LONGWALL FACE OUTPUTS
PRESENT 'STATE OF THE ART' -- ALTERNATIVE FUTURE TRENDS

By

D. H. Fawcett¹ and G.R. Duncan²

ABSTRACT

Having passed through a number of previous phases the best longwall results in Australia have shown a significant increase in the last two years.

The results expected from a longwall face can be estimated from the ideal production rate, determined by the capacity of the equipment and the conditions in which it is installed, the utilisation, and the available operating hours.

Book analysis of the results achieved suggests that, on average, recent improvements arise from the higher capacity equipment recently installed; the utilisation has in fact reduced slightly.

Review of the constraints which limit the longwall results, i.e. shearer speed, AFC capacity, support advance rate, and man travel speed, shows that little improvement can be expected in the ideal production rate in thinner seams. In thicker seams the AFC often proves the overriding constraint and further increase in equipment size could lead to increased future ideal production rates and is expected.

In all cases a concerted effort to increase the utilisation achieved is likely. For deep mines with thin to medium seams the offers the most viable path to improvement; by contrast thick seams with highwall/shallow access may benefit from further increase in equipment size.

INTRODUCTION

The use of longwall has already passed through a number of phases in Australia which are briefly summarised—

1. 1982. Supported support longwall installations were first introduced with initially disastrous results.

2. 1985–75. From 1985 onwards further installations were made on the South Coast of N.S.W. where underground conditions are considered generally more difficult than in most other Australian coal mining districts. Overall results remained disappointing despite using 'state of the art' equipment of the time. supports were damaged and were replaced by ever stronger versions, each usually the strongest yet made. Move times between faces allowed for supports to be overhauled at the surface.

3. 1974–79. The introduction of chock/shields from Japan at South Buli in 1974 marked a significant change. There had been no greater yield strength than the chocks they replaced but operated through to 1987 without need to send chocks to the surface. The use of chock/shield supports spread during the next five years and by large solved previous roof control problems. Progressive introduction of improved associated longwall equipment, i.e. shears, AFCs, pumps, and electrical equipment saw gradual but not marked improvement in results.

4. 1980–82. The first face outside the South Coast was installed at Angus Place in late 1979 and immediately showed much improved results. More chock/shields and larger shears and AFCs were ordered for existing installations.

5. 1986–87. During this period many new longwall installations were made, often in mining conditions regarded as inherently better than on the South Coast. In the process the size of all equipment except the supports, which had been quickly sized at a maximum yield load of 600 t/m at Westcliff, was radically up-graded—

<table>
<thead>
<tr>
<th>Year</th>
<th>Largest Shearer</th>
<th>Largest AFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>300 kW</td>
<td>270 kW</td>
</tr>
<tr>
<td>1987</td>
<td>100 kW</td>
<td>150 kW</td>
</tr>
</tbody>
</table>

Best panel results were generally 7000 tpd and average results some 4500 tpd. Overall utilisation achieved was generally 35% ± 10.4%; in many cases the outbye conveyors could not accept the face peak loads and this served to limit results.

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FIG. 1  FACTORS DETERMINING IDEAL PRODUCTION RATE

IDEAL PRODUCTION RATE \( \text{tph} \) \( \times \) OVERALL UTILIZATION \( x \) AVERAGE OPERATING HOURS per week \( \times \) ESTIMATED AVERAGE PRODUCTION \( \text{tpm} \)

DELAYS AND DISCOUNTS

<table>
<thead>
<tr>
<th>CONSTANT FACTORS</th>
<th>VARIABLE FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation</td>
<td>Variation</td>
</tr>
<tr>
<td>Successful</td>
<td>Predominant</td>
</tr>
<tr>
<td>From face to face</td>
<td>From face to face</td>
</tr>
<tr>
<td>But sometimes</td>
<td>But sometimes</td>
</tr>
<tr>
<td>Inevitable</td>
<td>Inevitable</td>
</tr>
<tr>
<td>Poor drilling</td>
<td>Effective shift factor</td>
</tr>
<tr>
<td>Oiling, greasing</td>
<td>Learning curve</td>
</tr>
<tr>
<td>Mechanical/electrical breakdown</td>
<td>Outlay net delay</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Increase in travelling</td>
</tr>
</tbody>
</table>
| Face operation delays | Predictive geological hazards - i.e. faults, dyke, poor roof or floor, ground water,
| Panel failure     | Other delays      |
| Tandem drift removal | Other delays |
| Coal loss         | Other delays      |
| Unexpected geology| Other delays      |
| 1                 | Days per week     |
| Shifts per day   | Available operating hours per shift |
| Travelling time   | Travelling time   |
| Shifts per face  | Shifts per face  |
| Roadside tolerance | Roadside tolerance |
| Normal Shift      | Normal Shift      |
| Length           | Length            |

FIG. 2  FACTORS DETERMINING ESTIMATED ACTUAL PRODUCTION RATE

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It is believed that we are now entering a new phase in this progression-

- The recent upgrading of longwall equipment has yet again increased 'state of the art' limits - Ulan uses the world's most powerful shearer and AFC.
- Outbye conveyors are being installed which match more nearly the face peaks.

The improvement in results from the faces is still continuing. From the stage in 1980 when a number of faces had achieved a best day of 18,000 - 14,000t, the newer installations, at Central Colliey, German Creek, (the first installation in Queensland), and at Ulan Colliey N.W. have since achieved-

Central Colliey - 22,100 tonnes in one day, 81,000 tonnes in one week
Ulan Colliey - 24,000 tonnes in one day, 6,440 tonnes in one shift, 4,217 tonnes per shift over an extended period.

It is believed that these recent improvements are closely correlated with the equipment capacity which determines the 'ideal' production rates. Generally the overall utilisation appears to have altered little during the past six years and indeed the estimated average of 35.7% achieved on 63 recently completed panels in Australia (1980 onwards), is very similar to the pre-strike results reported recently, from a sample of 90 faces over 8000 shifts in the U.K. of 35%.

Two alternatives, or more likely, some combination of both, present themselves for future improvement in results-

- Further increases in the capacities of the AFC, shearer, and in the support advance rates.
- Increase in the utilisation achieved within each day, each week and each year.

Factors affecting these are reviewed in this paper.

LONGWALL PRODUCTION ESTIMATING SYSTEM

A system developed over the past four years to estimate longwall production results has aimed to allow rational review of all the factors affecting longwall performance.

This approach appears supported by some good correlations with recent results and also by general back analysis of faces worked during the last five years.

The capacity of the longwall equipment selected, the mining conditions, the operation cycle selected, (i.e. Bi-Di or Uni-Di), and the face length allow the 'ideal' output in tonnes per hour to be calculated, Fig. 1. This allows for no delays whatsoever, not even oiling of the machines.

The 'ideal' output is translated into expected production results using the available operating hours, (as given by the shifts worked and available time at the face each shift) and using a utilisation factor which can be estimated by compounding a large number of factors, Fig. 2. As shown these factors include the learning curve, extended travelling time, allowance for maintenance and various types of breakdown, operational and face end delays, delays caused by geological hazards/variability, delays caused by other hazards, (say gas, water etc), and delays when preparing to withdraw the face or start a new face etc.

'IDEAL' LONGWALL PRODUCTION RATES - CONSTRAINTS

A number of aspects can constrain the ideal production rate.

SHEARER SPEED

The measure most frequently used to estimate shearer speed is the 'specific energy' measured in kWh per cubic metre. This is sometimes determined from an actual machine performance but more often estimated from a knowledge of similar seams.

It does not appear to be a factor solely dependent on the seam itself - rather it is derived from the application of the particular shearer drums in that seam. The power is used to both cut the coal, (and may vary with the picks used and their lacing), and also to load the coal through the drum and in the trailing; if a drum has poor loading characteristics and choice, then a higher specific energy would be measured and a slower speed given.

The power available to each drum of a double ended shearer depends on the motor configuration (i.e. single or double motor machine). The maximum speed will also be limited by the shearer haulage characteristics.

Using these factors and the expected web, the maximum shearer speed for each part of the face
cycle can be estimated but may afterwards prove to be limited by one of the other constraints.

WEB

The effective web cut by the shearer is largely determined by the equipment design. Increase in web depth will increase the prop free front distance, increase the roof support length, and increase support advance ram lengths it will also require careful review of the loading characteristics of the shearer drum. A nominal web of 1m, (giving generally 0.95m effective advance) is now common before any further increase is made the potential effect on roof control will need to be carefully evaluated.

ARMOURED FACE CONVEYOR - CAPACITY AND STRENGTH

The load carried by an AFC is limited by:

- The carrying capacity, (volume), of the conveyor determined by its width, spill plate height (partially), and chain speed;

or

- the power which can be applied, (kW), which in turn may be constrained by the chain strength.

Generally the chain strength has proved the practical limitation in Australia prop-free front distances are not limited by rigid legal regulation. The load, in tonnes per hour, which can be carried may be limited by the allowable chain tension, (set by the chain strength at an acceptable factor of safety), which is also determined from the conveyor length, face gradient, the appropriate power indexa, (no-load index, coal load index), and load.

The size of chain in use has increased markedly over the past years as also has the motor power; a typical AFC in 1982 would have two 35mm chains and 250 kW motor power, the Ulan installation has two 38mm chains and 1050 kW motor power.

SUPPORT ADVANCE RATE

At this stage supports are normally 1.5m wide; narrower supports were used in the past, wider supports may be desirable in thicker seams in the future.

The cycle time for an individual support is normally guaranteed by the manufacturer and it is now commonly 9-10 seconds per support, some 30% of the cycle time common 15 years ago. Current support advance rates are thus 9-10 m/min.

MAN TRAVEL SPEED

The speed at which a man can travel along the face is constrained by the room available, i.e. by the width of, height of, and any obstructions in, the travelling track. Whilst modern chock designs offer superior tracks, the height available is inevitably limited by the seam height, (i.e. seam less the thickness of canopy, and base).

The travel speed acts as an overriding constraint in the thinnest seams; it could also act as a constraint, if the most powerful available equipment were installed in seams of 2.0 - 2.4m thickness.

FACE END OPERATIONS

These involve raising and lowering of drums, reversal of sels, cutting in on the snake, advance of the drive heads etc. The exact operations depend on the cycle chosen and these are rarely a major constraint. Careful selection of equipment can however minimise the time lost.

COMBINATION/BALANCE OF CONSTRAINTS

The way in which these equipment constraints combine within a He-He cycle is illustrated in Fig. 1.

The 'ideal' tph given by the full longwall cycle constrained by each of the major separate factors - shearer, AFC, support advance, and travel - are shown separately for a range of face lengths in a 2.5m seam using equipment which was 'state of the art' circa 1982.

Depending on the specific energy, (0.25 and 0.25 kWh/m² shown), two face performance characteristic curves are formed for the equipment:

- 6 Specific Energy = 0.25 kWh/m²

The constraints are formed by:

- face length 45 - 160m - The support advance rate which gives a slightly lower 'ideal' tph than the AFC or s h e a r e r constraints.

- face length 160m - 400m - The AFC rate determined by the kW and chain strength.

- 6 Specific Energy = 0.25 kWh/m²

The constraints are formed by:

- face length 45 - 210m - The shearer speed determined by its kW.

- face length 210m - 400m - The AFC rate determined by the kW and chain strength.

Similar characteristic curves can be produced for alternative blends of equipment and specific energies. Each gives a different face length for the optimum ideal tonnes per hour.
FIG. 3 BALANCE OF CONSTRAINTS
(2.75m SEAM, 1982 STATE OF ART EQUIPMENT)

FIG. 4 AFC CONSTRAINT ALTERNATIVE ESTIMATES

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FIG. 5 COMPARISON OF FACE CYCLES

FIG. 6 COMPARISON OF WEB DEPTHS FOR BI-DI CYCLE
As will be seen, the optimum output normally occurs at a face length where the AFC first forms the overriding constraint. The estimation of this constraint poses some difficulties. On very short faces the limit is usually provided by the physical capacity, (volume), of the conveyor. However as the face is lengthened the 'KW/Chain Strength' installed limits the load which can be carried on the full conveyor length as shown by the lower curve on Fig. 4. Ideally a shearer on a longer face, which is cutting from tailgate to main gate, should gradually increase its speed, (i.e. loading rate), as it progresses along the face leaving a shorter loaded length of AFC ahead. If this could be exactly judged then the average load carried by the conveyor over a full shearer run would be as shown in the upper curve on Fig. 4 (called the average incremental load). However, failure to judge this correctly could lead to overload and the conveyor would stall. In practice therefore, an experienced shearer operator will allow some safety margin to avoid stalling the conveyor and the resultant load will lie between the two previous limits. Correlation with face results suggests the central curve shown on Fig. 4 calculated using modified AFC factors and used for all evaluations in this paper.

The comparison between Bi-Di andUni-Di cycles for two particular cases is shown in Fig. 5. Generally Uni-Di cycles give higher ideal outputs for the shortest faces and give lower AFC peak loads. For longer equipment Uni-Di may also give slightly better results on the longest faces but this advantage is lost when higher capacity equipment is used.

Comparison of the effects of web depth for the same two cases is shown in Fig. 6. As noted earlier use of a 1m web is now normal; increase to 2.5m would require careful review of possible effects on roof control.

Applying these general principles to seams of different thicknesses - a family of characteristic curves is generated as shown in Fig. 7. The dominant constraints in this instance - '882 state of the art equipment - vary with seam thickness:

- For thin seams, i.e. 1.5m, the man travel speed constrains the overall results and the full capacity of modern equipment is not utilised. The time lost at the face ends means that longer faces give slightly better ideal production rates. However the increase is minimal for face lengths of more than 200m.

- For medium thickness seams, say 2 - 3m, the shorter face lengths, up to some 200m, are constrained by the support advance rate or the shearer kw. Beyond 200m the AFC is normally the ruling constraint and ideal outputs fall exponentially.

- For the thickest seams, say more than 3m, the AFC would normally prove dominant throughout. For faces up to some 190m in length the AFC carrying capacity and the face end times condition the production rates which increase to a maximum. Thereafter for longer faces the AFC kw constraint gives exponentially falling production rates.

For each set of equipment a locus of the optimum production rate for varying seam thickness can be drawn as shown, in Fig. 7 for '882 state of the art equipment' and in Fig. 8 for '887 state of the art equipment'. If the loci for different sets of well balanced equipment, (a constraint caused by significant lack of capacity of one item can mask general trends), are combined, a further chart can be constructed which suggests the possible trends of optimum production rates, Fig. 9. This demonstrates a number of underlying features of longwall installations:

- The benefits of using higher powered equipment increase as the seam thickness increases. Negligible benefit is given in the thinnest seams by going beyond the '882 equipment. However in a 3m seam the increase will be very significant if '887 equipment is used rather than '882 equipment.

- The trends suggested beyond '887 capacities indicate significant potential for further increase in ideal production rates if the physical problems of working a 6m section can be mastered and if AFC capacity can be further increased.

- All curves for a given seam thickness show initial increase until the man travel speed becomes the overriding constraint. Thereafter the rate of increase is much reduced. At this point of change automation must become attractive; this could be partial if support advance and mining were fully automated, as is now possible, and the shearer operators were carried on the machine, again easier in thicker seams.

EQUIPMENT AND IDEAL LONGWALL PRODUCTION RATE TRENDS

Review of the equipment in use since the beginning of '882 shows the equipment trends in Table 1-

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FIG. 7 VARIATION WITH SEAM THICKNESS
(1982 STATE OF ART EQUIPMENT)

FIG. 8 VARIATION WITH SEAM THICKNESS
(1987 STATE OF ART EQUIPMENT)

FIG. 9  OPTIMUM TRENDS VARYING WITH INCREASING EQUIPMENT CAPACITY

FIG. 10  FREQUENCY OF ESTIMATED RATES (1982 onwards)

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Table 1
Longwall Equipment in Use

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>State of Art</th>
<th>State of Art</th>
<th>State of Art</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>122m</td>
<td>155m</td>
<td>200m</td>
<td>200m</td>
</tr>
<tr>
<td>2.5m</td>
<td>2.8m</td>
<td>2.3m</td>
<td>3.5m</td>
<td></td>
</tr>
<tr>
<td>Cycle</td>
<td>Uni-Di</td>
<td>Uni-Di</td>
<td>Bi-Di</td>
<td>Bi-Di</td>
</tr>
<tr>
<td>Effective Web</td>
<td>0.2m</td>
<td>0.25m</td>
<td>0.30m</td>
<td>0.45m</td>
</tr>
<tr>
<td>Specific Energy (kW/km)</td>
<td>0.235</td>
<td>0.25</td>
<td>0.30</td>
<td>0.45</td>
</tr>
<tr>
<td>Shearer</td>
<td>285kW SM&lt;sup&gt;1&lt;/sup&gt;</td>
<td>375kW SM&lt;sup&gt;1&lt;/sup&gt;</td>
<td>460kW DM&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1080kW DM&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>AFC</td>
<td>340 kW</td>
<td>600 kW</td>
<td>700 kW</td>
<td>1050 kW</td>
</tr>
<tr>
<td>Chain Speed</td>
<td>1.1 m/s</td>
<td>1.1 m/s</td>
<td>1.25 m/s</td>
<td>1.24 m/s</td>
</tr>
<tr>
<td>Chains</td>
<td>2 x 20mm</td>
<td>2 x 20mm</td>
<td>2 x 30mm</td>
<td>2 x 34mm</td>
</tr>
<tr>
<td>Chock Advance Time</td>
<td>18 secs</td>
<td>12 secs</td>
<td>10 secs</td>
<td>9 secs</td>
</tr>
</tbody>
</table>

Note 1  SM - Single Motor
2  DM - Double Motor

Ideal Production Rate Trends - 1982 Onwards

Computation of the estimated results of 63 faces completed since 1982 and 14 incomplete faces (as at end 1987) shows the Ideal Production Rates summarised in Fig. 10 by the frequency achieved for different 'ideal' production rates. This indicates the wide range of equipment capacity in use during the period. The effects of applying this range of equipment to a 3m seam is indicated in Fig. 11.

Possible Future Equipment Trends

Equipment

The largest production equipment now in use includes a 1080 kW Shearer and a 1050 kW AFC and is applied in coal expected to be relatively hard to cut.

The benefits from its more general use would be negligible in the thinnest seams but increase as the seam section worked increases. Thus ideal production rates with this equipment in 3.5 - 4.5m seams would be almost twice that given by average 1982 equipment. More widespread use is thus likely in mines in which the much larger AFC peak load generated, i.e. 3600 tph from a Bi-Di cycle compared with 1250 tph from a Uni-Di cycle with the smaller equipment, can be accepted. Many existing deep mines with drift/shaft haulage or extensive conveying systems to the surface would find such peak loads too large to accommodate by contrast new mines constructed with open cut highwall, or shallow access could be designed initially to absorb such peaks or even more.

The benefits of increased face capacity in those mines which could accommodate the peaks, (or be adapted to do so), must be balanced against the greater capital cost not only for the face equipment but particularly for the conveying system through to the surface stockpile. Some recent comparisons suggest that in 2.5 - 3.5m seams, at least, the overall benefit of further increasing longwall equipment capacity beyond 1986 state of the art levels is becoming marginal. In thicker seams however further increase in equipment capacity may well prove viable.

The critical constraint in thicker seams is invariably given by the AFC. It is believed that 3000 tph AFC chains could be manufactured and coupled with some reasonable further increase in AFC pan width would allow regular AFC peak loads of 3000 tph; an increase of 15% beyond the largest yet. (This increase in chain size would increase the sprocket size and the height of the AFC drive and prevent its use in all but the thickest seams).

A further possibility in the thicker seams could be the use of intermediate drives to reduce chain tension and allow the full volume capacity of longer conveyors to be used. This is not likely to be available in the short term however.

The shearer is rarely a constraint at this time; modest increases in shearer size would however appear feasible in the thicker seams if needed in the future.

Increases in support advance rate appear more likely to arise from the use of wider chocks in the future i.e. chocks at 2m centres rather than the current 1.5m centres.
FIG. 11 VARIATION WITH EQUIPMENT CAPACITY
(3m SEAM)

FIG. 12 ESTIMATED RESULTS FROM PANELS COMPLETED
(Jan 1982 onwards)
LONGWALL UTILISATION TRENDS

GENERAL

The utilisations achieved on all the longwall panels worked in Australia since 1952, (77 at the time this paper was prepared), have been estimated from the average production rates achieved and the estimates earlier made of the 'ideal' production rate. To do this it is necessary to estimate the available operating hours and these have been computed from the basis of the shifts manned each day rather than shifts declared as operated only. This shows a lower utilisation than often claimed but is believed to be perfectly realistic. One of the factors which must be increased in the number of shifts effectively operated each week and indeed mines which have operated longwall for some time appear to achieve this. All the subsequent figures are thus the estimates of utilisation achieved against available manned hours each week and include any nominal maintenance shifts.

As noted earlier the overall utilisation is a combination of many varied factors. These are summarised in Table 2.

The review which follows is drawn from a-break-down analysis of the 63 longwall panels completed since 1952 and, also in part, of the 14 current incomplete panels. The data on which this is based, is for most items totally accurate; however some factors, particularly average manned shifts for the panel, are not easily identifiable and some degree of estimation and judgement has been used when assembling the data. It is thus possible that some individual results which are subject to a degree of error, despite this it is believed that the trends shown are in fact correct and illustrate the actual relationships usefuly.

PRODUCTION TRENDS

The estimated production results and the trends shown by annual averages, for all panels worked since January 1952, are shown in Figs. 12 and 13. The improvement shown for 1966 is in part nominal; many incomplete panels are included.

UTILISATION TRENDS

The estimates of overall utilisation, (measured against manned shifts), for completed longwall panels show some decline over the period 1952 - mid 1967 and now average some 30%, Fig. 14.

It appears that while the average daily production shows some increase during that period, the majority of the most recent increase must be due to the high production from the most recent installations (Central, Ulan, etc). If recent faces are omitted from the review the remaining faces show little change in output and utilisation.

Given the experience gained in longwall operation in Australia over the last 25 years one might have expected that both the utilisation and the longwall output would steadily increase. Indeed analysis of the results from a number of mines which have completed more than 3 longwall panels shows a general increase in utilisation with successive faces in several mines. By contrast other mines which have experienced well publicised difficulties with geological or mechanical problems show a wide variation in utilisation.

One of the factors which can much affect utilisation - coal clearance capacity (i.e., conveyor, bin, drift, etc capacity) - has been reviewed and indeed shows a steady increase from 1952 onwards, now averaging some 40% more, Fig. 15. The maximum coal clearance capacity has significantly increased in the last two years as mine management have upgraded or installed conveyors which can more nearly match the peaks given by the longwall faces. However the ratio of AFC Peak Load to Coal Clearance Capacity has in fact increased during the same period, i.e., the AFC peak loads have on average increased more than the outbye conveyor capacity, Fig. 16.

A further factor of significance - the effective shift factor, (i.e., ratio of longwall operating shifts to manned shifts), - has steadily increased on average over the period from 3.04 to 3.24 per day as the mines have improved the production/maintenance ratio. The maximum number of effective operating shifts has also risen and currently averages 16 out of a possible 20 per week on the best faces.

REVIEW OF OTHER FACTORS AFFECTING THE UTILISATION

Seam Thickness

The average seam thickness has remained at 2.5m over the period but the range has progressively increased and has encompassed 1.4 - 3.5m over the last 1 - 2 years. No trend in utilisation with varying seam thickness is apparent, Fig. 17; however this combined with increased 'ideal production rate' in thicker seams shows an increasing trend in daily production, Fig. 18.

Face Length

No trend can be distinguished between face length and utilisation, Fig. 19.

Ideal Production Rate

As the ideal production rate increases the utilisation generally reduces in value and in range. This suggests that lower powered faces achieve results closer to the ideal production rate than higher powered faces.
### TABLE 1

**LONGWALL UTILISATION FACTORS**

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>DESCRIPTION</th>
<th>RANKING OF EFFECT OF DELAY</th>
<th>POSSIBLE IMPROVEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>Include factors that do not vary with layout or conditions for which variations cannot be forecast but which will occur.</td>
<td>1</td>
<td>Working practices</td>
</tr>
<tr>
<td>Operators Availability</td>
<td>Any loss of operators availability within the available shift time for the mine.</td>
<td>1 - 2</td>
<td>Equipment condition monitoring, Improved maintenance</td>
</tr>
<tr>
<td>Pittls/ails</td>
<td>Allowances for pick changing and routine oiling and greasing.</td>
<td>2 - 3</td>
<td>Maintenance, Equipment monitoring, Training - maintenance operators</td>
</tr>
<tr>
<td>Mechanical/ electrical breakdowns</td>
<td>Allowances for breakdowns/repairs for the longwall equipment.</td>
<td>3</td>
<td>Training operators, Equipment selection i.e. Install coal breaker, Retracting, Improved ventilation</td>
</tr>
<tr>
<td>Face operation delays</td>
<td>Allowance for departures from the 'ideal cycle' due to: poor control, support delays, mining problems, large coal loads, gas monitors, and simple human failure to maintain repetitive cycles.</td>
<td>3</td>
<td>Training operators, Equipment selection i.e. Install coal breaker, Retracting, Improved ventilation</td>
</tr>
<tr>
<td>Pre/Post start finish delay</td>
<td>Covers preparation for face withdrawal and start up delays.</td>
<td>1 - 2</td>
<td>Organization, Training, Withdrawal heating</td>
</tr>
<tr>
<td>Coal losses</td>
<td>Small losses occur whilst mining.</td>
<td>1</td>
<td>Equipment selection, Operator training</td>
</tr>
<tr>
<td>Tandem drive removal</td>
<td>If in use, an allowance is assumed for removal of tandem drive installations from longwall gate tracks.</td>
<td>1 - 2</td>
<td>Organization, Training</td>
</tr>
<tr>
<td>Geological Irregularities e.g. seams/faults</td>
<td>Cutting delays and/or roof support delays may occur due to unknown adverse geology.</td>
<td>1 - 2</td>
<td>Equipment selection, Mine layout, Exploration - strata control, Improved roof support</td>
</tr>
<tr>
<td>Variable</td>
<td>Includes factors which vary due to deviation from layout or foreseeable conditions and for which the variation for each longwall panel can be estimated.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective Shift Factor</td>
<td>Allowance for differences between operating and planned shifts/day</td>
<td>2 - 3</td>
<td>Equipment maintenance, Organization and planning practices</td>
</tr>
<tr>
<td>Output belt delays</td>
<td>This can be a major delay factor. Delays caused by conveyor stoppages will occur and the delay effect is multiplied as conveyors rejoin in sequence.</td>
<td>1 - 2</td>
<td>Maintenance, Equipment selection, Training - maintenance crews - belt patrol</td>
</tr>
<tr>
<td>Travelling time</td>
<td>As distance from the face increases, so does the two way travelling time to each face.</td>
<td>1 - 2</td>
<td>Maintenance - equipment and travelling roads, Equipment selection, Location of mine services, Mine layout</td>
</tr>
<tr>
<td>Adverse Geology</td>
<td>Delays caused by poor roof and/or floor may occur and may be assessed to vary for each face.</td>
<td>1 - 3</td>
<td>Strata control investigation, Roof support, Mine layout</td>
</tr>
<tr>
<td>Face and delays</td>
<td>Assumes delays in production owing to delays at inleggers and tailgates, and normally assessed to vary with the depth of cover.</td>
<td>1 - 2</td>
<td>Equipment selection, Improved roof support, Operator training</td>
</tr>
<tr>
<td>Effect of facecycle开出</td>
<td>Delays are assessed from the thickness and angle of the face and the throw and angle of fault intersecting each face.</td>
<td>1 - 3</td>
<td>Equipment selection</td>
</tr>
<tr>
<td>Unit Di Cycle</td>
<td>The use of a Unit-D cycle when cutting faults axes to avoid blocks of material passing beneath the machine may be assessed to lengthen the cycle time.</td>
<td>1 - 1</td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>Excessive gas may interrupt the mining operations</td>
<td>1 - 2</td>
<td>Increased pre-cavings, Post- rhythms</td>
</tr>
<tr>
<td>Dust</td>
<td>Excessive dust may suggest reversion to Unit-D cycle</td>
<td>1 - 2</td>
<td>Improve dust suppression</td>
</tr>
</tbody>
</table>

---

*Note: Ranking of Effect: Utilisation Factor (F)*

<table>
<thead>
<tr>
<th>Rank</th>
<th>Effect</th>
<th>Utilisation Factor (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Least effect</td>
<td>1.0 - 1.05</td>
</tr>
<tr>
<td>2</td>
<td>Medium effect</td>
<td>1.05 - 1.05</td>
</tr>
<tr>
<td>3</td>
<td>Greatest effect</td>
<td>&lt; 1.05</td>
</tr>
</tbody>
</table>

---

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193.
FIG. 13  TRENDS FOR ALL PANELS
(Including incomplete panels)

FIG. 14  TRENDS FOR ALL PANELS
(Including incomplete panels)
FIG. 15  TRENDS FOR ALL PANELS  
(Including incomplete panels)

FIG. 16  TRENDS FOR ALL PANELS  
(Including incomplete panels)
FIG. 17 VARIATION OF ESTIMATED OVERALL LONGWALL UTILISATION WITH SEAM THICKNESS - 1982 ONWARDS - ALL LONGWALL PANELS

FIG. 18 VARIATION OF ESTIMATED ACTUAL PRODUCTION RATE WITH SEAM THICKNESS - 1982 ONWARDS - ALL LONGWALL PANELS

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196.
Binning Constraint

Analysis of the longwall faces completed since 1972 shows that 53% of the faces were constrained by the support advance rate, 29% by AFC capacity, 8% by man travel speed, and 5% by shearer power. Generally the faces constrained by the support advance rate have a slightly higher utilisation than those constrained by other factors. Faces with a slower support advance rate show the higher average utilisation.

During the period reviewed some 80% of the faces used a Uni-Bi cycle. This has now reversed since the introduction of higher capacity equipment.

AVAILABLE OPERATING HOURS

A typical average distribution of the time balance during a year is illustrated in Fig. 26.

In most present circumstances about 36% of the year is lost to production due to:

<table>
<thead>
<tr>
<th>Reason</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week-ends</td>
<td>104</td>
</tr>
<tr>
<td>Public holidays</td>
<td>10</td>
</tr>
<tr>
<td>Mine shut-down</td>
<td></td>
</tr>
<tr>
<td>(for annual holiday)</td>
<td></td>
</tr>
<tr>
<td>Allowance for strikes</td>
<td></td>
</tr>
<tr>
<td>&amp;/or bad weather</td>
<td>10</td>
</tr>
</tbody>
</table>

Given the high capital cost of a modern longwall installation and its associated services, (in particular high capacity conveyors), this loss must be the subject of serious debate.

Of the remaining 62% of the year some is lost due to crib (and travel) leaving 57% of the year as available operating time (when manned on 4 shifts per day).

The current overall utilisation of 35.7% applied to this shows that only for 20% of the year, i.e. 74 days in total, is the ideal production rate achieved. As noted earlier, although this appears low it matches the pre-strike experience in the U.K.

This overall combination of time lost and relatively low utilisation gives such a, perhaps startling, result that our future attention must clearly be directed to improving it wherever and by whatever means possible. Since the overall result arises from the combination of many varied individual factors a sudden radical change is unlikely; more probable is a gradual but significant improvement arising from continued concerted effort.

Coupled with this it will also be essential to ensure timely development of successive longwall panels; whilst not within the ambit of this paper, it must be stressed that development rates have proved an overriding constraint in a number of the more successful longwall operations.

ALTERNATIVE FUTURE TRENDS

In summary, alternative future trends are:

- further increase in face equipment capacity, (and in outbye conveyor capacity),
- increase in available operating time and utilisation, or
- most likely, some combination of both.

As seen at this time, further increase in equipment capacity will only be viable in seams of 3 - 3.5m thickness and more. Current technology suggests a top working limit, (for single pass longwalling), of 4.5 - 4.8m however a proposal to MERDCC to develop a face in 8m could if pursued successfully and coupled with a further increase in AFC capacity, open the way for another significant increase in ideal and actual output.

For medium seams, of 2.3 to 3.0m in thickness, some increases in ideal production rates from longer faces may appear possible with the use of even higher capacity AFC's than currently available, dependent on detailed review of AFC (drivehead sizes) sprocket and these however will require increase in the capacities of the underground conveying systems and thus have a high associated capital cost. It appears unlikely that such bigger face equipment will be generally viable.

For the thinnest seams of less than 2.3m thickness no ideal production rate benefits will be given by use of bigger equipment than now available, indeed many could not justify the use of current state of the art equipment.

It is believed that, subject only to market demand for the product, a concerted effort must and will be made to increase the available operating hours and the average utilisation currently obtained. On the one hand though industrial engineering is needed on the other, careful and detailed analysis of the many varied factors will be followed by remedial engineering and re-organisation, - certainly no panacea exists.

In fact, a number of notable longwall installations are now achieving utilisation, (measured against manned shifts), of over 50% i.e. half as much again as the average. Compared with average results these represent a 50% gain in daily production from the longwall and require no extra capital. This path to improvement is in fact inevitable for many mines, particularly deep mines, where the cost of increasing the coal clearance capacity to match increased face equipment size would prove prohibitive.

These trends suggest potential future results in the ranges:

<table>
<thead>
<tr>
<th>Seams</th>
<th>tpd</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 6m</td>
<td>30,000</td>
</tr>
<tr>
<td>3.5 - 4.5m</td>
<td>17,000</td>
</tr>
<tr>
<td>2.5 - 3.5m</td>
<td>12,000</td>
</tr>
<tr>
<td>1.5 - 2.0m</td>
<td>9,000</td>
</tr>
</tbody>
</table>

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197.
FIG. 19 VARIATION OF OVERALL LONGWALL UTILISATION WITH FACE LENGTH - 1982 ONWARDS - ALL LONGWALL PANELS

FIG. 20 AVERAGE TIME LOSSES