks for leveling.

Fig 8d



Auger storing unused flights on one side  
with coal production on opposite side

Fig 8e



Loading single auger flight. Note flights  
stored on ground

Fig 8f

### Depth of Penetration

The depth of penetration can vary from as little as 12 ft (one flight) to 200 ft and is governed by three controlling factors: (a) the miner's estimate of geology of the coal seam, (b) the power capabilities of the auger unit, and (c) his estimate of the risk and his ability to recover the auger cutting head as the depth of penetration increases.

His estimate of the geology takes into account seam thickness and undulation, and thickness between supporting coal pillars to be left. If he encounters rock at any point during the augering, he moves out and on to the next hole.

The torque and frictional forces which develop during the augering process increase as flights are added and depth of penetration increases. Lighter powered machines with matching transmissions, therefore, will penetrate to a lesser depth than higher powered machines. In either case, the auger operator, knowing his machine and its capabilities, is reluctant to tax his machine to the limit.

The cutting head is often the most valuable single component of the machine, and its loss is a severe economic blow to an independent operator. Once the initial penetration is made into the coal seam, the cutting head bores ahead without guidance and the operator has scant knowledge of the actual conditions at the cutting end. He has a physical sense of feel and gauges to show pressure and RPM. He can observe the cuttings for signs of clay or rock, and after the first hole is bored, has a knowledge of conditions in the adjacent hole. If, by chance, he should experience a roof fall or penetrate old underground workings or drill out an aquifer, his risk of losing the drill head is high. These factors also influence the operator's decision as to how he is to auger the next hole. It also accounts for the relatively low coal recoveries that are realized, due primarily to variables of depth, pillar spacing, and size of auger hole as compared to the relative dimensions of the coal seam.

Some auger miners are willing to deviate from conventional practices and take greater risks. This group has developed novel ways of augering, such as producing square holes to increase recovery. As a result of these innovations, coal recoveries of 50% and higher have been reported, as well as depths of penetration of 300 ft. However, these results are the exception rather than industry wide practices.

### Single and Multiple Seams

For the situation where overburden stripping is required before augering commences, the overburden is removed followed by removal of coal to form a bench. The auger is then moved in. For a single seam and a relatively straight highwall, the procedure is rather straightforward with the stripping, coal removal, augering of the seam, reclamation, and backfilling. This cycle repeats itself along the coal seam and the highwall face.

Due to the complex geology of the deposits, mining of multiple seams presents many variations in auger mining procedures.

The following are examples of mining procedures that may be used for multiple seams. If the parting is less than 12 in., the upper seam can be stripped, the coal removed, the bench established, and the seam augered. Then, the lower seam can be worked in a similar manner. It has been reported that with thin partings or multiple seam augering, with little material between seams, the depth to which the lower seam can be safely augered has been less than the depth of the upper seam holes.

Continuing with another variation of the stripping procedure, for a multiple-seam situation where many feet of overburden separate the seams, the following eight-step procedure can be followed (Refer to Fig 8g):

The cycle starts by removing overburden (1) and removing the exposed coal. The next step again removes overburden (2) and removes the exposed coal. From the bench established in step 2, the lower seam (3) is augered.

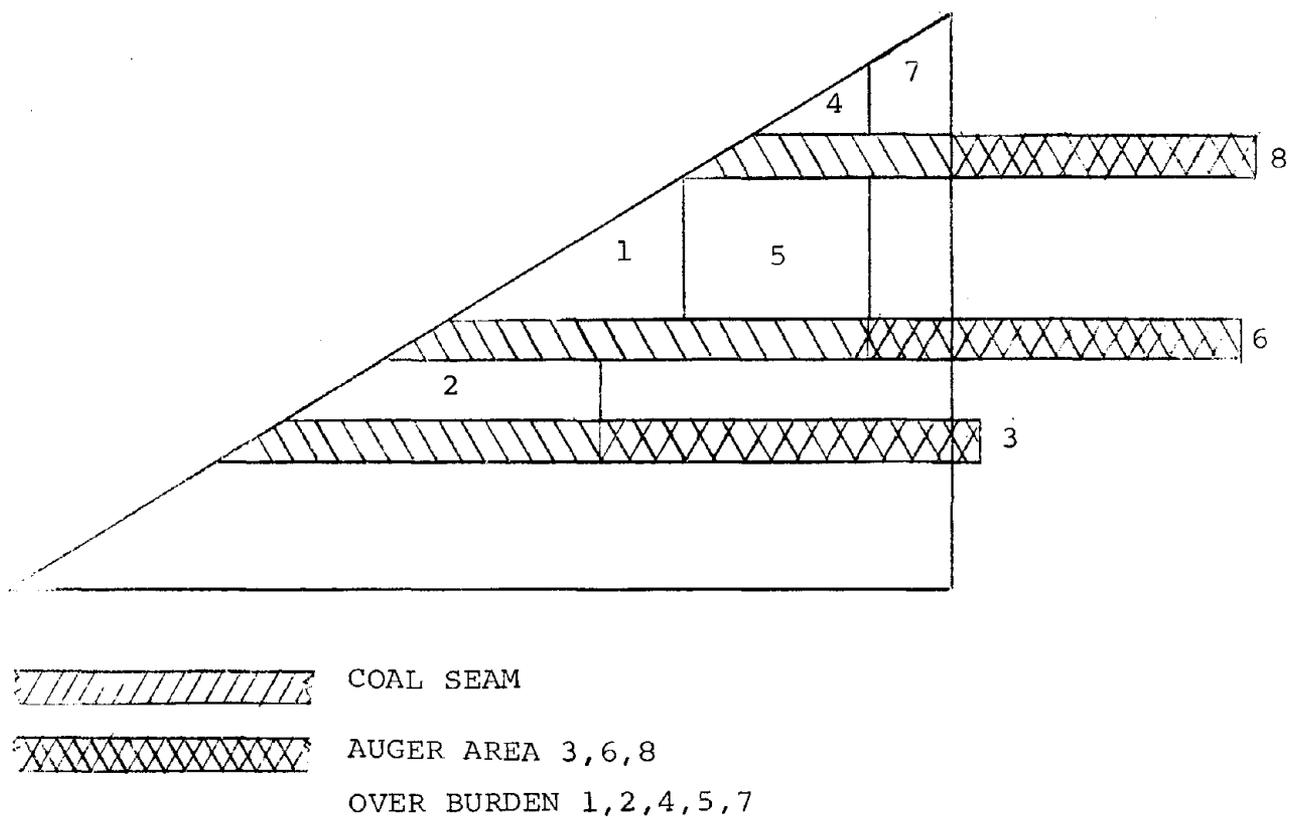
At this point, the upper seam overburden (4) is removed and the exposed coal recovered. The operator continues by removing overburden (5) and recovering the exposed coal. From this bench, the middle seam (6) is augered. The end of the cycle is to remove overburden (7), remove the exposed coal and, from this bench, make the final augering pass (8).

#### Interface of Equipment

Auger machines work in conjunction with other surface mining equipment such as dozers, front-end loaders, and trucks. Fig 8a shows a typical arrangement of equipment in an augering operation.

Bulldozers and front-end loaders are utilized to do pioneering work, remove overburden, develop haul roads and prepare the bench for the auger. Sometimes, they are also used to maintain haul roads. Motor graders also are used to maintain haul roads.

The equipment used in the final step of coal removal in an augering operation is the coal truck, used to transport coal from the pit either to preparation plant or a stockpile. Due to the relatively low order of magnitude of production of current augers, most coal haul trucks used have a capacity in the 20-25-ton range although various operations have used haulers up to 75-ton capacity. At this point, the dozers, front-end loader, small dragline, etc., previously used for surface mining and bench preparation, are used for reclamation of the mined area and in some cases, due to recently enacted legislation, auger holes are plugged.



Surface Mining And Augering Three Seams  
Of Coal in Eight Steps

Fig 6g

## CHAPTER 9

## PRODUCTION AND RECOVERY

Auger Mine Production

During 1973, according to Keystone Coal Industry Manual, 602 bituminous and lignite operating companies produced 573,857,573 tons of the 591,000,000 tons of total production. On this basis, approximately 15% of the total estimated 4,000 bituminous and lignite companies accounted for 96.9% of the total coal production. Augering, during the same year, produced 14,200,000 (preliminary estimate) tons of coal or approximately 2.4% of the total reported.

The annual production of the top 50 bituminous coal producing companies (see Fig 9a), each reporting tonnages in excess of 2,000,000 tons per year, accounted for 409,157,204 tons of production. Only six of these major companies indicated company-owned augering operations. Their combined output of auger coal totaled 779,212 tons.

A total of 139 companies report production of coal by auger mining. Some of these companies report auger production separately, while others report augering as part of their surface operations.

Analysis of the production statistics indicates that as the annual production of individual companies decreases, the number of companies undertaking augering operations increases. Thus, in the smallest classification, 9, with 212 companies each reporting annual production of 100,000-200,000 tons per year, 59 companies indicated portions of their production as being derived from augering operations (see Fig 9a).

1973 U.S. Coal Production by Company  
Ranked by Production

	<u>Annual Production Classification</u> (tons)	<u>No. of Companies Operating</u>	<u>No. of these Companies Augering</u>	<u>Maximum Individual Company Auger Production</u> (tons)
1	+ 3,000,000	31	5	274,412
2	+ 2,000,000	19	1	205,000
3	+ 1,000,000	30	6	225,000
4	+ 700,000	20	6	252,590
5	+ 500,000	33	8	283,747
6	+ 400,000	32	9	335,334
7	+ 300,000	64	18	170,581
8	+ 200,000	88	27	139,800
9	+ 100,000	<u>212</u>	<u>59</u>	77,339
		<u>529</u>	<u>139</u>	

Source: Keystone

Fig 9a

Individual company annual auger production in 1973 ranged from a reported low of 218 tons, to a high 335,334 tons for all classifications.

Of significance is the fact that while the major producers of coal show very low tonnages attributable to auger mining, many of this group subcontract to auger miners in order to be free to devote their major consideration to surface or underground operations.

From 1952 up to 1970 auger mine production steadily increased to 20,027,000 tons per year. In the 2 years, 1971 and 1972, auger mine production declined to 17,332,000 and 15,554,000 tons.

Auger Mine Location

Fig 9b shows auger mine locations by states' output per man-day and total annual production for the years 1968 through 1972.

As indicated in the tabulation, the greatest number of mines are located in Eastern Kentucky. In 1972, 239 mines located in this State produced 8,779,000 tons, or 56% of the total 1972 auger production.

Auger Mine Statistics

	1968			1969			1970			1971			1972		
	No. of Mines	Output Tons Per Man-day	Total Annual Production (000 Tons)	No. of Mines	Output Tons Per Man-day	Total Annual Production (000 Tons)	No. of Mines	Output Tons Per Man-day	Total Annual Production (000 Tons)	No. of Mines	Output (Tons) Per Man-day	Total Annual Production (000 Tons)	No. of Mines	Output (Tons) Per Man-day	Total Annual Production (000 Tons)
Alabama	2	13.95	63	1	11.14	39	3	28.31	143	4	80.04	73	1	60.01	49
Illinois	1	35.72	10												
Kentucky (E. and W.)	151	45.37	6,229	150	48.10	7,211	207	39.60	9,859	265	45.66	9,406	244	51.50	8,917
Eastern	146	44.60	6,013	149	48.06	7,197	202	39.60	9,554	257	45.68	9,236	239	51.59	8,779
Western	5	87.59	216	1	81.40	14	5	39.63	305	8	44.51	170	5	46.28	137
Maryland	7	37.27	99	7	20.67	83	6	43.87	111	6	26.74	102	9	21.73	65
Ohio	54	47.36	1,468	46	42.79	1,602	45	30.51	1,422	30	52.66	973	35	34.40	621
Oklahoma	1	100.00	6	1	113.92	9	1	92.54	7	1	55.15	2	-	-	-
Pennsylvania	55	36.36	667	61	43.25	622	54	34.08	661	57	26.11	544	55	30.53	542
Tennessee	9	37.04	232	11	36.55	238	7	51.85	157	11	30.79	316	9	35.19	281
Virginia	65	43.10	1,520	82	47.64	1,621	83	47.35	1,895	103	41.65	1,829	122	47.85	2,100
W. Virginia	109	35.12	4,974	111	31.05	4,924	153	26.40	5,772	113	29.13	4,074	99	30.69	2,979
Wyoming										1	34.26	12			
<b>Total</b>	<b>454</b>	<b>40.46Avg.</b>	<b>15,267</b>	<b>470</b>	<b>39.88Avg.</b>	<b>16,350</b>	<b>559</b>	<b>34.26Avg.</b>	<b>20,027</b>	<b>591</b>	<b>39.00 Avg.</b>	<b>17,332</b>	<b>574</b>	<b>43.00 Avg.</b>	<b>15,554</b>
<b>Total Annual Auger Production of All States as % of Total U.S. Production</b>			<b>2.8</b>			<b>2.9</b>			<b>3.3</b>			<b>3.1</b>			<b>2.6</b>
<b>Average Value of Augered Coal (Per Ton f.o.b. Mine)</b>			<b>\$3.53</b>			<b>\$3.81</b>			<b>\$6.08</b>			<b>\$6.57</b>			<b>\$6.54</b>

NOT REPRODUCIBLE

Fig 9b

Output per manday in 1972 averaged 43 tons for all states. It is interesting to note that 1 auger mine in Oklahoma reported a high of 113 tons per manday in 1969.

The tabulation also shows that the average value of augered coal per ton, fob mine, increased from \$3.53 in 1968 to \$6.54 per ton in 1972.

#### Comparative Mining Production Rates

The following table shows that the average auger production per manday is substantially greater than either underground or surface mining production per manday.

	<u>Production per Manday</u>				
	<u>(short tons)</u>				
	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>
Underground mines	15.61	13.76	12.03	11.91	11.66
Strip mines	35.71	35.96	35.69	35.95	36.00
Auger mines	39.88	34.26	39.00	43.00	45.33

Source: Keystone Coal Industry Manual 1974

#### Manufacturers' Criteria

Coal recovery (Fig 9c) from an auger mining operation, according to a manufacturer of auger mining equipment, varies from 40% to 65%. The chart shows that for thin seams, the percent recovery increases as the number of heads increases. The chart also shows the anticipated coal production per 100 ft of penetration. The Salem Tool Co. "Coal-Q-Lator" was used to compute the annual production to be derived as a result of using various diameter single-, dual- or triple-auger heads, as summarized in Fig 9d. Operational factors influencing coal recovery are: auger diameter, seam thickness, and thickness of rib (pillar) left between holes, as shown in Fig 9e.

In addition to this, there are geologic factors such as undulation, curving highwalls, and irregularity of the coal seams (deviation in thickness) which also influence recovery.

There are also mechanical factors: as each hole is drilled, the column of auger steel sags due to its own weight as it advances.

Coal losses are further increased when drilling on a contract basis, as is frequently the case. The contractor is paid per ton of coal produced; therefore, when local, physical conditions at the highwall or within the coal seam become adverse, he may not drill the hole to its full length in order to pre-

Production - Tons/100 Ft Length

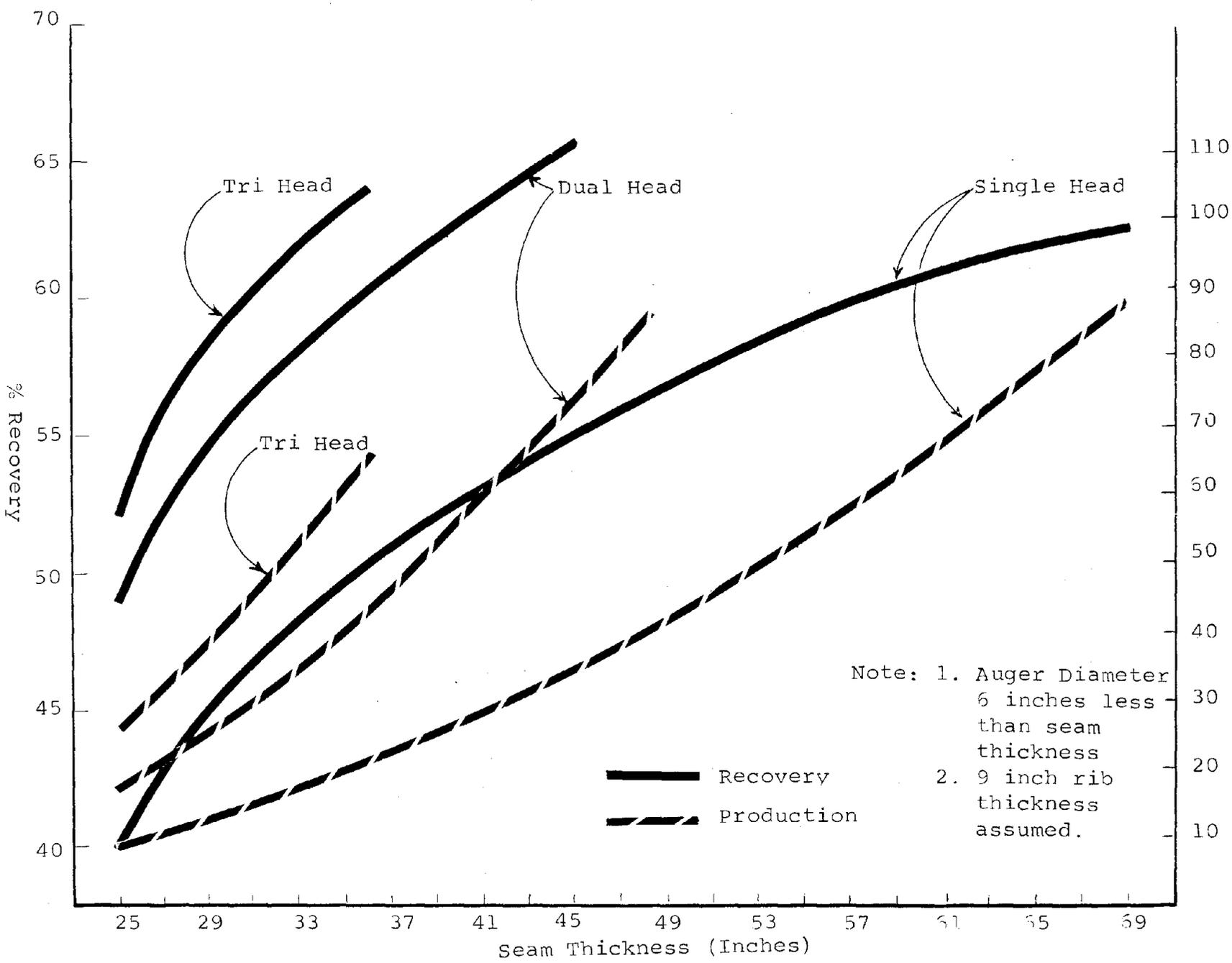
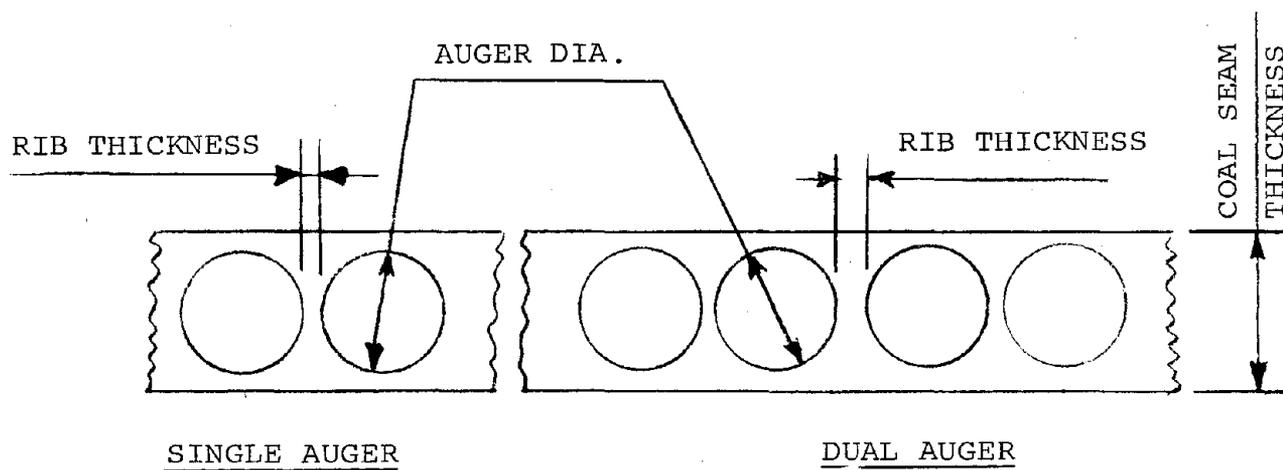


Fig 9c

Potential Coal Recovery by Augering  
by Model and Auger Diameter

Single Auger	Cutting Diam In.	Tons/150' Hole	Tons/Yr
	30	30.0	90,000
	36	43.2	129,600
	42	58.8	176,400
	45	67.5	231,300
Dual Auger	19	24.9	74,700
	21	31.2	187,200
	25	44.2	132,600
	27	52.2	157,600
	30	64.6	193,800
Triple Auger	19	37.8	113,400
	21	47.7	143,100
	23	57.9	173,700

Note: Above table based on 2,400 hr/yr  
and Salem "Coal-Q-Lator."



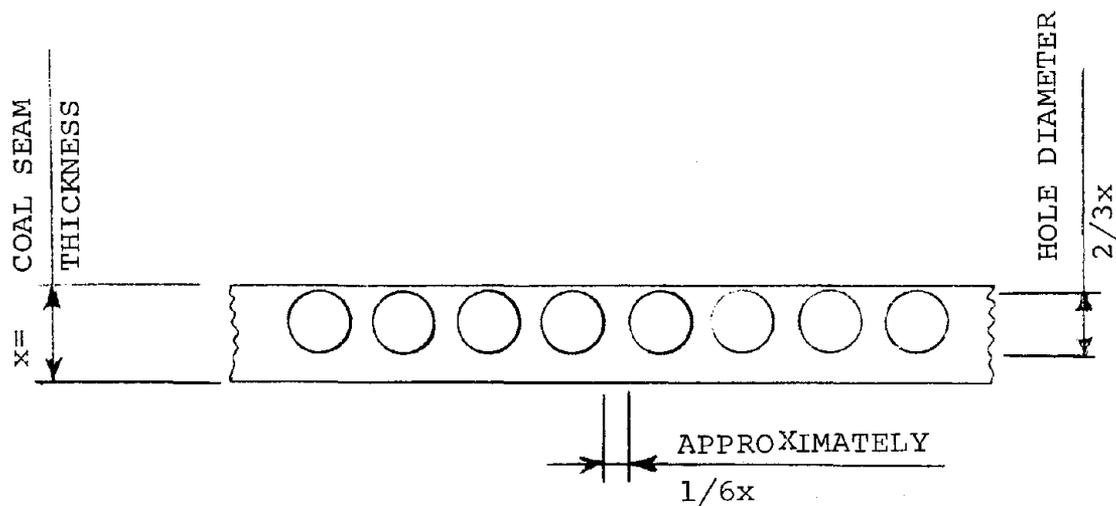
Factors Affecting Coal Recovery

Fig 9e

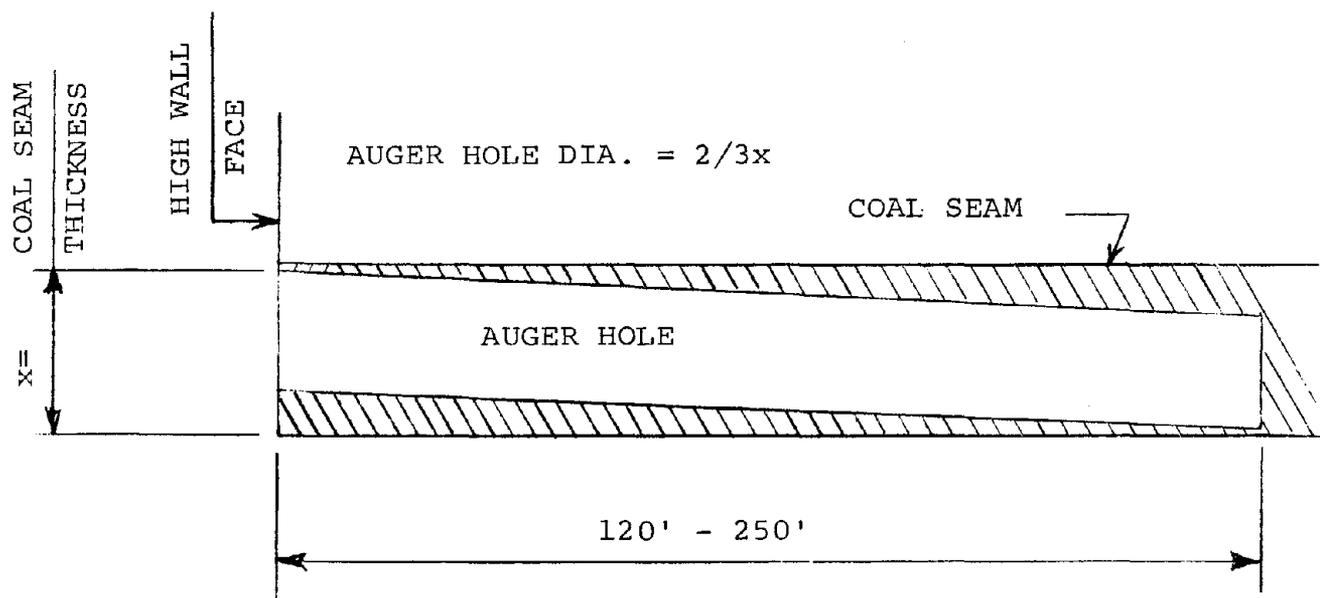
maturely move on to a site where drilling is more rewarding according to the terms of his contract. Short holes decrease resource recovery. Fig 9f graphically shows a plan and longitudinal view of an auger hole, while Fig 9g indicates unmined, nonrecoverable coal as a result of deviations with plane of the highwall.

#### Multi-head vs. Single-head Auger Production

The three basic types of augers can be classified as single-, dual-, or tri-head. Each of these has certain advantages depending on the seam thickness. In order to achieve optimum recovery, the proper auger-head arrangement, hole diameter, and rib thickness left behind must be matched to the thickness of the seam that will be mined. The tri-head yields the best potential recovery in coal seams up to 37 in. thick; the dual-head from 37 to 40 in. thick and the single-head for seams from 46 in. to the present design limit of 7 ft. Fig 9h shows the relationship between the auger hole diameter, taken as 6-in. less than the seam, and the estimated tons produced during a 7-1/4-hour shift for the three types of auger heads. In general, the tri-head auger will recover about 10% more coal than the single-head, while the dual-head auger will recover 5 to 10% more coal than the single-head auger. The reason for the increase in recovery for the dual- and tri-head auger over the single-head is that most of the area between the cutter heads is also extracted and recovered by dual- and tri-head augers, whereas a thicker rib or pillar is left between each auger hole bored by a single-head auger.

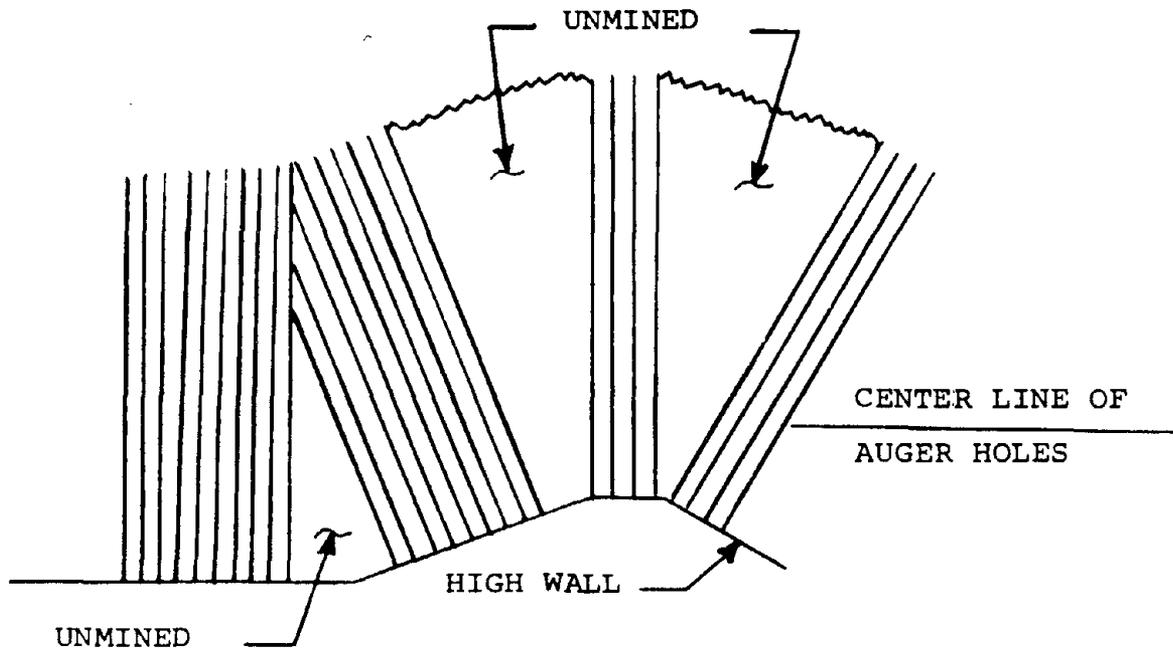


Spacing of Auger Holes  
As Drilled From The High Wall Face



Longitudinal Section of An Auger Hole

66



Plan of Auger Holes Drilled in a Coal Seam  
From a Curving High Wall

Potential Auger Production  
(per 7-1/4 Hour Shift)

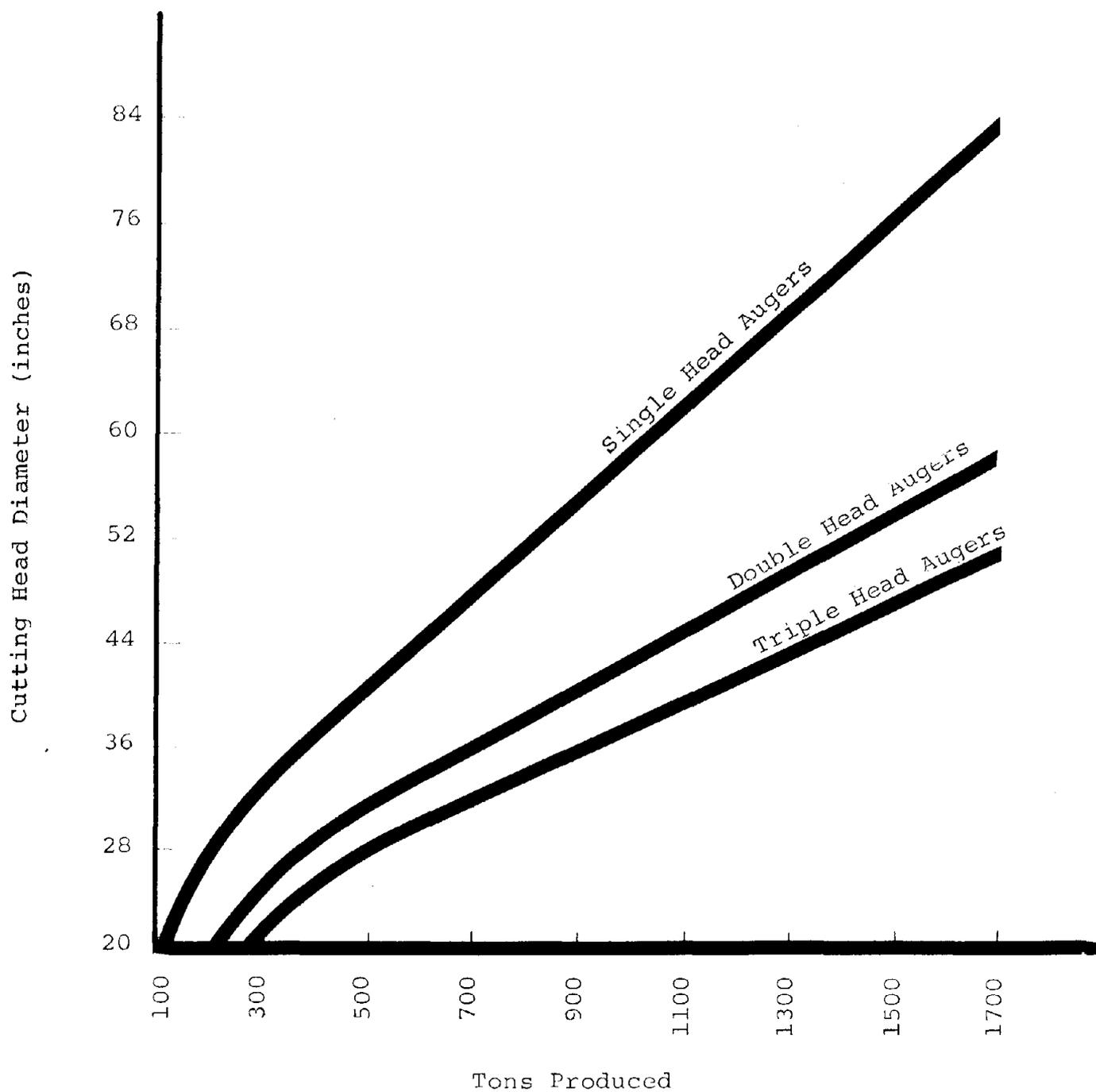


Fig 9h



## CHAPTER 10

### MANUFACTURING OF AUGERING EQUIPMENT

#### Present Manufacturers

There are three manufacturers producing augers for the surface mining industry:

1. Advanced Mining Equipment Company (Joy and Compton)\*
2. Long-Airdox Company
3. Salem Tool Company (AMCO)\*

The Fairchild Equipment Company of Beckley, West Virginia, also produces an auger miner designed primarily for underground continuous mining operations.

#### Specifications and Annual Production

Machines of various sizes and types (Fig 10a) are being produced by the three above-mentioned manufacturers at a total rate of 50 to 55 per year (1974).

#### Methods of Manufacturing

All three companies are producing to order, and each has backlogs. Each company has the capability of expanding production, if the market indicates continuing demand, and hard-to-get component parts become available.

Long-Airdox Company is not committing capital to develop or expand their surface auger product. They manufacture only one model. Their other mining equipment, mainly for underground mining, is receiving their major attention.

The largest auger currently being produced and in use is the Salem Model 1600, with a 48-in. cutting head. This auger has produced up to 1,000 tpd in a 54-to-60-in. seam.

One manufacturer expressed confidence in his ability to produce a 10-ft-diameter auger - to be driven by an electric or oil motor.

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\* Acquired or merged.

Specifications - Coal Augers

<u>Manufacturer &amp; Model</u>	<u>Weight Less Augers (lb)</u>	<u>Max. Length (ft-in.)</u>	<u>Width (ft-in.)</u>	<u>Primary Power (HP)</u>	<u>Aux. Power (HP)</u>	<u>Carriage Thrust</u>		<u>Auger Length (ft-in.)</u>	<u>Auger Diameter Range</u>			<u>Estimated Price 1974</u>
						<u>Push (lb)</u>	<u>Pull (lb)</u>		<u>Single (in.)</u>	<u>Dual (in.)</u>	<u>Triple (in.)</u>	
<u>SALEM</u>												
1500	-	31-8	21-6	282	149	17,800	10,700	12-0	30-42	-	-	\$150,000
1600	78,800	34-0	26-3	510	185	-	-	12-0	30-48	-	-	300,000
MC MUL-T	112,000	31-0	18-3	510	200	32,500	15,900	12-0	30-48	18-30	16-22	500,000
<u>COMPTON</u>												
28	94,000	36-7	19-0	425	220	-	-	12-6	28-48	24-38	18-24	250,000
36	110,000	44-0	19-0	425	220	-	-	20-0	28-48	24-38	18-24	300,000
<u>LONG-AIRDOX</u>												
155-H	22,000	25-6	8-0	227		10,000	10,000	8-0	18-42	-	-	95,000

Fig 10a

The three companies use basically the same standard production procedures, i.e., subassemblies fabricated in-shop or purchased, are brought to a location in the plant where the equipment is assembled. Time from order to delivery is currently running 15 months. Frames are either welded plates, pipe sections, or combinations of both. Auger flights used to remove the coal are of varying lengths, with different manufacturing techniques being used to flute the thick-wall pipe.

Advanced Mining Equipment Co. fabricates their flutes by their exclusive patented method of taking circular plates, cutting slots of specific opening width, length, and spacing from the inside diameter radially outward; continuing one of these slots through to the outside; welding the proper quantity of plates to make the desired auger length to each other, then stretching (opening the assembly) on an hydraulic machine to form the desired pitch, I.D. and O.D. The flutes are then welded to the pipe section. Up to 3/4-in. plate and 7-ft O.D. flutes can be fabricated by this method (see Fig 10b). This photograph also shows the cutting head and lead section, designed for maximum penetration and accurate guidance. Each cutter consists of a steel casting of fixed diameter with double helical spirals directly behind the cutting bits. This spiral is located on the outside circumference of the casting. The spiral, during rotation, causes a sucking action removing the coal from the cutting area very rapidly. Replaceable carbide bits spaced at regular intervals around the periphery of the cutter and in the section at the center of the bit provide the necessary cutting action on rotation. A breaker is located in the central section of the head and this is also replaceable. The central section of each cutter is cast in the shape of a helical spiral to assist in breaking and cutting the coal. On twin auger cutters, guidance for the cutting heads is by suspension of the head and lead section between two bearing surfaces which are adjustable to allow corrections for uneven cutting.

Examination of the individual cutting heads as manufactured by the three principal producers of augers indicates that each cutter is of fixed diameter and that the cutting action takes place on both the periphery and the internal area. An important factor in the design is the spiral section which guides, breaks and feeds the coal to the following flight sections. A failure to move material through this breaker will prevent further cutting. Additionally, reversal of the direction of rotation of the auger string will move material along the scrolls back towards the cutting head and the blind end of the auger hole.

Combinations of dimensions have been developed to provide: (1) the I.D. to properly fit the pipe section used as auger shaft; (2) the O.D. to fit respective cutter heads, and (3) pitch to transport the coal with least stress and damage.

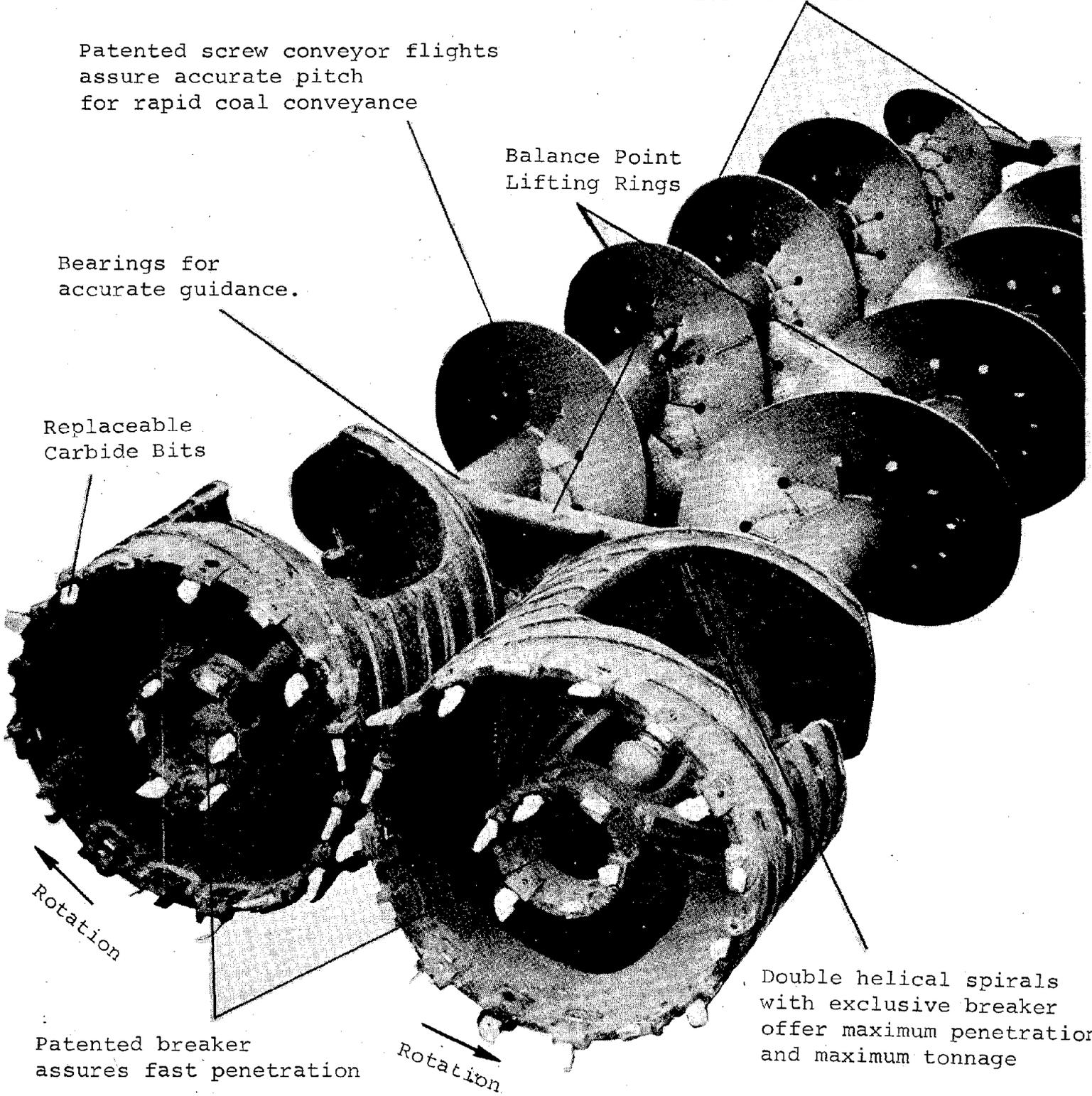
Small tie-bars  
for lower resistance

Patented screw conveyor flights  
assure accurate pitch  
for rapid coal conveyance

Balance Point  
Lifting Rings

Bearings for  
accurate guidance.

Replaceable  
Carbide Bits



Double helical spirals  
with exclusive breaker  
offer maximum penetration  
and maximum tonnage

Patented breaker  
assures fast penetration

Rotation

Rotation

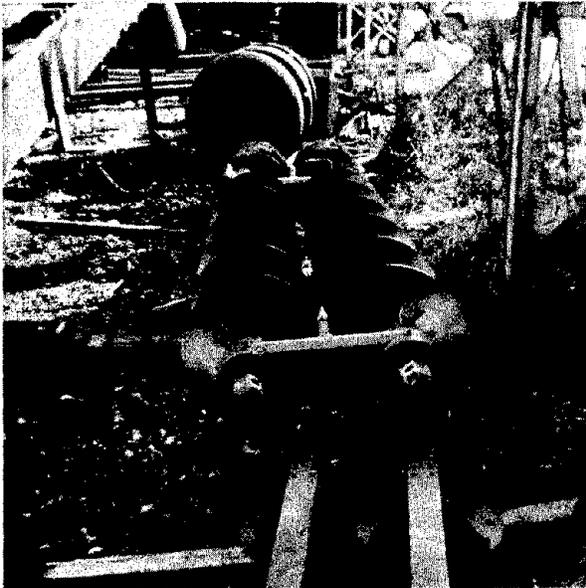
Cutting Head

First Flight of Twin Auger

Fig 10b

The cold working process is claimed to be advantageous, increasing the strength of the plates.

The shaft of each flight has a solid male end (square or hex shape), and a female end (same shape) with holes for pins (see Figs 10c and 10d). The drive mechanism has a hole of the same shape as the male end of the flight (see Figs 10e and 10f).



Intermediate flight of twin auger.  
Note hex head male ends and  
footpads in background.

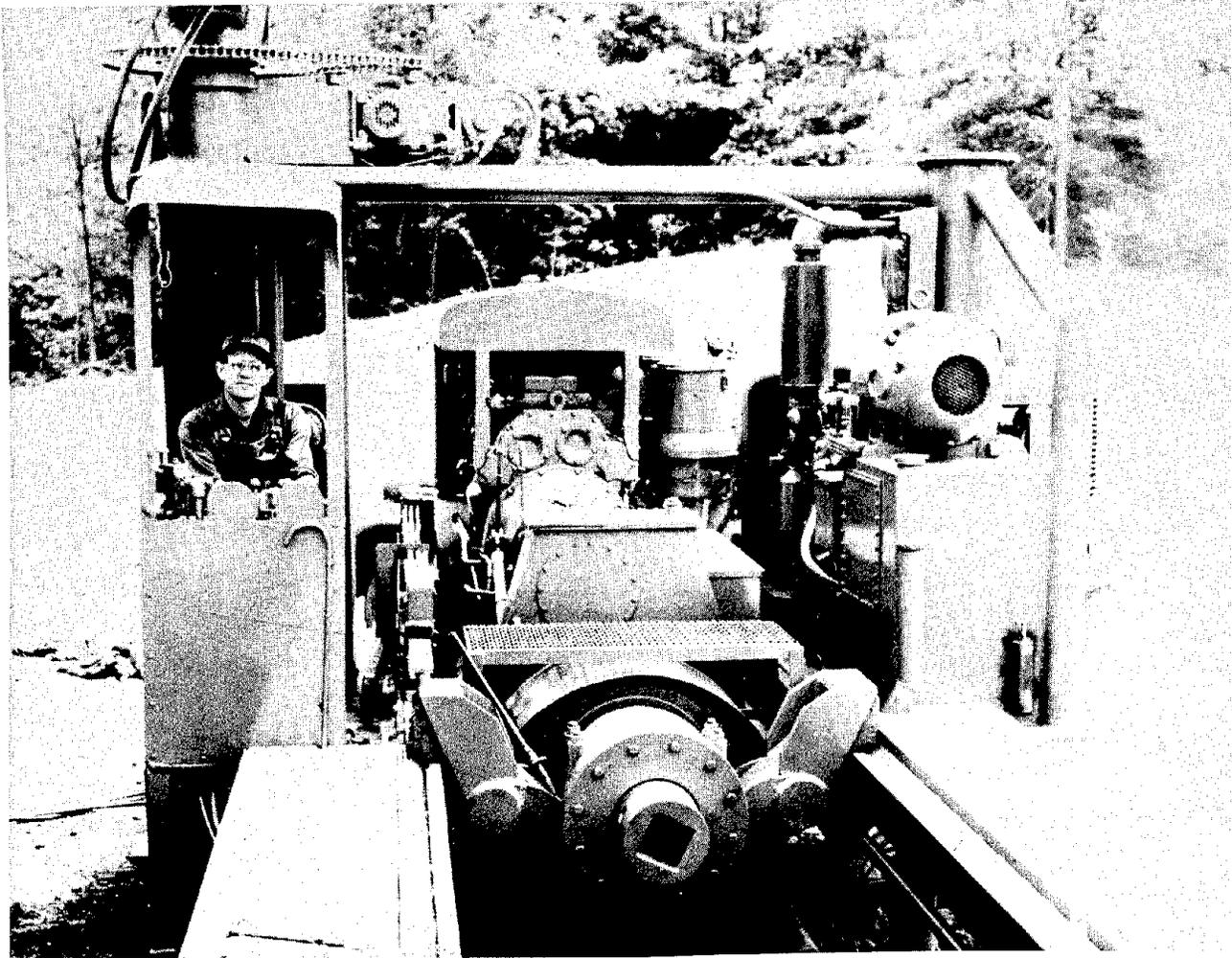
Fig 10c

Female ends of single auger  
flights. Note pins.

Fig 10d



74

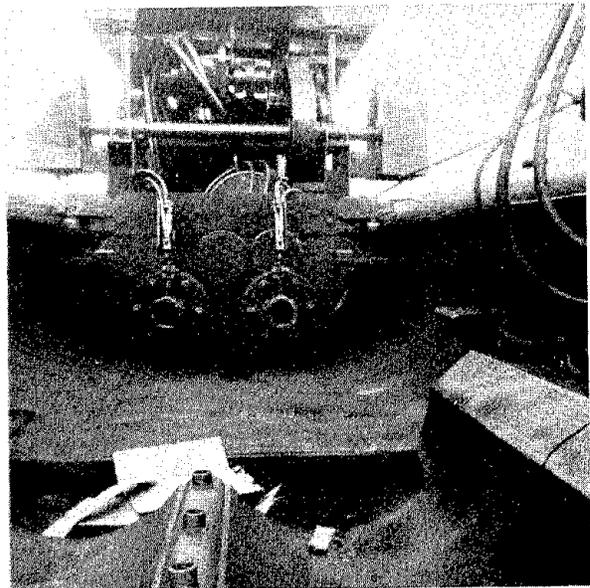


Drive mechanism of single auger

Fig 10e

Drive end of twin auger

Fig 10f





## CHAPTER 11

## AUGER SAFETY

Auger mining has many inherent safety hazards that are common to all forms of mining and some hazards that are peculiar to auger mining operations. Auger safety hazards will therefore be treated here in two broad categories. First, we will consider those hazards which are more or less associated with auger mining. There are highwall spalling, highwall collapse, hazardous entry into abandoned underground workings, auger machinery hazards, and compactness of auger operation. Second, under general hazards we will treat those cases of hazards requiring the use of personnel protective equipment that is also used at both surface and underground operation.

Specific Auger Mining HazardsThe Highwall

The base of the highwall can be a very hazardous place to work. Drilling and blasting to create the highwall and exposure to the elements and weathering tend to alter the composition of the face and serve to increase the potential hazard of rock fall. Auger mining conducted at the base is particularly susceptible to this risk of safety to men and machines. Auger miners in general have come to accept this condition as a normal hazard of the trade and before undertaking any augering operation will carefully scrutinize the highwall face for any signs of loose rock or seam cracks.

Improper augering can produce highwall shearing and subsidence of great magnitude as well as rock slides. The very nature of the augering process undermines the base of the highwall in order to recover additional quantities of coal, thereby increasing the potential hazard in direct proportion to the height of the highwall. Geologic faulting within a given area can also produce unstable highwalls. Highwall collapse has been known to bury augering equipment in its entirety. In at least one case, a large coal mining company, instead of relying upon experienced subcontractors to carry out an augering operation, purchased a new machine and elected to learn the art of augering. The end result was that the machine was buried under rock and the entire operation abandoned.

In another such case of highwall collapse, on one of the Engineers visits to an auger mine, the machine was operating and pictures were taken of the actual operation. A few days after the visit, this machine was also partially buried as a result of highwall collapse. In this case, the operator had cut into a previously driven hole located just beyond an abrupt change in contour direction and had allowed too little support material to remain for the highwall. The operator ultimately recovered his machine flights and auger bit.

These examples of highwall collapse are cited to indicate that although the augering machine is located on the surface - that this machine is also subject to the hazards of the highwall, and the machine safety is contingent upon the operator's assessment and evaluation of the geology and stability of the highwall. Too much deviation in drilling operations or failing to provide adequate space between holes or in pillar support, lack of experience in augering, or his own zealous efforts to achieve as much coal as possible can result in loss of machine.

#### Highwall Spalling

Among the most prevalent hazards encountered in the auger system, that of spalling off of the highwall of rock slabs or loose material are among the most serious.

It was noted that at most mines visited, canopy protection for operators was not of sufficient strength to protect the auger operators from spalling of any material. Most protection provided consisted of only thin sections of steel, welded together with screening material used for the canopy.

#### Highwall Collapse

Similarly, no protection is provided for the operator in case the highwall collapses and buries the machine.

Improvements in design are necessary to overcome these potential problems. Only one auger that was visited had a full length walkway with exits at the rear of the machine for an emergency escapeway. This should be a mandatory design feature of all augers since it provides an important protection in case of imminent highwall failure by allowing the auger operators a fast means of egress from the danger.

Proper size and spacing of auger pillars and adequate monitoring of highwall condition are critical to prevent a highwall slide and consequent burial of the auger. During the course of this study, it became apparent to the field teams that the spacing of auger pillars by most auger operators was done by either rule-of-thumb, or other inadequate criteria. Many operations leave either 6-in. or 8-in. pillars regardless of whether a seam is 100 ft or 500 ft below the top of a mountain. Pillar spacing becomes especially critical when a strip mine has left an island of overburden and coal because the economics do not justify further stripping. The procedure many times is to auger completely around the island, thus entirely undermining this mass of rock with the exception of the small 6-in. and 8-in. pillar. If pillar spacing is inadequate, the highwall will slide causing probable serious injury to operators and effectively destroying the auger.

One of the prevalent techniques used by the auger operators to evaluate adequacy of pillars is to see if the coal in the pillars of the adjacent levels begin to crack or spall under the weight of the highwall. If this situation occurs, they then increase the pillar width between the next hole by a few inches and see if this pillar remains intact. There are two problems with this approach. First, haphazard adjusting of pillar design is no substitute for an adequate initial pillar design. Second, to determine if the pillars between previous-mined auger holes are spalling, one must be at the right place at the right time, i.e., in front of several pillars that have resulted from previous mining, all the time. Detection can be considered to be exceedingly limited. Some operators improve their chances of detecting highwall movement by placing a small wooden prop in the mouth of several of these holes at spaced intervals to give an early warning. Although this method improves chances of detection, it is not a reliable method of insuring the safety of the auger crew and equipment.

#### Hazardous Entry into Old Underground Workings

There have been several occasions where an auger has broken into abandoned underground workings which have contained hazardous quantities of water or gas. Care must be exercised in the drilling of auger holes to ascertain the limits of previous underground workings. Failure to accomplish this can result in the destruction of life and machinery from flooding or explosion. In the absence of accurate maps, augering into seams in regions where underground mining has taken place many years previously, can be most hazardous. A possible method of attacking seams with the auger in this case would be to design a sensing device that would be in front of the auger cutting head. This device would stop the forward thrust and prevent a major destruction of machine or possible injury. The small leak could then be sealed by the insertion of a plug placed in the hole by utilizing an attachment placed in the front of the auger head.

#### Auger Machinery Hazards

The auger has certain hazards associated with moving parts. It has a potential for accidents since each of the two or three operators must constantly see and know what the others are doing. There is a need for a fail-safe system that would shut down the auger due to machine failure or auger crew members doing something wrong. This system would enhance the safety of operators and crew.

#### Compactness of Operation

Auger operations generally tend to have several pieces of equipment operating in a confined area. This is especially true in the cases where an auger operates from a narrow bench. Because several pieces of equipment such as front-end loaders and haul trucks, operate in such a congested situation, visibility is obscured and the potential for collision is greater than for more spread-out operations.

### Operating Hazards

Personal protective equipment is an essential requirement for machinery operators and augering is no exception.

### Noise

At no auger operation visited was hearing protection worn by any of the operating personnel. Although no decibel recordings were taken by the survey teams, it seemed to all investigators that maximum permissible decibels were exceeded by operation of auger machines.

It is generally recognized that auger operators after years of operation alongside a diesel have difficulty with the sense of hearing.

Observation on scene was that conversation was next to impossible due to noise levels, especially by the diesel exhaust.

APPENDIX



## AUGER MINE VISITS

Five auger mining operations were visited in order to observe current operating practices and solicit operators' opinions on the present state of auger technology.

Mine No. 1

This auger operation has a new Salem - Model 1600 (single-head) machine producing 400 tons of coal per 9-hour shift using a two-man auger crew, plus an additional operator for front-end loader.

The operator expressed the opinion that he could produce 1,000 tons per day, 200 tons more than the manufacturer claims, under favorable conditions and as the crew became more experienced. He would use a three-man auger crew plus one operator on the front-end loader.

The pit itself was small, approximately 100 ft x 150 ft, and, as is common in most augering operations, is sodden when it rains. Although the sump pump was working well, operating conditions were poor which adversely affected all the equipment.

The front-end loader was making a ramp for the trucks to enter the pit and also would load them. At times, the auger was producing coal faster than it was being hauled out by truck, which required the front-end loader to move the coal to keep the way clear for the auger to work.

The auger, with a 44-in. cutting head, was working in a 50-in. seam with an average penetration of 150 ft. This operator used 42-in.-diameter auger flights for his first three sections to recover as much coal as possible, and to provide control. Succeeding flights which convey coal and drive the head were only 36 in. in diameter. The operator claimed the reduced diameter reduced the frictional drag in the hole, thus requiring less horsepower. This contractor adapts his augers for more efficient handling based on his particular experience. Machine control levers are raised for the convenience of the auger operator; lifting holes are bored in auger flights at the balance points to ease handling; and additional guards are added to protect the equipment and operator from flights stored alongside the machine (on the ground) which can roll into the machine. This was especially necessary because of the small area of the pit.

Mine No. 2

In this mine, two 24-28 inches seams are currently being augered and a third larger seam was recently completed. The lower seam that is now being re-worked was previously augered with a small single-head auger to depths of about 100 ft. A considerable amount of the remaining coal is being recovered by reaugering with a larger dual-head machine to depths of 150 to 200 ft. In this particular operation, the land, coal reserves, and all equipment are owned by one organization. A washing facility is available to this operation permitting the removal of rock and clay if mined.

There were three dual-head augers with diameters of 24, 26 and 36 in. at the site. One was manufactured by Joy, one by Compton and the third by Advanced Mining, which has taken over the first two companies. This presented a unique opportunity to observe design improvements on the same make of equipment, since design and manufacture of augers had passed from Joy to Compton to Advanced Mining. Engine horsepower and the associated gearbox capacity have increased, distance between the highwall and the outer skid has decreased, and the newest model features a conveyor that can be mounted on either side.

Production of the three augers averaged 600 tons per day each, with the machines drilling from 150 to 200 ft deep holes as reported by the operator. The pillars left between holes were observed to be approximately 12 in. wide.

One area was measured where a 28-in. seam was being augered with 26-in.-diameter cutting head for a 59% recovery with very little rock being recovered. However, due to the curvature of the highwall similar to Fig 9g, recovery was estimated by the operator to be 50%.

The drilling rate for a 15-ft section varied between 1 and 3 minutes; the longer times occurred as the hole got deeper. A greater amount of rock was seen coming out of the deeper holes, suggesting that either the drill string sagged, or that the coal seam undulated or pinched.

Four men operate each auger; one controls drilling pressure and torque, one hoists flights from the left side, the third hoists flights from the right side and runs the conveyor, and the fourth helps in hooking and unhooking the hoisted flights and maneuvers trucks into a loading position. Auger sections are coupled automatically, by means of a square socket and spring loaded pin arrangement, once they have been lowered into the auger carriage. Sections can be added in less than half a minute. The initial flight, however, requires that the machine must be positioned for proper alignment to match the coal seam. The carriage is aligned with the horizontal coal seam by using bubble levels on the auger frame and set up parallel to neighboring holes by eye and the practiced hand of experience.

The biggest maintenance problem on the older machines is with the conveyors which wear rapidly due to coal dust; the power plant, gearbox, and hydraulics require minimal maintenance. Occasionally the coupling pins shear when pulling the auger string out, and this either causes a lost head and flights or damaged equipment if it can be retrieved. In one case of a subsidence the entire auger flight and head were lost.

One 24-in. coal seam of this mine was originally augered by an 18-in. diameter head, leaving 30 in. pillars. They are now reaugering this section, using a twin 24-in. auger. The procedure is to line up one 24-in. auger with the 18-in. hole and start into the seam. The other auger of the twin lines up in a 30-in. pillar. This procedure was working well and penetrated from 150 to 200 ft. The bench in this area had a width of 30 to 40 ft and the highwall height was 10 to 20 ft.

### Mine No. 3

In a third mine, a 34-in. (cutter head) auger manufactured by Providence Machine and Electric Company was augering in a 38-in. seam. Four-inch pillars were being left between holes. A 63% recovery was realized with 50% of the mined product consisting of pieces over 2 in. in size. The operator reported that the auger is capable of penetrating to 230 ft.

The loading conveyor was attached to an old mini-dozer which supplied power to run the belt. An hydraulic jack elevates the conveyor which enables it to load either small or large haulage trucks. This conveyor was more manueverable than the conventional conveyors which are attached to the auger machine.

The operator said "that with a 44-in. head, the auger produced 1,100 tons in an 8-hour shift and with a 39-in. head, the auger produced 900 tons in the same time." Three men are required to operate the auger and loading conveyor. The first controls the drilling pressure while the second attaches and detaches auger flights. The third man runs the conveyor during truck loading and a bulldozer at other times. The machine has established a 90% availability record with no major breakdowns since it was put into operation.

In addition to augering in several of its own locations, this company also augers for a nearby large coal company. Because of the company's need for auger equipment that can be moved with ease from pit to pit, its machines are an excellent match for this set of conditions. Within a pit, it can be easily moved with a dozer and also can be easily transported to other pits by placing the machine on a lowboy truck. This machine can be set up in a matter of few hours when required to move.

### The Auger in Rescue Work

The operator of this auger told of a unique application for this machine that was tried at one of these properties in 1971. The roof had settled over the entrance leading to several pieces of expensive mining machinery. It was not safe or economical to go back through the settled section of the underground mine to remove the machinery through the original entries. The auger was used to drill three parallel holes to reach the machinery from a more stable area on the opposite side of the mountain. One additional hole was augered approximately 100 ft away for ventilation and escape, if necessary. After the three 48-in. parallel holes were made, the pillars between them were extracted and the roof was bolted, thus establishing an entry for the removal of the equipment. This entry was approximately 250 ft in length. The machinery was extracted successfully through the entry, thus saving approximately \$250,000 of equipment. This special application of the auger for rescue of equipment can also be employed to rescue men. It should be noted that good maps of the underground mine were available and a surveying team was also needed.

### Mine No. 4

This operation works in a 36-to-46-in. coal seam in a hilly area with slopes ranging from 5° to 15°. On the hilly side of the operation, a dragline excavated a pit approximately 1,000 ft long, 50 ft wide, and 60 ft deep. After the coal on the pit bottom was loaded out, a Salem Model 1500 single-head auger was set up to drill around the perimeter to depths of 180 ft. The auger was not in operation on the day of the visit due to heavy rain, but 32-in. auger holes were observed in a 36-to-46-in. coal seam. The seam rolled very little, but there were local variations in the top. Using an average 40-in. seam with 5-in. pillars the operator claimed a 54% recovery to depth when augering on a straight highwall. The highwall is straight, except at the very end of the pit. The superintendent stated that a penetration to 180 ft is usual and an estimate of 50% recovery overall is reasonable.

### Mine No. 5

This mine was part of a small contour stripping operation in a difficult-to-mine area.

After blasting, a dozer and loader first removed the overburden, then stripped and loaded the coal from the exposed seam. This procedure was continued as long as the coal seam followed the contour. In between overburden removal and coal loading tasks, the dozer and loader prepared a bench for the auger to work from. The 20-to-30-ft highwall was not stable, and there was evidence of partial highwall slides.

The coal haulers were on a contract basis and were paid by tons hauled so the drivers would not come to the pit unless they could receive a full load. The haul trucks were 40-ton aluminium body tractor trailers.

The Salem auger was purchased in 1968 as used equipment. It was penetrating to a depth of 70 ft due to a poor seam and an unstable highwall. The augered coal was stacked on the ground to the side of the auger until there was sufficient coal to load a truck. The operator said that they worked a sun-up to sun-down day.

The operator of the equipment checked it over before starting, watched it during the day, and kept it clean. The superintendent said that the men knew that if the equipment was down, it would reduce their pay. This method worked well and every one worked as a team. The superintendent stated that auger recovery was from 300-400 tons per day and would usually call for coal haulers every other day.

The auger was operating with a 5-man crew, 2 of which were trainees. The owner of this mine stated he was looking for another used auger as he was preparing to open another mine shortly.

Auger maintenance, other than fuel and oil, was performed on a downtime basis. The equipment superintendent claimed a 90% availability for the auger on a 10-hour day. Shortly after viewing this operation, it was learned that the auger was partially buried by a highwall collapse. There were no injuries and the auger was being salvaged.

## LITERATURE SEARCH AND BIBLIOGRAPHY

Limited information is available on the subject of augering from the various sources which were checked. "Coal Age", "Coal Mining and Processing", "Coal Mining Engineer" have all had articles on augering. These were mostly limited to the eastern regions. "Coal Age" articles starting with August of 1959 through current dating were available in FB&D files. Prior to 1959 the files at McGraw Hill Publisher were used.

The FB&D geologist secured data from the U. S. Geological Survey Office at Reston, Virginia, and the Bureau of Mines, in order to develop his estimates of the coal reserves. Geologic sources used as reference in this phase of the work, along with laws pertaining to auger mining, are recorded in the Bibliography.

University files, including the University of West Virginia, have no current articles or Doctorate thesis papers on auger mining. Enrollment in mining courses has decreased. Education in various fields has been up and down, based on the economy which would prevail in each of the respective fields of endeavor. "Mining Engineering" of March 1975 stated the following:

"...Student enrollment is increasing and starting classes are up. There is a faculty shortage. More mining schools are plagued by financial problems and mining curriculum accreditation needs an overhauling..."

The search also revealed little or no R&D money was being spent by manufacturing or industry. An evaluation of all of the articles obtained as a result of the literature search reveal that augering was done on a direct economic basis which was related directly to the price of coal.

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