IMPLICATIONS OF HIGH PRODUCTIVITY LONG WALL SYSTEMS

By

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ABSTRACT

The areas of impact when employing high productivity long wall systems are reviewed and the financial implications of the most significant areas highlighted. A distinction has been made between availability and utilization. The need for more efficient delay recording, together with increasing control and utilization of the systems has been identified and the measurability of the latter discussed. The increased use of electronic delay reporting directly from the operating unit as the basis for operational control and a pre-emptive maintenance philosophy is seen as an important area of achieving higher performances from existing long wall production systems and configurations.

INTRODUCTION

Advances over the last 10 years in average production from Long Wall (L.W.) faces has been quite spectacular, as shown in Fig. 1, which traces the daily output from L.W.'s for South Bulli over the last 20 years.

South Bulli is distinctive in many aspects:

- It has nearly the longest operating history of any Australian coal mine.
- It is at present the only Australian mine with two L.W. faces.
- It has a 16 km underground coal clearance conveyor system which is amongst the longest in Australia.
- It has high overall face productivity, but also has an exceptionally high proportion of non-face employees.
- It is one of the largest Australian underground coal mine, both in terms of capacity and workforce.

South Bulli has a long history of L.W. operations, and the Taiheiyo face, which was put into service end 1975 became one of the first installations which achieved production rates of 1,000 t/shift. This was significantly provided the breakthrough necessary for wider acceptance of the mining technique under Australian conditions. This installation was replaced, in 1987, by a unit which has achieved over 4,000 t on a shift under Bulli seam conditions.

Fig. 1 also illustrates the daily output from the Taiheiyo face installation over its life and clearly shows the improvement achieved over the period which can in part be related to debugging the system and in part improving the overall operating efficiency through bottleneck elimination, e.g. shear capacity, etc.

Further increases in productive capability are essential to stay in the (export) business, but present productivity levels highlight shortcomings which need resolving before a further quantum jump over the next 10 years may be achieved.

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The AusIMM Illawarra Branch, 21st Century Higher Production Coal Mining Systems—Their Implications, Wollongong, NSW, April 1988

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AREAS OF IMPACT

Fundamental to any systematic elimination of system shortcomings or weaknesses is a basic understanding of these and, where necessary, a quantification of their impact on the overall production process. As computer-based management information systems become more widely used in the industry the systematic collection of relevant production/delay data allows reliable analysis of these to be undertaken. As with most performance monitoring systems, there is a considerable learning curve effect which is closely related to gaining a practical appreciation of the outcome of the analyses. To further this understanding the following areas of impact in relation to high productivity L.W. faces as currently employed at South Buli are discussed:

- development
- outbye systems
- operational availability
- operational management

DEVELOPMENT

Many exciting developments are taking place in making machinery available to the industry which is capable of greatly improving the development rates. From a planning perspective, the impact may be reduced by increasing the L.W. block geometry and by optimising the layout which, in turn, decreases the development ratio. Typical layouts in the Southern District require 4.6 m of development per m of L.W. face movement. For unfavourable geometrical conditions, ratios of 6 have been reported against a theoretical minimum of 2.1.

This ratio has a significant bearing on the development requirements, as shown in Table 1.

Because of the retreat mining technique adopted in Australia, the development is required to be completed before a L.W. block may be commenced, which means that planning and performance monitoring assumes a pre-emptive function to avoid delaying the L.W. startup or reaching a situation where targets cannot be met because of too great an underperformance prior to the review date.

The development ratio is significant when considering the overall production cost impact. Fig. 2 illustrates typical face production costs against daily production rates and shows that for a 5,000 t/day production level the development costs are some 30% of the unit production cost. At 10,000 t/day the development becomes some 45%. As shown in Fig. 2, the relative weighting of the development cost does depend on the assumed daily development advance rate. From the figure it is clear that the greatest return on effort is achieved by maximizing the L.W. productivity in the short term. There is, however, every incentive to increase the development performance in addition to those required to keep up with the higher productive face.

<table>
<thead>
<tr>
<th>L.W. Extraction (tonnes/day)</th>
<th>Seam Thickness (m)</th>
<th>Dev. Ratio (m/m)</th>
<th>Development Requirement (m/day)</th>
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<tbody>
<tr>
<td>6,000</td>
<td>2</td>
<td>2.5</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.5</td>
<td>29</td>
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<td>6.5</td>
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<td>25</td>
</tr>
<tr>
<td>10,000</td>
<td>2</td>
<td>2.5</td>
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<td></td>
<td>3</td>
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<td>3</td>
<td>7.5</td>
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<td>20,000</td>
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<td>42</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7.5</td>
<td>83</td>
</tr>
</tbody>
</table>

Fig. 2 - Face production costs

The AusIMM Illawarra Branch, 21st Century Higher Production Coal Mining Systems—Their Implications, Wollongong.
NSW, April 1988
200.
OUTBYE SYSTEMS

Coal handling is a major problem in older mines where the coal clearance system is restricted by the capacity of the outbye system, be it belt or winding capability.

The most obvious method of alleviating this situation is by increasing the width, speeding up the belts, or establishing a new entry to the workings. A cheaper, and probably more effective approach, would be connected with increasing the availability and the capacity utilization of the coal clearance system, conveyor belts in particular beyond the limits currently accepted as the norm.

An essential aspect in winning the availability battle is through more effective monitoring and control. Analysis of belt delays as recorded at South Bulli reveal that over 30% of these are of a duration of less than 60 minutes. Of these, over half are in the "don't know", "incorrect reason" category. Continuous electronic delay recording and subsequent analysis is vital to achieve high availabilities of belt systems.

The capacity utilization mainly relates to the smoothing out of peak loads over the system and avoiding running the belts empty. The most effective method of achieving this is by product flow equalization through the construction of a surge capacity normally in the form of a bin as close to the face as possible. A futuristic approach would be to try to interlink the production unit with the belt load capacity available when product flows from other sections, such as development, have been taken into account. Such an interdependence would reduce the need for systematic belt overdimensioning to cope with peak loads. The practicality of this concept has yet to be demonstrated and would depend to an increasing extent on the predictability of the output performance of the production units in a real time environment. Such a capability could be tied to an inbuilt temporary overload capacity which would be able to lessen the significance of minor peak surges.

OPERATIONAL AVAILABILITY

The operational availability of the L.W. unit is determined by two factors - the availability of the L.W. system itself and the opportunity of the system to operate as dictated by outbye availabilities, such as the coal clearance system, etc.

The financial implications of this unproductive time are quite significant, as illustrated by the following example which calculates the cost of lost production.

Assuming a daily production rate of 10,000 tonnes, with 70% recovery yield and an FOB product price of $60-$40/tonne. Under these assumptions, the revenue loss per shift would be $420,000 - $294,000. Assume 15% return on the operation, the simplistic approximation of foregone profit would therefore be $63,000 - $44,000 per shift.

Typical availability of a L.W. over a block for South Bulli conditions is given in Table 2.

Table 2

<table>
<thead>
<tr>
<th>Delay categories</th>
<th>% of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyor belts/bins</td>
<td>19</td>
</tr>
<tr>
<td>L.W. system - operational</td>
<td>5</td>
</tr>
<tr>
<td>- mechanical</td>
<td>9</td>
</tr>
<tr>
<td>- electrical</td>
<td>5</td>
</tr>
<tr>
<td>- others (strike)</td>
<td>4</td>
</tr>
<tr>
<td>Overall availability therefore</td>
<td>63%</td>
</tr>
</tbody>
</table>

Source: Underground production reports.

The above analysis is based on a 5 day operational week, with planned maintenance scheduled for weekends.

Each L.W. system has its own availability - capacity relationship, as illustrated in Fig. 3, where the characteristic curves have been plotted for three different longwalls, the Talleya installation, a Dowty/Mitsui Milke face cutting 0.75 m web and a similar face operating on a 1 m web. The performance levels reported are those predicted after allowing for the outbye belt delays.

![Graph](attachment:image.png)

**Fig. 3** - Longwall performance

Availability vs. theoretical tonnes

The AusIMM Illawarra Branch, 21st Century Higher Production Coal Mining Systems—Their Implications, Wollongong, NSW, April 1988 page 201.
As the productive levels at the face increase, the necessity for positive control of the conveyor belt operational availability becomes more critical, as discussed in the previous section. Aspects in this would be more efficient design of transfer points, such as by employing trajectory chutes, dynamic starting and stopping of the belts and continuous non destructive testing of the belts and joints.

**LONGWALL MOVES**

In a wider perspective the overall availability of the L.W. to cut coal is greatly influenced by the time required to move the L.W. unit on completion of the block. This depends very much on the geometrical constraints of the layout and, fortunately to a lesser extent, on the physical limits as dictated by the equipment. For a block size of 1.5 M t, which would take 200 days to complete at an extraction rate of 7,500 t/day, a 20 day L.W. move would constitute 10% of the overall L.W. availability. At 20,000 t/day the same move would be 27% of the available time, which is unacceptably high, even a 10 day move would still represent a 13% availability component.

During the period of move, the coal beneficiation plant would depend on a ROM stockpile to continue operating. The cost of such a stockpile is in two areas; the interest charges for the capital tied up in stock and the yield loss as a result of the aging of the coal. If one takes the interest rate to be 15% and assumes a yield loss of 2% per annum as a result of aging of the coal on the stockpile, the annualized cost of a 200,000 t stockpile is $933,000 - $577,000, depending on ultimate FOB price.

This means that the value of a reduced L.W. move time for an operation which has a washing capacity constraint is only the stockpile loss equivalent. However, for an operation with no output constraint the value of a shorter move would be $250,000 - $176,000 per day, which could justify the purchase of (duplicate face) equipment to achieve this aim, as illustrated in Appendix A. It should be noted that the ultimate labour element has been assumed to be the same for a sequential and parallel move situation. The lack of mine labour is always a problem during the moves and the concept of temporary external specialist assistance has considerable merit.

**OPERATIONAL MANAGEMENT**

Operational management embraces several areas; those covering longer term aspects, which are collectively referred to as "planning", and those relating to the daily operation.

**PLANNING**

**Saleable output prediction**

Depending on the nature of the deposit, overall control and predictability of the variability of the final production is of paramount importance. For this, geological data gathering, in conjunction with a critical determination of yield, product split and quality variation over the block, are necessary. A detailed 'risk' assessment of any deviation from the planned output requires a comprehensive geological model of the deposit which is updated using the most appropriate tools (such as in seam seismics, detail drilling, etc.) for the purpose.

In the future it should be possible to make predictions for a multi product wash, based on the geological profile of the L.W. block and relate this to the budget timing. This not only allows a production based measure of performance to be achieved, but coincidentally, a saleable output target to be considered.

**Reserves**

Historically reserve boundaries have not taken into account the extraction method employed and the impact of surface and known geological features on the efficiency of the probable layout. L.W. systems require regular blocks with an increasing length requirement. This last aspect is currently very much limited by existing equipment capability (performance and reliability) which is expected to change rapidly in the near future and to a lesser extent the ability to adequately ventilate.

The overall reserve base starts becoming important as highlighted by the following statistic. At South Bulli some 50 M t were mined from the Bulli seam over the last 100 years, 24 M t over the last 15 years and 61 M t are planned to be mined between now and the turn of the century. This means that significantly large reserve bases are needed in the future to support an operation for longer than the 15-25 year planning time horizon currently adopted for project evaluation purposes.
Ground control

Ground conditions fortunately now generally play a minor role in relation to the L.W. performance. This does not mean that faces are not affected by poor ground conditions, but the strata behaviour around the face is sufficiently well understood to minimize the adverse conditions resulting from poor face alignment, horizon control, incorrect support setting characteristics, etc.

An area of concern is the gate ends, particularly during the final stages of the L.W. block where the face slows down and stress redistribution gives rise to abnormal conditions which are manifested by poor roof conditions, excessive rib spall and floor heave. These conditions can become a major delaying factor in achieving the production requirements, particularly in areas of restricted seam height. It generally delays the efficiency of the L.W. draw-off operation, by affecting trafficability of roads and working clearances for the equipment.

Whilst the basic mechanics of the strata behaviour can be readily postulated, the support medium (roof bolts, cable bolts, etc.) should be designed to achieve controlled deformation in such a manner as not to impede the progress of the L.W. as it moves towards the drawing off position and allows the dimensional integrity of the drawing off headings themselves to be guaranteed.

Ventilation

Several interesting problems start to emerge at higher rates of extraction, particularly in relation to O₂ control and dust. With significant levels of in seam O₂, most of the liberation takes place after the coal has been cut. Methane levels can reach values where it becomes necessary to consider placing the conveyor in the return airway or pre-extraction drainage be contemplated.

Dust is a major problem for the Bulli seam and much research effort is directed towards reducing the impact of dust makes even further, such as tests relating to mist screens, water injection and agglomerant cutting which are at present being conducted at various mines. The minimisation of operator exposure is both an effective and practical way of reducing the potential impact.

DAILY OPERATION

There are several aspects which have to be taken into account when considering the daily operation of the extraction system.

Delays as shown in Table 2 are recorded and subjected to detailed analysis. As indicated on the table, the delays are sourced from underground production reports which are not always the most reliable. The ultimate aim would be to have direct monitoring of relevant variables from the equipment itself, but in the meantime the gradual improvement of the base data through more effective feedback, communications and by raising the awareness level at source allows meaningful conclusions to be drawn from such data. When allowing for availability delays the difference between average performance and peak performance still shows a significant under utilisation of the equipment, as illustrated by the following calculation.

From Table 2 an overall operational availability of the L.W. of 63% is reported (excluding strikes).

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average performance</td>
<td>2,200 t/shift</td>
</tr>
<tr>
<td>Rated capacity</td>
<td>750 - 1,000 t/h</td>
</tr>
<tr>
<td>Availability</td>
<td>63 %</td>
</tr>
<tr>
<td>Therefore maximum</td>
<td></td>
</tr>
<tr>
<td>average practical</td>
<td></td>
</tr>
<tr>
<td>performance</td>
<td>3,500 t/shift</td>
</tr>
<tr>
<td>Achieved max</td>
<td></td>
</tr>
<tr>
<td>performance</td>
<td>4,600 t/shift</td>
</tr>
<tr>
<td>Underutilisation</td>
<td>26 %</td>
</tr>
</tbody>
</table>

The measure of utilisation is represented by the relative inclination of availability/performance curve as shown in Fig. 4. Use of this relationship cannot as yet be regarded as a practical management tool, due to the current shortcomings in the report reliability underlying the availability determination.

Fig. 4 - Long wall performance

Availability - capacity utilisation
As underperformance is as yet not recorded it can only be indirectly quantified. This is an area where significant productivity increases may be realized once systematic reporting of these occurrences can be achieved, by monitoring the shearer speeds, cycles or alternatively recording the belt carrying capacity from each production area.

Training

The management and operation of a mining system valued at over $17 M, which is capable of forgoing profit at a rate of up to $250,000 per day, cannot be effective enough. Management techniques and operational procedures should match the sophistication of the equipment itself. A degree of professionalism should be encouraged which would require crew selection and aptitude determination to be carried out as part of the human resource management of the mining operation.

Strict discipline as to operating conditions and attitudes, a preventative maintenance strategy and regular reinforcement of standards which includes those relating to safety, is regarded as important in achieving the maximum performance from both equipment and crews.

Computer based data gathering and interactive diagnostic systems are becoming available which would greatly improve the effectiveness of the maintenance programming and the ultimate operational control.

From an operational perspective maximum benefit target solutions can be more readily identified and progress towards their elimination followed up with more precision and definable targets with the availability of reliable performance data.

CONCLUSION

The L.W. equipment at present in use in Australia has demonstrated that it is capable of extremely high output levels. Not only has the longwall system reached a high level of maturity, but the operators themselves appreciate the potential of L.W. systems and as a consequence have been willing to employ these in areas of "good" mining conditions, such as the Western District of N.S.W. and Queensland.

Much has been achieved in the area of mechanical/electrical reliability and availability. Overall operational availability has traditionally been the target area of management's focus in an endeavour for a cheaper tonne. A measure of underperformance, utilisation, is difficult to quantify, but it is confidently predicted that with the introduction of electronic monitoring and control systems of the operations, better management of existing systems will lead to even higher productivity levels.

To be able to manage the future systems, a less traditional management approach is required, where a more interactive managerial control philosophy with regular reinforcement training and quality type circle feedback would become a useful starting point. Performance monitoring must find its basis in reliable information which should be gathered at source using electronic techniques which are now becoming available.