The applicability of longwall mining to American coal seams

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THE APPLICABILITY OF LONGWALL MINING

TO

AMERICAN COAL SEAMS

by

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A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE,

MINING ENGINEERING

Rolla, Missouri

1963

Approved by

(Advisor)

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Professor R. F. Bruzewski for the guidance and assistance received throughout this study.

Thanks are also due Mr. John Peperakis and the other officials of the Kaiser Steel Company for their cooperation in making a study of the Sunnyside Mine possible.

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INTRODUCTION

Objective

The objective of this thesis is to show that mechanized longwall mining can be applied to thinner American coal seams with greater advantage than the conventional mechanized room-and-pillar methods now being used, provided that the proper equipment is employed in an effective manner.

Status of American Coal Mining

Mechanical production in underground bituminous-coal mines is increasing because of the development of new and improved mining machines, with the attendant evolution of compatible techniques of mining. The continuous mining machine, for example, digs and loads coal from a solid face in one uninterrupted operation without the need for conventional cutting and blasting. Similar improvements have been introduced in nearly all other phases of coal mining and handling. However, most cost-cutting efforts have been directed toward thick-seam (5 feet or greater) room-and-pillar mining, with relatively little thought for thinner seams and practically none for the longwall method of mining, which, in the United States, remains in the antiquated stage.

The conventional system of longwall mining requires an abnormal amount of roof support and specialized labor for its installation. This, when considered with the present day cost of labor, has rendered longwall uneconomical in the light of modern room-and-pillar mining. On the other hand, room-and-pillar mining cannot be applied to the deeper coal seams because of the excessive roof pressures encountered. The method also limits the total possible recovery to about one-half of the coal reserve. Both these factors tend to seriously decrease the Nation's available coal resources.

The use of continuous mining machines in room-and-pillar mining is usually dependent upon thick seams for high productivity and low cost. However, the number of operations in thick seams is constantly decreasing. Statistics show that over eighty percent of the American coal mines presently operate in seams that are less than 5 feet thick, and over sixty percent of the mines are working seams less than 4 feet thick. Unless new machines and/or better mining techniques are developed, the future of the present form of continuous room-and-pillar mining appears limited.

In order to conserve the Nation's coal resources and assure a high productive future for its coal mines, the United States Bureau of Mines began investigating the feasibility of adapting the apparently more efficient mining methods of other countries to American seams. Their study revealed that longwall mining was particularly suited to thinner seams, that it was applicable to greater depths, and that it permitted almost complete recovery of the coal. Also, it was found that longwall mechanization in some of the foreign countries was approximately abreast to that of American room-and-pillar mining. The longwall method seemed to offer the combined advantages of increasing thin-seam productivity, extending the recoverable coal reserves, and possibly decreasing the overall cost of mining.

In order to further investigate their original studies, the United States Bureau of Mines and a few American coal companies tested some of the foreign machines and techniques in their own mines. Most of the procedures attempted proved operational, but the resulting overall production costs were higher than those usually attained with continuous miners in room-and-pillar mining. This, as before, was because of the excessive amount of labor required to maintain adequate roof support with conventional systems. The high cost of roof support was decreased, however, by using longwall mining with the retreat system, which eliminated the packwalls that are necessary when advancing. But, the roof support problem was found to be almost completely overcome by the substitution of self-advancing hydraulic roof jacks for conventional supports. This recent development eliminated the need for specialized labor and lowered the total labor demand to a level commensurate with that of modern mechanized room-and-pillar mining.

It appears that longwall mining techniques have now been improved sufficiently to compete with modern room-and-pillar mining on a production cost basis, and with a resulting greater overall coal recovery. The method could also permit mining of certain seams of high quality coals that heretofore could not be mined because of their excessive depths. But in spite of all the apparent advantages offered only a few of the six thousand American coal mines have, to date, attempted mechanized longwall mining. This situation prompted the writing of this thesis, for it is firmly believed that a much greater number of this Nation's coal mines could reap substantial added profits by converting to this method.

In order to obtain a measure of the success with which longwall mining is being applied in this Country, one of the foremost experimental longwall-mining operations was visited and studied by the writer and his findings are reported herein.

THE LONGWALL METHOD

The longwall method of mining coal is applied effectively to a variety of geologic conditions and, therefore, it has many modifications. Its principal characteristic, however, is that the entire coal seam is extracted as nearly as possible in one operation, with the overburden being allowed to cave either partially or completely. In some cases, certain coal pillars may be left unmined in order to afford roof support over access routes. In others, the voids created in extracting the coal are backfilled (stowed) with waste material so as to limit the amount of caving. Variations are also possible in the geometry of the working face, which may be straight and of limited length or circular so as to entirely circumscribe the working area, the latter method now being practically obsolete. The mining may be conducted outward from the point of principal access (advancing) or in a direction which is opposite (retreating), the former requiring considerably more hand labor for constructing packwalls but offering the advantage of earlier production.

Conditions Suitable for Longwall

Longwall mining can be applied in most coal seams, with effective adaptation entailing only the selection of proper equipment and compatible techniques to suit the seam condition. However, certain environmental conditions are more conducive to safe and efficient productivity.

Seam Inclination

Generally, the lower pitches are more suitable for highly mechanized mining, with flat seams providing the ideal condition and a thirty-degree dip being the maximum practical limit. Steeply pitching seams are usually mined with only partial mechanization and with correspondingly more hand labor.

Seam Thickness

Modern mechanical roof supports are designed for seam thicknesses ranging between 2 and 10 feet. The optimum range for total mechanization is between 4 and 7 feet. Seams that are thinner than 2 feet are mined with difficulty, due primarily to the restricted working height. Thick seams are usually exploited by the most difficult method of slicing and stowing. Both extremes of seam thickness tend to reduce the effectiveness of modern longwall mechanization, and thereby decrease the possible face productivity and overall mining efficiency.

Depth Below the Surface

Because this method permits total caving and normally requires only short spans, thick overburden and the resulting high roof pressures are less troublesome to the longwall system of mining than to any other mining method. There is practically no limit to the depth at which longwall can be used.

Roof and Bottom Conditions

Good roof conditions are important for efficient longwall mining. The ideal roof is one that is elastic and pliable and settles gradually in the mined-out area, or one that is medium-hard and capable of standing over short spans but falls behind the roof supports as they are advanced. Strong, solid roof that is self-supporting over large areas is not desirable unless the stowing method is applied.

The ideal bottom is strong, tough, and free from heaving near the face. A soft bottom is less troublesome to longwall mining than it is to the other methods, because of the special broad-base mechanical supports that are now available for use under such conditions.

Nature of the Coal

Hard coal is suitable for all systems of mining but, because it is more difficult to break by mechanical means, it has a deterrent effect upon highly mechanized production. Extremely soft and friable coal, on the other hand, breaks too easily and often limits the applicability of all mining methods with the exception of longwall. It appears that some form of longwall mining can be applied to all types of coal. However, the greatest mechanized productivity is obtained in those that are of medium hardness and friability.

Gassy seams offer little difficulty to longwall mining because of the highly efficient ventilation that is possible with the normally concentrated arrangement of working places.

Deterrent Conditions

Because longwall mining efficiency depends upon a constantly advancing working face and complete caving, it demands uniform geologic conditions and an overlying surface that can be disrupted without ill effects. Thus, excessive faults, dikes, cut-outs, and water-logged goafs may seriously limit the use of this method as does the existence of surface structures and improvements and large overlying bodies of water that may increase mining costs beyond practical limits.

Labor Requirements

In the past longwall miners were usually more experienced and highly skilled than those who worked in room-and-pillar mines. This is no longer so, however, with the introduction of the self-advancing mechanical roof-support system. At present, the requirements are about equal for all modern methods of coal mining.

MODERN LONGWALL MINING EQUIPMENT

As stated earlier, the improvements in longwall mechanization have approximately paralleled those for room-and-pillar mining. However, the face operations of the two methods are not the same, and therefore, the mining equipment for each has been developed independently according to the individual needs. As a result, modern longwall machinery bears only a vague resemblence to the present-day room-and-pillar equipment, even though the degree of mechanization in each case will approximate that of the other.

Coal Cutting Equipment

Coal-mining machinery improvements are made not only to enhance the method being employed but also to suit the various underground conditions that are encountered. Because of this, longwall coal cutters have evolved into many forms, which for convenience are classified according to their major cutting-mechanisms.

Chain Coal-Cutting Machines

The original and present basic form of chain coal-cutter is the longwall undercutting machine. It gave satisfactory service in the earlier days of face mechanization and is still being used in many mines. Many modern cutter-loaders incorporate this principle.

The simplest undercutting unit is shown in Figure 1. It can be operated either by electric power or compressed air, the latter being the most suitable in gassy seams. The haulage assembly consists of a small, motor-driven drum that winds an anchored rope, which propels the machine along the coal face. A gear head transmits power to the cutting unit and also acts as a pivot and lock for positioning the jib as needed for sumping-in and cutting. Undercutting machines are available in many sizes with appropriate chain and propelling speeds to suit various working conditions. The maximum standard jib length is about 10 feet and the minimum machine height is 12 inches.

Many modifications of jib cutting-machines are used in seams that are hard and less than 3 feet in thickness, or where the coal reserves do not warrant reorganization into highly mechanized faces. The machines are easy to install, simple to operate, and relatively inexpensive. Their main disadvantage is usually that additional work is necessary to mine the top coal.

A modification of the longwall cutter (Figure 2) incorporates a top cutting jib driven from the bottom sprocket so as to permit overcuts as well as undercuts. The height of the top jib is usually set by means of a hydraulic cylinder or extension ring (Figure 3) to match the coal seam thickness, thereby facilitating the removal of top coal. Various types and shapes of jibs have been developed.

The British-made Meco-Moore cutter-loader (Figure 4) was developed in 1934 to combine the work of cutting and loading into a single unit. The complex and heavy mechanisms included two horizontal jibs and a special shearing jib that formed a vertical cut behind the

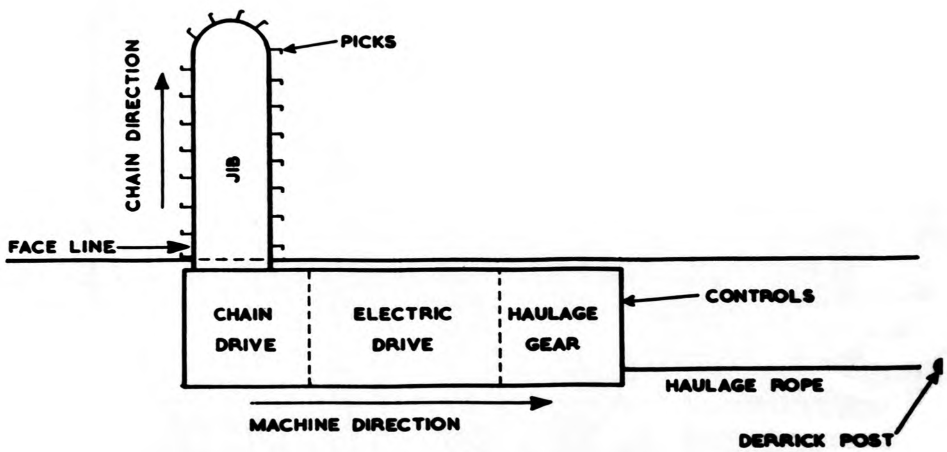


Figure 1. Basic Form of Longwall Undercutting Machine. (35)

Figure 2. Double Jib Arrangement for Thick Seams. (8)

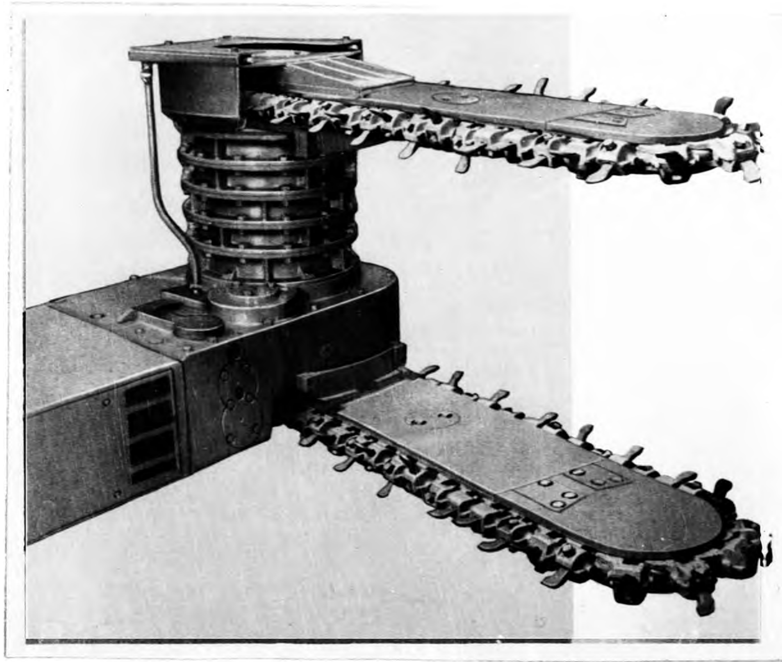


Figure 3. Double Jib Arrangement with Extention Rings. (10)

Figure 4. High-type Meco-Moore. (35)

coal face. The loader unit consisted of an endless rubber belt that was fitted with a steel lining and a rotating horizontal bar, which transfered broken coal to the conveyor.

A modification of the Meco-Moore (Figure 5) has a pick-drum breaker attachment for roof trimming. This machine is designed for operation in thinner seams and is less dependent upon good seam conditions. However, a stable roof is desirable.

The Gloster-Getter (Figure 6) is another British-made coal cutter-loader with vertical and horizontal cutting jibs. This unit is propelled by a vertical rope drum at speeds of 1 to 6 feet per minute. It can be used in hard coal and under difficult mining conditions.

The Dosco Miner (Figure 7), a Canadian product, is the largest and heaviest machine in this group. It consists of a multi-chain, ripper-type cutting and loading head, that can be moved vertically and extended horizontally, a belt cross-conveyor, and a crawler-type mounting. The mining is accomplished by advancing the operating cutter head into the bottom coal and gradually raising it until the top of the seam is reached. By repeating this cycle, coal is carried over the head, onto the cross-conveyor, and discharged to a face conveyor. After each cut, the machine is advanced and the fallen coal is bulldozed forward and loaded in the next cutting cycle.

The Dosco Miner produces the best results in medium hard coal and in seam thicknesses ranging between 4 and 7 feet. The roof must stand unsupported over a longer span than that required for other machines in this classification. The greatest disadvantages of this unit are its high initial cost and the large amount of airborne dust and fine coal that it creates when in operation.

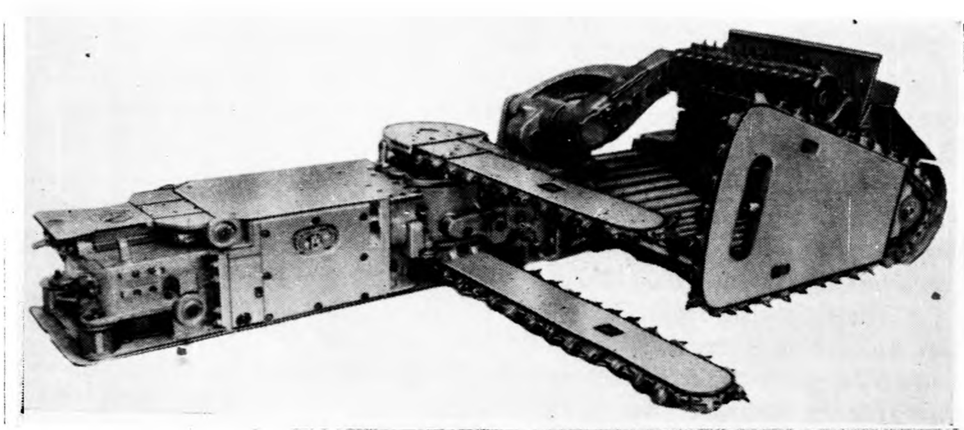


Figure 5. The Meco-Moore with Drum Attachment. (35)

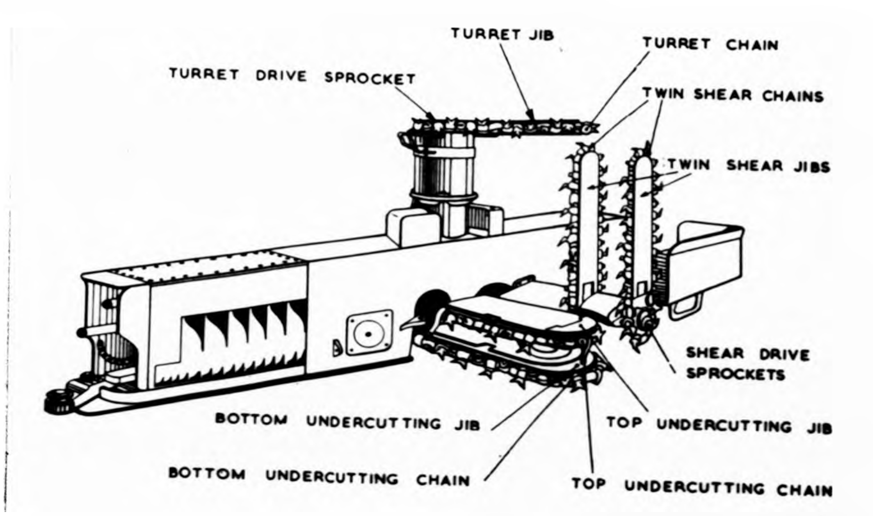


Figure 6. The Gloster-Getter. (28)

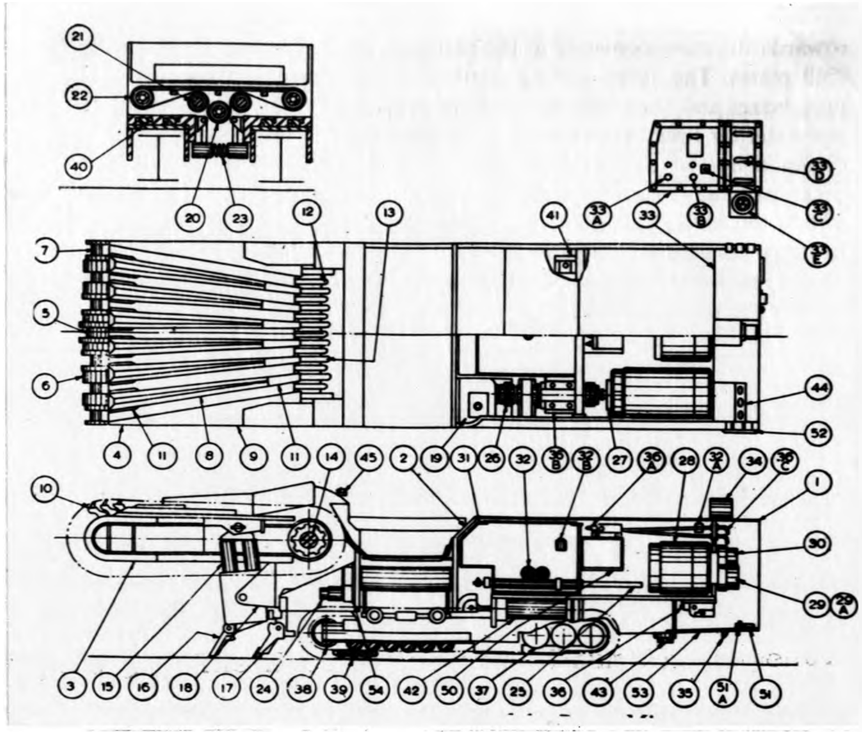


Figure 7. The Dosco Miner. (26)

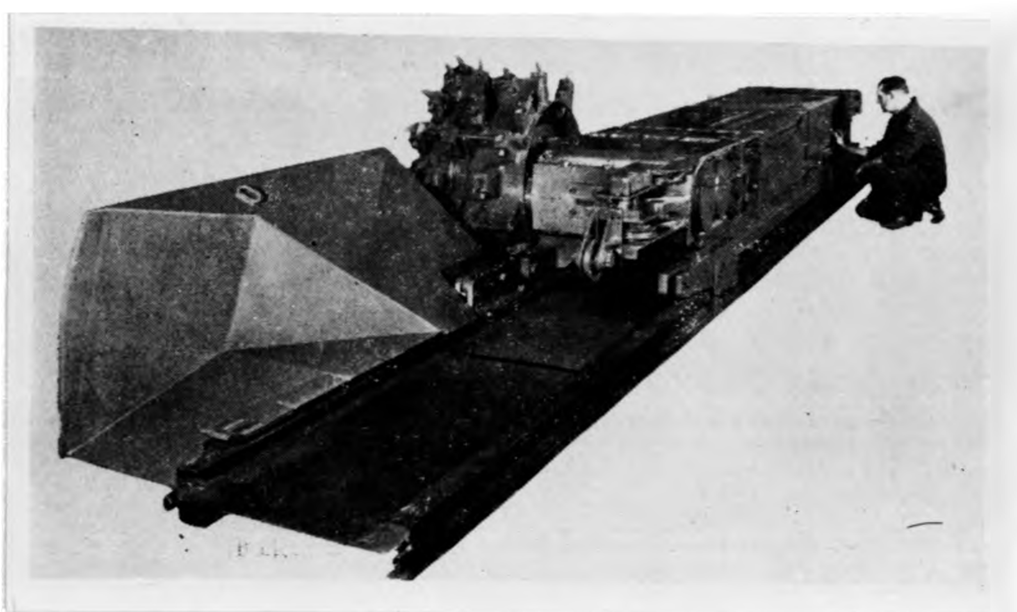


Figure 8. The Anderton Shearer-Loader. (3)

Drum and Disc Cutters

Drum and disc cutters are capable of high productivity but, like the Dosco Miner, they create considerable amounts of airborne dust and excessively fine coal. The hazard of the airborne dust, however, has been reduced to some extent through the use of improved water sprays and more effective face ventilation.

The Anderton shearer-loader (Figure 8) is a British machine that breaks and loads coal from the solid as it travels atop a chain conveyor. Its rate of travel is adjusted to the seam condition by an electronically controlled transmission. As the cutting load increases, the travel speed is automatically decreased, and vice versa, so as to constantly maintain an optimum strain on the drive mechanisms.

The principal parts of the Anderton machine are shown in Figure 9. Its cutting drum, including the cutting picks, is 5 feet in diameter and rotates at 60 revolutions per minute. All inner picks are installed at right angles to the drum surface, and the outer row is angled outward to provide clearance for the drum side. A plough or loading blade is attached behind the machine to deflect broken coal onto the conveyor and also to clean up the sheared coal that falls to the floor.

The shearer-loader can be used under relatively poor roof because of the short span afforded by its narrow depth of cut.

The Eichoff shearer-loader is basically similar to the Anderton machine. It is available with various cutting drum diameters and lengths, and with an adjustable haulage speed. A recent modification

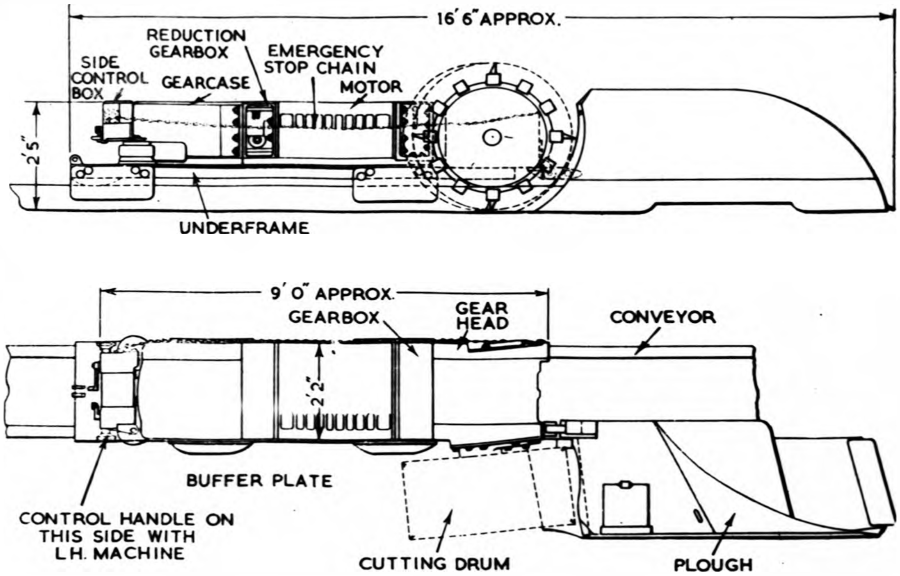


Figure 9. Main Features of the Anderton Shearer-Loader. (35)

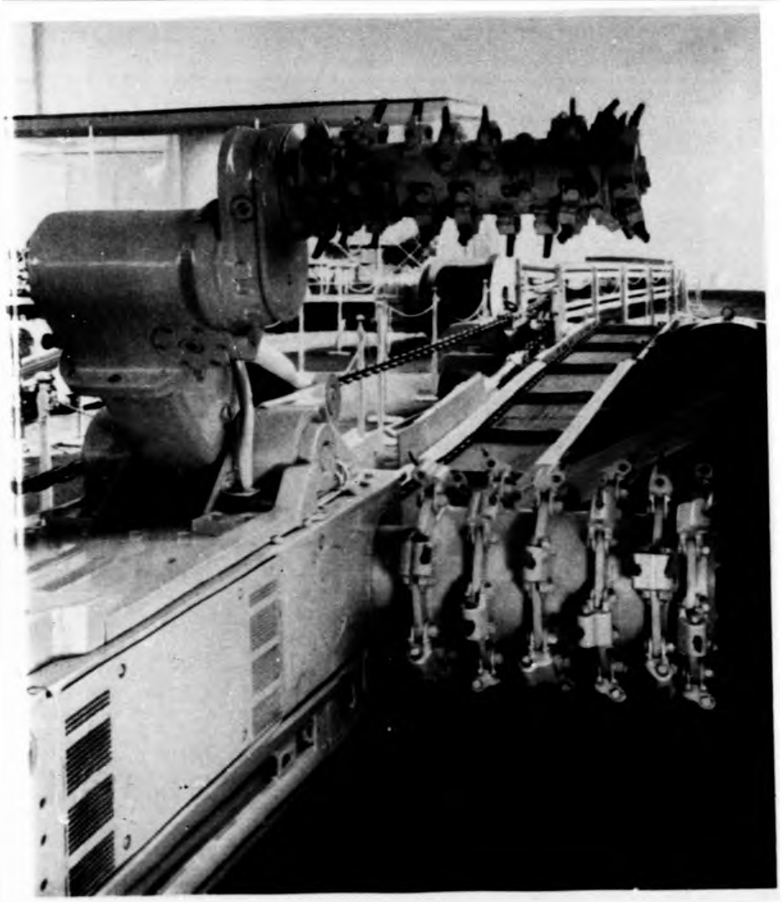


Figure 10. The Eichoff Shearer-Loader. (9)

(Figure 10) incorporates an overcutting drum on a movable hydraulic arm, that regulates the top-cutting level according to the seam height. It is best suited to seams ranging between 4 and 6 feet in thickness.

The Spiral Vane Disc cutter was designed by an English manufacturer to utilize the advantages of the shearer-loader and to cut the coal in a manner that results in the production of large sizes and with the creation of only small amounts of airborne dust. Its cutters (Figure 11) are mounted so as to prevent broken coal recirculation and attendent deterioration. The coal is pre-cut and then wedged or sliced from the face, thus permitting larger lumps to be broken. The cut coal falls to the floor and is spiralled onto the face conveyor with the aid of a specially designed plow.

Rotary Head Cutters

The distinguishing feature of this group of machines is that the cutting head rotates about an axis that is parallel to the longwall face. They cut at right angles to their direction of travel, thereby wedging the coal from the working face. This results in even more lump coal than is possible with the spiral disc cutters.

The Anderton-Boyes Longwall Trepanner (Figure 12) is a typical example of the rotary head cutters. This unit has cutter heads mounted at both ends to permit operation in two directions. In addition, it has horizontal and vertical cutting jibs that are adjustable to suit the seam conditions.

The Trepan-Shearer (Figure 13) is a combination of the Trepanner and the Anderton-shearer-loader. It has the high pro-

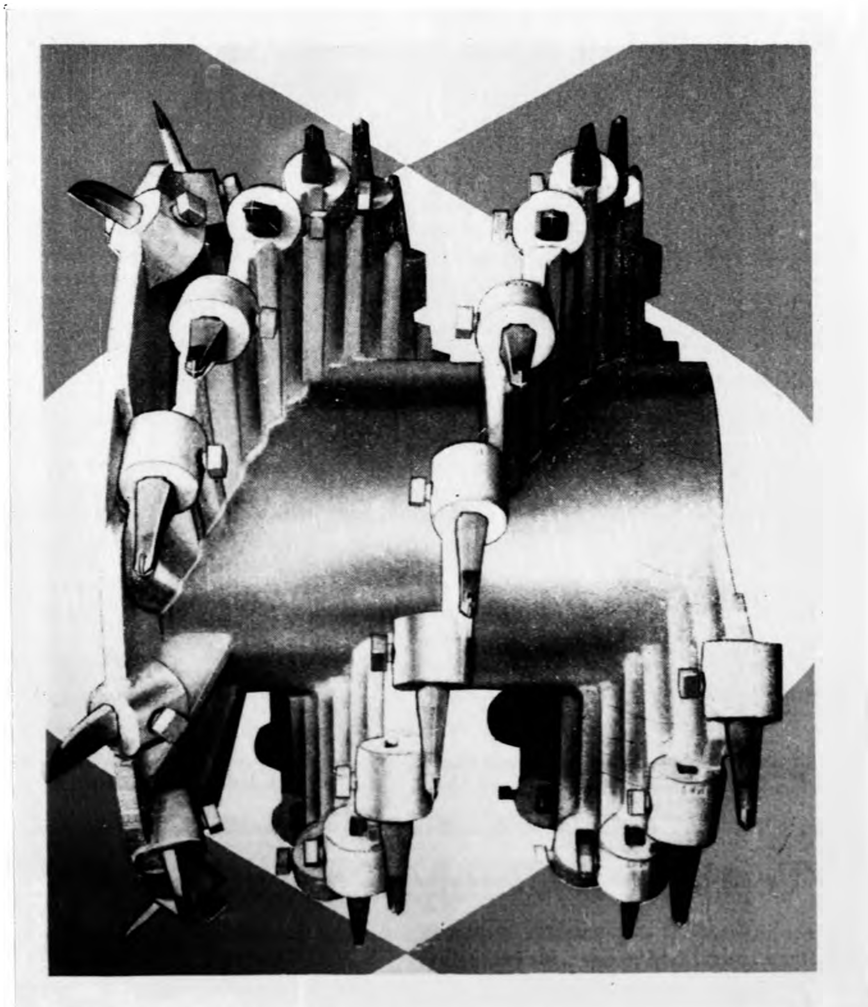


Figure 11. The Spiral Vane Disc Cutter. (7)

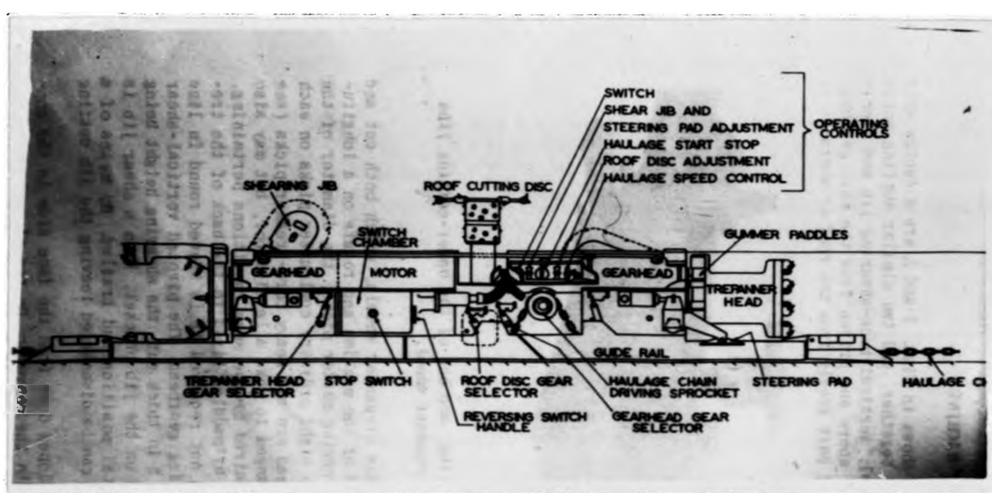


Figure 12. A. B. Longwall Trepanner. (30)

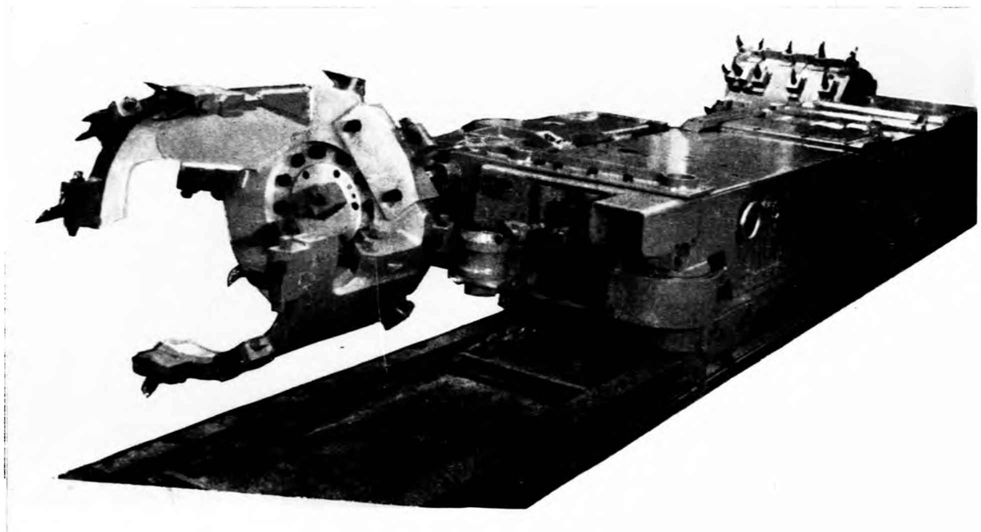


Figure 13. The Trepan-Shearer. (32)

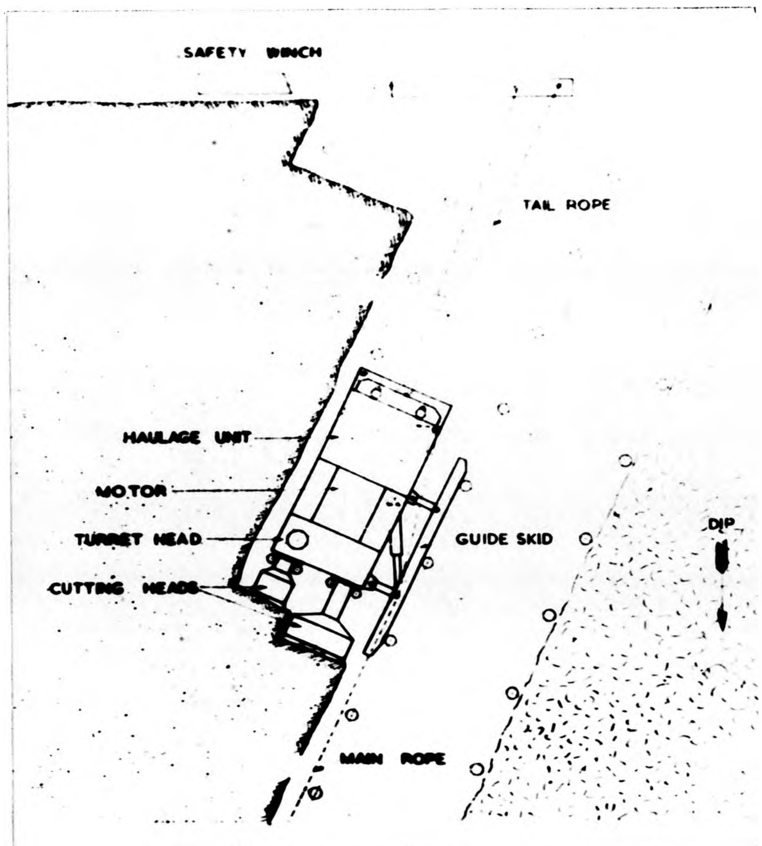


Figure 14. The Alacchi Cutter. (27)

ductivity of the shearer and the lump coal cutting ability of the Trepanner. This unit operates in one direction only and is best suited to medium hard coal.

The French-made Alacchi Cutter (Figure 14) is equipped with two rotary cutting heads for use in steeply dipping seams. This unit is propelled by winding an anchored rope while being held against the coal face by a hydraulically controlled skid, which rides against a line of face props. Broken coal slides along the inclined floor to the loading point.

The Russian UKT rotary head cutter (Figure 15) is designed for mining thin seams of very hard coal, including anthracite. Its cutting head, composed of four boring heads with attached rotary picks, produces up to 70 tons per hour with a 5-foot cut.

The Midget Miner (Figure 16) is similar to the Russian UKT cutter in appearance and output. It produces a considerable amount of fine coal, however.

Ploughs

The first coal plough was developed by German engineers during World War II as a means of conserving man-power and increasing coal production. Since then, it has been modified and improved so as to become one of the most effective tools that are presently available to longwall mining.

A plough consists of one or more vertical cutting blades mounted on a base plate, which in turn rides on an anchored chain conveyor. The cutter is towed along the face by chain or rope as it shears or ploughs a slice of coal from the solid and guides it

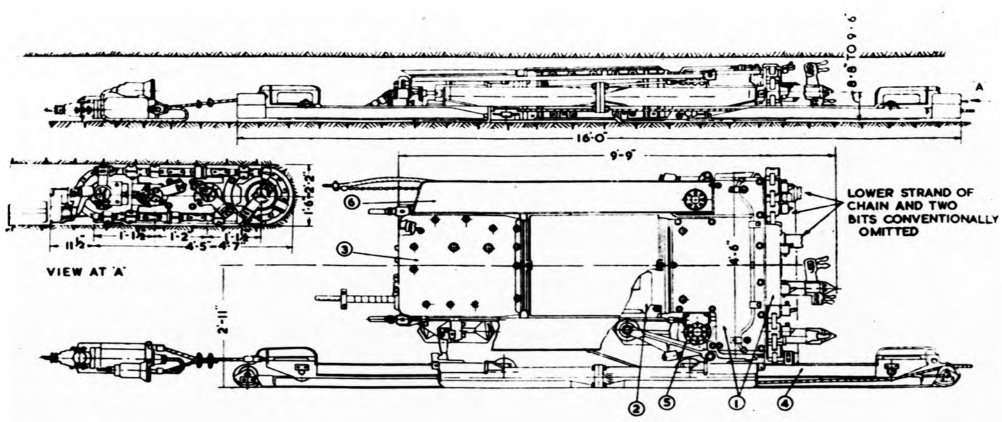


Figure 15. UKT Rotary-head Cutter. (35)

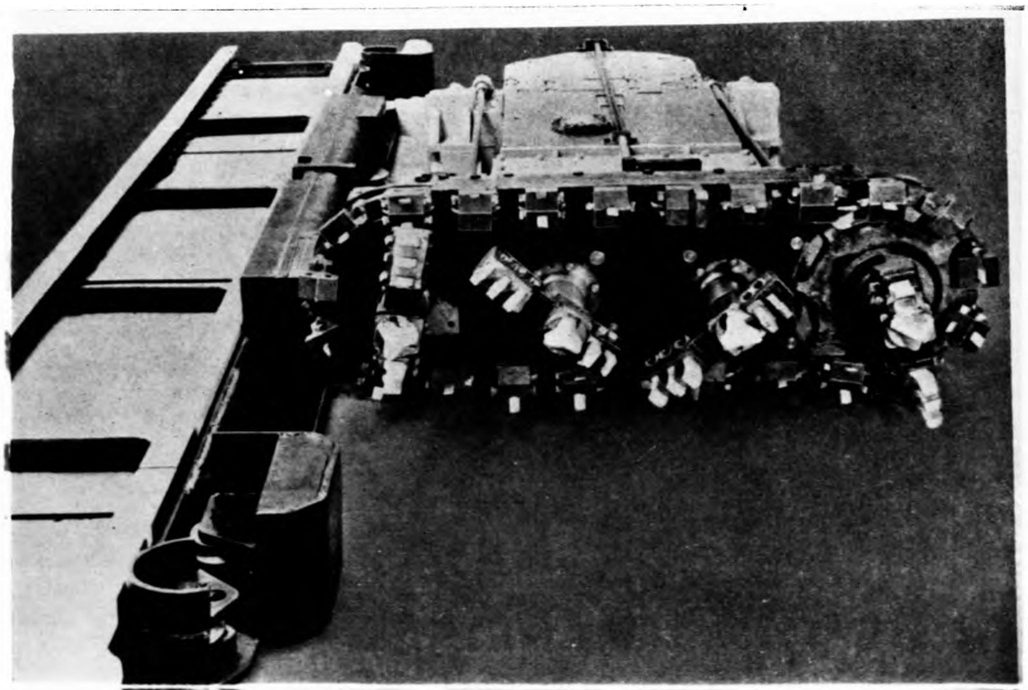


Figure 16. The Midget Miner. (25)

onto the conveyor. After each slice, the whole assembly is shifted to the face and the cycle is repeated.

The cutting height is usually one-half to one-third of the seam thickness, the remaining top coal collapsing of its own accord or being brought down by pneumatic picks. The coal should part readily from a good back, and the floor should be strong and level.

Hard coals may limit and even prevent successful operation of the plough. Tough seams may cause serious difficulties in maintaining cutter alignment, or require towing forces that exceed the power capacity of the drive unit. Some hard coals can be ploughed by the costly process of preliminary undercutting and blasting or by utilizing percussion activated cutter blades. Continuously and intermittently activated units have both been used with success.

The angle of cleat should be less than 45 degrees from the direction of plough travel for high productivity and good lump coal, with a 20-degree cleat being about optimum.

Coal ploughs are designed to operate in two directions. However, if the unit cuts equal amounts of coal as it travels back and forth along the longwall face, the chain conveyor by being unidirectional will carry about three times as much coal on one pass of the plough as it will on the next. This fluctuation in the conveyor loading is decreased by arranging the plough to cut at its maximum rate when travelling in a direction which is opposite to that of the face chain. Thus, when properly applied to suitable seam conditions, the coal plough becomes one of the most effective longwall mining machines that are presently available.

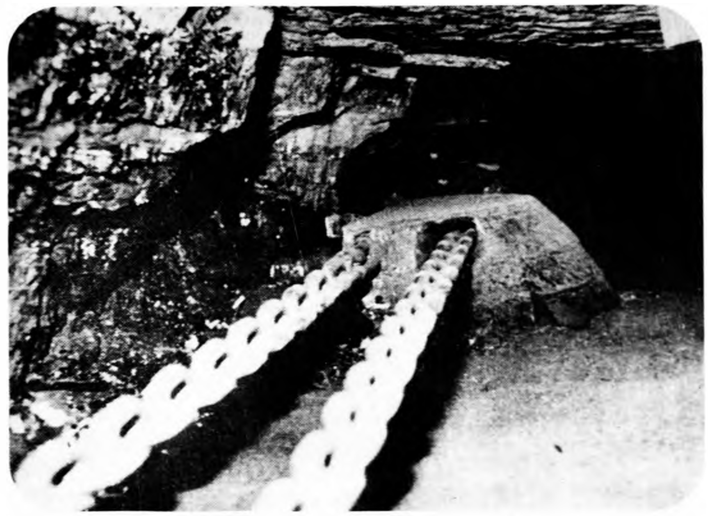
The Kohlenhobel is the original form of coal plough. It is symmetrically designed for cutting soft German coals in two directions. The unit is 21 feet long, 2 feet high, and weighs 2.5 tons. Although its travel rate is low, it cuts thick (e.g. 28-inch) slices in coal that is suitable.

The Westfalia Ram Plough (Figure 17) is the simplest type of unit evolving from the original plough. This cutter was developed for working thin and fairly steep seams and without the usual face supports or stowage. The unit operates without a chain conveyor and is pulled back and forth by a pair of taut pull-chains. The broken coal is normally moved to the loading point by gravity. More than one planer can be used on a single working face, in which case a separate drive unit may be used at each end. The Westfalia Ram is one of the most economical longwall cutters when used under appropriate conditions.

The Westfalia Lobbehobel (Figure 18) is an example of fast-moving and thin-cutting plough. The machine cuts in two directions at speeds up to 75 feet per minute while taking a 6-inch slice. Its specially designed chain-conveyor is equipped with pneumatic pushing cylinders that advance the whole unit after each cut and hold it in position during the planing operation. This particular design has been modified by many manufacturers.

The Umbauhobel (Figure 19) is a modification of the Lobbehobel. It has a separate drive for the conveyor and plough, therefore being applicable to a wider variety of seam conditions. More than one planer can be used simultaneously on a single conveyor set-up.

The Ram Plough in Working Position



Body of the Ram Plough

Figure 17. The Westfalia Ram Plough. (37)

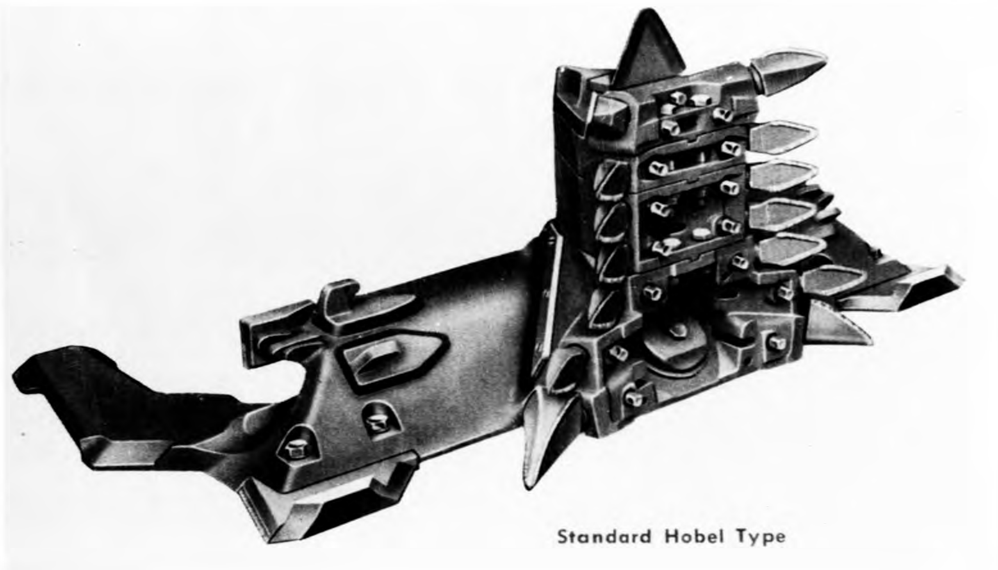


Figure 18. The Westfalia Lobbehobel. (37)

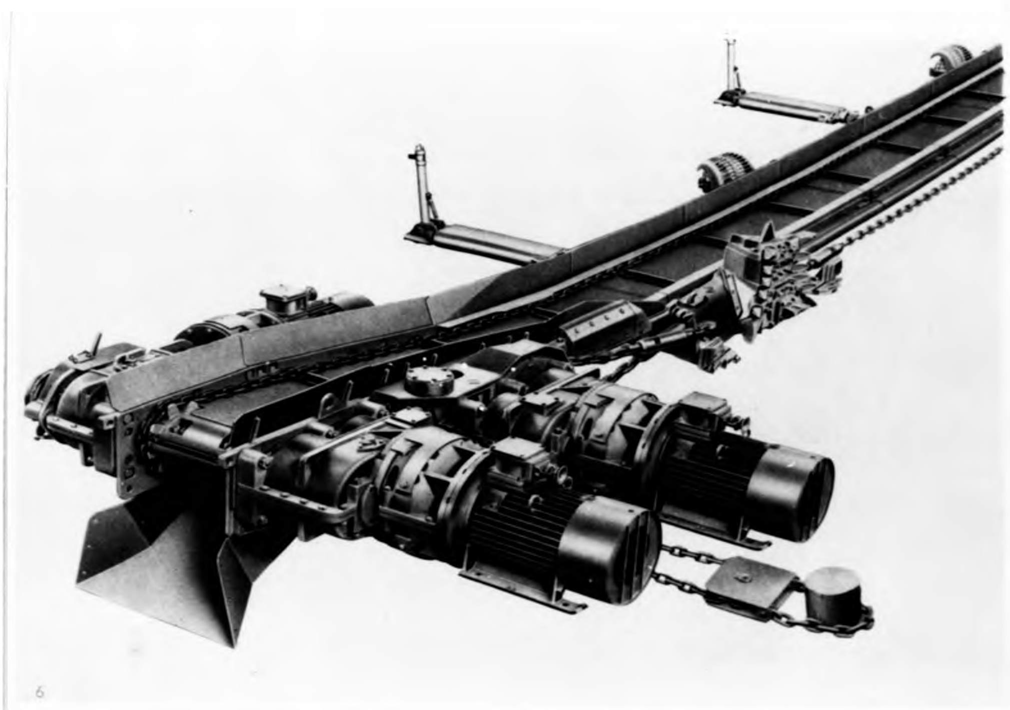


Figure 19. The Umbauhobel and Conveyor Unit. (37)

The Einbauhobel (Figure 20) is another Westfalia machine designed for two-way cutting. In this case, the blades are arranged in a stepped order to facilitate a series of thin successive cuts, which make this unit particularly applicable to the harder coals.

The Howood Slicer (Figure 21) and the Somson Stripper (Figure 22) are typical examples of the "activated" plough. These machines are designed especially for hard British coals. Their principal distinguishing feature lies in the motor-driven movement of the cutting teeth.

The Howood Slicer rides astraddle of its special chain conveyor and cuts and loads in two directions. In very hard coal, the seam is usually pre-cut.

The Somson Stripper is self-propelled and independent of the face conveyor onto which it feeds. Its mid-section wedges against the back by means of a vertical hydraulic jack while the cutter is thrust forward with a horizontal cylinder. The vertical jack is then lowered, the mid-section hydraulically advanced, the jack reset, and the cycle repeated.

Roof Support Equipment

Many types of steel props have been developed since the beginning of this century. The original rigid supports evolved into mechanical yieldable types and, in 1946, into the hydraulic yielding props. Recently, other modifications have produced the self-advancing hydraulic chocks that have virtually revolutionized long-

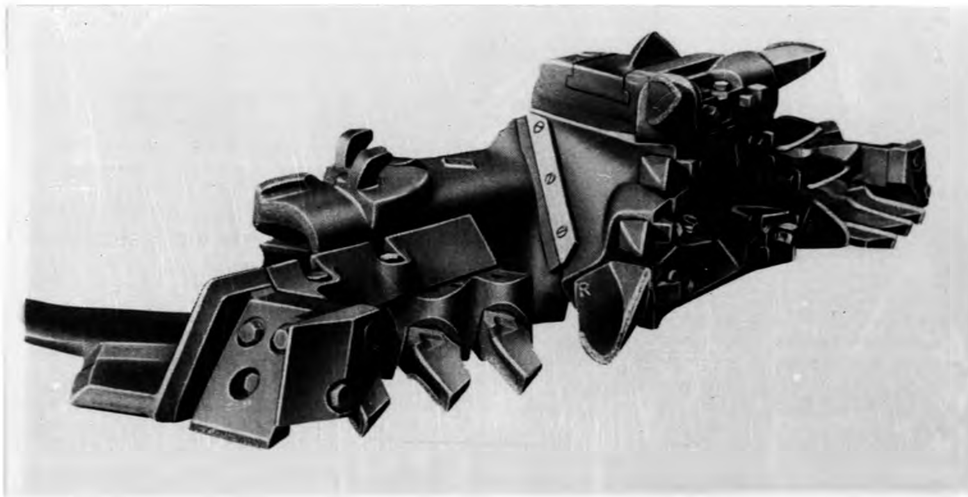


Figure 20. The Einbauhobel Hard Coal Plough. (27)

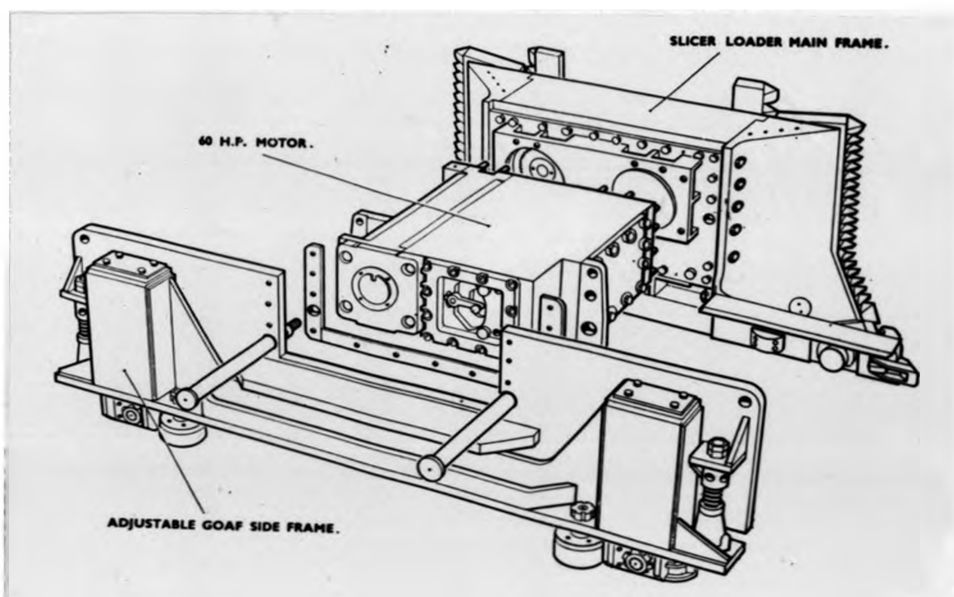


Figure 21. The Howood Slicer. (35)

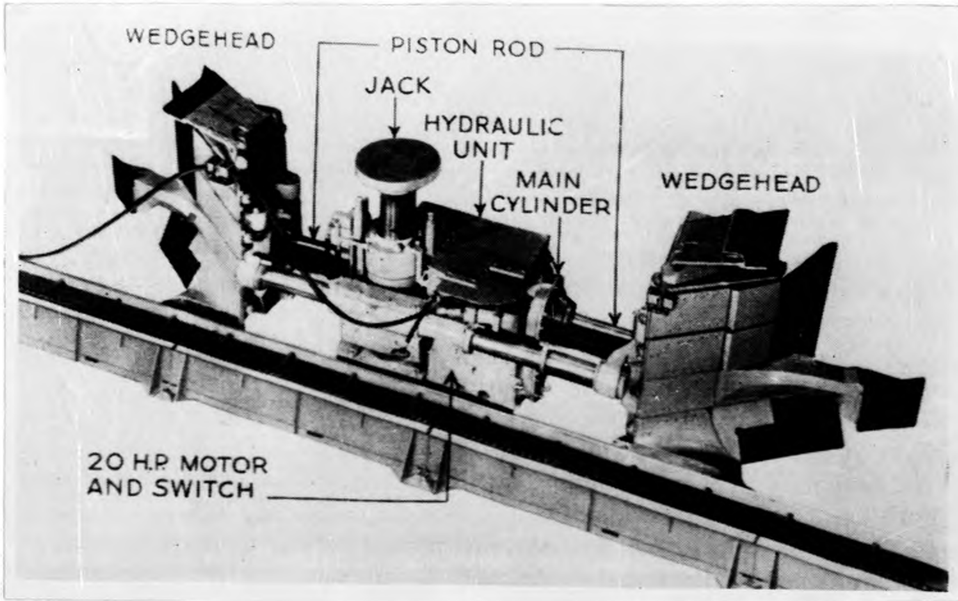


Figure 22. The Somson Stripper. (35)

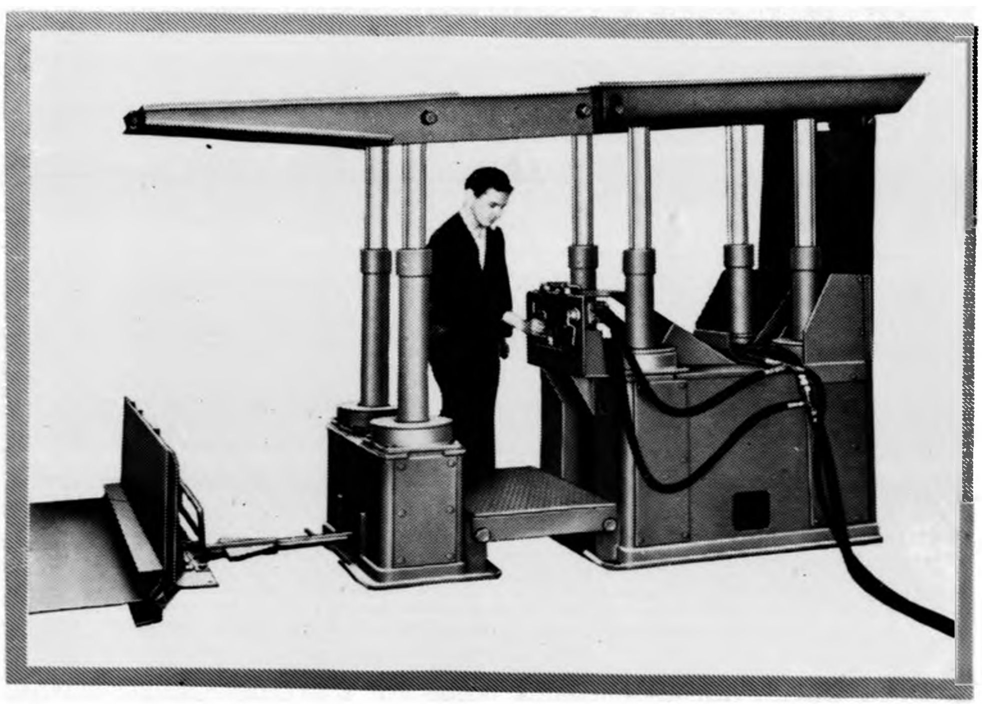


Figure 23. The Gullick Seaman Six-leg Chock. (4)

wall mining. This development eliminated the long non-productive time involved in advancing supports by hand, thus greatly reducing face labor requirements. As a result, the coal-cutting operation became the greatest time-consumer which, in turn, prompted further advances in that area.

Today, the coal mining industry is faced with the challenge of automation that is expected to inspire even further advances in the support system. This may lead to remote, and possibly automatic, control of all face operations. Such experiments are already under way in France, England, and Germany. Any further improvements quite likely will be of lesser significance, however, when compared with that which has already been accomplished.

In general, the powered chocks provide support in the immediate area of the working face, with the advantage of rapid withdrawal, advance and reset. They slowly yield at pre-determined loads, usually with gradually increasing resistance so as to permit uniform convergence of roof and floor with unparalleled safety in the working area. Their maintenance costs are normally low but, because of their great bulk, the costs for removal for major repairs are relatively high.

Some of the hydraulic roof supports are designed to use oil as the pressure fluid whereas others contain water with about two percent of soluble oil added. The fluid is normally pressurized with centrally located pumps and distributed through pipe lines. A few of the older models operate without return lines, in which cases the discharging fluid is sprayed into the goaf as the props are collapsed. Others are independently operated with individual pumps and built-in reservoirs.

The setting and yielding loads of the props are usually adjusted to suit the roof condition as dictated by experience. Each operation must be studied and the supports manipulated so as to achieve the most desirable form of caving for that particular situation. This may involve gradual settling or fracturing. In each case, the prop loads and distribution will be more or less unique.

The Gullick-Seaman Chock was the first power-operated support system to be developed. The original unit, which went into operation in 1954, consisted of four hydraulic legs placed in a square frame with a bearing area of 5 square feet. A double-acting hydraulic ram, located in the base, advances the conveyor and chock. A specially designed box canopy is fitted above the legs to carry two 7-foot cantilever bars. Its yielding load is set at 11.2 tons.

Recent modifications of the Gullick-Seaman Chock contain six and five legs, as shown in Figures 23 and 24. The six-leg unit can be used in seam thicknesses between 6.5 and 10 feet, whereas the five-leg chock is limited to coal that is between 2.5 and 6 feet thick.

The Dowty Roofmaster Self-Advancing Support (Figure 25) is a British innovation of the powered chock and consists of two separate units, one with three legs and the other with two. These are advanced alternately as shown in Figure 26, with one providing support while the other adjacent unit is moved forward. Each unit is composed of the usual yielding hydraulic jacks, a head-beam that will bend only after the props have ceased to yield, and a large base plate whose area is equivalent to about 3 square feet per jack. The beams are attached by means of cone-and-socket connections that permit some lateral movement, thereby providing good contact with

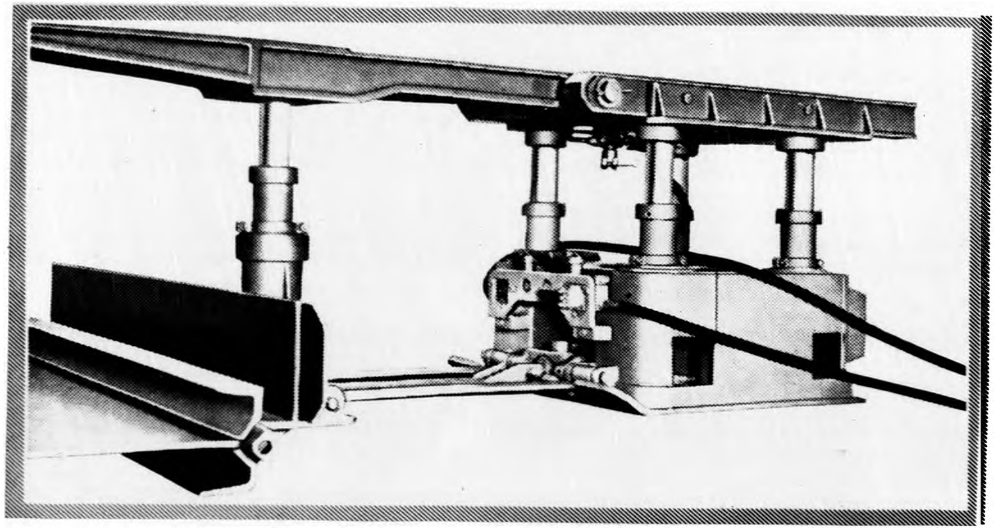


Figure 24. The Gullick Seaman Five-leg Chock. (4)

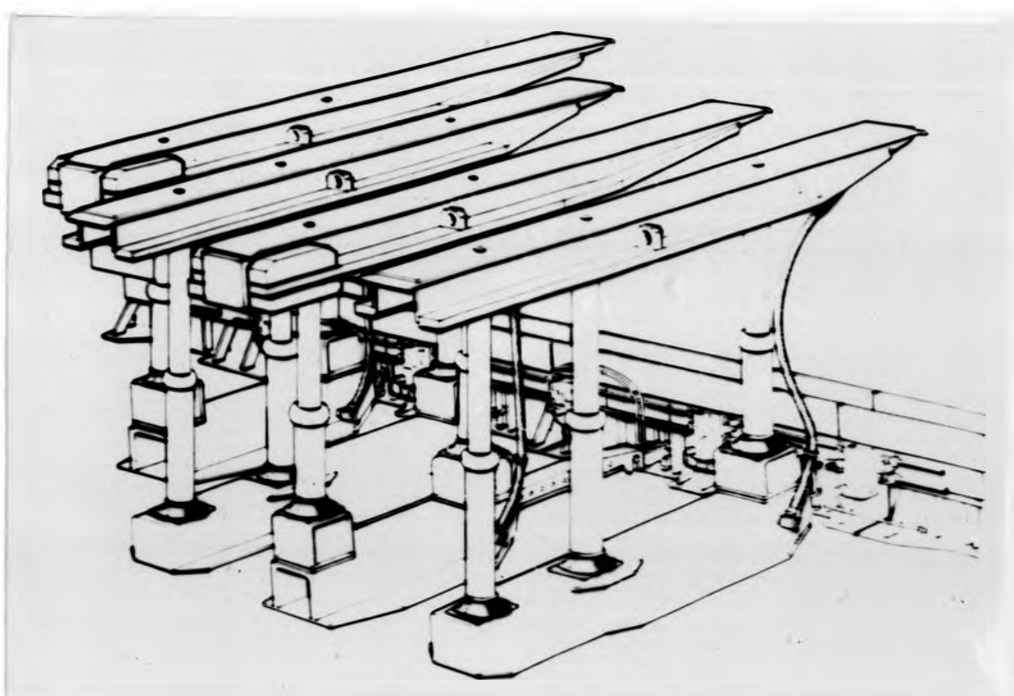


Figure 25. The Dowty Roofmasters. (12)

the roof. This particular type of support is rapidly gaining in popularity.

The Dobson Self-Advancing Support (Figure 27) comprises a pair of units, each of which has two hydraulic jacks. Their separate bases are connected by a double-acting hydraulic ram that facilitates their alternate advancement in a manner similar to that of the Dowty support. Each prop will carry a maximum load of 25 tons and an initial setting force of 8 tons. Rubber bushings at their bases and ball joints above permit good contact with the floor and roof surfaces. Special hydraulic rams can be fastened to their base plates as needed to advance the face conveyor.

The Schwartz Hydrofant (Figure 28) is a single oversize hydraulic jack that stands on a 16 by 20-inch base plate and can be fitted with either a crown plate or roof bar. It can be operated with oil, or water, and by portable pump or distribution line, the pump providing higher initial setting loads which may range to 35 tons. The jacks are collapsed by spring and advanced by hand.

The Desford Goal Post (Figure 29) is made up of two 50-ton chocks, placed one before the other, and advanced alternately by means of an interconnecting ram. Each unit has a bearing area of 10 square feet to withstand high roof pressures on a weak floor. The Somemi Support, the Sahe Somemi, and the Sahe are versions of the Desford design.

The Westfalia Lunen support (Figure 30) is similar to the Dobson unit but with an initial setting load of 25 to 30 tons and with a yielding load of 40 tons.

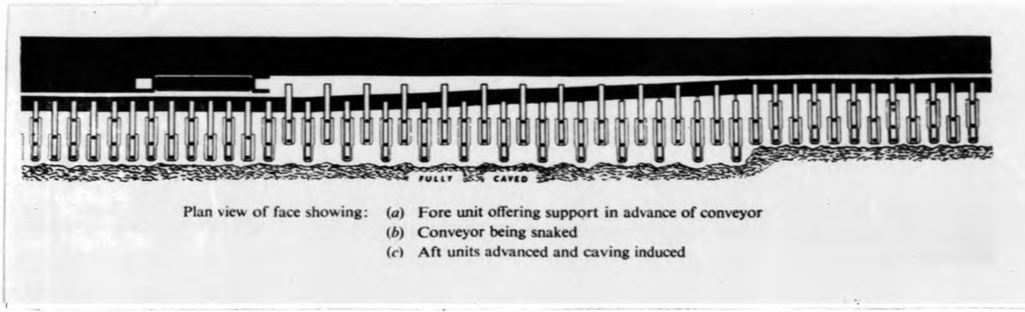


Figure 26. The Roofmasters Installed. (23)

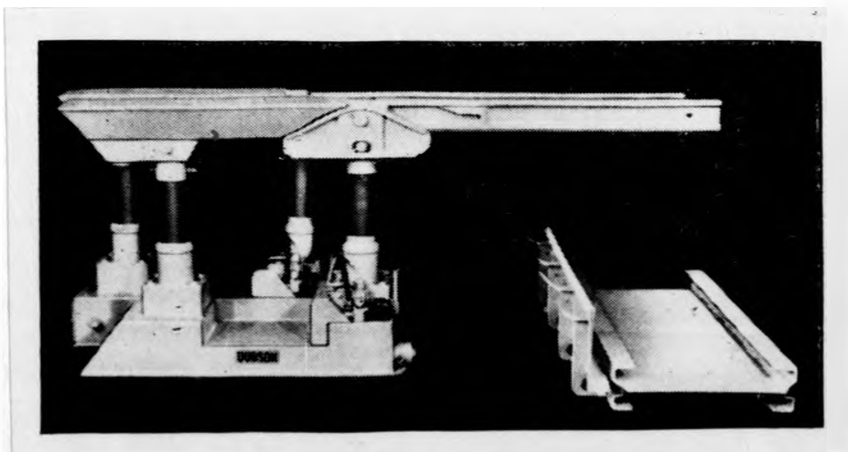


Figure 27. The Dobson Self-Advancing Support. (5)

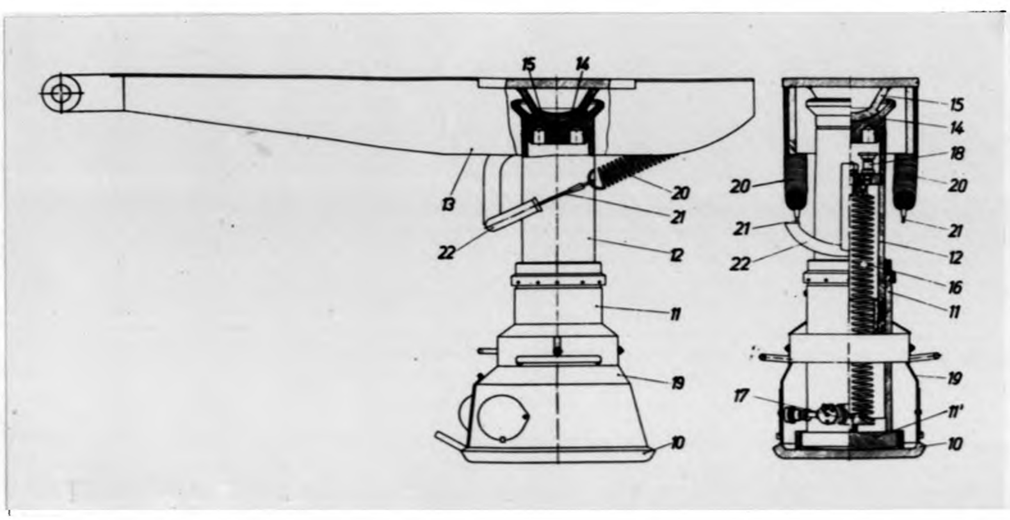


Figure 28. The Schwartz Hydrofant. (27)

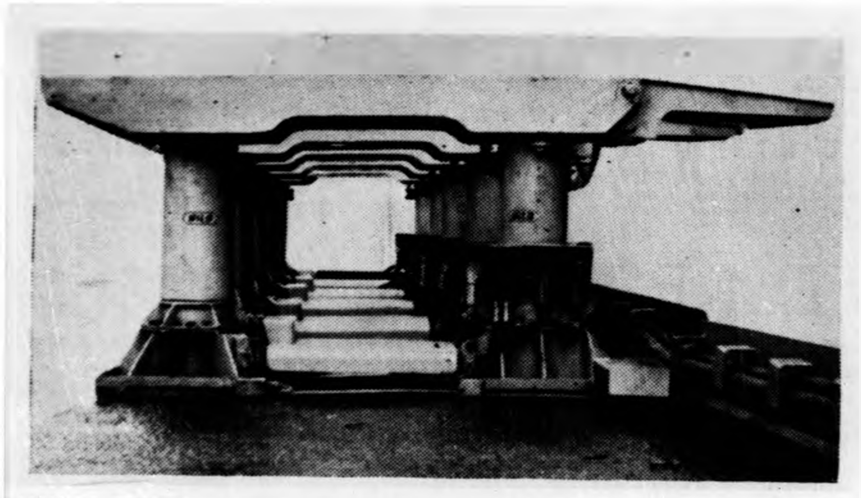


Figure 29. Goal Post Type Desford Chocks. (5)

Figure 30. Westfalia Lunen Hydraulic Chocks. (37)

The Hoesch Walking Support (Figure 31) is available in 4 and 6 prop units to withstand corresponding roof pressures. Each of the hydraulic jacks is double acting, with a collapsed length of 40 inches, 25-inch extensibility, and a load bearing capacity of 30 tons. All props are connected to a spring steel roof-bar through individual universal joints.

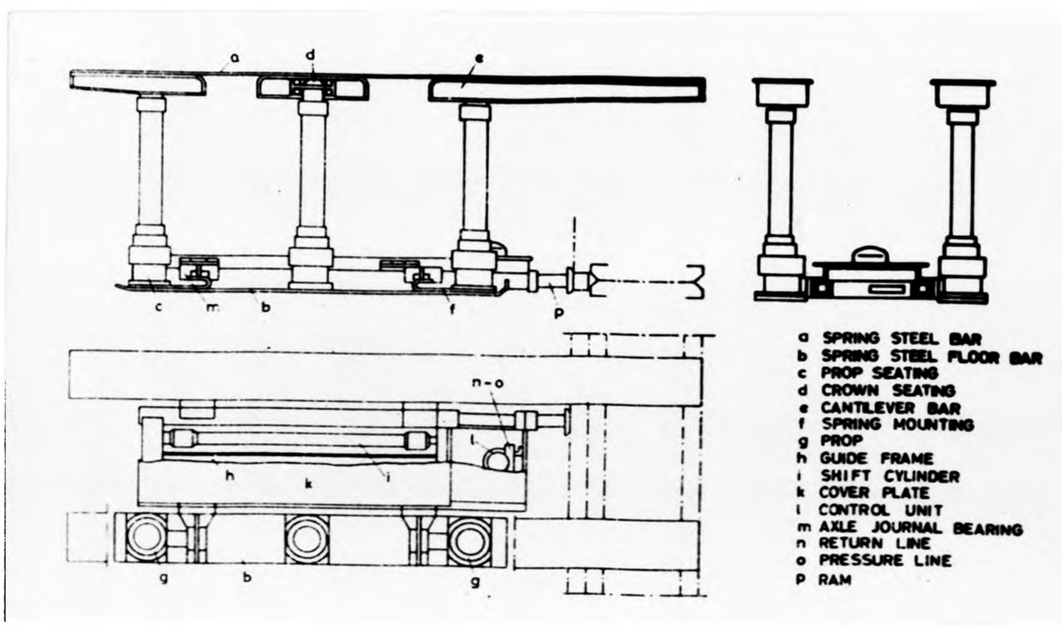


Figure 31. Hoesch Six-Prop Fram. (27)

LONGWALL MINING IN THE UNITED STATES

During the period when European longwall methods were first being attempted by American coal companies, the German coal plough was the most commonly used. Because of this and its apparent promise of high productivity, many of the original investigators adopted this machine without sufficient consideration for their individual seam conditions. As a result, some of the original attempts terminated in dismal failure because of this oversight. However, it was soon learned that high output could be achieved with the coal planer only when the mining conditions were suitable.

The introduction of self-advancing hydraulic supports rendered longwall mining even more appealing to the American coal miner. Several companies began experimenting with various other types of equipment with the hope of finding the ideal units for their particular seams. Although several partial successes have been reported, no exclusively longwall-mining operations are known to exist at the present time. One of the greatest probable deterrents to the evolution of the methods in this country is the complete lack of American longwall-equipment manufacturers, who normally would carry the brunt of the necessary broad scale investigations.

Eastern Gas and Fuel Company

The first American mining company to experiment with the modern longwall method was the Eastern Gas and Fuel Company. They installed a German coal planer in their Stotesbury No. 11 mine with yielding steel props and wood cribs for roof support (14). A seam that was 31 to 38 inches thick was mined by the retreating system (Figure 32) in order to avoid the high cost of packwalls. The coal was soft and friable, and parted freely from the roof. The seam characteristics were particularly suitable to the coal plow, and as a result the operation is a complete success.

Because of advantages realized from the first attempt, a second similar coal planer was installed at the Stotesbury No. 8 mine, as shown in Figure 33 (13). The coal was similar in nature to that of the No. 11 mine, but it was from 36 to 52 inches in thickness, with high roof pressures, large undulations, with grades up to 20 percent. In spite of the adverse seam conditions, the operation produced better results than those normally obtained with the conventional room-and-pillar method.

With the advent of the self-advancing roof supports, the Eastern Gas and Fuel Company attempted a completely mechanized longwall operation in their Keystone Mine at Keystone, West Virginia (1). A combination of the German coal planer and power-driven roof supports made it possible for this operation to become one of the most successful in the history of American longwall mining.

The coal seam at the Keystone Mine is between 46 and 54 inches in thickness and includes a 4 to 6-inch bone layer near its middle. It is overlain by approximately one thousand feet of shales and sandstones, and with a good shale floor underneath. All other conditions appear conducive to efficient longwall mining.

The mining plan that was adopted is shown in Figure 34. With this arrangement, a crew of 10 laborers and 1 foreman advance the

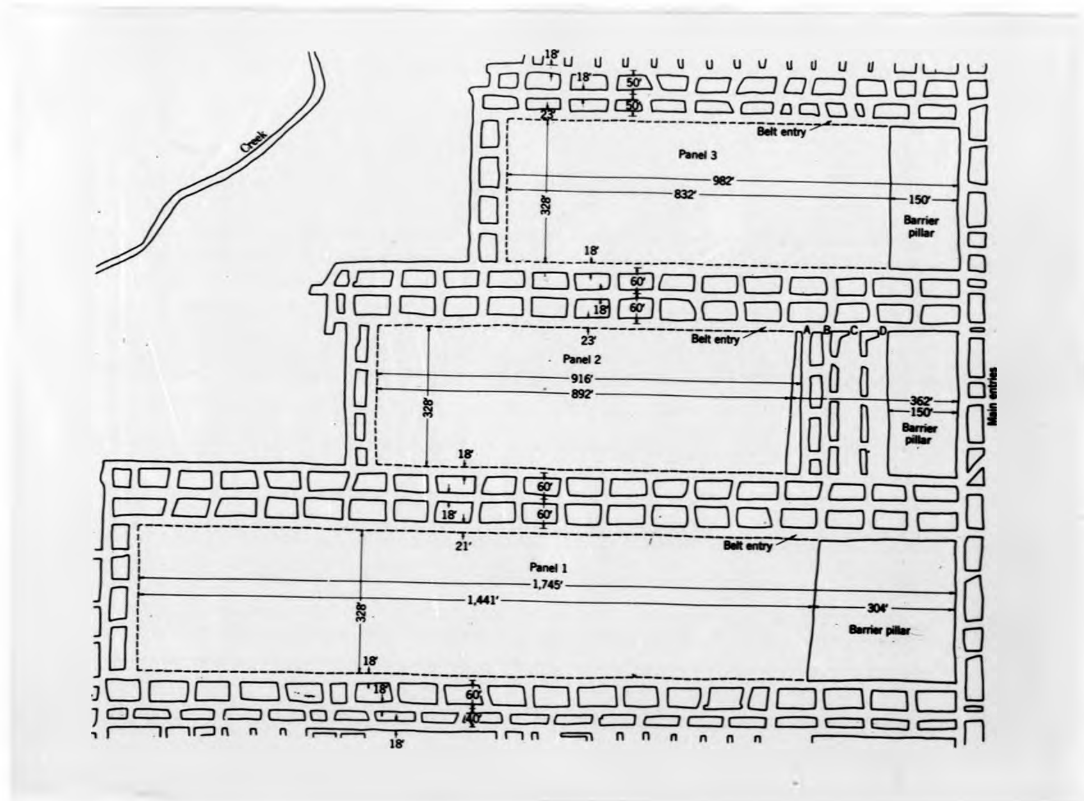


Figure 32. Plan of Three Panels at Stotesbury No. 11 Mine. (14)

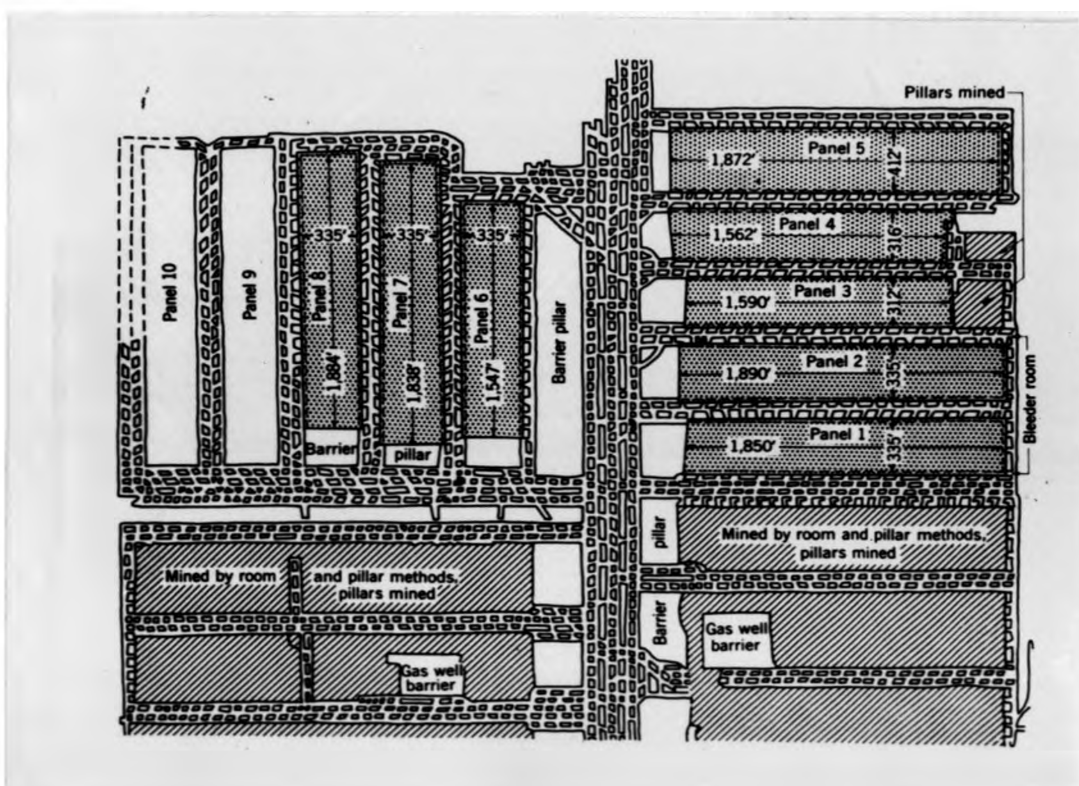


Figure 33. Area Mined with Planer at Stotesbury No. 8 Mine. (13)

longwall face an average of 9 feet per shift at about one-half the cost and twice the output that is normally achieved with a continuous miner in a room-and-pillar operation. More detailed production and cost comparisons are shown in Figures 35 and 36, respectively.

The longwall method was tried in the Pine No. 1 Mine of the Pine Township Coal Company, according to the plan shown in Figure 37 (13). Here, the coal is 41 to 48 inches thick and contains numerous partings at various levels in the seam. Its extremely shallow overburden is between 100 and 200 feet in thickness. After 3 years of experimentation, the operation was abandoned primarily because of excessive labor requirements.

Island Creek Coal Company

A coal plough was installed in the Island Creek Mine No. 22 (13), at Holden, West Virginia, in a seam that apparently was not suited for this type of mining. The coal was hard with a fairly tough layer near its bottom and with a strong bond to the roof rock that required drilling and blasting. A soft underclay further complicated the operation. After one year of unsuccessful trials, the longwall section was discontinued.

A second longwall attempt was made by the same company in their Amherst No. 4 mine where the 39 to 42 inches of coal appeared more suitable. The soft and friable coal is underlain by a clay of varying hardness and with an overburden between 150 and 1000 feet in thickness. This operation evidently was not a success because it was discontinued.

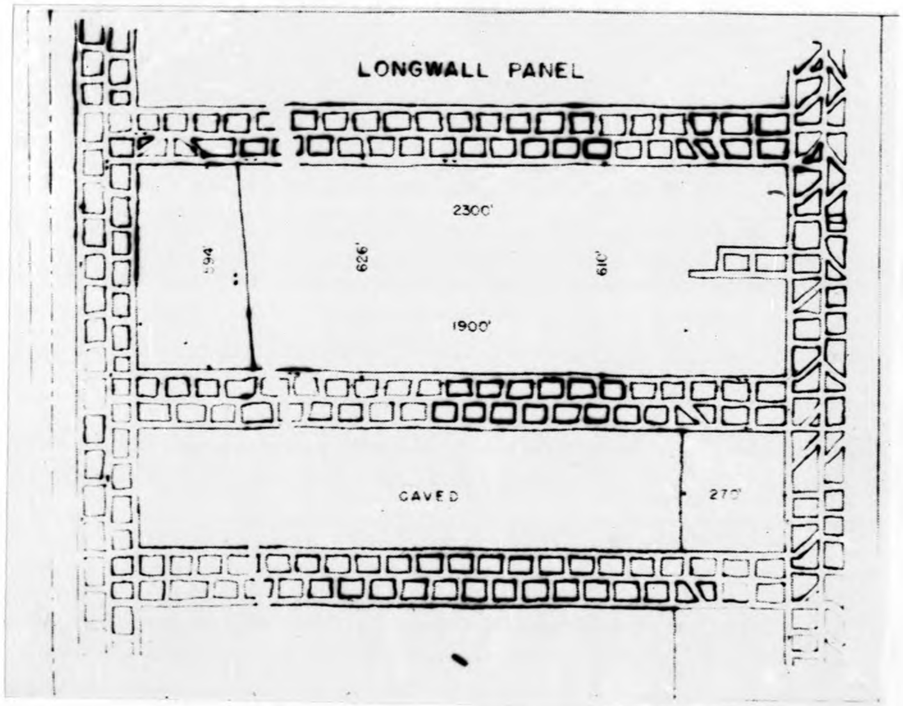


Figure 34. Longwall Mining Area at Keystone Mine. (1)

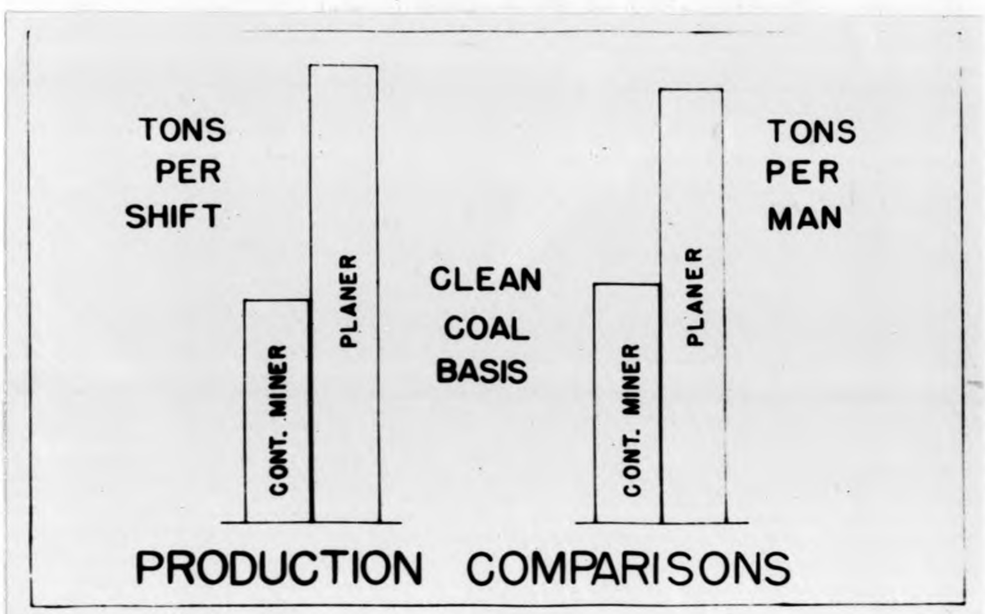


Figure 35. Comparative Production Figures at Keystone Mine. (1)

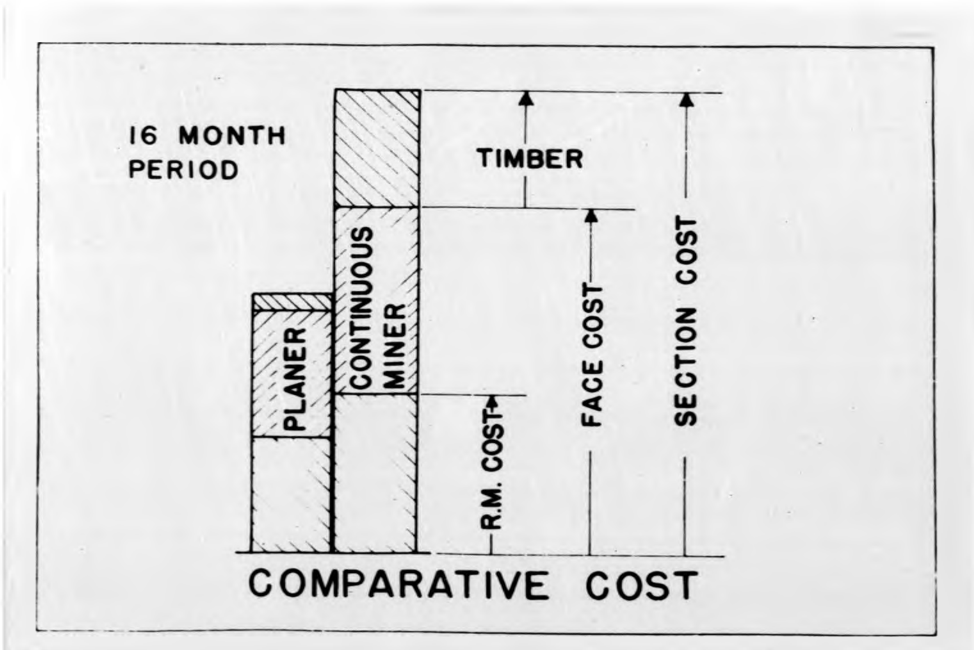


Figure 36. Comparative Cost Figures at Keystone Mine. (1)

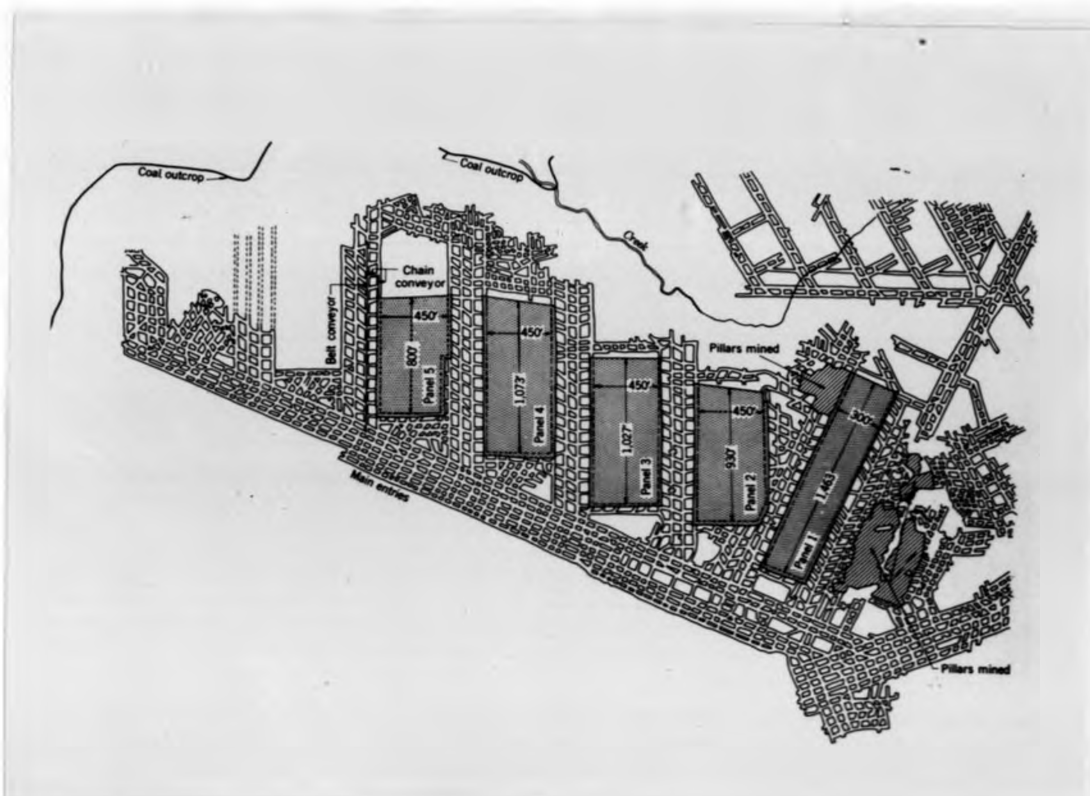


Figure 37. Area Mined with Planer at Pine No. 1 Mine. (13)

Barnes and Tucker Company

The Barnes and Tucker Company tried unsuccessfully to use an Anderton-Boyes Trepanner and roof jacks on a longwall face in their Lancashire No. 15 Mine, at Bakerton, Pennsylvania. Apparently, the seam conditions were not suitable.

Lone Star Steel Company

An Anderton Shearer-Loader with Dowty roof jacks was applied to a 600-foot longwall face at a Lone Star Steel Company mine near McAlester, Oklahoma (11). At present, they are mining 400 tons per shift from a seam that is 38 to 40 inches thick. The results are satisfactory and future improvements are expected.

Old Ben Coal Corporation

The Old Ben Coal Corporation is attempting longwall mining with a standard American continuous miner. Although first-hand information is unobtainable, it appears this company has installed a Joy 6CM ripper-type miner with Stahlunion hydraulic jacks in a 7-foot seam near West Frankfurt, Illinois. The relative success of the operation has not been announced at the time of this writing.

Kaiser Steel Company

The Kaiser Steel Company is attempting a longwall operation that is similar to that of the Lone Star Steel Company. Evidently, all conditions favor this system, for the results to date have been very gratifying. Even though the operation is considered as still being in the initial experimental stages, it has already proven itself more economical than conventional room-and-pillar mining.

The author was permitted to study this mining system for three weeks and reports his findings in the paragraphs that follow.

SUNNYSIDE NO. 3 COAL MINE

The Sunnyside No. 3 Coal Mine, of the Kaiser Steel Company, is located in a canyon about 7 miles north of Sunnyside, Carbon County, Utah. It produces a good grade of metallurgical coal that is utilized entirely by the company. Because of this, the mine operates only as required to fulfill the needs of the organization, or on an average production basis of 3 days per week with a subsequent 4-day shut-down.

Description of the Coal Seams

Two major coal seams exist in this area (Figure 38). They are separated by 20 to 30 feet of sandstone and sandy shale, and lie under a cover that consists of about 1000 feet of sandy shale, sandstone, and a few thin coal seams. The upper coal layer is about 4 feet thick, relatively soft, and with very little bonding to the roof. The lower seam is 5 to 6 feet thick, fairly hard, and with a very rigid bond to the roof rock. Both seams are enclosed by strong shales or sandy shales and dip at about 7 degrees to the southwest. All of the longwall mining activities are confined to the lower seam and in an area from which the coal of the upper seam has been partially exploited by room-and-pillar methods.

Face Development

An experimental longwall operation is being conducted in a panel that was originally intended for room-and-pillar mining. It

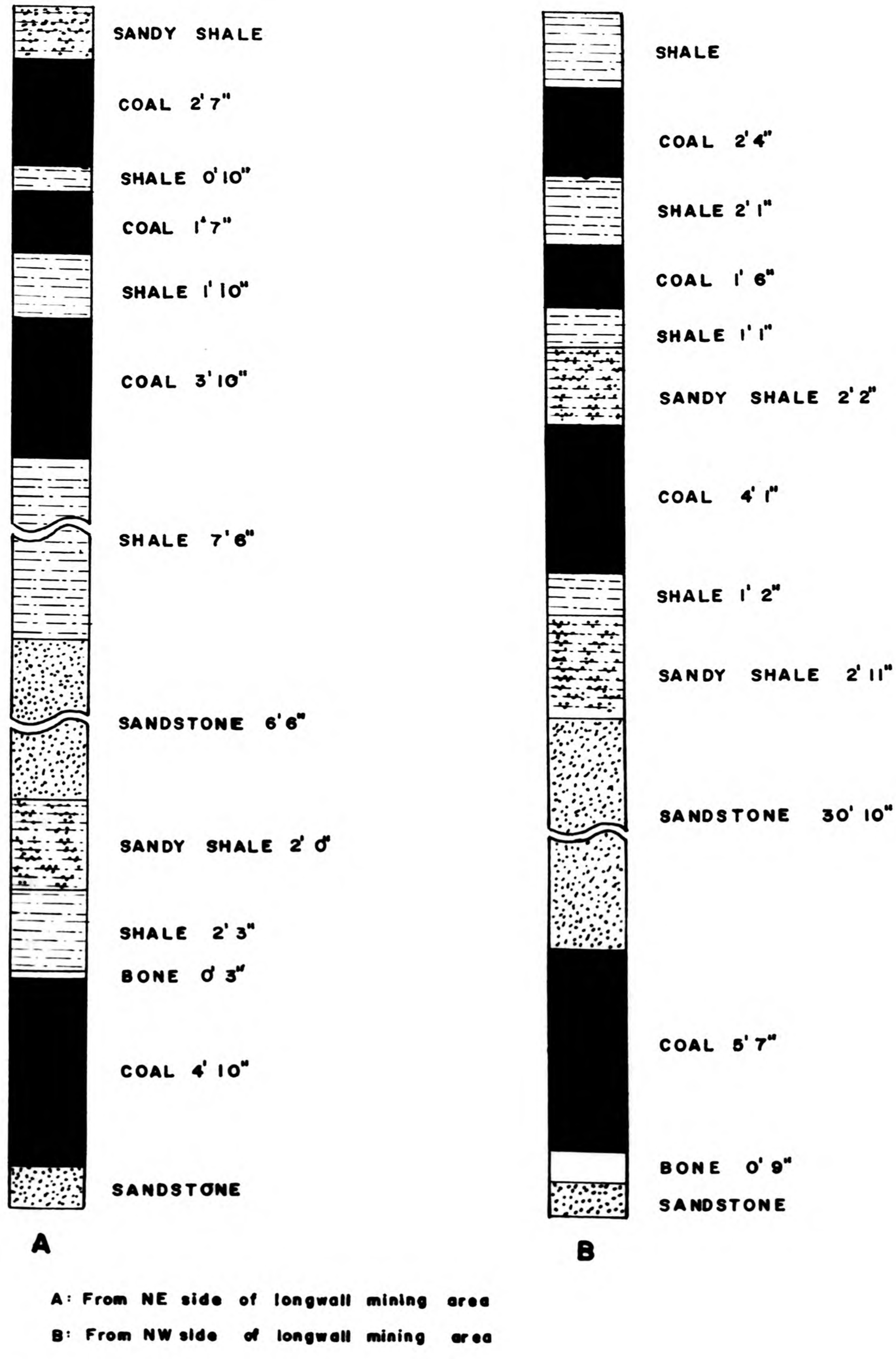


Figure 38. Cross Sections of Sunnyside Coal Measures.

was developed with three entries on each side of a coal block that is 280 feet wide and 2300 feet long. All entries were driven 20 feet wide and on 60-foot centers and bottom-brushed to provide a 7-foot working height. Crosscuts are spaced at 80 feet. A relatively short longwall face was then formed by driving a cross-entry through the short (280-foot) dimension of the panel at its inby end. The face is now being retreated toward the main slope and along the 2300-foot dimension of the coal block. The combination of retreating with multiple entries eliminates the high cost of packwalls, which would otherwise be required.

Conventional room-and-pillar equipment has been used in developing the area. A universal cutting-machine, with a pair of drills attached, was employed for preparing the coal face, after which a Joy loader, shuttle cars, and rail cars were used for transferring broken coal to the main slope. Roof bolts and steel crossbars have been placed with a standard two-arm roof bolting machine, but occasional wooden props were set by hand. A crew of nine achieved sixty feet of advance and produced three hundred tons of coal per shift. It is planned to develop 750-foot longwall faces in the future with the use of continuous mining equipment.

Face Operations

An Anderton Shearer-Loader (see Figures 8 and 9) is used for cutting and loading at the longwall face. As described earlier, this machine rides atop an extra-heavy chain conveyor as it simultaneously cuts and loads coal directly from the solid. The conveyor channel is composed of 5-foot sections that are joined by flexible couplings, which permit about 4 degrees of bending along its centerline. This ability of the conveyor to "snake" affords good alignment with an uneven coal face.

Roof support is accomplished with Dowty Roofmaster, self-advancing, hydraulic props (see Figures 25 and 26), placed on $2\frac{1}{2}$-foot centers along the conveyor length. The props are powered by high pressure pumps that are placed at each end of the face and connected through distribution lines mounted on the conveyor trough. Alternate props are fastened to the chain conveyor by double-acting hydraulic rams that are used to advance the mining machinery and roof supports as required. Dowty Duke single props are installed by hand as needed for additional support at the face ends.

The mining operation is commenced with the shearer at the discharge end of the main conveyor and with all props in position. The cutter is towed by steel cable atop the aligned conveyor trough, as its rotating drum cuts and loads a slice of coal that is about 2 feet thick. Alternate (2-leg) props are moved forward to support the newly exposed roof as the machine passes. At the end of the cutting cycle, the rotating drum is partially disassembled so as to clear the newly-advanced cantilever bars of the two-leg props, and the machine is then returned to the starting point. Spilled, broken coal is plowed onto the conveyor during the return trip, and the tail-end drive and adjacent trough sections are moved forward by hydraulic rams as clearance at the new face becomes available. Finally, the head drive is repositioned with the aid of an electrically operated hoist, all of the 3-leg props advanced, the shearing drum reassembled, and a new cycle started. The entire operation is per-

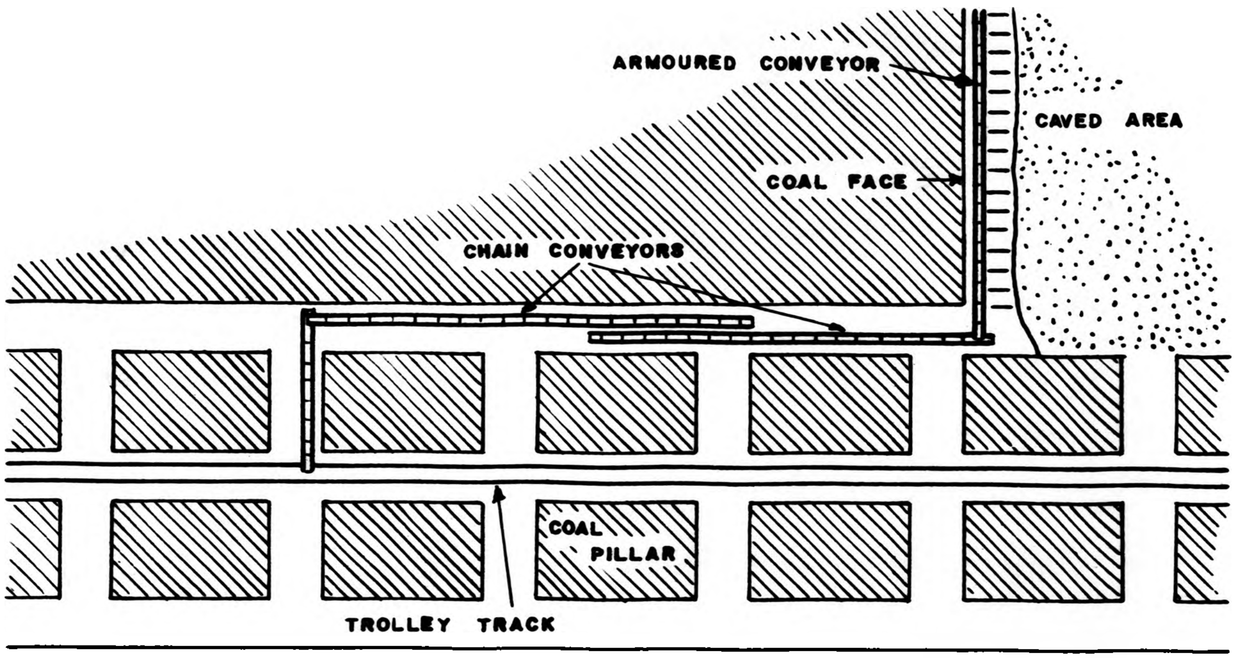


Figure 39. Layout of Sunnyside Longwall Transportation System.

formed by a team of 11 men.

Each cut along the face yields about 110 tons of coal and takes about 1½ hours. The broken coal is moved along the face conveyor (Figure 39) and then over a telescoping combination of entry conveyors to a train of twelve 5-ton cars for transport to the main slope. A single trolley locomotive performs the rail haulage, requiring 10 minutes for each round trip. Because two such trips are necessary to transport the total coal tonnage of each cut, the operation must be halted at mid-cycle to await the return of the train.

As the face and support line advances, the back is allowed to break and settle to the floor, thus preventing excessive roof loads from settling on the props. The effectiveness of this action is disrupted in the roof-bolted areas along the entry ribs, however, where the artificially stabilized back remains in position to overload entry pillars.

The shearing action of the cutting drum creates a large amount of potentially explosive dust that cannot be completely suppressed with water sprays and controlled ventilation. Besides forcing the machine operator to wear a face mask, the remaining airborne dust poses a serious explosion hazard in combination with methane gas issuing from the strata.

A room-and-pillar operation with a Joy continuous miner is being conducted in an adjacent area under conditions that are similar to those of the longwall experiment. Each of the two working faces require 11 laborers but the longwall method permits 500 tons to be mined per shift whereas the room-and-pillar section yields only 400, thus establishing their relative productivities at about 45 and 36 tons per man-shift, respectively. Furthermore, the longwall operation is recovering about 50 percent more coal than its counterpart. The initial investment in longwall face equipment is higher, however.

Although production cost data are not available for publication, the writer has been informed by company officials that the longwall operation is already more economical than room-and-pillar mining in spite of its experimental nature and attendent lack of deliberate design. Much better results are expected with future modifications and more experience with the method.

Comments on the Operation

The coal that is being mined by the longwall method at the Sunnyside Mine is hard and rigidly bonded to the roof rock. It can most efficiently be mined, therefore, by a full-face cutting machine like a shearer-loader. The variable thickness of this seam poses a disadvantage to the single-drum, fixed height Anderton unit that is being used, however. An excessive seam thickness will result in unmined top coal and an extremely thin condition cannot be mined without a change in drum diameter. Perhaps a double-drum, such as the Eichoff Shearer-Loader (Figure 10) could be used to greater advantage. Also, the Anderton Shearer-Loader is designed for cutting in only one direction. The section productivity could be increased significantly with a unit that is two-directional. Furthermore, a different cutter design such as the Spiral Vane Disc Cutter (Figure 11, pp. 16 and 18) may remedy the dust hazard that presently is being tolerated.

The overly stable back along entry ribs that places excessive burdens on entry pillars could probably be induced to cave by removing the roof bolts. Any added labor cost would be compensated by the salvage value of the bolts and cross bars.

The discontinuity of face operations for lack of transportation is resulting in about one hour of idle time per shift. A change from rail to belt conveyor haulage is planned by the company and is expected to eliminate this loss completely.

A shut-down of four consecutive days per week permits the floor to heave and, thereby hampers cutting machine performance in the early stages of resuming operation. The difficulty can be obviated by more favorable production scheduling.

The overall coal recovery and productivity will be improved by increasing to face length from its present 280 feet to 750 feet and by installing an efficient mechanical device for robbing entry pillars.

These and many other modifications of lesser importance are being considered by the capable staff of the Sunnyside Mine, and new areas for improvement are still being sought. When the longwall operation is eventually converted to a full-scale production status, it will unquestionably be even more advantageous than presently indicated in a comparison with the present room-and-pillar method being employed by the company. All of its desirable characteristics will be further magnified when the system is modified.

SUMMARY AND CONCLUSIONS

Coal mining in the United States is accomplished almost exclusively by the room-and-pillar method. Because of this, all significant advances in face mechanization have been directed toward improving coal productivity by this method. The present status of the resulting evolution is represented by the "continuous"mining machine that is capable of unsurpassed production when applied under ideal conditions, namely, in thick seams, under low roof pressure, and with strong top and bottom. Those seams that are suitable for highly mechanized mining, are rapidly being exploited, however, and with only partial recovery of the available coal. As deeper and thinner seams are mined by the room-and-pillar method, coal productivity and recovery will be decreased accordingly.

The longwall method of mining is less affected by depth and seam conditions and is conducive to highly mechanized production and nearly complete coal recovery. Furthermore, flat-lying, thin coal seams that are on the verge of being too deep for room-and-pillar mining are nearly ideal for extraction by the longwall system. This fact has prompted the U. S. Bureau of Mines and several coal companies to experiment with the method. In some cases, the results were gratifying, whereas in others, they were completely discouraging. A study of the data published on these investigations revealed that the failures were apparently due to

(1) absence of completely mechanized roof support, or (2) improper face equipment. The degree of success achieved in all cases was closely related to the above two factors. It is to be emphasized, however, that the failures were caused by improper choice of equipment rather than by proper equipment unavailability.

The fact that improper equipment has been selected is often realized only after a considerable amount of testing has been accomplished. Because the machinery is expensive and the operation is of an experimental nature, however, the situation is not usually remedied. Instead, the mining technique is altered in order to overcome the shortcomings of inadequate machinery and the operation is continued with only limited success. With the advent of American longwall machinery production, local equipment manufacturers will assume the burden of more widespread experimentation and thereby, offer the operator much greater benefits than are now attainable.

The successful application of longwall mining is demonstrated by the Keystone and Sunnyside mines. Other operations have reportedly achieved favorable results but of lesser note, and the few that terminated in failure, apparently did so for reasons which could be overcome. Thus, it is shown that the longwall system can be applied to American coal seams with greater advantage than the modern, mechanized room-and-pillar method, provided that the proper equipment is used in the most effective manner. Furthermore, it is strongly indicated that future longwall operations will prove considerably more advantageous than those being attempted at the present time.

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