REFORMATION OF THE HYDRAULIC STOWING MINING METHOD

By
Liang Yinhua
Kang Fengyi
Zhou Bingwen

ABSTRACT

The hydraulic-stowing mining method is most effective for mining thick coal seams. It is superior to the sliced cover-caving and artificial mining method and the fully mechanized sublevel-caving mining method for the following reasons: a much higher recovery rate is achieved, there is much less surface subsidence and roof pressure, there is no hidden danger of gob fire, and much less methane emission and coal dust problems, etc. However, its superiority is overshadowed by its backward stowing technique which makes mechanisation of mining and stowing difficult, causes bleed water interference to production and to the environment and is uneconomic because of the high cost of stowing material. These disadvantages limited its application to coal seams that are difficult and not suitable to be mined by other mining methods. The remedy is in reforming it thoroughly to permit mining of otherwise unminable seams and this paper presents the reformation.

CURRENT HYDRAULIC-STOWING MINING METHOD POPULAR IN CHINESE COAL MINES

Fig. 1 shows the flowchart of hydraulic stowing.

From the figure the following can be seen:

(1) Stowing material, in most cases, is supplied from an open cut operation or stone quarry, usually far

from the coal mine. The field is actually a small-scaled open cut mine. If the material is cut from a weathered rock bench or waste dump, it must be sieved and crushed first. All of these factors make stowing material costly.


Fig. 1 Flowchart of Hydraulic Stowing

(2) Flushing slurry is made through a flowing course in which stowing material and water are brought into an inclined mining ditch; they are mixed with each other as the inclination promotes their flow along the ditch. The motion of the flowing slurry inside a flushing pipeline derives from the hydraulic head of the pipeline. Consequently, mixing is not thorough; air may be sucked into the pipeline which could bar the slurry flow; the water in

1. Fuxin Coal Mines, Liaoning, China

11th International Conference on Ground Control in Mining, The University of Wollongong, N.S.W., July 1992.

358
the slurry is excessive. The greater the water content, the lower the flushing capacity and the more difficult the handling of bleed water, thus the flowing distance of slurry is limited.

(3) Mud and small particles of stowing material precipitated from bleed water are mostly cleaned manually or mechanically and dumped onto a surface waste dump. The cleaning, transportation and dumping of such waste involves much auxiliary work.

Fig. 2 gives a general view of the stowing work of an hydraulic-stowing longwall coal face.


Fig. 2 Stowing Work in Longwall Coal Faces

From the figure we can see that the work includes erection of several kinds of dewatering barricades, extending the face pipeline from the upper gate, matting the part of the floor of the runway and material-handling way of the next cycle, setting up fittings for protecting mining machines and driveheads of conveyors from inundation by bleed water, cleaning the drain in the lower gate and other water ways, recovering props in the space to be stowed, flushing, dismantling the pipeline, hemibarricades and protective fittings, and cleaning sediments intercepted by hemibarricades and settled in the conveyors and running-in conveyors and other mining equipment. All of these operations must be carried out once per complete mining and stowing cycle. They are complicated, laborious and repetitious and take up much non-productive time, consume a lot of materials, are subject to flushing accidents and affect production due to bad workmanship or difficulty in mechanization. In addition, increased flow pressure could cause an intrusion of water and packing material, thus making the handling of bleed water even more difficult.

All the above disadvantages show that the method is backward technically and economically. Table 1 shows the difference in several important technical and economic indices between the method and the artificial-roof mining method based on statistical data of the Wulong Coal Mine. This mine has produced coal chiefly by these two methods for more than thirty years.

Table 1 Comparison between Several Technical and Economic Indices of the Two Methods

<table>
<thead>
<tr>
<th>Mining Method</th>
<th>Mechanization Proportion</th>
<th>Face Output</th>
<th>Labour Capacity</th>
<th>Production Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyd. S</td>
<td>13.4%</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Art. R</td>
<td>77.7%</td>
<td>1.5</td>
<td>1.45</td>
<td>0.87</td>
</tr>
</tbody>
</table>

The interior economic results, complicated stowing work, pollution of environment, difficult handling of bleed water and precipitates from it and the interference in production makes the method unacceptable to mines without special necessity.

However, the method should not be disregarded because of its disadvantages and its excellent effect on technical methods make it superior to the artificial roof.

Table 2 Comparison between Several Technical Indices of the Two Methods

<table>
<thead>
<tr>
<th>Mining Method</th>
<th>Subsid. Factor</th>
<th>Extract. Rate</th>
<th>Emission Rate of Methane</th>
<th>Roof Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyd. S</td>
<td>8-32%</td>
<td>80-90%</td>
<td>5.0-8.0m³/m³/min</td>
<td>Av. 10m²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Max. 20m²</td>
</tr>
<tr>
<td>Art. R</td>
<td>60-80%</td>
<td>70-80%</td>
<td>4.1-6.0m³/m³/min</td>
<td>Av. 18.6/m²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Max. 33.6m²</td>
</tr>
</tbody>
</table>

mining method. Table 2 shows the superiority of the
hydraulic stowing method in comparison with the artificial roof mining method.

The cost of mechanization and labour, by using sub-level caving, is 2 to 3 times greater and production costs 60%-70% higher than that of stowing and manual labour. Also sub-level caving has the following disadvantages:

(1) The amount of caved coal drawn from sliding doors of powered supports depends upon thickness and dip of coal seams, the hardness of the coal, physical-geological properties of roof rock, the drawing capacity of the sliding door and skill of operation. Recovery of caved coal follows a stochastic process with many uncontrollable factors. Again, a huge and high gob needs large chain pillars. Hence, its actual overall recovery rate is 20 to 30% lower than that of the hydraulic stowing method according to the author's estimation. This loss in coal recovery may influence the economic recovery of coal.

(2) As powered supports work under top coal, the roof rock is out of their control. It caved as it will. Sudden caving of large immediate roof may damage the supports. If it caves soon after the top coal collapses, a large part of caved coal is buried by caved rock blocks.

(3) Methane accumulated near the roof and close to the gob side of the top coal, and lack of adequate ventilation, threatens the safety of mining even though no explosion has yet occurred.

(4) Spontaneous combustion of coal lost in the gob also poses a serious hazard. Some gob fire accidents have happened in China. Gob fire can be prevented by injection of nitrogen which is a costly exercise.

(5) The subsidence factor is the same as that of the artificial roof mining method.

Based on the above discussion, the hydraulic stowing mining method is excellent in mining very thick coal seams even though its superiority has been overshadowed by serious disadvantages caused by its backward stowing technique. The authors maintain that this method may resume its importance in mining very thick coal seams by fundamental reformation as follows.

USE OF A BETTER AND CHEAPER STOWING MATERIAL

A good stowing material should be: 1) made up of a reasonable size composition so that fine grains may fill the gaps in between the coarser ones to form a dense and compact stowed body for reducing roof pressure and surface subsidence, 2) easily mixed with water, flushed and dewatered, 3) of moderate specific density for reducing water consumption and settling more quickly, 4) of moderate content of clay and earth matter, preferably less than 10%, for reducing slurry in pipes and solidifying stowing body without making bleed water muddy, 5) of less than 20% of smaller than 1 mm sized particles to minimize losses via drained water 6) without combustible components, 7) with less than 5% of water content for preventing freezing during transportation in winter, 8) rich in resources and stable in supply and 9) cheap. The following are those used in China today:

(1) Weathered granite, gneiss or siliceous conglomerate, which is costly because of processing, stripping top soil, crushing and sieving and because of relatively long distance transportation. Yet because of its mineral composition it can be easily mixed with water, flushed and dewatered. Its graded grain size and high quartz content make the stowed body dense and compact with a subsidence factor ranging from 10 to 15%. As its specific gravity is around 2.6, too heavy to be carried by water, water consumption is high, mostly 3 or more times the quantity of stowing volume, and the distance of slurry flow is limited. Its muddy content ranges from 5 to 15%, just right for flushing. In addition, the service life of flushing pipes is shortened by 1/5 to 1/4 because of the sharp edges and roughness of its hard coarse grains.

(2) River bank sand is used only by mines near streams with plentiful bank sand. Its cost is the same as weathered rock because its deposit is relatively thin and
scattered and the mining conditions are usually difficult. Compared with weathered rock, it is better for flushing because it has been carried by stream water so that flowing resistance is lower, with a reduction of around 30% in consumption of water and an increment of around 20% in flowing distance of slurry under the same conditions of flushing. Yet its content of tiny particles, smaller than 1 mm, in size and silt is approximately 30%. This increases loss in drained water and makes handling of the drained water difficult. The subsidence factor is 15 to 20%, 5% lower than that of weathered rock.

(3) Crushed and sieved waste from the mine dump or nearly the open pit mine is used for stowing because it is convenient and cheap and reduces the land used for piling up waste and pollution of the environment. The disadvantage is unstable composition, with some components such as combustible carbonaceous shale, clay shale and argillaceous sandstone which are unsuitable for stowing. Burnt rock is best among all the kinds of waste because it has all the advantages of weathered rock and river sand. The exception is that the stowed body is less compact because of its weaker strength. However, it becomes somewhat cohesive when mixed in slurry. This partially compensates for the weakened strength and makes the subsidence factor around 20%. Hard waste without weathering, such as well cemented sandstone, behaves as weathered rock does. Weathered or weak waste, such as soft sandy shale, results in a loosely settled stowed body with a subsidence factor approaching 30% and turbid bleed water.

(4) Waste from the washery is even cheaper and more convenient because it can be used without processing. It is good for flushing because it has been already washed and drained water is much cleaner. Bleed water is much cleaner because those that may run off with bleed water have already been mostly washed away. It has the serious disadvantage of containing 6.1 to 10.7% of fixed carbon. Its stowed body is not so compact that the subsidence factor is higher than 20%.

(5) Oil shale after refining has been used by the Fushan Coal Mines for more than 50 years because it is supplied by nearby refineries at a very low price. It can be carried further (by an increment of 20 to 30% relative to that of weathered rock) by less water (by a reduction of 30 to 50% relative to weathered rock) and dewatered more quickly with 80% of water removed from slurry within 5 minutes, 3 to 10 minutes quicker than others) with relatively clean water because of the purification effect of processing and its low volume weight - 1.08 to 1.13 t/m³. However, 0.5 to 0.6% combustible oil remained. River sand is added to seal the periphery of the stowed body. Again, the subsidence factor is around 30% caused by low volume weight and weakened strength which make the stowed body neither dense nor compact.

(6) Pulverized coal ash from power plants is good for stowing the mined out space in the room and pillar mining method with sealed dewatering devices, but is not good for stowing the gob of longwall coal faces with flushing barricades, because its particles are too tiny, with sizes smaller than 1 mm. It is good because its silica and alumina content amounts to around 60% and 20% respectively. Its volume weight is smaller than 1 t/m³. The pulverised coal: 1) can be easily mixed with water and dewatered and remains in suspension for a long time, 2) is capable of being carried by water of nearly equal volume, 3) can be all-pervasive but piles up loosely, 4) is easily cured and set due to the volcanic ash activity, 5) has a compressive rate of 20 to 25% under a confining pressure of 10 MPa, 6) runs off with bleed water through open-topped flushing barricade and 7) causes less wear to the flushing pipes. A trial stow of the gob of one of the hydraulic stowing longwall coal faces in the Xinwen Coal Mines was carried out. Measures were taken to accelerate the settlement of the particles and reduce their loss. The trial was successful because the loss was reduced to less than 4%, but the flushing capacity reached 100 cubic m/h only and flushing had to be performed intermittently because of the long dewatering time of 35 to 50 minutes. This trial was not expanded because the result was not ideal and measures are complicated.
Table 3 Cost Proportion of the above Stowing Materials

<table>
<thead>
<tr>
<th>Code No.</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost P.</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>1.67</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

As described above, none of these materials alone are good for stowing in all respects. The best choice is to use an excellent compound as a substitute. A compound made up of pulverized coal ash from power plants and burnt rock from mine dumps, with the former as stuffing and the latter as skeleton was tried. Some 300 laboratory tests have shown that the most reasonable proportion of the two mixes vary between 5:5 and 4:1. With such proportions, the compound makes a very dense and compact stowed body with the least loss because the former fills all the gaps of the latter with no or with very little surplus, and the latter act as a filter, holding the tiny particles in the gaps and checks the loss. Further, the activity of volcanic ash of the former and the cohesive function of the latter cement themselves in a gripping state as a solid. Table 4 shows the relationship between the content of burnt rock and the corresponding comprehensive ratio of the compound. From the figure it can be seen that under a pressure of 1.47 kN/cm², the compressive ratio ranges from 10.86 to 10.92% as the content of burnt rock ranges from 50 to 60%. This would make the subsidence factor less than 10%. To accelerate the settlement of ash particles and so reduce their loss with drained water and make the stowed body even denser, some polypropyleneamide was added into water to make it a solution with a concentration of 4g/cubic m. According to tests with the flushing slurry would further increase the strength of the stowed body by 20 to 100 or 30 to 70 N/sq cm. This makes the compound a very good stowing material with the following advantages:

(1) Both the ash and burnt rock arc waste and can be used without processing so it would be very cheap. Their use may also reduce dumping land and pollution of the environment.

(2) Water consumption may equal the volume stowed.

(3) Its stowed body would be much more compact and denser than others, and the subsidence factor would be the smallest. With such a strong stowed body, roof pressure would be even smaller than that listed in Table 2.

(4) Less of ash particles would be reduced to the minimum, and bleed water would thus be relatively clean.

(5) Wear of pipes would be reduced, and would approximate, that caused by oil shale waste.

**REFORMATION OF SLURRY MAKING AND FEEDING**

The conventional method of slurry preparation and feeding consisted of mixing stowing material with water. The mixed slurry is pumped thorough a flushing pipe system to the gob. The mixing of the slurry is carried during the flushing state. This technique is undesirable because of the above stated disadvantages.

In the proposed reformation, process, pulverised coal ash is used in conjunction with quarried burnt rock. The fly ash is thoroughly mixed with water to form a thick slurry with the fly ash remaining in a suspension state. This is then pumped through the flushing pipe system together with the crushed burnt rock to the gob to be stowed. It is worth noting that the crushed burnt rock is fed into the flushing pipe system via an hydraulic feed. It is not allowed to pass through the pump in order to protect

---

Table 4 Compression Ratio of the Compound under a Pressure of 1.5 kN/cm², cm with respect to its Composition

<table>
<thead>
<tr>
<th>Ash in</th>
<th>8.2</th>
<th>7.3</th>
<th>6.4</th>
<th>5.5</th>
<th>4.6</th>
<th>3.7</th>
<th>2.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Rock</td>
<td>19.9</td>
<td>18.4</td>
<td>16.5</td>
<td>14.7</td>
<td>10.9</td>
<td>10.0</td>
<td>12.3</td>
</tr>
</tbody>
</table>

experience, the settling time of ash particles in such a solution is reduced by half. On the basis of foreign experience, it was suggested that mixing 3 to 5% of cement or lime and an equivalent amount of quick setting agent

---

11th International Conference on Ground Control in Mining, The University of Wollongong, N.S.W., July 1992.
The hydraulic feeder was used to take part in hydraulic hoisting of coal blocks with excellent results.

1. 2 Coal Outlet Gate, 3, 4 Pressurised Water Inlet Valve, 5, 6 Water Discharge Valve, 7, 8 Coal Inlet Gate, 9, 10 Filling-up Water Inlet Valve, 11, 12 Automatic Air Discharge Valve, 13 Adjusting Valve, 1, 11 Hydraulic Feeder, III Coal Pipeline

Fig. 3 Sketch of Working Principle of the Hydraulic Feeder

It is usually a cylindrical device connected to a pressure fluid pipeline. It is charged with solid material from a bin first and then discharges the material into the pipeline under the action of pressurized water. It is used in pairs to charge and discharge in rotation to make bleeding continuous. Fig. 3 is a sketch showing its working principle. As shown in the sketch, there are two feeders set up in parallel and a series of valves controlled pipes and gates fitted onto them. The working procedure is as follows: 1) open valve 6 for discharging water with pressure exhaust till the feeder becomes empty; 2) open gate 7 to charge the feeder with solid material; 3) close valve 5 (6) and gate 7 (8) as the feeder is full; 4) open valve 9 (10) to saturate solid material with water, with air in the feeder discharged through the automatic valve 11 (12); 5) close valve 9 (10) and open gate 1 (2) and valve 3 (4) to let in pressurized water and discharge solid material into the pipeline under the wash action of pressurized water, and 6) close gate 1 (2) and valve 3 (4) as all solid material is discharged to prevent pressurized water entering into the pipeline. All the operations are performed either mechanically or hydraulically, and all the steps are carried out continuously under automatic monitoring.

Fig. 4 shows the flowchart of our reformed system of slurry making and feeding. As shown in the figure, pulverized coal ash is fed into stirrer 2 by pipeline 1 branching from the ash discharge pipeline of a nearby power plant. Pressurized water is fed into the stirrer for mixing by pipeline 5 and its pump 6, which serve the feeders too. Polypropylene-amide and cement with its quick setting agent, are added through pipes 3 and 4 respectively.

Fig. 4 Flowchart of the Reformed Slurry Making and Feeding System

The four are put into the mixture in the proportions 1:2.5:4:40/40:40 m:5%. Ash slurry is discharged from the stirrer and sucked into filling pump 7 which, in turn, delivers the pressurized slurry into flushing pipeline 8. Simultaneously, burnt rock, (in an amount 1.5 times that of ash) is charged into the two hydraulic feeders 11 and 12 by a belt conveyor 9 and through bin 10. Under the action of pressurized water, the feeders feed the charged burnt rock into the flushing pipeline, and pressure-exhausted water returns to reservoir 14 through pipeline 13. Feeding burnt rock into pipeline 8 this way may cause hydraulic impact.
Such impact would make burnt rock mix with ash slurry thoroughly. The impact certainly causes energy loss must be accounted within the kinetic energy that the filling pump would deliver to the ash slurry. Whether the impact would block up slurry flow depends on the direction of entry and velocity of burnt rock and the energy of the ash slurry. This must be carefully considered in the design. For satisfactory stowing of a mechanized longwall coal face, the stirring capacity of the stirrer and the delivery capacity of the filling pump should be 360 to 600 cubic m/hr or more, and the flushing capacity should be 250 to 450 cubic m of stowing compound per hour.

FULL MECHANIZATION OF HYDRAULIC STOWING LONGWALL COAL FACES.

In order to surpass the artificial roof mining method on all economic and technical indices, to overcome its backward feature and to expand its application to all very thick coal seams, the hydraulic stowing mining method should be reformed to reduce its stowing cost, simplify and mechanize its stowing technique and control the drained water flow along the coal face. In addition with the use of a cheap and good stowing material, the reformation can be carried out by 1) developing a sectorally structured integral and movable flushing barricade, basically made of metal and plastics for long-term use to cut down stowing cost, 2) developing a face drainage system of the same structure and same materials to control drained water flow and to eliminate most of the complicated work such as setting up hemibarricades and protective fittings, matting floor, cleaning sediments and running-in motors, etc., 3) developing quick connecting and flexible flushing pipe system for simplifying the work of extending pipes, 4) developing special powered supports for holding these flushing facilities as stowing and move them forward as the coal face advances and 5) fitting the supports with a shearer mounted on a heavy-duty flexible chain conveyor and a shear for expanding their use to extraction so that stowing and extraction can be carried out at the same time.

A set of prototype powered supports have been made by refitting several scrapped Gallick chock supports fitted with flushing facilities. A simulated test was conducted with success. On the basis of the test, a five-leg powered support was subsequently designed. Fig. 5 shows the cross-sectional layout of the prototype powered supports fitted with flushing facilities.

PROTOTYPE POWER SUPPORT

The powered supports for hydraulic stowing longwall coal faces differ from others because the mined-out space must be supported before stowing and an additional space must be maintained for laying the flushing pipes and for operating them and the flushing barricade. They must also have the function of holding and moving these facilities

In the primary development, two kinds of prototype powered supports were employed, one serving extraction and the other serving stowing which were laid alternately as shown in Fig. 6. Those serving as extraction supports provided the working space for extraction and the space for laying operating flushing facilities. They move forward as the coal face advances. Those serving as stowing supports provide stowing space as well as flushing operating space. They move forward only as the space to be stowed is wide enough for flushing so as to limit collapse of the stowed body and widening of roof span due to collapse. According to the authors' observation, a flushed stowed body usually collapses as the barricade is removed and forms a slope with a repose angle of 30 to 35°. This collapse can only be reduced if the stowing compound is used containing some remnant water.

The extraction support is refined by fitting a rear bar onto the canopy of the Gallick chock. The base is also enlarged to reduce the contact pressure to around 150 N/m², so that the sinking depth of the support into the floor of the stowing material may be a negligible, about 1 mm. After refitting, the support was 5.24 m long and 1.1 m wide with maximum working height of 3.24 m.

The stowing support was refitted by cutting the Gallick chock into two halves with each half as an
individual single-frame type. It was fitted with a rear base, a rear leg and a rear bar and the base to the frame's. It was fitted in this way to reduce the support free space between two neighbouring extraction supports, holding flushing facilities and supporting both flushing operating space and space to be stowed. Its canopy was fitted with side shields.

1 Extraction Support, 2 Stowing Support, 3 Flushing Barricade, 4 Face Drain, 5 Face Conveyor, 6 Working Space for Retraction, 7 Partition, 8 Space for Flushing Operation, 9 Collapsed Slope of Stowed Body, 10 Rear Bar of the Stowing Support, 11 Rear Leg, 12 Rear Base

Fig 5 Profile Layout of Hydraulic Stowing Power Support

for guiding the way forward as it moves in between its two neighbouring extraction supports. Its double-acting advancing ram had a total travel of 1.2m. After refitting, it was 5.06m in strikewise length, 0.38m in dipwise length and 2.24m in working height.

The two kinds of supports were arranged as follows. In the dipwise direction, an extraction support and a stowing support make a total width of 1.35 m, equal to the length of a chain conveyor’s pan. In the strikewise direction, the front end of the canopy of the stowing support lags 0.3 m behind that of the extraction support. This makes the minimum span of roof control 5.88 m and a part of the stowing support’s rear bar, 1.35 m in length, buried in the top of the stowed body. This also makes the legs of the two kinds of supports stand as a partition, 1.6 m wide, between extraction and stowing excluding their mutual interference (Fig. 5) For limiting collapse of the stowed body, the flushing width of the area test was 1.2 m only. Consequently, the span of roof control reached its maximum of 6.88 m as the flushing width was reached. Then, the stowing support was moved forward twice for flushing by the width. The buried part of the rear bar was pulled out during the move and supported the space to be stowed before flushing. After flushing, this part of the rear bar was buried again, and the span of roof control returned to its minimum again.

MECHANICAL FLUSHING BARRICADE

The mechanical flushing barricade consisted of jointed sections and connected to the rear part of stowing supports for forward move. The advance of the barricade sections were coupled to the movement and advance of the stowing powered supports. The barricade sections were joined together flexibly in order to permit making as shown in Fig. 6. Fig. 7 shows a general layout of the flushing barricade.

1 Canopy of Extraction Support, 2 Front Bar of E. S. 3 Rear Bar of B. S., 4 Canopy of Stowing Support, 5 Rear Bar of S. S. 6 Flushing Barricade, 7 Face Drain

Fig. 6 Plan of Hydraulic Stowing Power Support Layout

MECHANICAL FACE DRAIN

The mechanical face drain is also made up of jointed sections. It is partly joined to the rear bases of the stowing supports and also joined to the flushing barricade. Its section is made up of fixed and movable frameworks and

**Fig. 7. Structure of Flushing Barricade**

The two fixed frameworks at both ends are integral parts of the two neighboring rear bases of the stowing supports. The two movable ones in the middle are joined with each other by steel strips and integrated to the bottom of the barricade by bolting. Their linkages are such that the frameworks can slightly swing and slide along the strips during staking. The strips are connected to the fixed frameworks by rotatable and extendable fittings for the staking section. A rubber or plastic plate is bolted on to the strips at the section's side and bottom. For checking leakage through the gaps caused by staking, the lower end of the side and bottom plate of an upper section is made overlapping the upper end of the lower section's plate.

The drain is 0.5 m in depth, 0.5 m in top width and 0.4 m in bottom width. It is certainly too shallow and narrow to accept the drainage water running off the upper part of the flushing barricade. To guide this part of the bleed water entering it, water-checking curtains are hung on the rear bars of the stowing supports. (Figs. 5 and 6)

**Fig. 8. Structure of Face Drain**


The drain is flexible unit with a length of 1.5 m. 3) A pipe unit, a flexible unit and a pipe unit are connected together as a section. This combination, 7.5 m in length is neither released for reducing connection work nor combined with others before staking to allow a degree of flexibility during staking. 4) A short pipe, a three-way pipe and a short pipe, again with a total length of 1.5m, are connected in turn as a flushing unit. Both the straight arm and branch arm of the three-way pipe are fitted with hydraulically operated sluice gates for controlling diversion of slurry flow. Another short pipe is connected to the sluice gate of the branch way and plugged into the upper part of the flushing barricade for leading slurry flushing the inside. 5) Two joint sections are fitted with a flushing unit as a flushing part. This joint is made through quick release connections after staking. All flushing parts are connected by quick release connections to form the face flushing pipeline and be in place by saddles, stools and sprags before flushing.

In flushing, firstly all the sluice gates of the branch ways of the three-way pipes, except the lowest one, are closed, whereas all those of the straight ways, except the lowest one, are opened for letting slurry flow flush the lowest part of the space to be stowed. Then the sluice gate of the upper branch way is opened, and that of the upper...
straight way is closed one after the other, in upward order to flush the space, part by part. After all the parts are flushed the holders are detached, and the pipeline is released into sections and flushing units.

**SURFACE SIMULATED TEST**

The surface simulated test was performed on a platform inclined at an angle of 10°. Its top was covered. Its back side and lower end was sealed. Its bottom was made of weathered rock blocks and grains. Nine prototype powered supports, four stowing ones and five extraction ones were on the platform and were fitted with a flushing barricade and a face drain. Flushing was done by a common pipeline 100mm in diameter with a flushing capacity of 120 cubic m/hr in which stowing material was 20 cubic m/hr. (Fig. 9)

The test was carried through the whole move of the powered supports and flushing facilities and flushing. Both supports and flushing facilities are reasonably structured and have behaved well. The following is the evaluation of the authors' achievements.

1. The mechanical flushing barricade, details of which are shown in Fig. 9.

   ![Diagram](image)

   1 Belt Conveyor, 2 Grizzly, 3 Mixing Box, 4 Flushing Pipeline, 5 Reservoir, 6 Pump, 7 Water Supply Pipeline, 8 Retraction Support, 9 Stowing Support, 10 Flushing Barricade, 11 Face Drain, 12 Platform, 13 Cover of Platform

   Fig. 9 Sketch of Simulated Test

2. Use of two kinds of powered supports, acting separately but in co-ordination, act as the link of the mechanization of extraction and that of stowing. This is because the advance of the extraction supports immediately after the advance of the coal face ensures that the extraction is progressing regularly without being hindered by the stowing operation. (3) The wide partition in the middle, together with the mechanical face drain and water-checking curtains, excludes any mutual interference between extraction and stowing operations. Though the drain suffered partial leakage due to the deformation of a rubber plate, drainage water leaking from it flowed as a discontinuous and tiny course which seeped into the floor beyond it and soon disappeared without damaging the stowing material nor entering the gap of the partition. As leakage can be checked by improving the drain, and as mechanized extraction would not influence stowing on the other side of the partition, thus in agreement with the authors' idea regarding the parallel operation of extraction and stowing.

However, although on the whole the authors' objective has been realized, there are still some defects requiring improvements. They are: 1) The stowing supports are unstable because they are too narrow. Their move along the gaps in between extraction supports becomes difficult whenever there is any deviation in gaps. 2) There is a lot of support free space outside the bars. The space becomes larger and larger as extraction supports move forward twice. This is a disadvantage in roof control. 3) The simultaneous move of the two kinds of supports makes the hydraulic system and operation complicated. 4) Rubber plates used for lining drain sections and fitting dewatering frames are poor in elasticity and tensility with the result that their temporary deformation due to movement cannot return to normal quickly and thus causes leakage. On account of the first three defects, the authors have developed special kind of powered supports suitable for hydraulically stowing longwall coal faces.
FIVE-LEG HYDRAULIC STOWING POWERED SUPPORT

This kind of powered support was developed on the basis that the full mechanization of extraction and stowing side by side could also be carried out without using specialized stowing supports. The essentials of the idea are: 1) Supports are of the same type and size for serving both extraction and stowing. 2) The 1.5 m in down-dip width so that the structure basic size of the flushing facilities may not be changed, 3) They are fitted with five legs, four in the middle for carrying the canopy and one at the rear for

Fig. 10 Five-Leg Hydraulic Stowing Power Support with Flushing Facilities

1 Canopy, 2 Front Bar, 3 Gliding Fore Bar, 4 Rotary Fore Bar, 5 Rear Bar, 6 Side Shield, 7 Four Bar Link, 8 Central Legs, 9 Rear Leg (one in the middle), 10 Upper Barricade Frame, 11 Lower Barricade Frame, 12 Face Drain, 13 Pipe Hanger, 14 Collapsed Stowed Body, 15 Base, 16 Double-Acting Advancing Ram, 17 FAC
holding the rear bar and flushing facilities. 4) Their front bars are fitted with two extendible parts, a rotary one and a gliding one, enabling them to serve the support of two rounds of advance of the coal face without moving them. This is possible because the roof pressure is only about half of that of the cover caving coal faces. Their rear part and flushing facilities can be moved, the first time after the coal face has advanced twice, and the second time for stowing after the coal face has advanced four times with a total travel of 2.4m.

5) The legs are double acting to get a working height up to more than 3.0m. Fig. 10 shows the overall design of the five-leg hydraulic stowing powered support.

This kind of powered support fitted with a set of flushing facilities may be used to equip a longwall coal face with a length up to 180 m and a working height of 3.0 m. With a flushing capacity of 200 cubic m of flushing material/hr and under the six-hour four-shift-a-day work system, a coal face may advance six or eight times and be stowed twice a day with a daily advance of 3.6 or 4.8 m and a daily output of 2,500 or 3,400 tonnes. This productivity is not lower than that of the fully mechanized artificial roof and sublevel caving longwall coal faces.

TREATMENT OF DRAINED WATER CARRYING STOWING MATERIAL RUN OFF FROM THE FLUSHING BARRICADE

The best way for treating drained water carrying stowing material run off from the flushing barricade is in two steps: stowing specially mined rooms by fine grains and sealing the gaps around the periphery of the stowage body or entrance of abandoned mining workings by tiny particles.

For making use of the fine grains, a special mining block in the deepest part of a mining section or level is designated to be mined by the room and pillar method. Its volume should be slightly larger than the total amount of run-off fine grains to be treated. The way for bleed water flow should be sloped at a minimum slope of 1.5%. Rooms and pillars should be the same size, the width greater than 10m. The entrance and exit of a room should be protected by the chain pillars of the upper and lower gates. The first set of rooms are mined one after the other in cutby or inby order in the bottom slice. After a room is mined out, two drawing pipes fitted with vertical branches are set up in it, their lower ends are extended from its exit and connected with valves. Their branches are filled of tiny dewatering holes and covered with dewatering cloth. Its exit is sealed by a barricade but with the lower ends of the pipes across the barricade. Thereafter bleed water is let in for settlement. Clear water flows out from the pipes by opening their valves. There should be two or three rooms for settlement, one for stand-by and one in preparation.

1 Special Way for Bleed Water, 2 Inlet of Bleed Water, 3 Outlet of Clean Water, 4 Seal, 5 Clean Water Way, 6 Raise for Opening Room, 7 Room for Precipitation, 8 Partially Precipitated Room (1) --- (10) Sequence of Opening and Using Rooms

Fig. 11 Mining Rooms for Treating Bleed Water

After all the rooms are full of fine particles, pillars are mined and equipped for settlement in the same way. After the bottom slice is stowed in this way, the successive slices are mined and stowed one after after another. (Fig. 11)

In the second step, precipitated water flows into the secondary precipitation sumps very slowly. This makes the tiny particles in it either precipitate or suspend in its lower level. As a result, its upper part is further cleared and overflows the sump. Once precipitate and suspended particles become dense enough, slurry is made by stirring it up with the scraper of the sump and pumping it.
In reality, the first step is the use of a variant hydraulic stowing mining method, mining rooms and their pillars and stowing them by runoff fine particles. The second step is a safety precaution for preventing mine disasters. In this way, the treatment of bleed water is no longer difficult and a burden but beneficial.

**CONCLUSION**

(1) The hydraulic stowing mining method is the most effective method for mining very thick coal seams though it is backward in many respects as compared with the fully mechanized longwall-sublevelcaving mining methods. Yet, its backward features may be changed by thorough reformation.

(2) Use of the stowing compound made of pulverized coal ash and burnt rock not only cuts down the cost by more than half and makes a more compact stowed body but also reduces land use in piling it and the pollution of the environment.

(3) Making and feeding flushing slurry mechanically, hydraulically and quantitatively not only makes slurry even and dense but also it flow under the promotion of kinetic energy. Water consumption is equal to the amount of stowing material carried. Flushing capacity may be raised up to 300 cubic m of stowing material per hour or more. Flushing extent may be expanded by raising pump pressure.

(4) Mechanical flushing facilities mechanizes all the stowing operations. Manual labour is liberated. Material drain is reduced. Reliability and safety of flushing are improved. Production environment of the coal face is cleaned. Stowing is no longer a hindrance to extraction but a factor in raising productivity.

(5) Making use of run-off stowing material carried by drainage water makes the treatment of drainage water no longer difficult and a burden but beneficial.

(6) The authors' idea of the thorough reformation of the hydraulic stowing mining method makes it possible to raise face and labour productivity and reduce the stowing cost to a great extent. The increased productivity would meet the level of the artificial roof and longwall-sublevelcaving mining methods. The reduced stowing cost would be offset by the cost of laying artificial roof and fireproof precautions. Realisation of the authors' reformation idea would overturn its backwardness in all respects and bring about significant changes in mining thick and very thick coal seams.

**REFERENCES**

"Study on Mechanical Properties of Fine Coal Ash as Stowing Material in Coal Mines (Sun Baozheng, Zhang Chunliang, 1986)"

"Some Problems on Hydraulic Stowing Mining Method (Sun Baozheng, Hai Kuoqhi, Zhang Chunliang, 1985)"

"A Study on Roof Pressure and Roof Convergence of Hydraulic Stowing Longwall Coal Faces (Liang Yinhua, 1988)"

"Full Mechanization of Hydraulic Stowing Longwall Coal Faces (Liang Yinhua 1989)"

"Coal Mining (China Coal Industry Publishing House, 1980)"