SAFETY LIMITATIONS OF LONGWALL FACE ADVANCE RATES

By

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ABSTRACT

Improvements in mechanisation should not be considered independently of safety and of environmental hazards. The need to keep gas contents within statutory limits may make the time needed to partially drain a gas-seam the effective control on face development times. Dust levels may provide an effective control on coal extraction rates on any one face. The combination of gas and dust on high output longwall faces may make it necessary for each one to be treated as a separate mine in terms of ventilation, and the face workers may need special protection.

Mechanisation and safety can be mutually beneficial when mechanisation combined with systematic safety assessment reduces accidents, and when a thorough study of how to reduce accidents and health risks indicates the best method to improve mechanisation.

INTRODUCTION

Increases in coal output from longwall faces have usually come from a spiral of development in which one bottleneck at a time has been tackled, and most specialists deal with their own field exclusively. In the progressive improvement of equipment, the complex interaction with safety and the underground environment is often forgotten or ignored until it emerges as a problem. Sometimes the emergence is as a disaster.

Historically, problems have been severe, and as an example one can cite the fact that between 1851 and 1913 there were 100 major coal dust explosions in the United Kingdom each of which killed more than 20 people, and the total death roll was 7,641. The worst was Senghenydd in 1913 which killed 444 miners. That sequence of explosions, more than anything else, led to a mines inspectorate and certificated mine managers.

Most of the explosions occurred at first through ignorance, and latterly through carelessness as mines entered the fast mechanisation cycle. Since those times, outputs have climbed from 500 tonnes per shift from 30 to 40 men filling on to a belt conveyor once in a 24 hour cycle to comfortably over 10,000 tonnes from a smaller number of men. In 1982, the Sunnyside Mine in Utah produced 26,497 tonnes of coal from one longwall in 24 hours.

Fortunately, accidents have not been scaled up in the same proportion as productivity, but they do still happen. In some aspects of longwall equipment, safety provided the impetus for changes that improved productivity. Haulage ropes that snapped dangerously were replaced with chains and then with fixed racks. Chock controls were moved on to adjacent supports and then grouped into blocks to move workers out of high dust count zones.

In contrast, some equipment improvements have fortuitously made mining much safer, and perhaps one of the safest places underground may well be within the massive steel structure of a modern chock shield support with a capacity of over 500 tonnes as long as no-one ignites a methane concentration.

It is not good enough, however, to rely on serendipity for safety. Each change in technology should be carefully examined for its potential to cause accidents: techniques such as systematic safety assessment are available (Johnston et al. 1980). It is not suggested that safety should handicap production, although it may be that the next set of production limitations will be environmental hazards, particularly gas and dust, and that solving those will increase both safety and production as described below.

LIMITATIONS ON FACE ADVANCE

A mining engineer's creed is to produce more mineral at a lower cost and with increased safety. The following topics are an unranked list of factors which affect production, and will be used to discuss the safety aspects involved.

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ENVIRONMENT
Methane and other seam gases
Dust production
Temperature and humidity
Noise

STRATA CONTROL
Face, roadways and T-junctions

GEOLOGICAL CONDITIONS

PRODUCTION EQUIPMENT
Development machines
Coalface equipment
Transport outbye
Materials handling
Maintenance problems

DEVELOPMENT RATES

INDUSTRIAL RELATIONS
The last is not the least important and is worth several papers in its own right, but suffice it to say that good conditions and a safe workplace certainly do no harm to industrial harmony.

ENVIRONMENTAL PROBLEMS
These have been seen as potential output limitations for over a century and so far have been progressively overcome by new techniques. A paper by Duckow and Walton (1964) discusses the approach 24 years ago. A report by a working party at the Mining Research Establishment studied these controls at the same time as plans were being prepared for the world's first Remote Operated Longwall Faces (MRE 1964). The conclusions were similar in both cases. Gas emissions were seen as a problem and were calculated to be proportional to output, and not to the rate of face advance. It was assumed that face air quantities would need to be about 1.2 m³/s, and that some operations would need to be segregated, because levels could rise to about 2 per cent. Dust suppression would also need to be improved, and that was for a planned output of 1500 tons per shift! Support strengths and abutment loads were seen as a cause for concern, but needed more study. In fact, the MRE report did influence that Establishment's research program for several years.

Thus these factors are also current limitations it is interesting to discuss them to see what needs to be done in the near future.

METHANE AND OTHER GASES

Climatic published material (Lunarzinski and Battino, 1983; Mitchell, 1983) the gas content of Australian coals varies from about 2 m³/t to 5 m³/t. The Bull seam in New South Wales has a range from 3 m³/t to 15 m³/t. For the gasser seams, the N.S.W. legal minimum of 10 m³/s of air on a longwall face is insufficient to dilute the methane, and mines such as West Cliff aim at about 20 m³/s at the last cut-through.

If one accepts normal guidelines on maximum air velocities for comfort, one tries to keep below about 1.8 to 2.0 m/s to avoid a high chill factor and dust pick-up. Assuming about 10 m³ clear cross sectional area inside the face support profile, 20 m³/s looks about a practical limit, especially when the shearer profile is deducted from the area available and allowance is made for turbulence. It is fortunate that N.S.W. winters are not cold for long periods.

Some simple calculations give an idea of the real problems involved. If one were mining at 5000 t/shift, or 1200 t/h, and all of the 15 m³/t of gas desorbed on the face, that would be 5 m³ of methane per second. To dilute it to 1.0% needs 500 m³/s of air, which is an air current of 180 km/hr. At the other extreme the mining rate would be 60 t/hr of coal for 200 m³/s of air.

Fortunately at present, gas drainage begins as soon as the development entry is started, and with the help of methane drainage drill holes and normal degassing in the development period, the chain pillars are probably almost drained of gas and the block of face coal is partially drained before mining starts. Against these aids must be set the cost of drainage systems and the time required to degas low permeability coals.

The time to drive a development heading is a limitation on output, but one has to consider that if it were driven faster, and a face were opened sooner, then maybe the district would be gassed out during production because too much methane was still in the coal.

A small proportion of methane leaves the mine trapped in freshly cut coal. It would obviously bewise to avoid all coal degradation and to maximise the size of coal cut on the face.

The methods used by Lunarzinski and Battino (1983) indicate that a 30 t a year mine with 3 m³/s of gas requires about 300 m³/s of air to leave a reasonable safety margin for ventilation. If comfort in main airways is considered, the total cross section of intake and return airways each needs to be about 150 m², and if the coal contains 15 m³/t gas then up to five times as much would be needed. To keep air velocities and quantities within a reasonable range, it may be that high production longwall faces in gassy seams will each need their own separate ventilation system to the surface.

At present, considerable effort is being put into designing faster development systems. It may be worthwhile to carry out a comprehensive study to find out the minimum time needed to drain a longwall block of gas to a
Level at which it can be worked safely. That would be the optimum time to develop a district, and further effort on development would be wasted. Future development could well consist of blocking out a panel with single roadways driven at high speed under special conditions to allow both strata pressure and gas pressure to be relieved. Normal face development would then follow at a prescribed interval.

Dust Production

Logically, if the output from a face is doubled, the production of dust will at least double because the dust particles are a function of the breakage process. In practice, since a higher output will use more energy, higher conveying speeds (at least in linear haulage rate), and probably higher conveying speeds, there will be more degradation during the cutting and loading process, and consequently dust production will be more than doubled.

Dust is very difficult to suppress at source, and almost impossible to remove economically once it is airborne. Some faces are already near the legal limit of dust production, and have to shear uni-directionally. It may be very difficult to increase production by any significant amount without exceeding 5mg/m².

Airstream helmets may become a necessity, in which case one could possibly look at a comfort fit, astronaut style, with multi coal face operations automated under visual control with operators each taking about 40 or 50m of face, tethered on an umbilical cord while shearing is in progress. Shearing could then be bidirectional.

It is essential to remember that although one worries about the minus five micron dust for health reasons, it is as important to worry about the explosive fraction of minus 100 micrometres. Both will increase proportionally, and there may have to be an opaque cloud of stonestud at the return end of the face to dilute the explosive coal dust.

Temperature and Humidity

With installed power in a district now reaching 4MW, and with mine workings becoming deeper, it may be that conditions underground will become uncomfortably hot. Fortunately, not all of the power is utilised at current rates of production, and the high airflow needed to dilute gas and dust can also carry away the heat.

Against that it must be remembered that increased production will increase the waste heat. If the cutters are used to remove the extra dust, then the humidity will rise as well. As workings become deeper there will be a reluctance to add extra ventilation shafts, and belt conveyors may become longer. In any case, there may be environmentalist pressure to reduce mine surface buildings so that output from mines may have to be combined and conveyed for longer distances underground.

Longer underground conveyors mean a longer time to evaporate dust suppression water into the air stream (and for gas to descend). Water conservation practices may need to be adopted, such as load sensors to control belt sprays, and careful spacing and sizing of sprays.

Air-conditioning is not a technical problem, but it may be expensive, and a pop-stick hazard. However, temperature and humidity are unlikely to be a severe handicap to production rates in Australia.

Noise

One of the restrictions on APC chain speed is the noise produced, the other is friction. The coal cutting process also creates noise. If the APC is speeded up to increase output, without any steps to reduce friction, it may be necessary for everyone on the face and in the gate ends to wear earmuffs. Maybe the umbilical cord suit mentioned above, coupled to an airline and a communication system, would also provide noise suppression in the helmet.

Strata Control

Loss of effective control of rock movement causes roof falls and endangers lives. The high strength of Australian longwall supports makes the space within a check shield reasonably safe. A longwall face, between the gate roads, advancing at current speeds, is probably safer now than it has ever been. The real problem is that the old art of strata control, learnt in bad conditions, is in danger of succumbing to the science of mathematics. As soon as the geological section of a face is averaged out to derive a handbook, pro-forma for mechanisation, there is a danger of roof falls or of iron-bound supports, even if they will normally sustain several hundred tonnes.

The learning curve for such items as face equipment draw-off roads has suffered a few hiccups. All rocks, and coal, have their yield limit, and can flow under pressure (even if as broken material) as well as fail violently.

Front Abutments

Leaving aside the local roof problems of face ends, and of ventilation roadways alongside goafs, there is the phenomenon of the front abutment. Rocks, especially those around an opening underground, fail by a slip mechanism. Each time a critical load is exceeded, part of the strata will fail and release the excess energy. The failure can be as a roof fall, or as roadway closure by side squeeze or floor lift, or as pillar collapse or rib spalling.

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In relation to high rock stresses, and failure mechanisms, it is germane to note that outbursts range from all gas, produced by gas pressure drive, through an intermediate mix, to a rock outburst driven by high strata stress. If high speed mining imposes increased rock pressures onto coal which is not well drained of gas, then the chance of an outburst increases.

It is of interest to speculate on the effect of increased rates of face advance. The front abutment phenomenon is well known, and it applies to development roadways as well as to longwall faces. Some problems have already emerged. In the United States, the Mid-Oxinten Coal Company’s Dutch Creek Mine operated in an outburst-prone coalbed (Cutch and Listák, 1986). Special dump valves had to be developed to unload the shield legs rapidly to prevent damage. It is a thick seam (8.5m) and was being extracted in two slices. Coal can store large amounts of elastic energy before it fails, which is why it makes good floors and roofs. However, when it fails under stress it can do so violently.

In the older technology of undercutting coal and shotfiring it, the front abutment took a violent leap forward of 1.5 to 1.8m. In a thick seam of two to three metres the noise of coal cracking, roof strata breaking, and of the waste caving, could be quite alarming, especially in the periodic weighting period under sandstone roofs.

One of the advantages of early shearer faces was that advance was by small increments at a steadier rate and at least part of the roof improvement in modern longwall faces can be attributed to the absence of the notorious (longwall) cutter break.

As shearer drum become wider, and as shearer haulage speeds increase, then there will again be less time for the front abutment to distribute itself. Speculatively, the stress peak will become higher and narrower. By definition, it is always over the coal edge, and the danger of violent coal spalling or of outbursts will increase. Flipper bars are already in use but have to be moved to the shearer through.

It may be that a small leading drum will be needed to cut below the flipper to destruss the coal before the tops are sheared. A leading small drum may also lessen dust production, according to USIM research.

Roadheads may also be affected. During development, the coal and rock will have fractured to about 10 radius around the gate. As the face retreats, the rapid approach of the high stress zone may cause that fractured rock to extrude rapidly into the pantechnician area.

Some mines with shale roofs have already had the gearhead trapped on occasions. Closure can be of roof, floor, or of coal ribs. In the old retreat face system at Coventry Colliery in the UK, under first weight conditions, the soft floor could lift at about a metre per shift and could close the roadway if left over a weekend.

A current problem in New South Wales is whether to approach a pre-driven face draw off heading quickly or slowly. In strong rock conditions it would probably make no difference for a narrow heading because a weak front abutment would cross it quickly with little damage to either roof or floor. In weak conditions, a high dynamic shock load could cause a weak roof to fail violently. If the pre-driven road was wide and had an initial large fractured zone around it, the effect would be worsened.

Mathematical models without a time variable related to the flow strength of broken rock cannot represent dynamic loading. Static pressure loadings cannot exist in moving rock.

**Geological Conditions**

Although rock strata can be catalogued, tested, and classified into general behaviour types, the particular combination of strata in any one location is the really important factor. If face advance rates are to be speeded up, it will be more important to have a good knowledge of the roof and floor variations along a panel, and perhaps even to accept that coal must always be left as a roof and floor, because its nature is more predictable.

Australian mines have been relatively lucky with the incidence of faulting and other disturbances. In a study by this author of 12 mines in the Warwickshire area (U.K.) several years ago, virtually every longwall face length (about 50 to 60 from memory) was controlled by faulting. It was impossible to determine an optimum length. Australian mines are not completely free of faults and dykes, and although the rate of face advance may not be affected greatly, the length of a face may be affected by the need to fit two or three of them in between faults that have too large a throw to cut out.

Modern machinery is powerful enough to cut through faults at low angles to the conveyor as long as one is willing to accept increased roof wear and increased dirt. If washery specifications are tight, it may be necessary to bypass the dirty coal as reject material.

**Reduction Machinery**

As long as machinery is kept in good condition, any developments to increase productivity are likely to increase safety in the long run. Ironically, the age of strained
In particular, gas and dust are likely to be a problem with increased output, and high gas levels could well be a limiting factor on face development. Dust make could be a problem with increased output on any one face.

If face lengths are increased, the centre core of a longwall block may not drain as well during the development period, and both gas and dust could cause the ventilation quantity needed to rise to unacceptable levels.

To protect miners from dust and noise, and perhaps enable them to work comfortably in high air velocities that would enable gas to be diluted, it may be possible for facewalkers to wear environmental suits connected to an umbilical cord and supplied with filtered air: each miner would monitor and control semi-automated operations over about 40 or 50 metres of the face.

Although there is no clear proof yet, it may also be that a coal face advancing rapidly with a strong coal under a hard roof may become susceptible to coal spalling from the face, and even to outbursts.

REFERENCES


