TWO-ENTRY DEVELOPMENT FOR LONGWALL MINING

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The two-entry mining system has been the predominant development method of mining at the Sunnyside Coal Mines of Kaiser Steel Corp., Sunnyside, Utah, since the onset of mining in 1897. This system has been effectively used for slope development as well as room-and-pillar extraction and is presently the major source of longwall mining.

Before the advent of the continuous miner and its associated multiple-entry development, the two-entry system was the most utilized system in the West. Utah Fuel and Union Pacific mines were using two-entry systems as their primary development techniques. This system, with its narrow entries and small pillars, gave a safe and reliable method of coal extraction under the shale and sandstone tops of the western United States coal mines.

At Kaiser Steel Sunnyside Mines, introduction of longwall mining for the purpose of increasing productivity, while creating a safer work environment, took place in the late 1950s. At that time, management was faced with the problems of rapidly increasing cover and extensive mountain bumps. These mountain bumps, which occur under deep cover (1200 to 2000 ft), are associated with the room-and-pillar method of mining.

John Peperakis, then manager of Sunnyside Mines, established longwall mining as the major mining method at Sunnyside. He successfully used the knowledge he received when assigned to the German coal fields after World War II. There he helped rehabilitate those mines and, in doing so, became familiar with the longwall mining methods of that era. By combining the two-entry system with the longwall method, he was instrumental in developing the viable retreat longwall mining system now used in the United States. Since that time, Sunnyside Mines has logged 161,000 advance ft of two-entry longwall gate development.

The two-entry system was initially subjected to a disadvantage when the laws were written because the multiple-entry concept generated by the continuous mining system was the most familiar practice. John Peperakis, being fully aware of the problems, approached the Bureau of Mines for variances concerning the two-entry longwall development system.

This two-entry system, established prior to the Mine Health and Safety Act, was justified by comparing the roof control problems (especially roof control at intersections), the violent mountain bumps associated with multiple faces, methane liberation rates and coal recovery.

The two-entry system was capable of cutting the number of intersections, reducing the amount of methane liberation and supplying maximum coal recovery in upper seams, which would lead to better roof conditions in lower seams.

Multiple-seam mining frequently occurs in the coal fields of the western United States. As many as five seams are minable in the same field, with maximum coal extraction in the upper seams.

Other mines located in the western United States have since applied for and have been granted two-entry development variances for longwall development. These mines have been extremely successful in terms of mine safety and the development of multiple-seam mining.

As the two-entry development for longwall mining is further discussed, every facet of mining must be analyzed and compared, including roof control and ventilation, mechanics and economics. In order to more clearly define the scope of the variances given and the restrictions that are placed by MSHA on the two-entry
development system, a comparison between a two-entry system and a three-entry system is fully detailed.

COMPARISON OF TWO-ENTRY SYSTEM

The items listed below are precautions for two-entry systems with belts on intake or return:

Continuous miner sections

1) Conveyor belts must be installed in the return air course to provide an intake escapeway separate and distinct from belt haulage.

2) Belt drives must either be permissible or be on a separate split of air.

3) All on/off switches must be permissible.

4) Fire sensors must be installed on 50-ft centers if air on belt lines exceeds 100 fpm, which is usually the case when belt entries are used as returns.

5) For each conveyor flight over 2000 ft, an additional cache of fire fighting equipment will be stored along the belt flight; again, this is if the air on the belt exceeds 100 fpm.

Longwall sections

When belt entries are used as additional intake on longwalls, the following shall be followed:

1) Certified personnel will make periodic checks with a permissible methanometer in the belt entry.

2) The drive will be isolated on its own split of air.

3) There will be a trained person on the belt to inspect for hot rollers, accumulations, etc.

4) There will be a curtain rolled up and hung near the headgate, enabling it to be dropped in the event of an emergency.

5) There will be an intake escapeway separate and distinct from the belt entry.

6) Because of the development of these entries with the belt on return air, fire sensors on 50-ft centers and the additional cache of fire fighting equipment is already on the belt.

CO AND METHANE MONITORING FOR BELT LINES ON INTAKES OR RETURNS

A permissible monitoring system developed by Conspec for carbon-monoxide and methane is being installed in the Sunnyside mine. Once this system is finished, some of the above mentioned precautions can be eliminated. The CO portion of the system monitors the air at each belt drive, tailpiece and at 2000-ft intervals between the drives.

The methane portion of the system monitors the air on belts in returns at the mouth of the entry and outby the tailpiece. If methane concentrations reach 1 percent, the belt and all electrical section equipment is automatically de-energized. Belt entries on intake air will be monitored at the tailpiece.

The system provides an audible and visual alarm at the continuously manned location on the surface, and when a predetermined amount of CO or CH₄ is detected, it identifies the sensor that was activated and its location.

If this system is de-energized for any reason, the belts in returns may continue to operate as long as they are patrolled and monitored by a qualified person. CO levels must be taken by hand with Draeger gas tubes and CH₄ with a permissible
methanometer at 30-minute intervals as long as the belts operate and the system is down.

Of the above mentioned precautions, the only item needing attention is separate and distinct intake escapeways when developing more than two entries.

Safety and compliance with the Mine Safety and Health Act has always been important in the two-entry system. Both continue to improve as new ideas and technologies, such as the mine monitoring system, are developed.

Ventilation in the two-entry system is very straightforward and functional. The course of the air flow is simplified. Curtains near the face are always spots of excessive air leakage and short circuiting. More complex problems occur as the number of openings increases. As shown in Fig. 1, the intake is in the track entry and the return is over the belt system. The standard brattice system is mostly used. However, a fan system can easily be adapted to the two-entry system. Compliance with all state and federal laws concerning air quantities and velocities is being observed.

The two-entry system requires that the belt conveyor, other than the drive unit, be located in the return air course. The return air course is the safest area to install a belt conveyor. Fumes, etc., from a fire originating at the belt will automatically flow out the return and not toward the face area where the majority of miners are located. Also, the reduced number of stoppages along the entries (about one-third) result in less air leakage.

As the longwall block is completed, both the belt entry on the headgate and the track entry are used as intakes. At only one point can they be connected before entering the longwall face. By doing so, it insures the ability of a short circuit of air in the belt entry. In the event of smoke or fire problems in the belt entry, the track entry will be a separate and distinct escapeway.

As shown in Fig. 2, the air at the longwall face splits. One split travels up the face and out the return. The other split continues through the supported track entry for other uses or to the return. The track entry is well supported as a competent airway to be used for the tailgate return for the next panel.

Between the future tailgate and the gob, a very strong yieldable wooden stopping is constructed, consisting of 3 x 10 x 10-ft crib blocks, with a pilaster crib for support being located in the center. This makes a distinct airway separated from the gob and a distinct return for the next panel (see Fig. 9).

As shown in Fig. 8, the bleeder system is functional. With a forced air fan and shaft in front of the longwall and a return shaft at the rear, the bleeder system is a positive and workable system. The tailgate to the bleeder system is not accessible but a positive flow of air and methane are liberated in the bleeder system.

Another positive factor in favor of two-entry development is the limited surface area opened to liberate methane with the same quantities of air as multiple-entry systems. This serves as a good example in a mine where methane plays a major role in safety and ventilation plans.

A two-entry system permits a reduction in surface exposure, i.e., roof, floor and ribs, resulting in fewer chances for roof fall incidents.

At the Sunnyside operations, as the two-entry system progressed with longwall mining, the violent mountain bumps associated with room-and-pillar mining subsided. Cover was still rapidly increasing. However, the stress was being relieved by the longwall method, insuring safer roof conditions.

During the development stage, roof control is established by using resin-type roof bolts on a full bolting plan. This gives stability in the headgate and the tailgate entries.

Intersections are weak points in roof support. By reducing the number of intersections, the potential number of intersection falls is also reduced. The area for coal dust to settle in is also greatly diminished as is the exposure to rib surfaces, making rib turnovers practically non-existent.

The tailgate entry is always fully cribbed on both sides using 8-ft centers (Fig. 2) so as to insure a return escapeway for the entire life of the panel. It is extremely critical to keep both entries well supported as both entries are most important to the adjacent panel.
The pillar size becomes important because it relieves the chances for bounces in heavy overburden. Sunnyside Mines' two entries are driven on 50 to 60-ft centers and centercuts are turned at 110-ft centers. The chain pillars are long and narrow and yield during the longwall cycle as it passes. As the second longwall passes, a complete yield of the pillar is experienced, producing 95 percent recovery of coal in that seam.

As the panel proceeds down dip, it has been proven at the Sunnyside Mines that chain pillars completely yield and there is a nonexistence of roof control problems, namely mountain bumps or overriding weight.

The process of caving the tailgate entry is costly and time consuming, but it is necessary to ensure a competent tailgate. The method of truss bolting is presently being evaluated. This system is proving to be more economical in supporting the tailgate by reducing the number of cribs, making a viable and effective means of secondary roof support for the longwall tailgate.

Longwall retreat is a fascinating aspect of rock mechanics. In a two-entry system, as the longwall retreats in a panel, three zones of abutment are created, two flank abutments and one forward abutment. It is this pressure that is most destructive to maingate and tailgate entries.

The maingate abutment pressure zone extends along the maingate chain pillars inby the longwall face. Some effects of abutment pressure can also be experienced a short distance out by the face. The effects of the pressure at the intersection located at the forward abutment with the maingate flank abutment are not as destructive because the entry is protected by an adjacent coal block and a solid coal block positioned in front of the longwall face. If a three or four-entry system was used, trouble could occur at this point but, with a two-entry system, it does not.

The most hazardous and troublesome location is the tailgate corner of the longwall face extending some distance out by the entry. It is here where the forward abutment intersects the tailgate flank abutment. The result of this intersection is intensified pressure.

The tailgate abutment extends along the entire length of the tailgate, continuing over the chain pillars into the worked-out area.

If three or more entry systems are used, two lines of chain pillars are created. These two lines form a width of chain pillar support and a resistance ridge that takes the bulk of the abutment loading and pressure. As a result, crushing of the chain pillars occurs, creating a failure of entry openings. This increases the problems of maintaining the remaining openings in a safe manner, and needless exposure of personnel to hazards of poor roof, poor ribs and mountain bounces is incurred.

The two-entry system has proven to be a safe and reliable method of longwall mining. It uses sound roof control procedures by exposing miners to a minimum amount of top and utilizes yieldable pillars to control mountain bounces. The reduced amount of surface area decreases methane liberation and satisfies the precautions imposed by MSHA to insure that separate escapeways are safe and effective. It also affords maximum coal extraction with minimum safety problems.

Closely following the safety aspects of a two-entry system come the mechanics of the system.

Kaiser Steel Corp. Sunnyside Coal Mines' present system of development uses conventional continuous miner equipment. The continuous miner and one shuttle car are used (see fig. 3).

The belt feeder and the belt are placed 20 ft beyond the last open cross-cut to allow maximum access to the face. One shuttle car is used because of the limited space in the system. The production takes place on two shifts with the third shift available for maintenance. Each section is equipped with a 500 ft capacity belt storage unit. This storage unit allows frequent belt moves that keeps the shuttle car haul short. The continuous miner cuts the entries 8 to 20 ft wide and makes a 20-ft cut in depth. While the continuous miner cuts coal in one entry, a double-boom roof bolting machine is working in the adjacent entry. Efficiency becomes most important in this system because of the limited number of faces to cut. If the bolting machine is properly operated, the continuous mining machine will continue operating, keeping men and equipment producing.
It is important for the section to move forward as rapidly as possible. The entries must be driven as straight as possible, allowing efficient function of the longwall.

The section is normally serviced by track haulage and a battery or a diesel-powered locomotive traveling within 500 ft of the face. A material car finishes the material move to the face. As the section advances, wooden stoppings are installed, making the fourth of cement blocks. This allows ventilation and access to the longwall as it approaches. The beltlines are heavily rock dusted using bulk rock dust systems powered by compressed air.

The longwall operation depicted in fig. 4 and 5 shows the track entry as a supply track and the belt entry adjacent. Material is easily accessible within 50 ft of the operating longwall. Fig. 5 shows a typical longwall move or setup in the two-entry system.

Additional systems are now being studied in trying to make the two-entry system more competitive with the multiple-entry system. Three of the innovative ideas under consideration are:

1) Remote control on the continuous miner making it possible to extend the depth of cuts under good top. This will reduce the moving time and enable the cutting of cross-cuts in one cut.

2) Continuous haulage from the continuous miner to the belt, furthering the efficiency of the haulage.

3) Bolting machines for the continuous miner or directly behind the continuous miner, eliminating moving time and increasing advance per day for longwall development.

The economic aspect of a two-entry development mining system is deceiving. In comparing a two-entry system with a similar three-entry development system, it has been proven that a three-entry system produces substantially more tons per shift in development. However, to obtain this tonnage requires more mining area and more shifts per panel gate (fig. 7).

In a four-panel longwall system block (fig. 6), the two-entry versus three-entry system comparison reveals the two-entry system advantage. A two-entry system requires less mains, bleeder and panel gate development to render the same amount of longwall coal. This more effectively conserves the reserves in the mine, prolonging its minable life. Although more tons are recovered in three-entry development, conversely more tons are lost in the extra row of chain pillars that would be recovered in a two-entry system. This all adds up to a 10 percent higher rate of recovery for the two-entry development system.

Since, in a three-entry system, there is an additional room to drive, support, isolate and maintain, the increased tonnage is offset by increased development costs. The slower advancing three-entry system requires 10 percent more shifts and is in effect 10 percent longer mining time to complete a panel, which is critical when waiting to move a longwall into production. Increased development tonnage in a three-entry system means a decreased percentage ratio of longwall versus development coal, which translates into overall higher development costs, even though total development cost per ton is relatively the same for both systems. Even with smaller underlying costs that have not been considered, at Sunnyside it has been found that two-entry development systems are more economical.

The attractive advantages of the two-entry system are:

1) Rapid development advance for longwall panels.

2) Maximizes the recovery if the mine is limited in reserves, i.e., a 25-million ton reserve of recoverable coal with a two-entry system compared to a three-entry system is the difference between 23,000,000 and 20,750,000 extractable tons, respectively, over the life of the mine. This is assuming the same pillar sizes are used for a three-entry system.

3) Conventional continuous miner section equipment can be used.

4) Manpower supervision is more effective because a smaller area requires development.
5) Roof control in development is safer because of the reduced number of intersections and decreased areas of open roof to be supported.

6) Methane liberation is reduced because of decreased surface area exposed in development.

7) Multiple-seam mining is more feasible because almost complete extraction of the upper seams relieves weight in the lower seams.

8) The ratio of development tons to longwall tons is low, allowing for more productivity and lower or equal overall cost to the mine.

However, there are always disadvantages to any system and the two-entry system is not immune. These are:

1) The laws are written for multiple-entry mining and did not allow for two-entry systems. Required variances are constantly subject to change and always controversial to those persons not fully aware of the safety advantages of the system.

2) The limited number of places to cut actually limits the potential for development production compared to the multiple-entry system.

3) A roof fall or a squeeze in the tailgate entry can completely stop a longwall section because there are not other entries to use for ventilation and escapeways.

4) Ventilation costs will rise because of less area as resistance increases the water gauge at the fan.

5) Longwall tailgates are costly to support and add resistance to the ventilation system.

6) Yieldable pillars cause excessive sloughage in development sections (under heavy cover).

Two-entry development for longwall mining is here to stay. Its capabilities will continue to prove it as a safe, economical and viable system for almost total coal extraction.

As it grows, knowledge and familiarity with the system and its advantages over multiple-entry systems will also grow.

We must constantly strive to improve within our industry. By doing so, we will create a safer and more economical means for producing coal.

References


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Fig. 1. Sunnyside 2-entry face ventilation systems

Fig. 2. Typical Sunnyside 2-entry longwall system layout
Fig. 3. Mining sequence for Sunnyside 2-entry system panel development
Fig. 5. Sunnyside 2-entry longwall starting room set-up

Fig. 7. Sunnyside 2-entry vs. 3-entry longwall panel system comparison
Fig. 6. Sunnyside 2-entry vs. 3-entry longwall panel block comparison
Fig. 8. Typical Sunnyside 2-entry system longwall block ventilation

Fig. 9. Sunnyside crib stopping