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Three Potential Longwall Mining Methods for Thick Coal Seams in the Western United States

By Richard H. Oitto

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

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THREE POTENTIAL LONGWALL MINING METHODS FOR THICK COAL SEAMS IN THE WESTERN UNITED STATES

by

Richard H. Oitto[1]

ABSTRACT

Three longwall mining methods practiced in foreign countries are described that have potential for increasing underground recovery and productivity in thick coalbeds of the Western United States. The methods are multislice longwalling, longwall caving, and high-face longwalling. Foreign practice and possible application in the United States are discussed.

INTRODUCTION

The Western United States has many coal seams that are 12 to 30 feet thick and are at depths that require underground mining. These thick seams are being mined by methods that often recover less than 30 percent of the coal. The coal not recovered is lost forever. This wasteful practice persists for two reasons. One reason is lack of technology for the safe and efficient underground mining of thick seams. The methods used now evolved from the underground mining practices of the Eastern United States, where seam heights do not exceed 12 feet and average about 5 feet. The second reason is lack of strong emphasis on conserving coal resources, a situation reflected by widely circulated statements that known U.S. coal deposits represent about 400 years' supply at present consumption rates. However, future consumption rates are projected to increase dramatically now that coal usage in the United States is being promoted.

In an effort to increase coal production and to reduce waste of coal deposits, the Bureau of Mines, under its program called Advancing Coal Mining Technology, sponsored contractural studies (5, 12-13)[2] of thick seam underground coal mining methods used in foreign countries. The objective of these studies was to determine the applicability of such methods for mining domestic coal seams thicker than 14 feet. Pertinent factors considered included safety, efficiency, productivity, and recovery. The studies sponsored by the Bureau indicate that two foreign thick-seam mining methods, multislice longwall

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[2]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

mining and longwall caving, have potential application in the United States. A third method, high-face longwall mining, also has potential but was not studied in detail to avoid duplication of an ongoing effort by industry. However, all three methods are discussed with respect to foreign practice as well as to their possible application in the United States.

DESCRIPTION OF METHODS

Multislice Longwall Mining

Multislice longwall mining also is known as multilift, multipass, and top-slice longwall mining. In this method, a thick coal seam is removed in slices parallel to the seam beginning at the top immediately beneath the roof rock (fig. 1). Generally, only two slices, an upper and a lower, are needed to extract most thick coal seams, but additional slices may be mined in thicker seams. A mining plan exists for extracting a 100-foot-thick seam in 10-foot-thick slices (5). A slice is extracted by longwall mining panels of coal conventionally in side-by-side succession. The lower slice can be mined either at the same time as the upper or top slice, termed simultaneous or concurrent mining, or after the top slice is completed, termed nonsimultaneous or nonconcurrent mining.

Simultaneous or concurrent mining involves longwall mining a top slice panel and the lower slice panel immediately under it at the same time. The lower longwall face lags behind the upper face at a fixed distance determined by experience. Excessive ground pressures may occur in the upper face if this lag distance is too small, or in the lower face if it is too great. Because the two faces cannot advance independently at full speed for maximum productivity and because two complete sets of longwall equipment are needed, a preferred alternative may be the nonsimultaneous or nonconcurrent system.

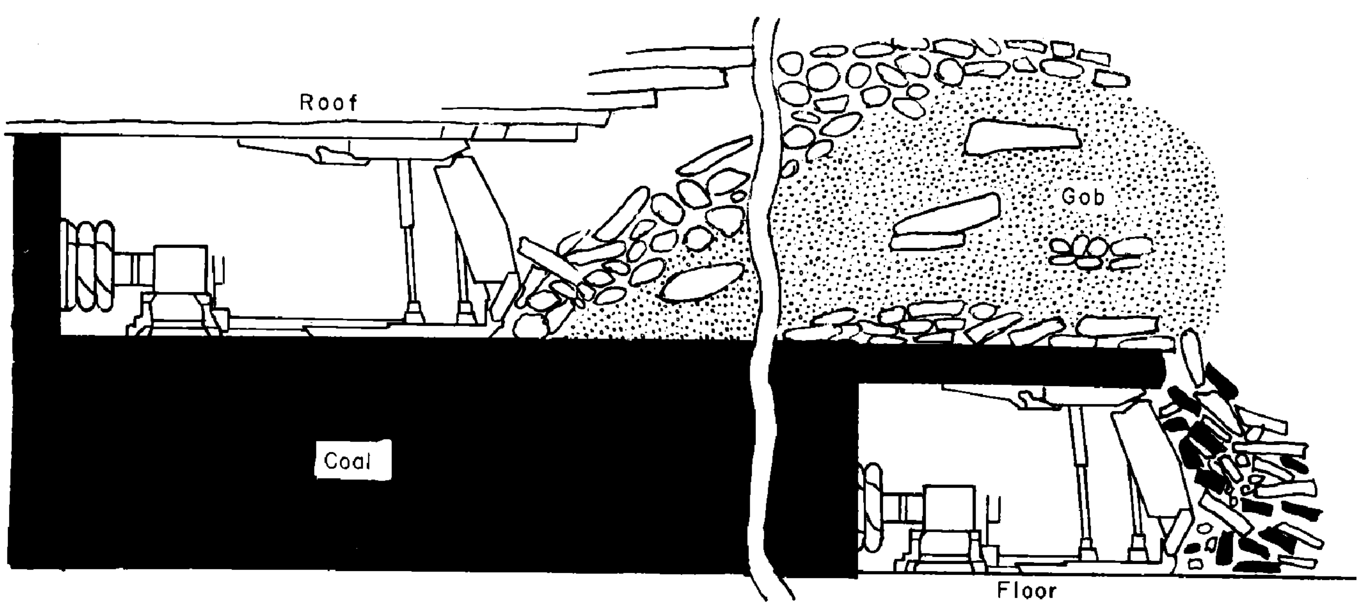


FIGURE 1. - Multislice longwall mining.

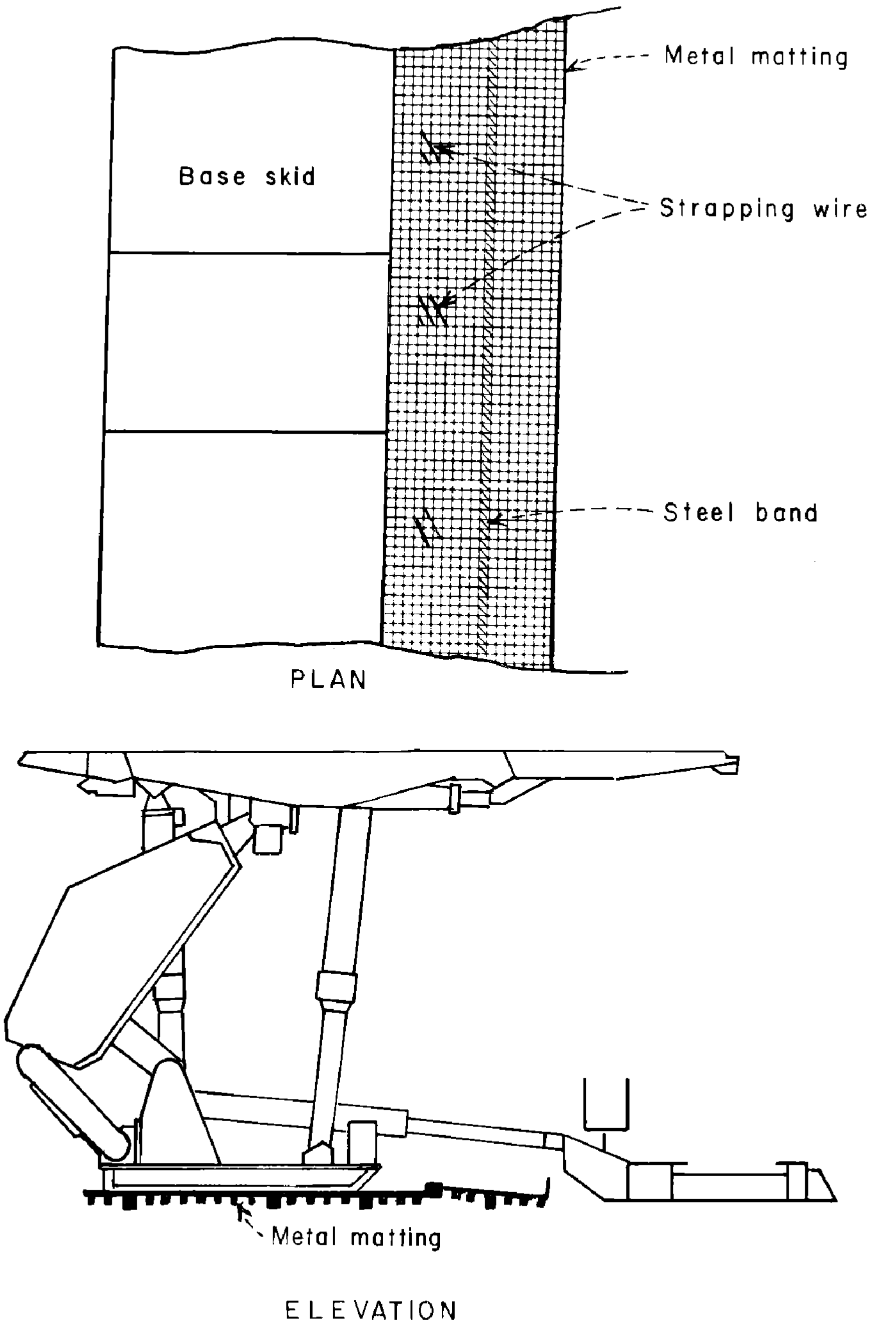


FIGURE 2. - Sectionalized metal matting installed between face conveyor and base of chock shield support.

In the nonsimultaneous system, all of the panels in the top or upper slice are longwall mined first, one at a time; then the panels in the lower slice are longwall mined, also one at a time.

Both the simultaneous and nonsimultaneous systems require that a roof be maintained over the working face of the longwalls in the lower slice. The roof may be natural or artificial and, depending on ground conditions, may consist of (1) metal matting or wire mesh, (2) a rock parting in the coal, (3) a layer of unmined coal, (4) gob solidified by injected sludge, or (5) any combination of these. Another form of roof, applicable only to the nonsimultaneous system, is gravity-compacted gob, the formation of which usually requires 1 to 2 years. An artificial roof for the lower slice is installed during extraction of the upper slice. When metal matting is used, it is laid on the floor of the upper slice between the face conveyor and longwall supports (fig. 2). If wire mesh is used, it is fed over or under the supports and trailed out on the floor behind the supports (fig. 3). The mats or mesh are overlapped to form a continuous layer that will prevent gob from flushing into the working areas in the lower slice. When a thick coal seam is split by a rock parting of sufficient thickness and competency, the parting may be used as a mining roof for the lower slice. When no suitable parting is present, a natural mining roof can be created by leaving a 3- to 5-foot layer of coal unmined between the upper and lower slices.

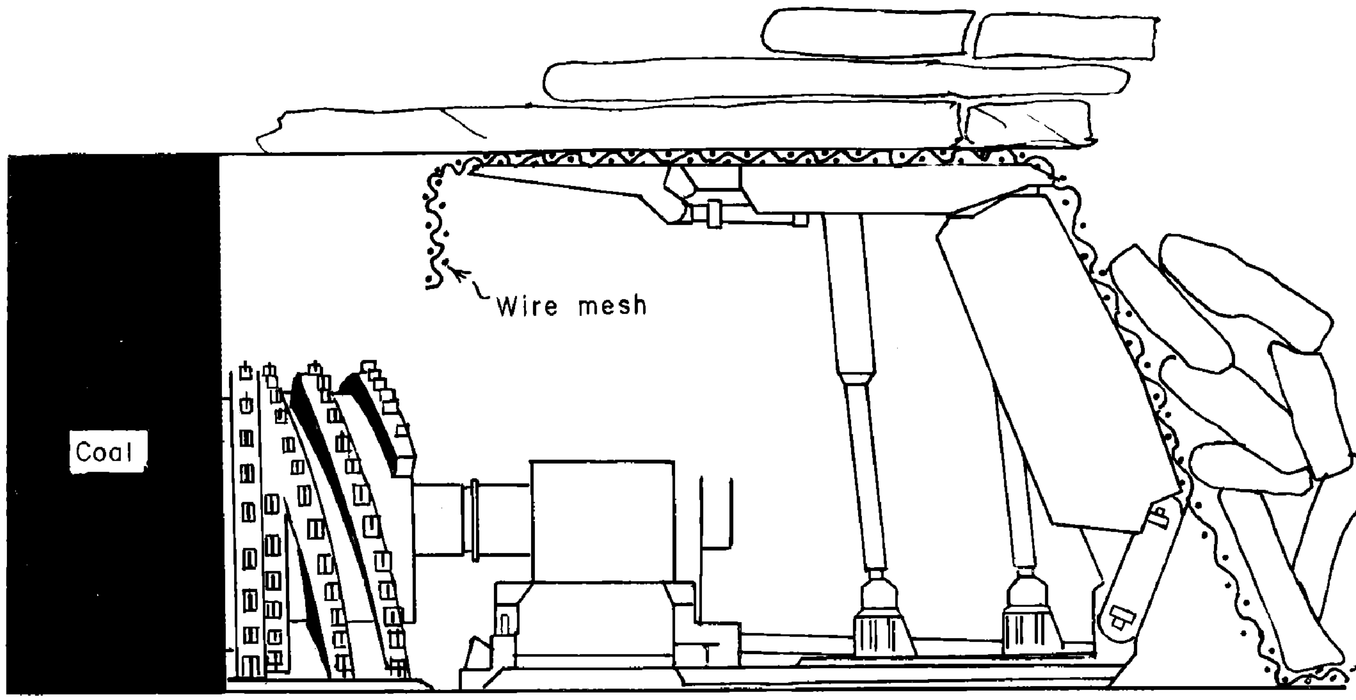


FIGURE 3. - Wire mesh fed over chock shield support.

Panel entries in a lower slice are located under the gob of the upper slice in a destressed area away from remnant pillar stresses of the upper slice. In an alternative arrangement, not widely used, upper and lower slices are served by common entries driven at the combined height of both slices.

Longwall Caving

Longwall caving is referred to also as longwall mining with sublevel caving. In this system, a 7- to 10-foot-high slice along the bottom of a thick coalbed is mined by a conventional longwall. The coal above the longwall supports caves at the gob end of these supports and is drawn onto a conveyor (fig. 4).

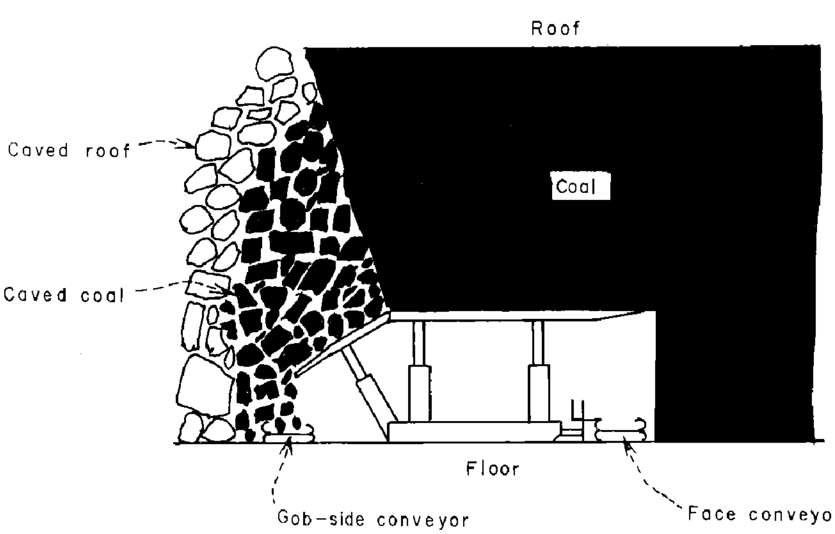


FIGURE 4. - Longwall caving mining.

The drawing of caved coal onto the gob-side conveyor is controlled in various ways. In one control system, the caved coal is restrained by wire mesh spread over the top and down the gob end of the longwall supports (fig. 5). Openings cut into the wire mesh allow the coal to pass through onto the conveyor. Another system uses steel bars hinged at the top rear of the longwall supports and angled into the gob at about 60°. Wooden lagging placed

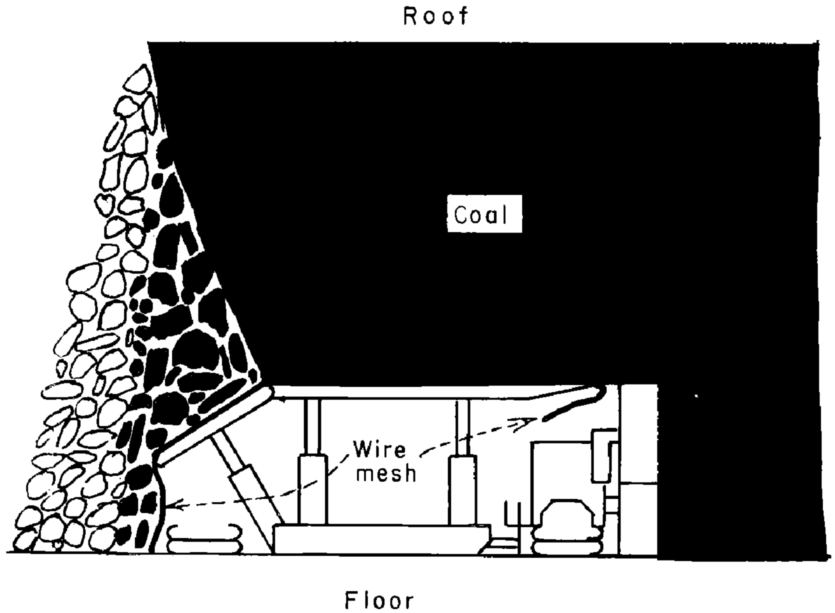


FIGURE 5. - Wire mesh restrains caved material.

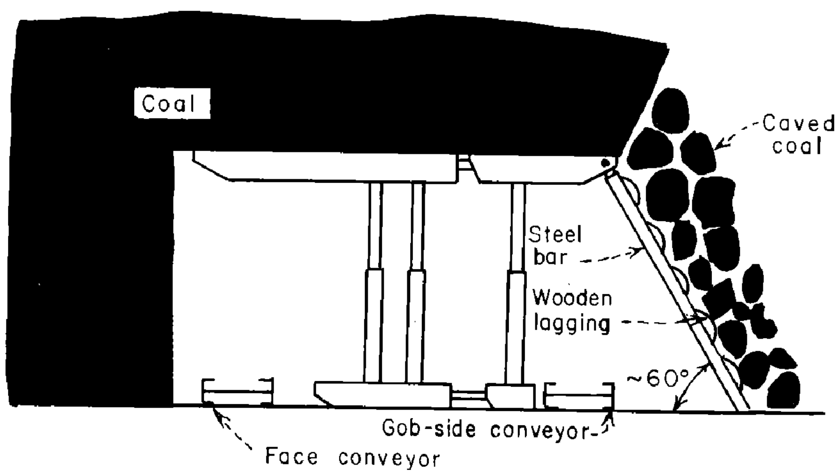


FIGURE 6. - Wooden lagging blocks caved material.

horizontally behind the bars is removed and replaced as necessary to regulate the flow of coal (fig. 6). A third system under development involves mechanized coal drawing by means of hydraulic steel gates at the rear of the longwall supports. In each of these draw-control systems, coal that does not cave naturally is induced to fall by blasting or by pulsed water infusion.

The percentage of coal recoverable by longwall caving depends on how well the caved coal runs onto the conveyor and on the skill of the draw-control operators. If not well-trained and attentive, operators may lose large amounts of coal in the gob or draw too much gob with the coal.

Coal drawing is a dusty operation if remedial measures are not taken. Dust can be reduced by water sprays and, in excessively dusty coalbeds, by infusing the seam with water ahead of mining. Good ventilation also helps control dust.

High-Face Longwall Mining

In the high-face longwall method, a longwall panel of greater-than-standard height is mined in one pass by means of special equipment. Most, if not all, of a moderately high coal face can be mined by this method. The York Canyon mine near Raton, N. Mex., has successfully mined a 10-foot-high longwall face using two-legged shield supports, a double-ended shearer with ranging drums, and an armored face conveyor. The Federal Republic of Germany currently has more than 20 shield-type longwall faces operating in coal seams at least 10 feet thick, some of which dip as much as 30°. A 15-foot-high longwall face at one German mine represents the former upper limit of available equipment. However, shield supports are now on the market for face heights of up to about 17 feet, and shearers that will reach even higher are being designed.

Panel layouts for high-face longwalls are the same as for standard longwalls. Panel entries often are driven seam height (the height of the longwall face). Seam-height entries increase coal recovery by eliminating or reducing the amount of coal wasted in the roof or floor, provide a larger cross-sectional area for ventilating air, and eliminate brow problems at the face-entry intersections caused by a face being higher than the entries. High entries are not used in mines where ground-control problems and economics favor standard-height entries.

In a recent paper about this mining method (7), L. J. Mayhew of Rocky Mountain Energy Co. calls for a conservative approach in selecting the operating height and the operating equipment for an initial high-face longwall--particularly in a new mine where ground conditions are untested and the work force is unskilled in longwall operations. Mayhew suggests starting off with mine-tested rather than prototype equipment at a height of 10 to 12 feet, and cautions against higher longwalls being considered until actual mining conditions have been determined. He also points out that the mine-tested coal shearers and shield supports now available for mining heights of 10 to 12 feet can be readily converted for use at heights of 15 to 18 feet. The cost of such conversion is considerably less than the second set of longwall equipment that otherwise would be required for the same range of seam or face heights.

A problem with the high-face longwall method is that large slabs and lumps of coal break loose along the longwall face. These oversized pieces of coal create jams on the face conveyor at the tail-entry end of the shearer and at the face conveyor-stage loader transfer point. Crushers or lump breakers mounted on the tail-entry end of the shearer and at the conveyor transfer point give some relief. Shearing in only one direction, from the tail entry to the head entry, or cutting the top half of the web on the first shearer run and the bottom part on the return run also helps but productivity decreases. In extreme cases, wooden dowels have been grouted horizontally into the face. Some shield supports have face plates that apply support to the top of the face and retract out of the way as the shearer approaches. Each of these techniques helps reduce the problem but none eliminates it. Inevitably, powered picks and sledgehammers also must be used to break the slabs and lumps of coal.

Moving massive longwall supports from panel to panel is not the problem it might seem to be. When York Canyon mine moved its shield supports the first time, they were the largest and heaviest supports in the United States. Those supports were efficiently and safely moved from the completed panel to a new face with no significant problems, although the floor at the completed face had undulations and was soft (9).

GENERAL GUIDELINES FOR SELECTING A METHOD

Some general guidelines for selecting a longwall mining method for thick coalbeds concern seam dip, seam thickness, coal properties, percent of coal recovery, and productivity.

Each of the three longwall methods described was developed for flat to slightly inclined (less than 25° pitch) coalbeds. The seam-thickness ranges for these methods are given below.

Multislice longwall...	14-100 feet
Longwall caving.......	18-40 feet
High-face longwall....	17 feet maximum (present upper limit of equipment)

Multislice longwall mining requires at least 14 feet of coal for two longwalls to progress at different elevations without being forced out of their horizons by undulations in the roof or floor. In theory, a seam 100 feet thick could be mined by taking several successive slices downward. An entry system has been developed for a 100-foot-thick seam (5).

Longwall caving gives best results in 18- to 40-foot coalbeds. In thinner seams, the volume of top coal for caving becomes too small to take advantage of the main feature of this method, which is high production of low-cost coal obtained by gravity flow. Also, thin layers of top coal often do not cave well. Where the top coal thickness exceeds 30 feet, excessive dilution of the caved coal by waste rock can occur due to the extended time that the top portion of the caved coal and waste rock travel downward together and mix. For acceptance in the United States, longwall caving is limited to friable coal that caves naturally by gravity. Unacceptable safety hazards are introduced where the coal must be forced to cave by frequent blasting, and productivity is reduced to unattractive levels where the coal caves in large blocks that require secondary breakage to fit onto the draw conveyor.

The maximum mining height for the high-face longwall method is about 17 feet, the upper limit of presently available longwall equipment.

Each of these three methods requires the same roof and floor conditions as standard, conventional longwalls.

Coal recovery in a panel is greatest for high-face longwall mining, followed by longwall caving and then multislice longwall mining. This ranking is based on panels being developed by a two-entry system in which entry spacing, pillar size between entries, and the longwall face length (upper face in the multislice system) are constant. Multislice longwall mining has the lowest recovery because of the shortened, lower longwall face that results from locating the lower entries away from the chain pillars in the upper panel. Longwall caving is second in recovery because of caved coal lost in the gob and coal left in the roof over entries. The high-face longwall also wastes roof coal over entries, unless entries are seam height, but aside from that suffers only the normal coal loss associated with standard longwalls. The multislice and caving methods also have the normal coal loss in addition to their specific coal losses.

Based on tons of coal produced per day, the ranking of these three methods, performing as designed in descending order of productivity, is longwall caving, high-face longwall mining, and multislice longwall mining. Highest

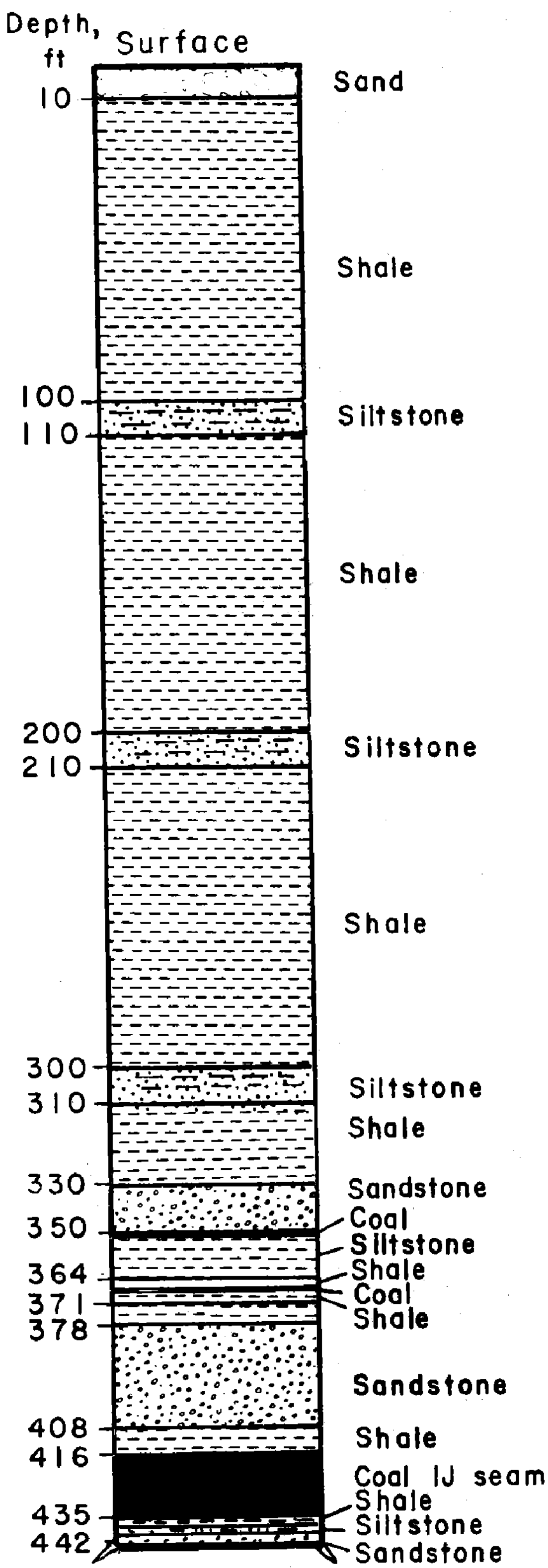


FIGURE 7. - Cross section of site in IJ coalbed.

productivity by longwall caving is dependent upon longwall mining and coal drawing being done simultaneously, a procedure that excessive dust generation could negate in the United States. High-face longwall mining ranks above multislice longwall mining for the same coal thickness because only one setup of the longwall equipment is needed for the high face as opposed to two setups for the multislice faces.

In extremely gassy coalbeds, nonsimultaneous, multislice longwall mining has an advantage over longwall caving and high-face longwall mining. The smaller face area in an upper longwall makes methane control less of a problem. Furthermore, the methane in the lower slice bleeds out of the coal and into the gob above after the coal is exposed by the upper longwall, relieving the methane problem in the lower slice.

POTENTIAL APPLICATIONS IN THE WESTERN UNITED STATES

A search for a typical thick coalbed in the Western United States for which the multislice longwall method could be designed revealed that geological characteristics and physical properties of coalbeds differ from bed to bed; thus no coalbed is typical. Because no typical coalbed was found, the contractor selected a site for which geologic information, rock properties, and mining experience were readily available. The site was near Emery, Utah, in the IJ coalbed. The contract called for designing a mining plan for multislice longwall mining, followed by a field demonstration of the method. Adverse market conditions for coal caused cancellation of the field trial.

Multislice Longwall Mining

Site in IJ Coalbed

The site in the IJ seam had 20 feet of coal that dipped 3° to 5° and was overlain by 350 to 500 feet of thick shales (fig. 7). Thin beds of coal and siltstone also were in the overburden. About 8 feet above the IJ seam was a thick, blocky sandstone stratum, a condition that is common in the Western United States. The coal was blocky and hard, having a grindability index of 40 to 45. In the immediate roof were two sets of joints, a primary and a secondary; the primary struck N 20° E, and the secondary N 84° W.

Spontaneous combustion of coal in the IJ seam at the site selected had not been a problem. However, self-heating could not be ruled out in the mine design for multislice longwall mining because of the coal composition. Its moisture, ash, volatile matter, fixed carbon, and oxygen contents were closely similar to coals in two underground mines in Utah where spontaneous combustion has occurred. Changes in the amount, size, and wetness of coal left behind in the gob by multislice longwall mining, as well as changes in air quality and air pressure across the gob, could have activated the self-heating process.

Mining Method

Nonsimultaneous, multislice longwall mining was selected by the contractor. Compared with the simultaneous method, the nonsimultaneous method required less capital investment because only one set of longwall equipment is needed. It also offers better roof control in the lower slice as a result of the upper slice gob having time to settle and possibly compact.

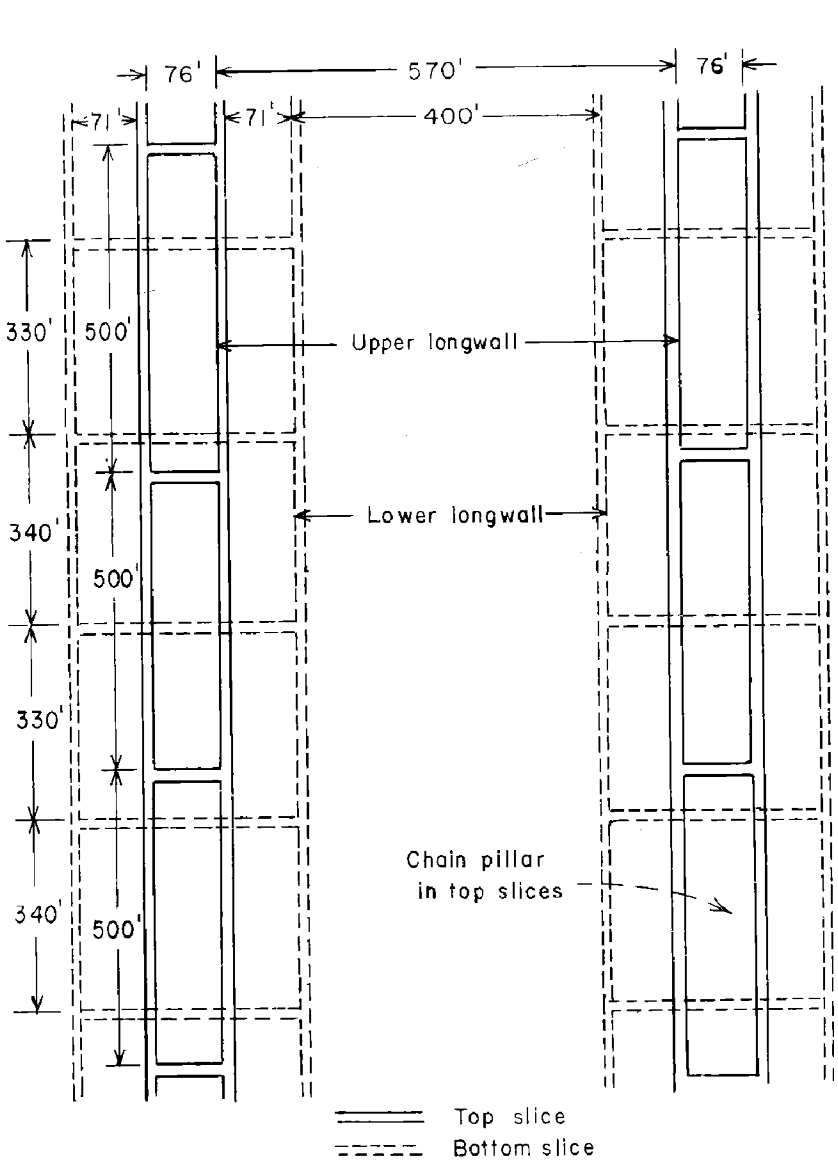
Panel Layout

The panels were laid out to take advantage of the seam dip to drain water away from the longwall faces and to provide a favorable angle between the faces and primary joints in the roof to promote caving behind the longwall supports. Barrier pillars were included around each set of four panels in a slice as a safety measure to facilitate sealing the area, should spontaneous combustion occur and get out of control.

Roof for the lower slice was a 3.5- to 4.5-foot-thick band or parting of low-grade, unmarketable coal in the middle of the IJ seam.

The floor for the lower slice was 1.5 feet of coal needed to protect the underlying fire clay from attacks by air and water.

The contractor, after considering many possible arrangements and numbers of entries for the longwall panels, selected three of the most promising layouts for serious study. Those three layouts, each a double-entry system, are shown in figures 8-10. A double-entry system was necessary to achieve a minimum of 60 percent coal recovery from each multislice panel and to lessen ground control problems experienced previously near the site. More entries would proportionately lower the percentage of coal recovered and increase ground-control problems in entries.



All the entries for the bottom lift are 16 ft wide and 8 ft high.

All the entries for the top lift are 14 ft wide and 8 ft high.

FIGURE 8. - Longwall panel layout with upper entries centered over lower entries.

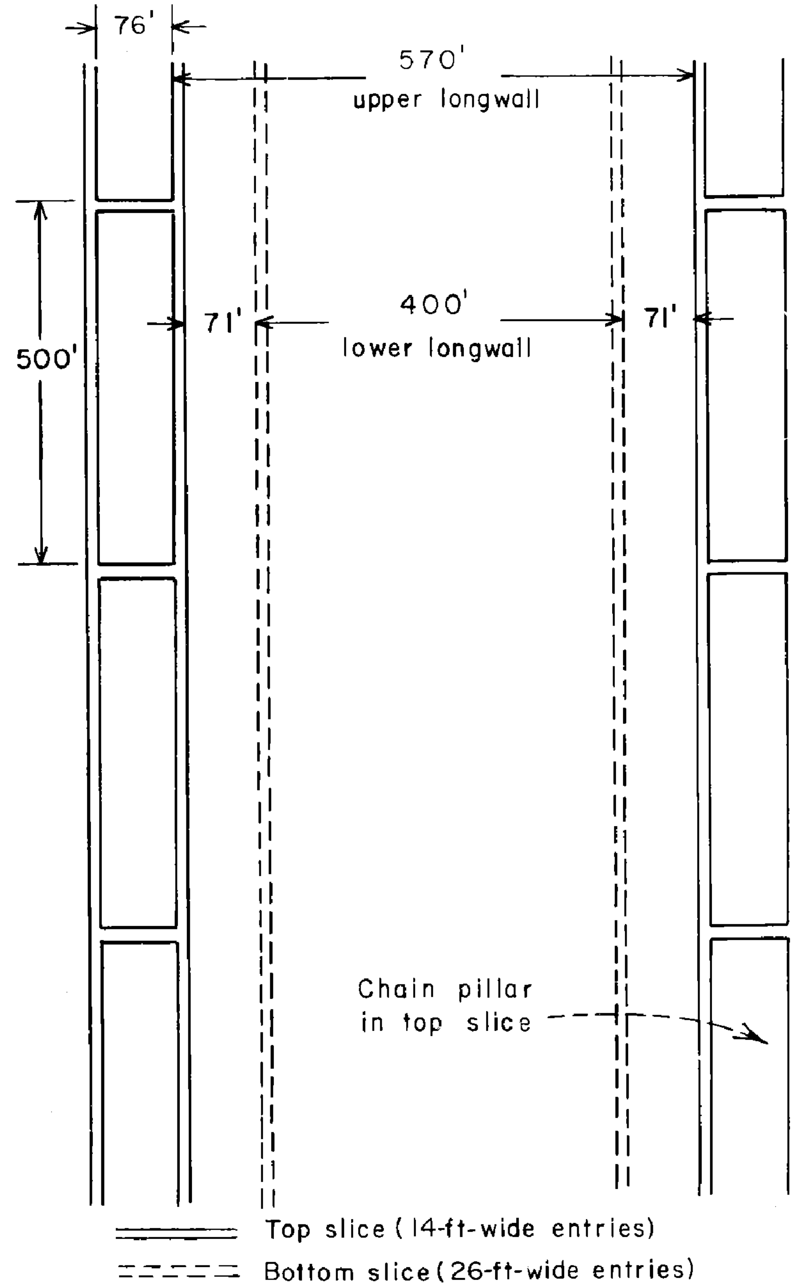


FIGURE 9. - Longwall panel layout with double entries for top slice and single entries for bottom slice.

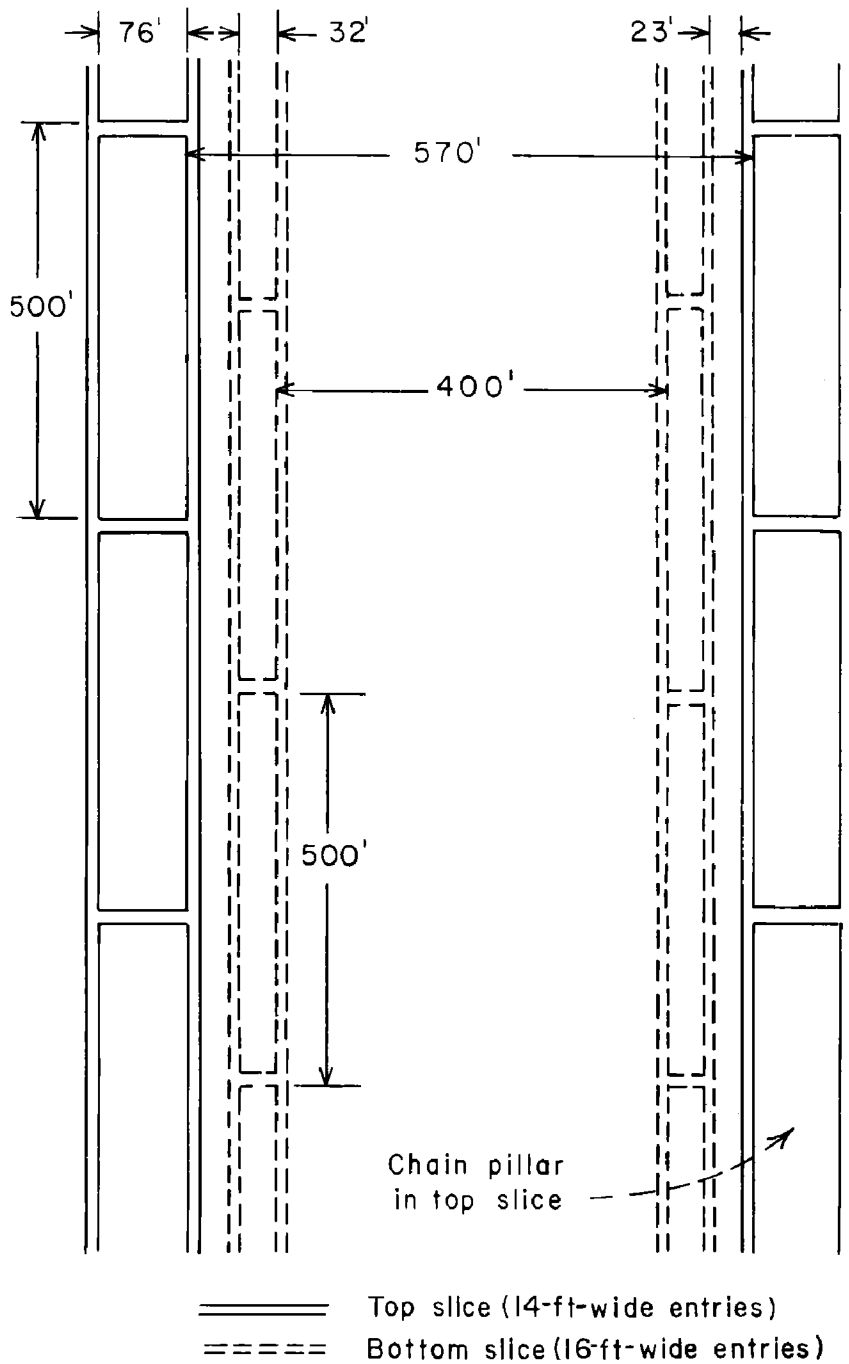
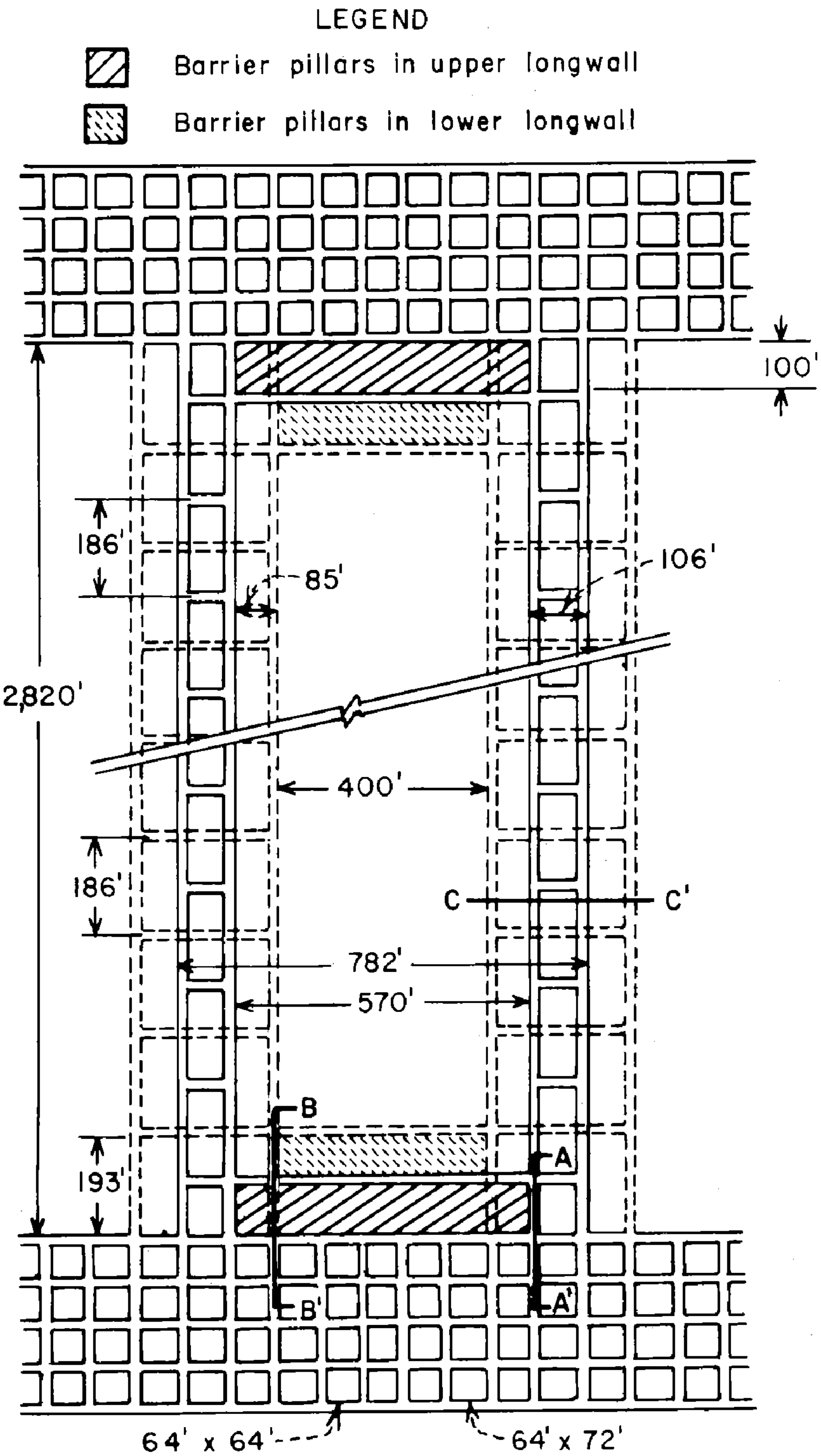


FIGURE 10. - Longwall panel layout with lower entries recessed inside upper entries.

Finite-element models of the three layouts were analyzed to select the most stable arrangement of entries from a rock mechanics standpoint. Assumptions made in the finite-element analysis were as follows: (1) Panels in the upper slice are developed by a double-entry system with 14-foot-wide openings 8 feet high, (2) upper and lower slices are each 8-feet high with 4-feet of coal left between them, and (3) initial vertical pressure is 500 psi with the lateral pressure equal to one-third of the vertical. Rock properties available from the site were included in the finite-element models.

The entry system recommended for trial after the finite-element analysis showed it to be the most stable is shown in figures 11-12. With this layout, longwalls in the upper slice are 570 feet wide by 2,620 feet long, and longwalls in the lower slice are 400 feet wide by 2,434 feet long. The dimensions for an upper slice longwall conveniently divided the area of coal to be mined into equal sections. The spacing of crosscuts between entries in both slices exceeded the 105-foot maximum set by Federal regulations and would have required a variance. The reason for this spacing was to reduce the number of intersections, which, in turn, would improve ground control and safety and minimize costs of maintaining the openings.

Lower panel entries were under gob and 85 feet away from the chain pillars in the upper panels, a location that placed the lower entries in areas of small stress concentration. Experimentation under actual mining conditions



NOTE: Entries and crosscuts 8ft high by 16ft wide. See fig 12 for cross sections.

FIGURE 11. - Plan of longwall panel entry system selected for trial.

probably would have reduced the 85-foot distance, placing the lower entries closer to the upper chain pillars as they are in foreign practice. In turn, the lower faces would have been wider and coal recovery would have increased.

Crosscuts connecting the lower entries passed beneath the chain pillars in the upper panels. Mine operators who have developed openings beneath pillars and have encountered the severe ground pressures often concentrated there might question the decision of having the crosscuts under pillars in this layout. Mining crosscuts under pillars might have been difficult but perhaps not a major problem considering the shallow overburden coupled with the relatively small stress concentration predicted by the finite-element model.

Ground Control in Entries

Mining the upper slice would have been a standard longwall operation. Thus, no unique problems were expected in maintaining the entries and crosscuts. Longwall mining of a lower slice under a previously mined upper slice, however, would have been a first in the United States and would have required an entry support system not yet used in coal mines in the United States.

The support system proposed for lower entries and crosscuts called for permanent steel crossbars and leg supports set on 3-foot centers with lagging between the crossbars. The mining and support installation

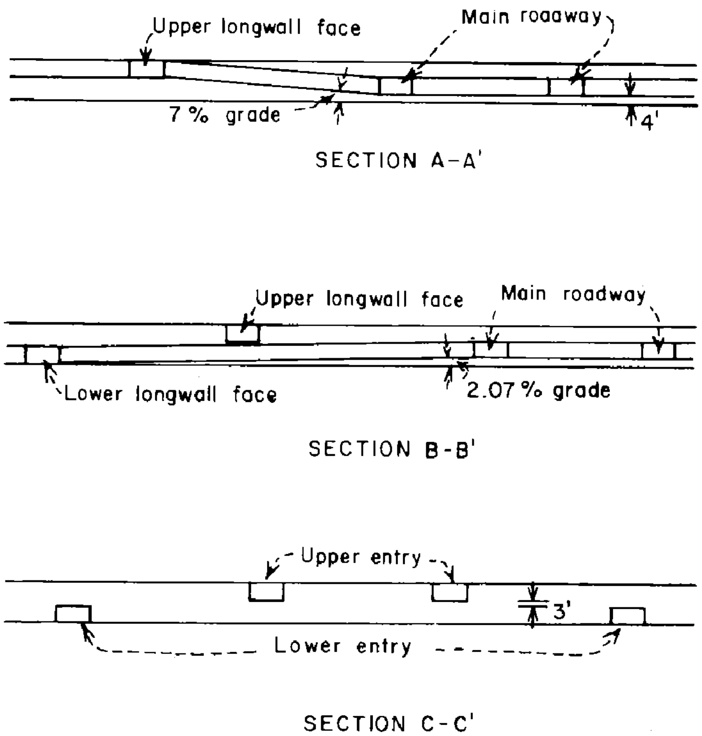


FIGURE 12. - Cross sections from figure 11.

sequence is described in detail in the contractor's final report (13, pp. 163-188). Briefly, the sequence in an entry or crosscut for a 9-foot-deep cut was as follows:

1. Mine left lift to a depth of 5 feet.

2. Set two hydraulic jacks with capboards.

3. Mine right lift to a depth of 5 feet.

4. Set two hydraulic jacks with capboards.

5. Set two temporary wood crossbars on hydraulic jacks starting at a distance of 2 feet from the last permanent support.

6. Mine left lift an additional 4 feet deep.

7. Set two hydraulic jacks with capboards.

8. Mine right lift an additional 4 feet deep.

9. Set two hydraulic jacks with capboards.

10. Set two temporary wood crossbars on hydraulic jacks.

11. Install three permanent steel sets with lagging placed between steel crossbars. Keep the last set 5 feet from the face to provide room for the cutting head of the continuous miner.

12. Remove hydraulic jacks.

Equipment Selection

The same set of longwall equipment would be used for both slices. Mining the upper slice would be a standard longwall operation, whereas longwall mining in the lower slice would be under vastly different conditions (beneath a mined-out area). Hence, the conditions expected in the lower slice governed equipment selection.

Chock shields were selected for the longwall supports. In the contractor's opinion, the chock shield has the major features necessary for successful multislice mining in coal seams of the Western United States. Those features are maximum load-carrying capacity and stability, gob-flushing protection in lower slice, ability to carry tip loads in case of roof fallouts ahead of the supports, maximum travelway and airway for servicing a face and controlling dust and methane, and support advancement while contacting the roof to minimize tramping the roof and to control fallouts.

The mining machine selected was a double-drum shearer with adjustable drum height. A crusher on the tail end of the shearer and extra clearance between the shearer and face conveyor were specified to minimize jamming by large lumps of coal, which commonly occur at faces in thick-seam operations. When necessary, roof fallouts could be conveyed away from the face.

Special features specified for the face conveyor and stage loader were a peak conveying capacity of 900 tons per hour, a crusher on the head-entry end of the conveyor or on the stage loader to prevent large pieces of coal or rock from damaging conveyor belts or clogging transfer points, and a device for preventing fines being carried back by the face conveyor.

The hydraulic powerpack and electrical equipment were standard.

Productivity

Productivity from an upper and a lower longwall panel was estimated at 1,200 and 1,000 tons per shift, respectively; taking into account equipment moves from panel to panel, this estimated production becomes 1,000 and 833 tons per shift. The crew size for an upper and a lower longwall was the same, 10 workers, not including service, support, and maintenance personnel.

Economic Feasibility

An economic analysis made by the contractor of the proposed multislice longwall application at the site selected indicated that coal produced would be cost competitive (f.o.b. mine site) with coal mined underground in the area by other methods (13, pp. 115-132).

Longwall Caving

Established techniques used overseas for drawing caved coal are too hazardous and involve too much manual labor for acceptance in the United States. Both the wire-mesh and the wood-lagging techniques for drawing coal place the draw workers in a confined, cramped, working space close to the cave, especially when hangups of caved coal are being brought down. This situation poses a serious hazard of personal injury to workers. Also, dust often is excessive by U.S. standards, and drilling and blasting to induce caving add more hazards.

Before longwall caving can be introduced into the United States, a longwall support with a mechanized system for reducing the manual labor and the safety and health hazards of drawing caved coal must be developed. A conceptual design of such a longwall caving support has been developed under a Bureau-sponsored contract (12).

Conceptual Longwall Caving Support

Three main criteria were identified and incorporated into the conceptual design. First, the drawing area must have sufficient room for ventilation and for free movement of draw workers, as well as easy access for servicing and repairing the drawing system and draw conveyor. Second, the productivity must be greater than that from longwall caving operations overseas. Third, the face-mining and coal-drawing operations must be as independent of one another as possible so that, if one operation breaks down, the other can be continued to a logical stopping point. A decision that also influenced the design was that, for greatest recovery of caved coal and for ease of drawing, the drawing area should be completely open along the draw conveyor (not obstructed by legs or linkages of longwall supports). Another decision was that the longwall caving support should be designed primarily for use in friable coal that caves by gravity and breaks mostly into sizes compatible with existing conveyor systems. Those sizes are lumps up to 16 inches for up to 10 percent of the total volume and an average lump size of up to 12 inches. Coal that is difficult to cave or that caves in large blocks was ruled out.

The conceptual design (figs. 13-15) is a four-legged, chock-type support, modified by the addition of a gob shield with a sliding gate for controlling the drawing of caved coal. Another modification is a platform at the rear of

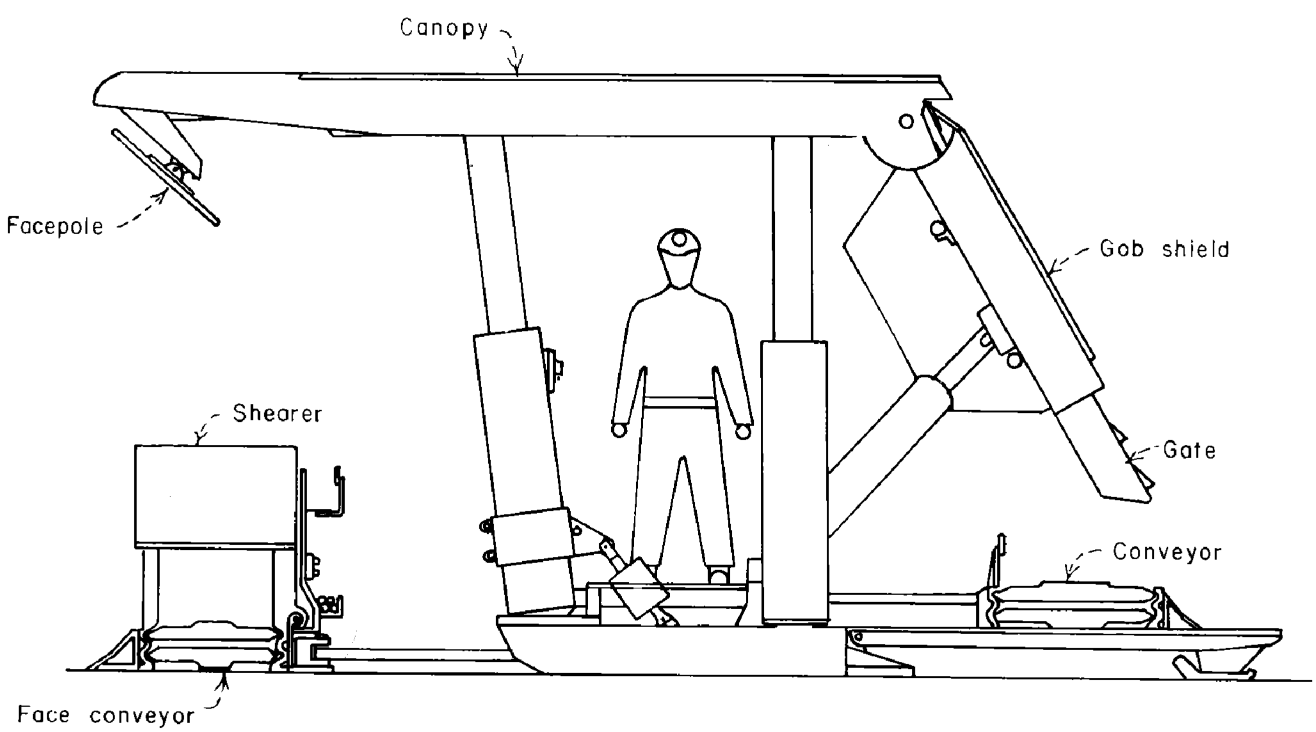


FIGURE 13. - Conceptual design for longwall caving support.

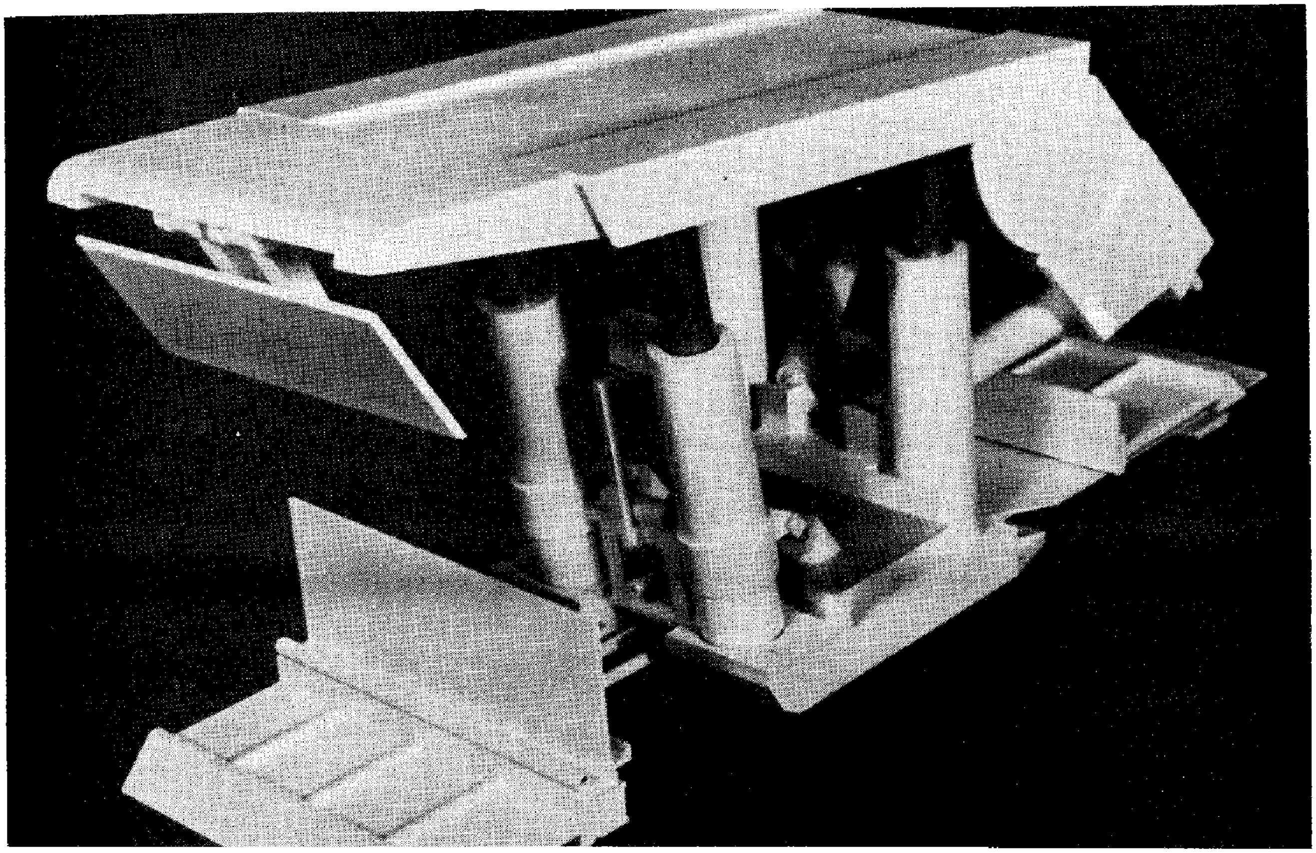


FIGURE 14. - Front view of model of conceptual longwall caving support.

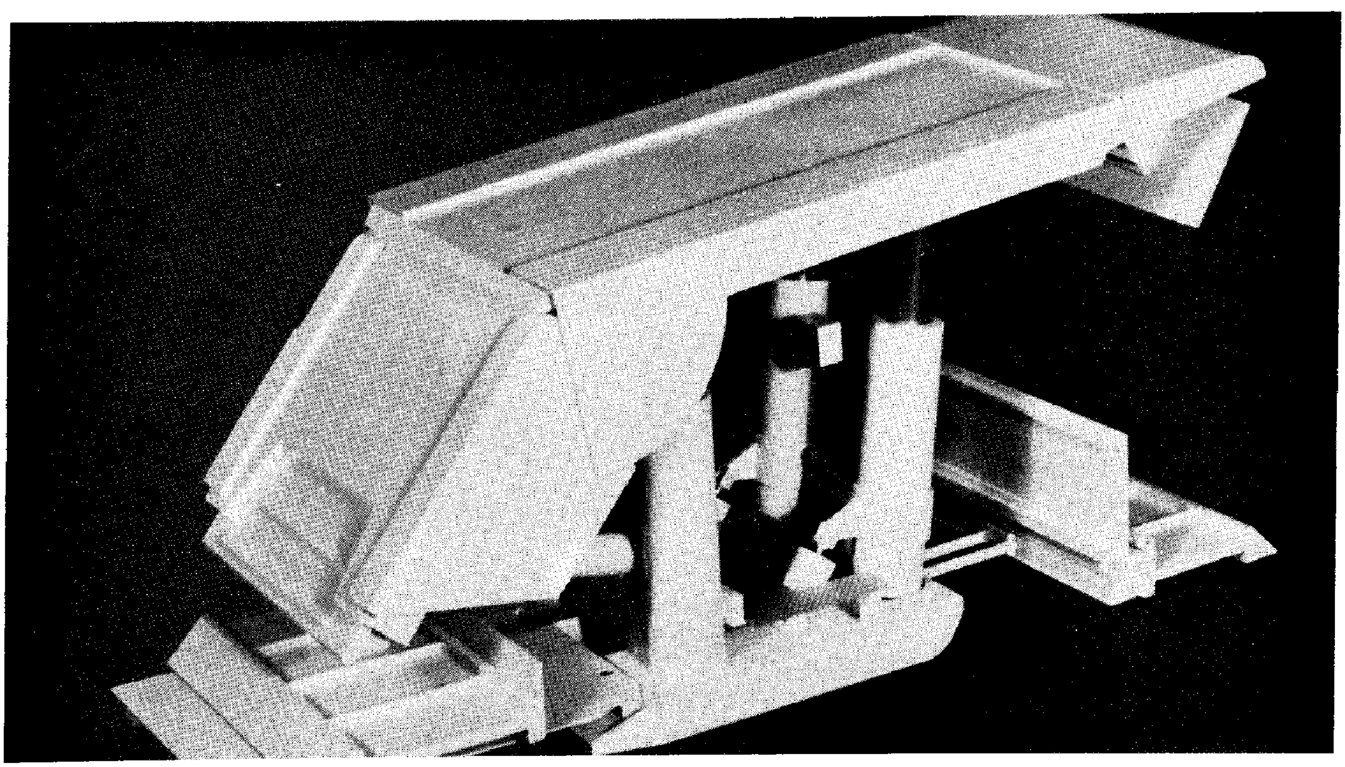


FIGURE 15. - Rear view of model of conceptual longwall caving support.

the support base that provides a smooth floor on which the draw conveyor can be positioned for coal conveying or withdrawn for the sliding gate to contact the floor and block the gob. Still another modification are flushing shields on the roof canopy to lessen the chance of roof coal dropping between supports into the working area. This feature eliminates the need for wire mesh to reduce flushing. Table 1 lists some technical specifications for the support. Complete specifications and details are given in the contractor's final report (12, pp. 29-96).

TABLE 1. - Specifications for conceptual longwall caving support

Support height range:		
Closed	inches	80
Open	do	125
Capacity	tons at 7,500 psi	397
Support legs:		
Setting pressure	psi	5,000
Yield pressure	psi	7,500
Support weight	tons	16
Canopy:		
Length:		
Forepole retracted	inches	173
Forepole extended	do	203
Width	do	78
Forepole capacity	tons	3.75
Base:		
Length	inches	160
Width	do	72
Effective floor contact area	square inches	5,000
Gob shield:		
Length	inches	66
Width	do	78
Gate extension	do	53
Gate width	do	68
Gate cylinder extension force	tons at 3,500 psi	23.5
Gate cylinder retraction force	do	18
Gob shield cylinder thrust	tons at 5,000 psi	91

A retractable forepole attached to the front of the roof canopy rotates forward to support the roof of a fresh cut when the one-web-back system of longwall mining is used. The forepole can also be rotated parallel to the face to serve as a face guard against falls of face coal.

The gob shield is hinged at the rear of the roof canopy and is supported at its lower end by two hydraulic cylinders that control its angle. The integral sliding gate of the gob shield is also hydraulically controlled. To start the flow of caved coal, the gate is opened by retracting it into the gob shield. Coal flow is stopped by closing the gate. If flow does not begin or stops due to arching, it can be started by sliding the gate back and forth or by changing the angle of the gob shield or both. Two horizontal ridges along the face of the gate help loosen stuck coal. In practice, caved coal would be drawn at several adjacent gates simultaneously in a sequential pattern along the draw line. Should it be necessary to blast the top coal, two ports 8.5 inches in diameter in the gob shield can be opened for drilling the coal, allowing the driller to remain under the protection of the roof canopy and gob shield.

The draw conveyor is a 36-inch-wide armored conveyor with two speeds, 254 and 305 feet per minute. The faster speed would be used only for speeding up the drawing process after a delay so that the face operation could proceed. Hydraulic cylinders position the draw conveyor where required on its platform under the gob shields.

Face mining would be done with conventional longwall equipment with no modifications needed for use with the longwall caving supports.

Longwall mining and drawing would be done simultaneously for maximum productivity if dust along the longwall working area can be kept from exceeding Federal standards.

The longwall support as designed cannot be used to support the roof at the intersection of the face and head entry because it does not have room for the drive unit of the draw conveyor and the stage loader, which extends back to the draw conveyor. Other supports would be needed for that intersection.

Hazards

There are two apparent equipment hazards unique to longwall caving that are also present in this conceptual design; both involve the conveying system. One hazard is caused by the stage loader being extended past the face conveyor to also serve the draw conveyor; this is a necessary arrangement but one that blocks the usual direct path around the stage loader to the longwall supports. This problem is solved by a crossover bridge for workers. The other hazard is the possibility that a worker might step or fall into the draw conveyor. A spill plate 16 inches high along the draw conveyor reduces the likelihood of a worker inadvertently stepping onto the conveyor. Recommendations for further lessening this hazard include antiskid surfaces with perforations to prevent oil and water from accumulating underfoot, an emergency stop switch on each support for the draw conveyor, handholds at strategic locations, and chains with snap-link ends strung waist-high between the rear legs of the supports to fence off the draw conveyor.

Methane and Dust Control

Because of the large volume of coal moved by the caving operation, methane and dust control will need special attention, especially if longwall mining and coal drawing are done simultaneously. Good ventilation is essential. The ventilation cross-sectional area between the face and front legs, in the walkway between the legs, and over the draw conveyor totals about 105 square feet when the longwall mining height is 9 to 10 feet. That area will pass 45,000 cubic feet per minute of air at an average velocity of 428 feet per minute. A portion of that ventilating air will flow past the supports into the gob, helping to keep methane and dust along the draw line from entering the face area. Degasification of the coalbed could be used if methane is excessive. Other dust-control techniques would include water sprays on the shearer, along the draw line, and at transfer points in the conveying system. If necessary, the coalbed would be infused with water ahead of mining.

Site in B Seam

Rock properties data, geologic information, and mining experience available from a 22-foot-thick area of the Mt. Gunnison B seam in Colorado were used along with theories of rock mechanics to design a panel layout for longwall caving (12, pp. 221-311). The area of the B seam selected is underlain by a fireclay and overlain by 500 to 2,000 feet of cover. In the cover, 70 to 120 feet above the B seam, is a massive sandstone stratum 20 to 225 feet thick that contains shale partings up to 12 feet thick. Also in the cover and 10 to 70 feet above the B seam is an unmarketable coalbed about 6 feet thick. Well-defined joint systems in the immediate roof allow it to cave readily. The B seam dips 3 to 5 percent and has moderately well-defined cleat systems that make it sufficiently friable for the longwall caving mining method. Gas samples taken from boreholes indicate that methane is present in the coalbed but not in troublesome amounts.

Panel Layout

The panel layout is similar to that of a standard longwall except for ramps that go down to the bottom of the thick seam at the neck of a panel (fig. 16). The ramps have a 5-percent grade through a 300-foot barrier pillar. Panel entries and crosscuts are 8 feet high, on 42- and 80-foot centers, respectively, with widths ranging from 12 to 16 feet, depending upon safe opening span and velocity limitations of the ventilation requirements. A three-entry system is shown, but a two-entry or a single-entry system would increase coal recovery and lessen roof control problems.

A panel is 600 feet wide including its head and tail entries and 3,000 to 6,000 feet long. Coal recovery in a panel is estimated at 55 to 60 percent. For a two-entry system, it would be 65 to 72 percent, and for a single-entry system, it would be 75 to 80 percent. These estimates are based on 85-percent recovery of caved coal and no mining of chain pillars.

A bleeder entry system of ventilation is proposed due to difficulties anticipated in isolating an active panel from adjacent mined-out areas unless excessively large barrier pillars are left between panels. Large barrier pillars would not only waste coal but complicate subsidence prediction and control. However, if self-heating of coal in the gob becomes a problem, barrier pillars may be necessary for sealing off a panel.

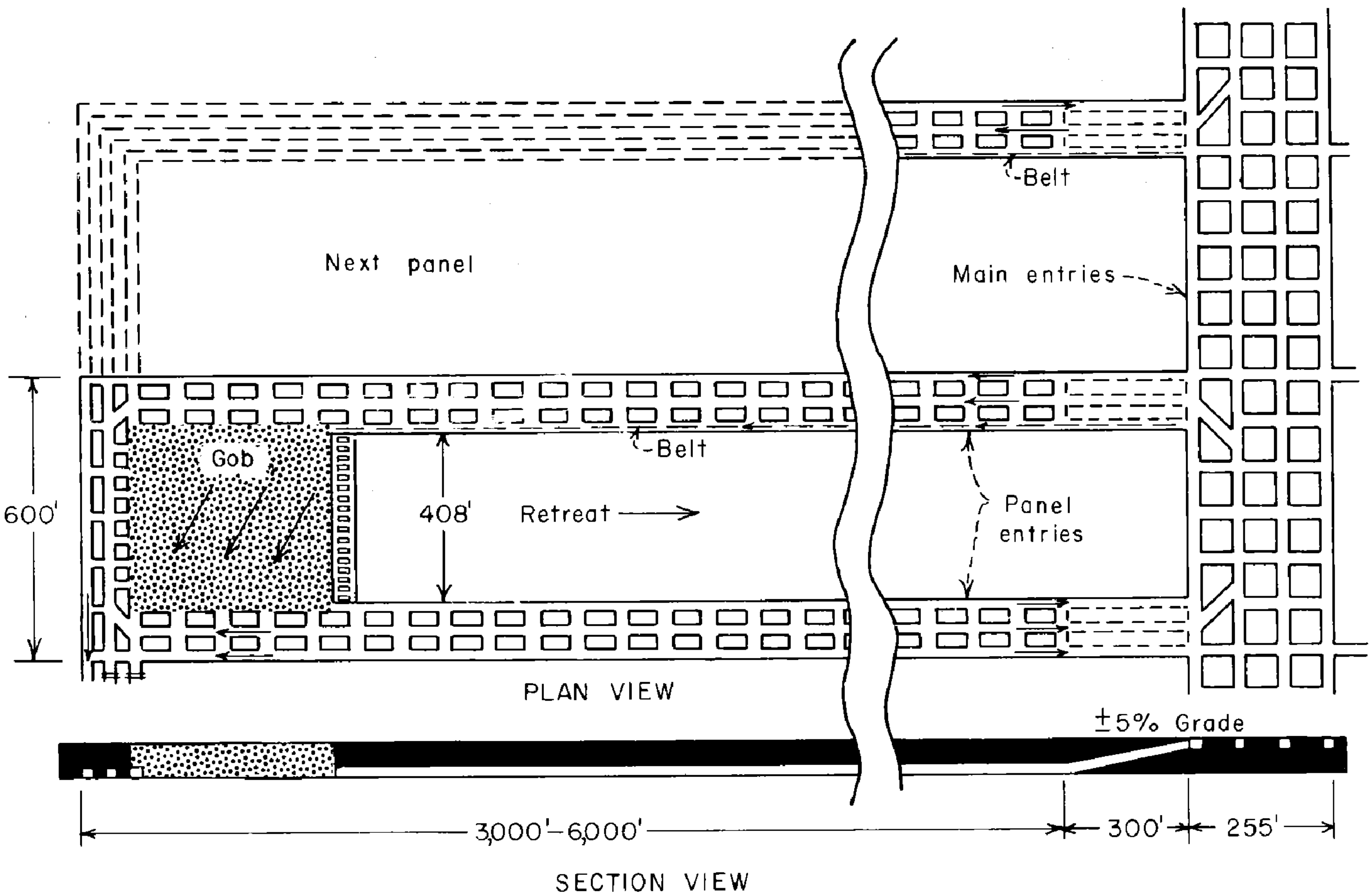


FIGURE 16. - Layout of longwall caving panel.

Productivity

Production from the 8- by 408-foot longwall face (shearer and armored conveyor) in a 3,000-foot-long panel is estimated at 900 tons per shift. Add 1,400 tons per shift from the drawing operation to the longwall output and the total production rate for a panel is 2,300 tons per shift, assuming that longwall mining and drawing are done simultaneously during most of the shift. Based on a longwall crew of 15 to 19 workers, the longwall caving panel would produce at a rate of 121 to 153 tons per employee-shift. Taking in account equipment moves from panel to panel, the estimated production rate is 102 to 129 tons per employee-shift. Service, support, and maintenance workers are not included.

Economic Feasibility

An economic analysis (12, pp. 342-355) based on discounted cash flow, constant 1976 dollars, and a 15-percent rate of return indicates a selling price of $12.30 per ton f.o.b. mine site. The analysis is for a hypothetical mine in the B seam using the longwall caving method and producing coal at an annual rate of 2.5 million tons of run-of-mine coal. With a preparation-reject rate of 12 percent, the salable product is 2.2 million tons per year. An annual tonnage of 20 percent less would increase the required selling price to $15.38 per ton f.o.b. mine site.

Whether these tonnages are attainable in practice can only be determined by further detailed design and testing of the longwall caving support and by an actual underground trial of the support and the longwall caving method.

Spontaneous Combustion

Generally, the spontaneous combustion hazard of coal is greatest in thick coalbeds. Although thick coalbeds of the Western United States are chemically and mineralogically of a type that is prone to self-heating elsewhere in the world, there have been few serious spontaneous combustion occurrences. Apparently, some of the factors that trigger self-heating of coal in other parts of the world have not yet been widely encountered in the Western United States. However, as underground coal mining activity increases in the West and deeper coalbeds are mined by methods that increase coal recovery, mining conditions might approach those overseas and increase the risk of spontaneous combustion. Some of the mining conditions that promote spontaneous combustion are (1) broken and crushed coal in gob areas and pillars, (2) large methane emission, and (3) high ventilation pressures.

Foreign experience has established that ventilated gob areas that contain coal prone to spontaneous combustion are extremely hazardous. Frequent fires in gob areas have resulted in elimination of bleeder ventilation of gob areas in most countries. Ventilation methods have been developed that keep the gob air stale while preventing hazardous concentrations of methane in working places. Similar strategy will become necessary in the Western United States should self-heating of coal become a problem in the future.

FOREIGN PRACTICE

Foreign practice described in the literature and observed firsthand by a contractor's study team is presented below. Details about mining practice, panel layouts, reasons for selecting longwall dimensions, production, crew size, etc., often are not included, partly because they are not included in the literature and partly because they were not available to the study team.

Multislice Longwall Mining

Mining conditions in thick coal seams in most foreign countries that use multislice longwall methods are adverse compared with those in the United States. Coal seams commonly are more than 1,650 feet deep and the coal in many seams is highly prone to spontaneous combustion; that is, broken coal can self-heat and ignite. Because of the severe ground pressures, many mines use longwalls that have single entries supported by steel arches on close centers. Because of the spontaneous heating problem, the gob of a longwall panel often is not ventilated by a bleeder entry system as the panel is mined. The entire panel is sealed immediately after it is completed. Methane gas concentrations also are a problem. Extensive drainage systems that bleed methane from the coal seam are maintained prior to and during mining of a longwall panel.

Japan

Miyanoura Mine

Miyanoura mine, one of three mines of the Miike colliery, Mitsui Coal Mining Company, Ltd., has used a multislice longwall mining system for several years (6). In this mine, a top and lower slice, each about 7 feet high, are mined simultaneously in a 14- to 17-foot-thick coal seam that dips 5° to 7°. Coal recovery is maximized by mining the entire seam thickness. Sectionalized steel matting laid on the floor of the top slice prevents gob from flushing into the working areas of the lower slice. Chock shields support the roof at the longwall faces in both the top slice and lower slice in the seam. Each chock shield has four legs rated at 60 tons each. Ranging double-drum shearers cut the coal; armored face conveyors move it to the head entry. The lower longwall follows 130 to 160 feet (about 10 to 15 days) behind the top longwall. Face length is the same, 330 feet, for the top and lower longwall. Both faces are retreated normal to the strike.

A single-entry system is used for the longwalls. Entries are seam height, approximately 19 feet wide, and supported by yieldable steel arches. Each entry is used twice to mine four retreating faces. Initially, an entry is the main entry for a longwall in the top slice and its companion longwall in the lower slice. Then it becomes the tail entry for the upper longwall and then the lower longwall in the next panel

Fly ash obtained from a power station near the mine is stowed between the floor and roof along the face side of the main entry in both slices as the faces progress (fig. 17). The fly ash seals the gob to prevent spontaneous combustion of coal left in it. Fly ash is transported in bulk form to a station underground where it is converted to a slurry and then pumped to the multislice longwalls. Forms contain the slurry while it solidifies.

Because the lower longwall is only 10 to 15 days behind the upper longwall, the gob of the upper longwall does not have time consolidate and, thus, an artificial roof is required. A strong artificial roof is needed because the gob contains blocks of sandstone. The roof is formed by placing sections of welded steel net (figs. 2, 18) on the floor between the face conveyor and base of the chock shield supports. Hooks on each section hold the sections together while the roof supports advance over them and when they are undermined later.

A crew of 21 face workers per shift operates the top longwall; 14 operate the lower wall.

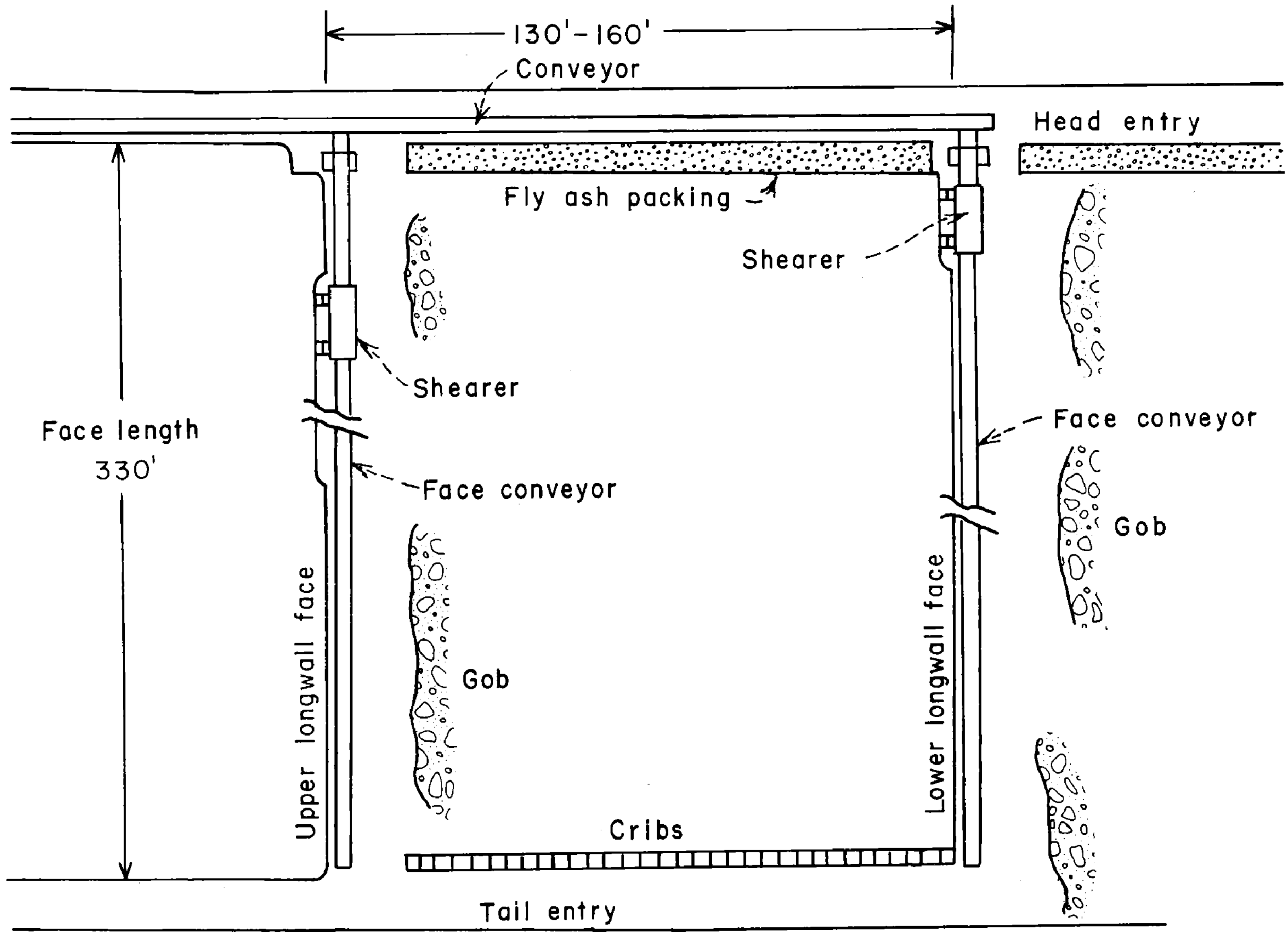


FIGURE 17. - Plan view of Miyanoura mine multislice longwall operation.

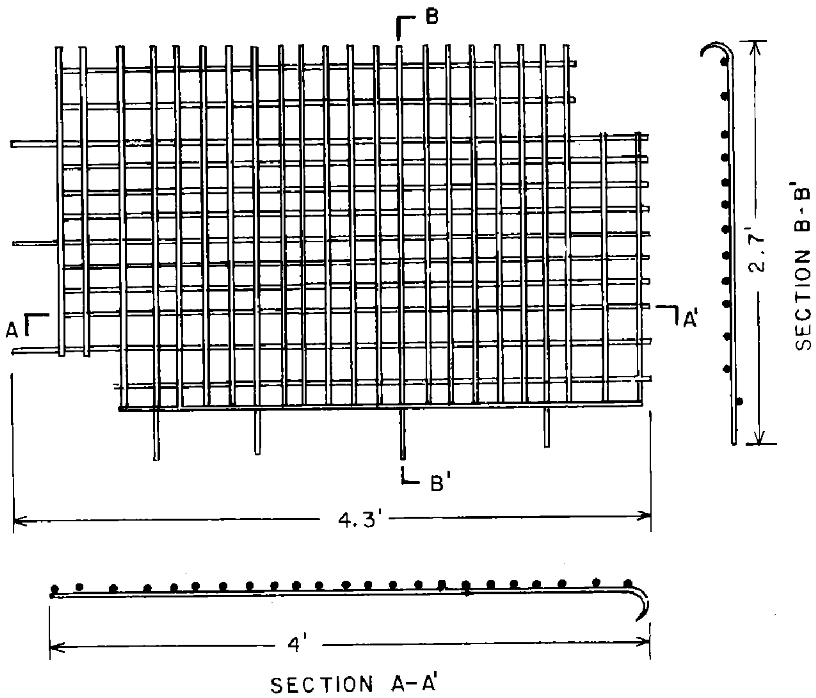


FIGURE 18. - Sectionalized steel net for artificial roof.

Kushiro Mine

Kushiro mine, Taiheiyo Tanko Co., Ltd., uses a nonsimultaneous multislice longwall system in a 16.5-foot, relatively flat seam. The top slice is separated from the 8.6-foot lower slice by a 3.3 to 4.9-foot rock layer, which provides the roof for the lower slice. Gob in the top slice consolidates except where water-bearing dikes and faults are intersected and keep the gob wet. In those wet areas, the layer of roof rock and gob above it tend to cave into the longwall face area, creating severe roof conditions. Chock shields with four 80-ton-capacity legs support the roof. Other face equipment includes a ranging double-drum shearer and an armored face conveyor. Face lengths in the top and lower longwalls are 230 feet and 170 feet, respectively.

A single-entry system is used in the upper and lower longwalls (fig. 19). Entries are 18 feet wide and the height of the slice. The lower longwall entries are recessed 13 feet inside the upper longwall entries to place them under gob, a location considered essential by mine personnel experienced in maintaining lower entries. Steel arches support upper and lower entries. Barrier pillars of coal separate completed longwalls in both slices. After retreat-mining of a longwall panel is completed, the head and tail entries are sealed with fly ash pumped into place in dams as a slime.

Minami Ohyuubari Mine

Minami Ohyuubari mine, Mitsubishi Mines Co., Ltd., operates two longwalls simultaneously in a 17- to 21-foot-thick seam that dips 20° to 23°. The mining heights in the top and lower longwalls are 7.3 to 7.9 feet. The distance between the faces ranges from 165 to 230 feet. Both faces are more than 660 feet long and are retreated normal to the strike, which results in a 20° to 23° pitch along the faces.

Wire mesh placed on the floor of the top slice and reinforced with steel bands restrains the gob from flushing into the lower longwall face. This artificial roof is supplemented by a sludge pumped into the upper-slice gob during mining. The sludge, a mixture of 95 percent tailings from the preparation

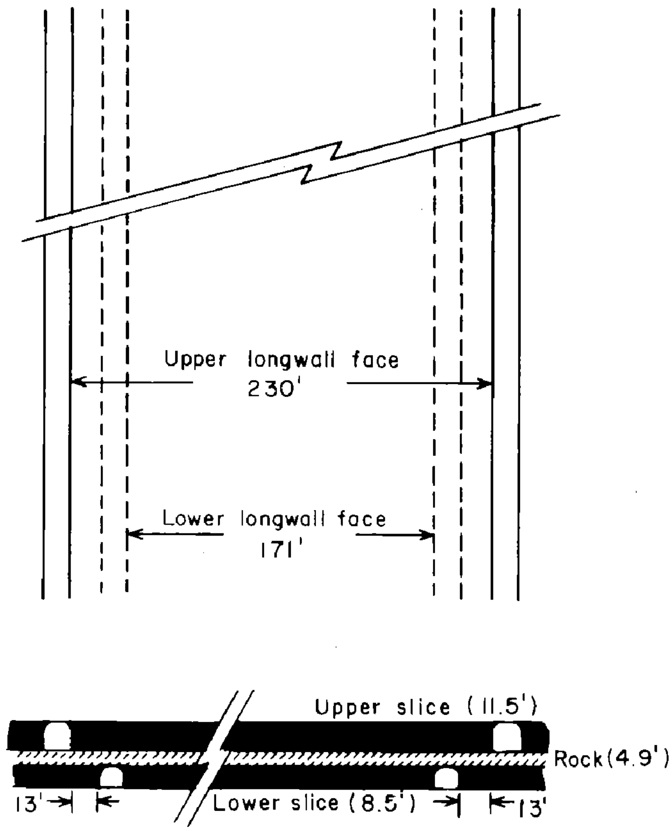


FIGURE 19. - Multislice longwall face layout in Kushiro mine.

plant and 5 percent cement, effectively solidifies the bottom part of the gob, mostly shale, even though the gob is undermined within a few weeks.

Roof support at the upper face consists of single hydraulic props and link bars of the pin-joint type. Coal is airblasted from the face onto an armored face conveyor. Airblasting is used due to the extreme gassiness of the coal seam.

Chock supports, a single drum shearer, and armored face conveyor serve the lower longwall. Methane gas is not a major problem in the lower longwall. Apparently, the methane bleeds out of the coal after it is exposed by the upper longwall.

Entrance to the longwalls is through a two-entry system; entries extend from the bottom of the lower longwall to the top of the upper longwall to serve both walls and are supported by steel arches. In places, the arches are installed in pairs with a 0.5-meter (1.6-foot) spacing between pairs to combat heavy loads. Packs are installed in the upper longwall along the head and tail entries to seal the gob, which self-heats, and to help keep the entries open for the lower longwall. The packing at the main entry is stone dust with a line of cribs on both sides. At the tail entry, a sludge pack is used with a line of cribs on the gob side. The sludge comes from the preparation plant and has cement added to speed solidification.

The combined coal output per shift from the upper and lower longwalls averages 635 metric tons with a crew of 21 workers per shift in the upper wall and 18 workers per shift in the lower wall.

Shimizusawa Mine

Shimizusawa mine, Hokkaido Tanko Kisen Co., Ltd., longwall-mines a 6.6-foot lower slice directly under compacted gob of a 6.6-foot upper slice mined 8 to 9 years previously. No artificial roof is used or needed. Single hydraulic props topped with link bars support the compacted gob at the lower longwall face. A fixed drum shearer cuts the coal; an armored face conveyor moves the coal to the main entry. A face is 462 feet long, dips 20° to 25°, and is mined on the advance.

A single-entry system provides access to the lower longwalls. Both the head and tail entries are under gob and are recessed 20 to 26 feet inside the old upper single entries. This spacing from the upper entries is based on experimentation which started with a 50-foot distance and, through successive trials, was reduced to 20 to 26 feet. Steel arches support the entries.

Mine personnel made the following interesting comments about using compacted gob for roof: (1) Bad roof only occurs if the old gob has not been drained correctly; (2) thick sandstone is no problem if a couple of meters of soft material occurs between the coal and sandstone. Experience has shown that the sandstone breaks into big lumps that set in the soft, shaley cushion, which reconsolidates almost into a new compact layer of shale.

England

Multislice longwall mining practice in the Daw Mill mine has advancing faces 8 feet high in the upper slice and retreating faces, also 8 feet high, in the lower slice. The lower slice is not mined to the gob; instead, a 3.3- to 5-foot layer of coal is left between the slices for roof support. Upper faces are approximately 760 feet long; lower faces are about 610 feet long, with their entries driven in the destressed area below the gob of the upper longwalls. After a panel is mined, it is sealed and monitored through pipes in the bulkhead seals for indications of spontaneous combustion.

A change being employed successfully is an advancing longwall 10 feet high instead of 8 feet (8). The 10-foot face uses 250-ton chock shield supports, two single ranging drum shearers with a chainless haulage system, and an armored face conveyor. Production from the entries is used to build packs at the face ends behind the supports to seal the gob along the entries. Head and tail entries are single entries driven arch-shaped 15 feet wide by 12 feet high. Nonyielding steel arches on 2.3-foot centers support the entries.

Head and tail entries in lower longwalls often are single entries and trapezodial in shape. These entries are 46 feet inside the pack walls of the upper longwall, placing them well within the destressed area below the upper longwall gob. Three-piece steel sets spaced on 3-foot centers support the entries. Wire mesh prevents loose coal from falling into the entries from the roof and ribs.

Poland

Poland uses a nonsimultaneous multislice method in which nine longwalls are completed, one at a time, in the upper slice before longwall mining commences in the lower slice. Opening a large area in the upper slice provides time for the gob to compact before being undermined. Gob is not undermined for 2 to 4 years, and, when it is undermined, 1 meter of coal is left between the gob and bottom slice for extra protection for the bottom slice. Gob compaction requires at least 60 percent shales and clays along with adequate water and overburden pressure. Fly ash or magnesium lime are added to a gob deficient in shale and clay to induce consolidation. The ash or lime is added to the gob directly behind the roof supports.

Romania

Thick coal seams in Romania have been longwall mined in two slices taken simultaneously (2). Where the lower longwall is 2 to 3 months behind the upper face, a 1.7-foot thickness of coal is left between the slices. Where the lower face is more than 6 months behind, no intervening coal is left because the marls and clays of the gob of the upper slice, helped by water infiltration, compact to form a satisfactory roof for the lower slice.

U.S.S.R.

A coal seam 18.5 feet thick has been longwall mined in two slices in the U.S.S.R., but no details were available.

General

In some coal mines, the top slice is backfilled as it is longwall mined. The following conditions necessitate this practice: (1) An exceptionally friable roof, (2) a strong roof that resists caving, (3) coal that readily self-heats, (4) aquifers in the overburden, and (5) surface-subsidence restrictions. Backfilling is done manually, hydraulically, or pneumatically.

Overlying the thick coal seams in some areas of Poland are massive, strong roof rocks that tend to cantilever instead of cave. The technique developed for this situation involves longwall mining the lower slice first and, as the face advances, backfilling with sand slurry to support the coal roof (11). After the roof has settled onto the backfill, the top slice is longwall mined conventionally. Labor and timber costs of backfilling triggered attempts to automate the lower longwall operation, but success was minimal.

India has also longwall mined above a backfilled slice (3). A 3-foot coal parting was left over the backfilled bottom slice, over which a middle slice was taken. A top slice was longwall mined over the backfill of the middle slice.

Research is being done, in Japan in particular, to reduce the costs of installing artificial roof. One approach is mechanization of the roof-placing activities; another approach is to eliminate artificial roof by working directly under the gob with longwall supports that quickly support the roof (gob) exposed by the shearer and provide contiguous roof coverage to prevent flushing of roof material.

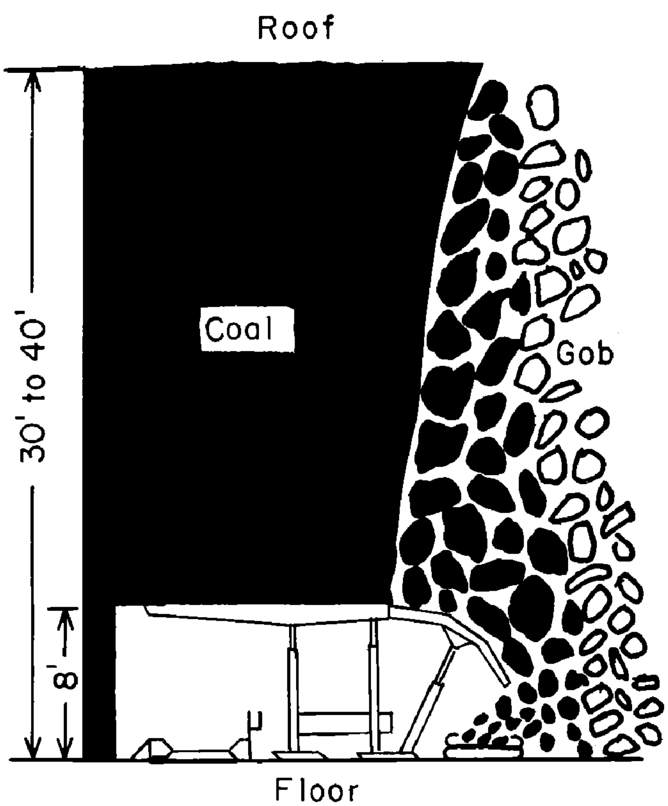


FIGURE 20. - Rozelay mine longwall caving supports.

Longwall Caving

France

France has used longwall caving for more than a decade. In Rozelay mine, the longwall face at the bottom of the coalbed is mined by a double-drum shearer and an armored conveyor. The roof supports are frame type and at the rear have curved extension bars called bananas (fig. 20), which can be moved up and down by hydraulic cylinders to induce flow of caved coal. Wire mesh placed over the frame supports prevents fractured top coal from flushing between the supports and also controls the drawing of caved coal at gob side. Caved coal flows through windows approximately 20 inches square cut into the wire mesh at locations above the gob-side conveyor. Several windows are drawn at a time, and flow from a window is stopped before waste rock from the gob becomes excessive as judged visually by the miners. Coal flow usually stops by itself when no longer induced mechanically or manually. When it does not stop naturally, the window is sewn shut. Hangups created by large blocks of coal are brought down manually, with explosives or hydrobreakage techniques, or are abandoned.

Spontaneous combustion of broken coal has been a problem in Rozelay mine, causing abandonment of some panels. A measure for reducing coal self-heating occurrences involved changing from advancing longwalls to retreating longwalls without bleeder entries to eliminate air leaks and airflow through the gob. Another measure is saturating the air in the gob with nitrogen. These solutions have permitted complete extraction of panels.

Darcy mine uses longwall caving also but advances a face by hand because the coal is so friable it sloughs excessively when a shearer is used and the overbreak creates roof control problems at the face.

Some data from a longwall caving panel at St. Eloy mines follow: Face length, 180 feet; face height, 8.6 feet; top coal thickness caved and drawn, 17.8 feet; and daily face advance, 4.9 feet. The daily production was 970 metric tons with 42 workers, or 23 tons per employee-shift. Conditions in this mine were not ideal in that the coal often was too cohesive to fracture and required blasting to loosen it for the drawing process. Under better conditions, the daily face advance was 7.4 feet on a 231-foot face.

Callier (4) states that longwall caving is most successful where the coalbed is 18 or more feet thick, the coal is friable, and the pitch of the seam is less than 20°. Steeper seams can be mined by the longwall caving method but require special techniques.

Problems encountered in France with this method are face sloughing, inexperienced draw workers leaving too much coal in the gob, and down time caused by coal and waste rock jamming the draw conveyor.

France is experimenting with roof supports that will eliminate the need for wire mesh and reduce manual labor in drawing caved coal. The experimental supports are two-legged shields that have hydraulically operated doors or gates at gob side that open to create windows for drawing coal. A hydraulically operated finger in the window induces flow of coal.

Yugoslavia

The greatest progress in mechanized mining, including longwall caving, in Yugoslavia has been in the Valenje mine (1). In this mine, 30-foot thicknesses of lignite coal are mined by longwall caving. The longwall face height is 6 to 8 feet, leaving 22 to 24 feet of top coal for recovery by caving and drawing. Because the coal is ligneous (woody), it often must be blasted to produce a good cave.

Frame supports, made to specifications by Hermann Hemscheidt Maschinenfabrik, support the roof at the longwall face (fig. 21). Telescopic bars hinged to the rear of the roof canopy hold back the caved coal and are retracted upward by internal hydraulic cylinders during drawing. Wire mesh is not used with these supports. Instead, wood lagging is placed horizontally across the upper part of the rear bars as needed to choke off caved coal or gob. Pegs on the bars hold the lagging in place. An armored draw conveyor between the base of a roof support and the rear bars moves drawn coal to the head entry.

A single-drum shearer cuts the coal at the longwall face, but a double-drum shearer is being considered to speed up mining at the ends of the face. Coal mined at the face is taken away on an armored conveyor. Face lengths range from 165 to 200 feet.

Ahcan (1) states that production costs for caved coal, even when blasting is done, are approximately one-fourth of the costs for the longwall mined coal, and that the total production costs for longwall caving are one-half the costs incurred for a standard mechanized longwall 9.9 feet high.

Operations research into longwall caving showed that a minimum advance rate of 6.5 feet per day could be expected in a panel 200 feet wide by 33 feet thick.

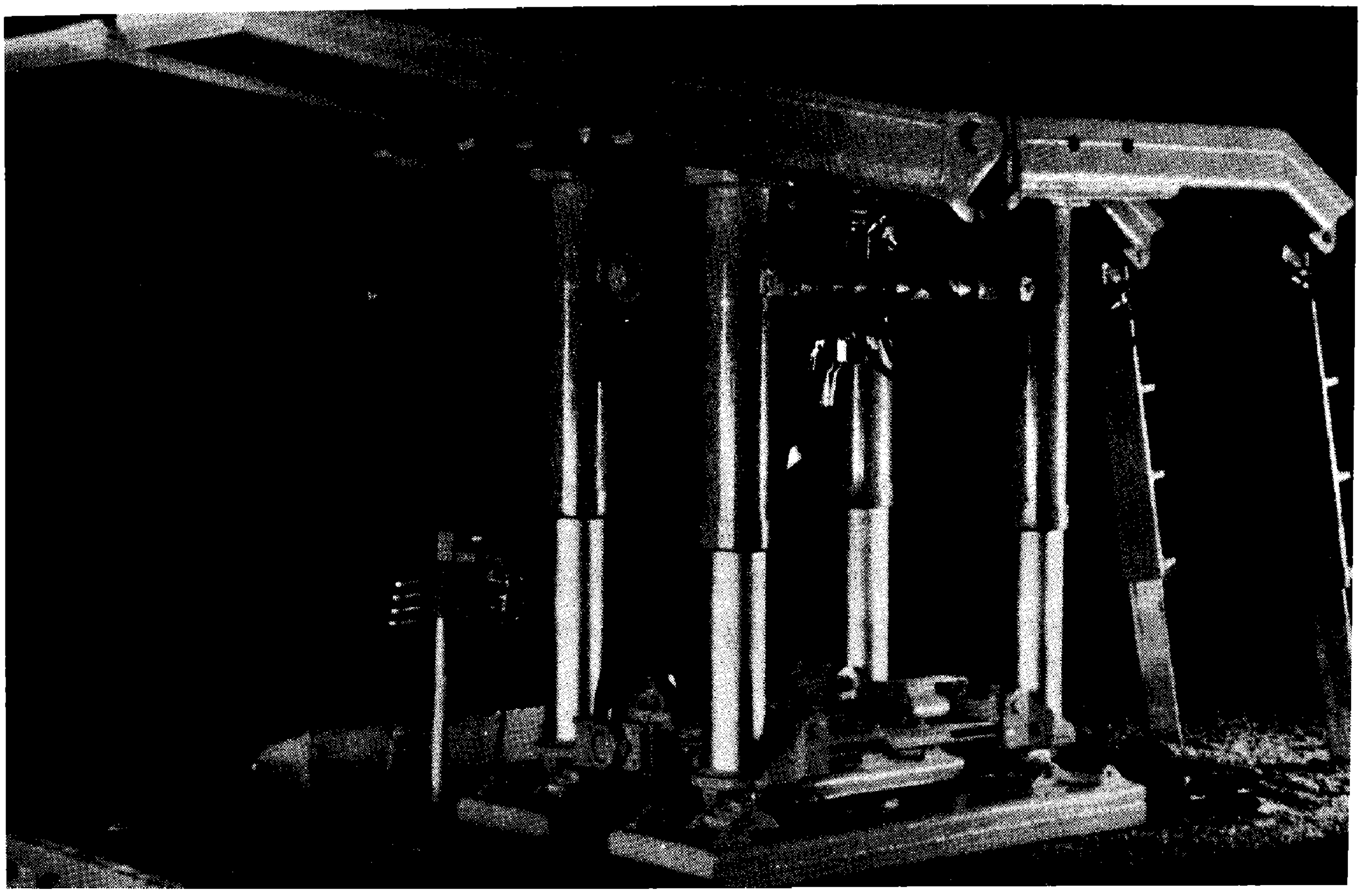


FIGURE 21. - Hemscheidt frame supports used at Valenje mine.

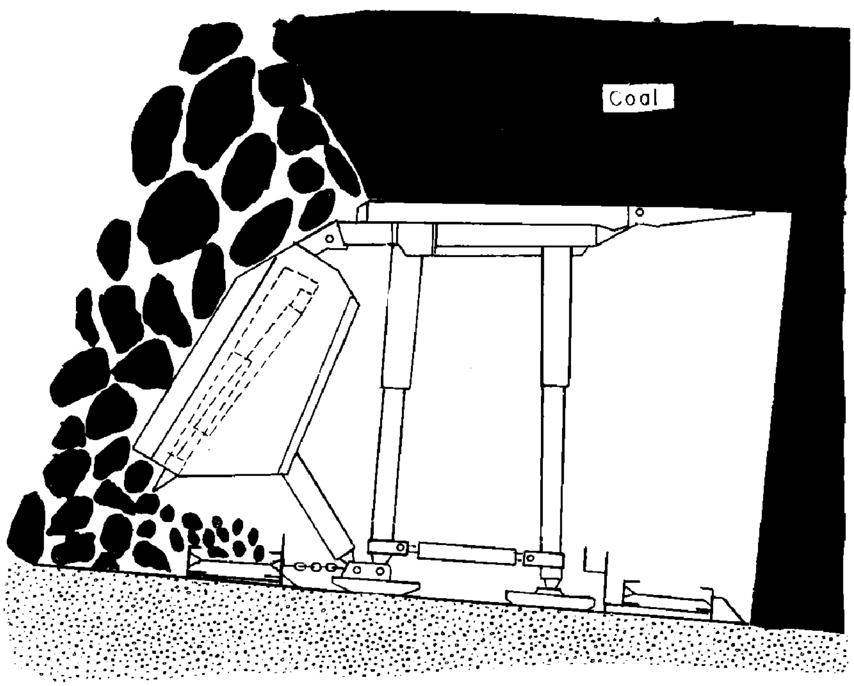


FIGURE 22. - Russian M-81V supports for longwall caving.

U.S.S.R.

An approach to longwall caving in Russia involves a novel prototype longwall support known as the M-81V (fig. 22). This support has a gob shield that has a sliding gate for shutting off the flow of caved coal or waste rock from the gob. The gob shield, which is pinned to the rear of the roof canopy and attached to the base of the support through a hydraulic cylinder, can be pumped to stimulate coal flow. By adjusting the angle of the gob shield and the distance its gate is open, the draw rate is controlled. The gate is designed for shearing lumps of coal. A gob side conveyor attached by chains to the supports is pulled along as the supports are advanced. Each support has only two legs, one front and one rear, connected near the bottom by a hydraulic cylinder and at the top by the roof canopy. Each canopy is connected to its neighbor by a sliding joint to provide vertical stability for the support and independent forward motion.

Face equipment used with the M-81V includes a ranging double-drum shearer and an armored conveyor.

An experimental application of the M-81V longwall caving system was started in early 1976 in a 19-foot coal thickness at a depth of 792 feet. The longwall, mined on retreat, dipped 10° to 12°, had a 158-foot face length and was 9 feet high. The success of this application, made in the Lenin mine, is not known because further information has not been made available.

Poland

Jaworzno mine has a longwall caving operation in a 15-foot coalbed that dips 6° and is 1,155 feet beneath the surface (10). Hemscheidt four-legged chocks rated at 280 tons support the coal roof along the 330-foot face; a double-drum shearer mines the face, and an armored conveyor moves the mined face coal. Wire mesh over the chocks reduces flushing between supports and restrains caved coal at gob side. An armored conveyor at gob side completes the machinery along the longwall. Coal recovery in a panel having a single-entry system is 80 percent.

SUMMARY

Three longwall mining methods used for mining thick coalbeds overseas have potential for increasing coal recovery and productivity underground in the Western United States. The methods are multislice longwall, longwall caving, and high-face longwall. In the multislice longwall method, the coal is removed by longwall mining a lift or slice at the top of the coalbed immediately beneath the roof rock, which is allowed to cave and becomes the roof of the lower slice which is also longwall mined. In longwall caving, a longwall at the floor of the coalbed undermines the upper coal, which caves and is recovered at the rear or gob end of the longwall supports. In high-face longwall mining, a single longwall is mined the entire coal thickness in a panel in one pass.

None of these methods as practiced overseas is directly transferable to the United States. In foreign countries, single-entry systems predominate in longwall panels. Single entries provide greater coal recovery in panels while reducing ground control problems created by intersections and chain pillars. Also, in foreign applications, the gob area of a panel is not ventilated by a bleeder system of entries as is required in the United States. Experience overseas has repeatedly shown that spontaneous combustion of coal is promoted in ventilated gob; hence, bleeder systems have been eliminated. Single-entry systems in longwall panels are not critical to the success of these longwall methods in the Western United States, but bleeder systems might have to be eliminated to curb self-heating of coal left in the gob.

Artificial roof such as wire mesh used in multislice longwalling in some countries would be prohibitively expensive and labor-intensive for use in the United States. Compacted gob or a layer of coal are more likely alternatives in the United States for the roof of a lower slice. A coal layer could add to the spontaneous combustion problem, however, because the coal layer is left behind in the gob as mining progresses.

In the longwall caving method, the drawing of caved coal as practiced overseas is too dusty, hazardous, and arduous for acceptance in this country. New longwall caving supports that mechanize coal drawing would help but would be unproved equipment subject to design modifications dictated by experience under actual mining conditions and continual use.

High-face longwall mining in the 15-foot-and-higher range would involve longwall equipment not yet proved under U.S. conditions.

None of the problems associated with transferring these three methods to the Western United States appears major. Revisions of Federal mining regulations (not relaxation but redirection for special conditions) would erase some of the problems; others would be solved by machinery modifications and procedural changes.

REFERENCES

1. Ahcan, R. (Progress in the Mechanical Extraction of Thick Coal Seams in Yugoslavia). Glückauf, Feb. 5, 1976, pp. 127-132.

2. Almasan, B. Rumania - Mechanization of Lignite Mining Satisfies Energy Demands for the 1970's. Min. Mag. (London), v. 122, No. 1, January 1970, pp. 30-37.

3. Bannerjee, S. P., and M. H. Maung. Convergence Studies in a Hydraulically Stowed Multi-Lift Longwall Panel. Colliery Guardian, November 1975, pp. 474-476.

4. Callier, R. Longwall Mining With Sublevel Caving. Min. Cong. J., v. 58, No. 12, December 1972, pp. 43-48.

5. D'Appolonia Consulting Engineers, Inc. Mine Entry System for Longwall Top Slicing of Thick Coal Seams. 1977, 385 pp.; available for consultation at the Bureau of Mines Denver Mining Research Center, Denver, Colo.

6. Maemura, S. Development of Self Advancing Support for Upper Face in Longwall Slicing System at Miike Colliery. Pres. at Fall Meeting, SME-AIME, Denver, Colo., Sept. 1-3, 1976, 19 pp.; available for consultation at the Bureau of Mines Denver Mining Research Center, Denver, Colo.

7. Mayhew, L. J. Application of Shield Supports in Longwall Mining of Western Thick, Pitching Coal Seams. Pres. at the Am. Min. Cong. Conv., Denver, Colo., Sept 26-29, 1976, 21 pp.; available for consultation at the Bureau of Mines Denver Mining Research Center, Denver, Colo.

8. Mine and Quarry. Ten Feet Tall at Daw Mill. July 1976, pp. 17-23.

9. Oitto, R. H., D. W. Wisecarver, and W. E. Sikes. Moving Longwall Shield Supports at the York Canyon Coal Mine, Raton, N. Mex. BuMines IC 8747, 1977, 19 pp.

10. Richards, O. J. Study of Coal Mining Research in Overseas Countries. Internal Rept. to the Australian Coal Industry Research Laboratories, Ltd., August 1977, pp. 35-36; available from the Bureau of Mines Denver Mining Research Center, Denver, Colo.

11. United Nations, Economic Commission for Europe. Symposium on the Methods of Working Thick Coal Seams, Bucharest, Sept. 5-9, 1966. United Nations, New York, 2 v., 1968, 169 pp.

12. Wallis, M. G., P. G. Reeves, D. P. Henneuse, C. W. Winters, J. B. Rusconi, and J. B. Page. Longwall-Caving Mining Method for Thick Coal. Design and Feasibility Study. Final Report, Volume 1. BuMines Open File Rept. 133a(1)-77, 1977, 425 pp.; available for consultation at the Bureau of Mines facilities in Denver, Colo., Twin Cities, Minn., Pittsburgh, Pa., and Spokane, Wash.; at the National Library of Natural Resources,

U.S. Department of Energy facilities in Carbondale, Ill., and Morgantown, W. Va.; and from the National Technical Information Service, Springfield, Va., PB 275 240/AS.

13. Wilson, J., F. Ucciardi, and W. Armstrong. Multilift Longwall Mining Methods for Thick Coal: Design and Feasibility. BuMines Open File Rept. 135-77, 1976, 329 pp.; available for consultation at the Bureau of Mines facilities in Denver, Colo., Twin Cities, Minn., Pittsburgh, Pa., and Spokane, Wash.; at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; at the U.S. Department of Energy facilities in Carbondale, Ill., and Morgantown, W. Va.; and from the National Technical Information Service, Springfield, Va., PB 272 460/AS.

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