CONTROLLING AND REDUCING HEAT ON LONGWALL FACES

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ABSTRACT: In recent years uncomfortably high ventilation temperatures have become more common on longwall faces in Australian coal mines. Increasing strata temperatures at relatively shallow depths in combination with high surface ambient temperatures, particularly in Queensland, have led to high intake temperatures. These have approached trigger levels that introduce reduced face operator exposure times. With the addition of heat from coal breakage and goaf caving on high production longwall faces the working environment has become uncomfortable and continuous exposure over a shift is potentially injurious to health. Typical strata temperatures at 200m depth are 35ºC increasing to 38ºC at 350m depth. The added heat from broken coal and rock on the face and in the goaf together with heat from machinery, that has been progressively increasing in capacity, results in wet bulb temperatures exceeding 30ºC and humidity of 95% to 100% on longwall faces. Management plans have introduced controls to limit continuous working times for personnel on longwall faces in the hot and humid conditions. This impacts on productivity and in some situations requires additional personnel in the panel crews.

Increased ventilation quantities are a partial solution because evaporative cooling rates and reduction in effective temperatures are minimal in high humidity conditions and less effective in the already high air velocity currents on faces. High air velocities also introduce other face environment problems with dust, increased pressure differentials and goaf leakage quantities which re-enter as additional warm air back onto the face. Spontaneous combustion risks also increase in thicker seam environments.

Depending on seam conditions more attractive approaches can be used such as three heading longwall development allowing a back return airway using the goaf as a partial heat sink and the introduction of direct cooling of air in the longwall panels by spray systems without disrupting the passage of employees and equipment.

INTRODUCTION

Hot and humid conditions in Australian coal mines have historically been associated with poor ventilation practices in face zones even though legislation has prescribed minimum requirements for air velocities and upper limits for the effective temperature. The introduction of higher capacity longwall equipment, longer panels and wider faces as well as alternative shift rosters over the last ten years has required a revision of the standards for the management of the underground environment.

The prevention of heat stress has become a major focus for longwall operations, particularly in the hotter climate of Queensland. This has led to the introduction of the Approved Standard for Management of Heat in Underground Coal Mines (QMD 99 7460) in 1999 following events demonstrating the unworkability of the existing legislation under extended shift working hours and the advances in heat stress knowledge and management.

The management of hot and humid conditions is principally achieved by increasing air quantities on the longwall face to reduce the effective temperature and introducing periodic rest periods and rotating work duties. Increasing the air velocity introduces problems with dust, pressure differentials across the face and goaf edge and less effect on reducing the wet bulb temperature in already high air currents. The benefits of increasing air velocities above 2 m/s diminish in hot environments (D Mitchell 1999).

An understanding of the limitations of the common heat stress indices as guides to safe working limits for workmen on high production faces and the principal heat sources is necessary when developing methods for controlling the work environment.

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Alternative longwall ventilation patterns to assist in removing heat generated at the face and spot cooling of intake air are practical and effective methods to reduce hot conditions. To implement these systems the application of three heading panels rather than the traditional two heading development is a recommended approach for modern high production panels over 3 km in length.

THRESHOLD LIMITS AND HEAT INDICES

In discussing methods of controlling and reducing heat input into longwall ventilation it is necessary that a benchmark be established for designing the ventilation system. A common upper temperature limit that has been used for design limits is an effective temperature of 28°C (Pickering, Tuck 1996; Graveling, Morris and Graves, 1988). The effective temperature is the most common heat index used in the underground coal mines. The maximum allowable effective temperature is 29.4ºC with reduced work times generally imposed by Heat Management Plans between 27.2°C and 29.4°C. The management schemes in place impose regular rest periods when the temperature is between these two limits.

However heat stress depends on a number of factors other than the effective temperature, notably the work rate, clothing worn and acclimatization of the person. The wearing of personal protective equipment is a barrier to body evaporative cooling and is not accounted for in the assessment of the effective temperature indices. Additionally the effective temperature scale is not suitable for high velocity areas. The effective temperature scale does not take into consideration radiant heat. Although radiant heat in mines is generally considered minimal compared to convective heat sources (Schneider, 1999) there is a definite radiant heat flux from the goaf that is experienced by face operators when at the rear of supports in the low air velocity regions. This may explain the higher mean metabolic rate recorded for a fitter working on a longwall face (Tranter, 1998).

A more common index used in industry and recognised by the ISO and national health authorities is the Wet Bulb Global Temperature (WBGT). This index includes the wet bulb temperature and the radiant heat within the work environment. The relationship is

$$WBGT = 0.7\, t_{wb} + 0.3\, t_g$$

Where

t_{wb} = wet bulb temperature (°C)

t_g = globe temperature (°C)

Tables have been prepared that equate the WBGT to work load and the recommended rest periods. It is a universally accepted method and can be readily applied to work procedures at longwall faces. Table 1 shows the recommended Threshold Limit Values for standard work load classifications. The work load expressed in W/m^2 is the metabolic heat produced by the body (Watts) when undertaking a physical activity expressed in terms of the body surface area. The typical body surface area is taken as $1.83m^2$.

Table 1 WBGT Index Recommended Rest Breaks

Work Load (W/m^2)	Work Rate			
	Continuous Work	**15 Minutes rest per hour**	**30 minutes rest per hour**	**45 minutes rest per hour**
Light < 120	30.0	30.6	31.4	32.2
Moderate 120 - 190	26.7	28.0	29.4	31.1
Heavy > 190	25.0	25.9	27.9	30.0

Source: Flinders University, NHMRC Occupational Health Guide, Heat Stress, Commonwealth Dept Health, 1980
OSHA Technical Manual, Section III, Chapter 4.

The classification ranges for work loads varies and references for hard or heavy work provides metabolic heat loads from 175 W/m^2 to above 345 W/m^2 (Commonwealth Department of Health 1980, Pickering et al 1996). The WBGT is heavily weighted by the natural wet bulb temperature and in high humidity conditions or where evaporation of sweat is restricted the reliability of the WBGT index is limited.

Therefore both the most common heat indices used in coal mines have their limitations (Bethea and Parsons, 2002). For ease of measurement on longwall faces the effective temperature determinations continue to be used in mines and values of Basic Effective Temperature (BET) can be substituted for WBGT. Reference values for both indices are representative of the mean heat effect over a long period of work and it is necessary for judgment to be made for work exposure times during heavy physical work.

Applying the correct rest breaks for the longwall face operators depends on the knowledge of the work activities and metabolic heat generation. Mines that adopt effective temperature indices use nominal temperatures for determination of rest periods without specific reference to the work activity. Insufficient studies have been conducted to determine the heat transfer rates for the various work classifications on modern high production longwall faces in Australia. One study carried out at mine in central Queensland (Tranter, 1998) provided the results shown in Table 2.

Table 2 Metabolic Work Rates for Longwall Operators

Classification	**Metabolic Work Rate W/m^2**
Panel fitter	131
Support operator	70
Shearer driver #1	102
Shearer driver #2	120

Peak metabolic rates at up to 300W/m^2 were recorded (Abt and Tranter, 1999) in the tests. It was also stated that little face production was carried out over the period of the tests. More studies are required to obtain realistic ranges for face operators, however it can be stated that for wet bulb temperatures above 26^{o}C periodic breaks may be necessary.

There is no direct scale equating WBGT to effective temperature, however in their literature review, Graveling et al equated a WBGT of 28.2°C to 26.8°C BET. From Table 1 and Table 2 this shows that for typical work rates on a longwall face the maximum BET for continuous work is closer to 26°C. However the BET is developed for essentially nude men. Therefore an allowance for clothing must also be considered.

Whichever heat index is selected it is considered that a more conservative initial trigger value for job rotation or rest periods be adopted due to the combination of clothing effects and the uncertainty of metabolic work rates, particularly with the variable conditions along the face.

In the months from October to March the mines in central Queensland experience high surface temperatures and combined with increasing strata temperatures and additional sources of heat in the underground workings. The nominal wet bulb temperature of 26^{o}C is often exceeded.

SOURCES OF HEAT IN LONGWALL OPERATIONS

Typical Surface Conditions

The temperature on longwall faces is influenced by numerous sources both in the vicinity of the working area and by conditions external to the face. In the longwall mines operating in the central Queensland Bowen Basin area, face conditions that have been tolerable during the cooler months of the year become hot and humid conditions in summer. The additional heat source is the high surface and intake air temperatures entering the mine. Dry bulb temperatures exceeding 35°C are experienced for more than forty days during the months from November to March. Figure 1 shows the twelve month mean dry and wet bulb temperatures in central Queensland (Bureau of Meteorology Australia). The comparative low wet bulb temperatures provide a measure of comfort as it is the wet bulb temperature which has the major influence, along with air velocity, on the cooling power and comfort of the working conditions. However for approximately six months of the year the wet bulb temperature is often between 20°C to 23°C which will allow only a rise of as little as 5^{o}C before rest breaks are required. As the intake air flows through the roadways there is a complex interplay of moisture increase through evaporation with an associated vapour pressure increase influencing the wet bulb temperature. There is a reduction in the dry bulb temperature and then a steady increase as strata temperatures and depth increases. A typical trend of measurements taken in mines is shown in Figure 2.

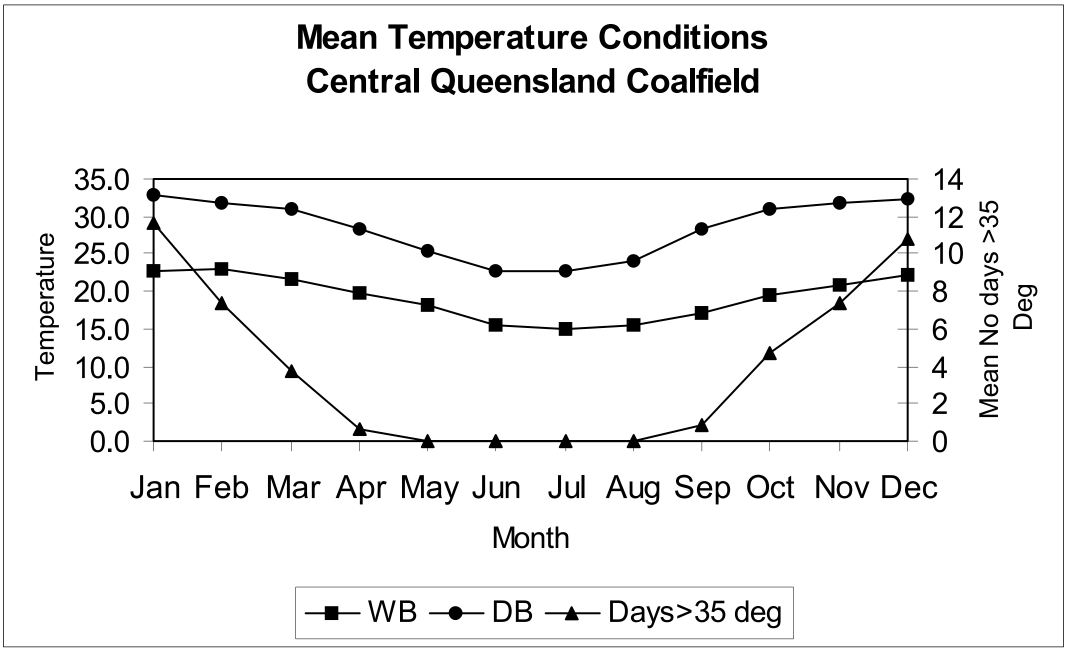

FIG. 1 - Twelve Months Mean Dry and Wet Bulb Temperatures in Central Queensland

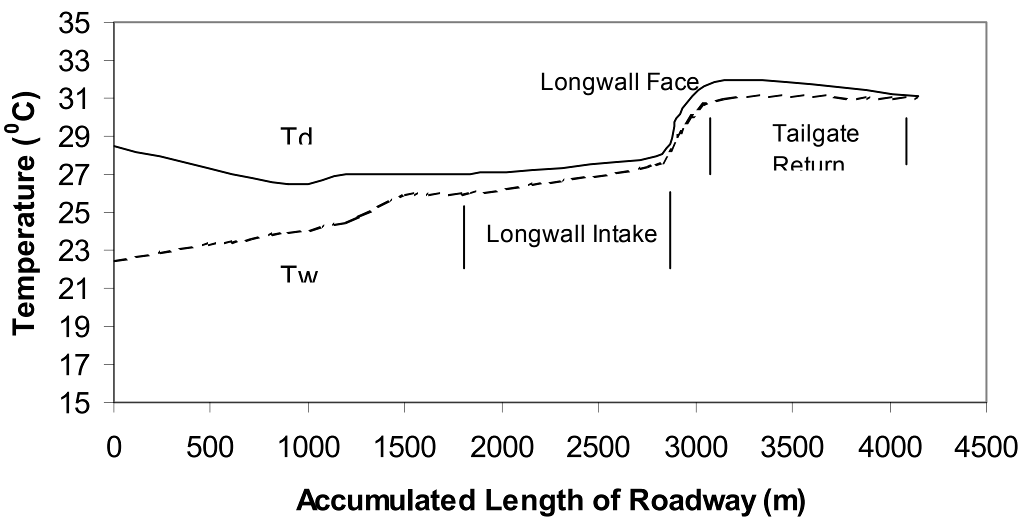

Figure 2 Typical Summer Underground Wet and Dry Bulb Temperature Trend

With increasing lengths of longwall panels the intake air is approaching 26°C to 27°C wet bulb at the longwall stage loader. There is very little margin available before heat management action must be implemented on the longwall face.

Temperature Increases Underground

The sources of heat in underground coal mines are well documented (Pickering and Tuck, 1996; Whittaker, 1979) however the following are noted for typical modern Australian longwall operations.

- The high rate of increase in strata temperatures at relatively shallow depths for the Bowen Basin coal mines;
- Autocompression which increases the wet bulb temperature by approximately 0.4°C per 100m, depending on the surface wet bulb temperature;

- Rapid production and therefore release of heat from broken coal and rock at the working face and within the goaf immediately behind the face;
- High face air quantities and pressures with consequently larger volumes of air sweeping the goaf behind the face and returning onto the face at various locations along the face at near to the strata temperature;
- Increasing equipment power with accompanying heat dissipation;
- Two heading development using a single intake traveling road and homotropal belt roadway and single return for longwall operations;
- Down dip advance of workings with consequent autocompression and strata temperature increase.
- Longwall pump stations in panel intakes.

The most significant of these sources of underground heat are discussed below.

Strata Temperatures
The heat gained or lost by the ventilation at the roadway perimeter is determined by the difference between the air temperature and wall surface temperature. The surface temperature is difficult to estimate and relationships have been developed between virgin strata temperatures, age of roadway, size of opening and the thermal properties of the surrounding coal and rock. The wetness of the airway walls influences the rate of latent heat evaporation and rise in wet bulb temperatures. Charts are available for determining the various coefficients to assist in calculating the surface temperature of airways. Along the older airways in main intakes the strata surface temperature is less than the summer air temperature and sensible heat is transferred to the surface reducing the dry bulb temperature. The most recently excavated airways in longwall panels will reverse the sensible heat transfer back into the air stream with the dry bulb temperature rising. The wet bulb temperature, which is the most important in assessing the ability for the body to cool, increases at 1.0.to 1.5 °C per km depending on the age of the panel development which may vary from months to two years over the period of longwall operation. It also depends on the degree of wetness and the presence of flowing water. For panel lengths now exceeding 3 km the wet bulb temperature increase is as much as 4.5°C along the length of the panel.

The rate of heat flow into the ventilation after a specific time following rock exposure per unit area of exposed rock is given by:

$$q/a = \sqrt{(kwC/\pi\theta)}\,(t_{vr} - t_{db})$$

where
q = heat flow energy (W)
a = area of exposed rock (m^2)
k = thermal conductivity of strata (W/m °C)
w = density of rock (kg/m^3)
C = thermal capacity of strata (J/kg °C)
θ = time since rock exposed (seconds)
t_{vr} = virgin strata temperature (°C)
t_{db} = dry bulb temperature of air

Larger air quantities will reduce the rate of increase in the air temperature, however unless the mine ventilation system and fan selection has been made in anticipation of high air quantities and associated pressures, particularly for single intake and return layouts, there is a limitation on the ability to increase the air flow into a longwall section. Other factors will also impose limitations on longwall face quantities such as dust and maintaining pressure differentials across the goaf within acceptable limits.

Rapid Production
Longwall mines have increased production rates over the last two to three years to beyond 5 Mtpa to 6 Mtpa. Over the last ten years the rate of production, taking into account face availability, has increased from approximately 700tph to more than 1400tph with peaks up to 3000tph. For strata temperatures of 35°C the heat liberated by the broken coal at a typical rate of 350kg/s can be calculated from:

$$Q = M \times C \times (t_1 - t_2)$$

Where
Q = heat flow (W);
M = mass flow of coal (kg/s);

C = specific heat of coal (J/kg °C);
t_1 = temperature of broken coal after cutting (°C);
t_2 = temperature of broken coal along panel intake (°C).

The temperature t_2 will be influenced by the air velocity, wet bulb temperature, traveling speed of the coal conveying system, wetness of the coal, the relative velocity between air and coal and the fragmentation of the coal. The use of motor cooling water for sprays along the stage loader and crusher contribute to increased wet bulb temperatures with the wet and dry bulbs depression typically less than 1°C at the last cut through of the maingate conveyor.

For coal with a typical specific heat value of 850 J/kg °C and assuming a 50% reduction in virgin coal temperature along the length of the maingate conveyor and a strata temperature of 35°C, the heat load into the ventilation is approximately 1200 kW. From the above equation the air temperature would rise by approximately 7°C. This is not the situation in practice where temperature rises along maingate intake airways have been recorded at least 2 to 3°C.

It is therefore now common practice to use a homotropal ventilation system for the maingate roadway. The single intake traveling road in the longwall panel is therefore required to ventilate both the longwall face and the maingate roadway. This typically requires 50 to 70m^3/s of air depending on the face dimensions and panel length.

Heat from Goaf Material and Oxidation
The collapsing goaf associated with rapid extraction rates presents a greater source of heat than the cut coal on the face. The rock or coal surface area is rapidly increased and the surface is considered to be at virgin strata temperature. Leakage airflow rates reach an equilibrium temperature similar to that of the virgin rock temperature. Typical goaf leakage quantities have been found to be approximately 20% of total face volumes and this has been indicated by studies (Longson and Tuck, 1985). For a face quantity of 40m^3/s as much as 8m^3/s would flow behind the supports re-entering the face at various locations but mostly near the tailgate. This air has been measured when emerging at the tailgate totally saturated at 33°C where the strata temperature is 34°C.

Oxidation of coal in the goaf produces heat which will add to the strata heated air leaking through the goaf. For each 1kg of oxygen consumed 12,675kJ of heat is produced. Therefore typical air quality measurements in returns showing an oxygen depletion of 0.2 to 0.3% would add as much as 400kW of heat. Much of this heat is retained in the goaf and is partially removed by the air. However, increased face quantities producing larger pressure differences and therefore more leakage, particularly further into the goaf, will carry additional heat back towards the tailgate end of the face.

Heat from Machinery
The increase in the nameplate power rating of the longwall equipment has accelerated over the last twenty years. Previous heat studies of longwall faces (Whitaker, Fiala et al) studied longwalls with face production rates less than 2000tpd and longwall equipment powers in the order of 600kW. The majority of the energy consumed by the electrical machinery is dissipated as heat. Thermodynamically, the only work is that against gravity. Total face power on modern longwalls is now above 4000kW and, assuming an overall operating rate at 60% of total nameplate power, with as much as 70% of the energy converted to heat an approximate heat load is 1680kW. Most of this heat is conducted away with motor cooling water however unless suitably disposed from the face it will eventually add to the temperature of the air stream. The dissipation of this heat is not instantaneous but is becoming a major source of heat at the working face.

The effects of autocompression, strata temperatures and strata water flow into the roadways plus stationary machinery such as conveyor drives, for longwall panels over 3km in length and at 250m depth of cover the wet bulb temperature can increase from a typical summer surface value of 22.5°C to 27°C at the intake side of the longwall face. The impact of machinery, goaf strata and oxidation can add another 5°C to the wet bulb temperature along the face.

In recognition of the limits placed on working times by the adopted standards and the inevitable progress towards deeper workings and higher capacity mining equipment it is apparent that alternative methods of ventilation have become necessary.

AN ALTERNATIVE LONGWALL VENTILATION ARRANGEMENT

Development

Two heading longwall panel development has been the established norm for many decades. The subsequent longwall ventilation is invariably by a single return and twin intakes or a single intake with homotropal belt road ventilation. This is sufficient for longwall ventilation as a classic U system. Gassier mines would establish a bleed return from the intake side around the goaf. However, without a return system around the goaf, the ventilation of the single section of roadway that remains as the longwall retreats requires boreholes or fans. There have been instances where the ventilation of this section of roadway has been by leakage back through the goaf to the longwall return.

A three heading longwall panel development provides many advantages for introducing additional ventilation options as well as operational advantages for the location of service equipment.

The development of two heading panels beyond 3.5km requires high ventilating pressures and when this method is combined with a simple U system of face ventilation and homotropal maingate ventilation a 7km single roadway results with ventilation pressure demands exceeding 900Pa.

A three heading longwall arrangement allows:

- The longwall maingate conveyor to be set up as a homotropal return retaining two intake airways into the panel. This provides increased ventilation capacity above that of a two heading section for less ventilating pressure;
- The second intake roadway can be used as a "heat sink" roadway when refrigeration is considered to be a necessary option above that of air velocity for combating hot conditions; or
- A direct contact cooling water spray station can be established in the one principal intake roadway while the second intake allows bypass for vehicular traffic around the fixed water spray station.
- Two longwall return airways with the ability to establish a back return roadway from behind the longwall face. This will provide a separate path for the face leakage behind the supports and not have this hot and humid air coming back onto the face, particularly in the walkway behind the support legs;

A suggested layout for the ventilation arrangement is shown in Figure 3**.**

The combined U system with a secondary back bleed return allows heat released from falling and broken goaf material and the exothermic oxidation of coal within the goaf to be directed via the face leakage flows away from the face. The volume and nature of the flow interaction between the face and goaf leakage depends to some extent on goaf compaction, however it has been found from numerous observations that leakage tends not to re-enter the face area until close to the tailgate roadway. A significant heat effect on workmen along the face is the radiant heat coming from the goaf material which can be felt in between the supports. Results referred to in Table 2 for a fitter demonstrate the potential threat from a combination of radiant heat and the low air velocity region towards the rear and base of supports when carrying out maintenance on supports. For a face length of 250m and an estimated strata collapse zone up to 10m the heat released into the immediate 20m of goaf is quite significant. This is more than sufficient to maintain a goaf atmospheric temperature at the virgin strata temperature and raise the wet bulb temperature to that approaching the strata temperature. These effects can be readily measured at the goaf edge near the tailgate supports. By directing the flow of air alongside the goaf to the next cut through will prevent this hot and humid air entering the face towards the tail end and into the return roadway itself where in many instances persons are required to work setting secondary supports.

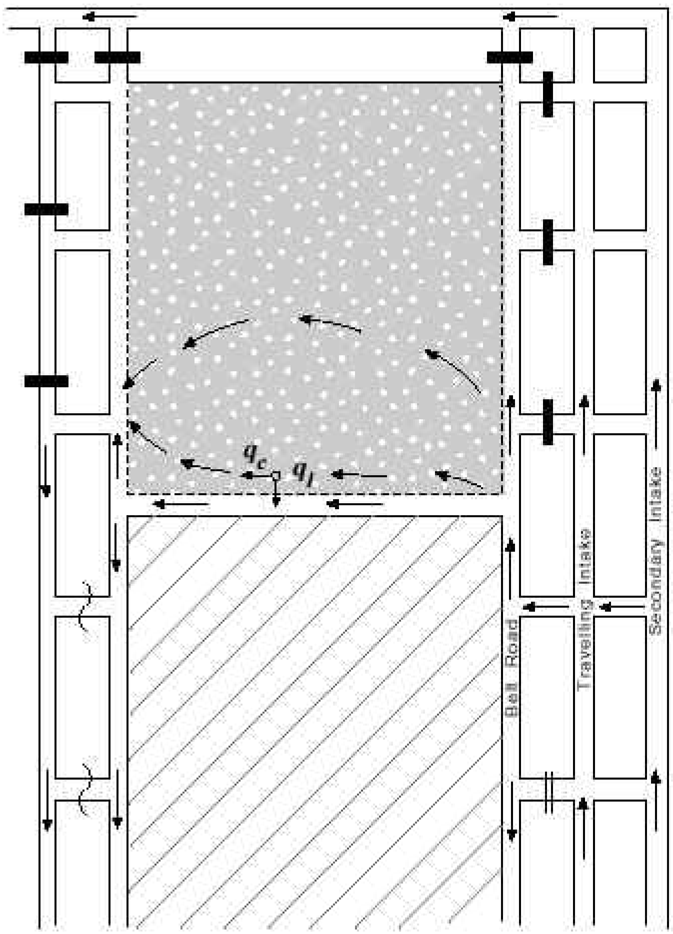

FIGURE 3
Face Ventilation Arrangement Using a Back Return

In thick seam operations the potential risk of spontaneous combustion needs consideration. Numerous articles have been written on the advantages and disadvantages of bleed or back return systems. Advantages in controlling methane in spontaneous combustion sensitive conditions using back return systems as opposed to bleed airways has been shown to be effective (Highton, 1979, McKensey and Rennie, 1988). More recent developments in goaf sealing technology and atmospheric monitoring enables this method of longwall ventilation to be seriously reconsidered to control heat convection from the goaf. The risk has been diminished by:

1. Increased rates of longwall extraction reducing the duration that air flows over sections of the goaf. Longwall retreat rates of 10m per day allow cut throughs alongside goaves to be progressively sealed within two weeks limiting the potential oxidation period.
2. Goaf seal technology has advanced significantly over the last ten years with the development of monolithic structures that are constructed to specific design criteria. The leakage through goaves due to poor sealing has been practically eliminated by these structures. The air movement through the goaf is influenced more by the ventilation pressure difference across the face which has been increasing in a desire to limit the effective temperatures. Well constructed seals have resistance values in excess of 50,000 Ns^2m^{-8}.
3. Continuous monitoring of the atmosphere behind seals and in longwall return airways together with regular gas sampling and analysis has increased the knowledge of and trends in goaf atmospheric conditions.

Progressively sealing the back return airway will maintain a positive pressure differential between the face and the open cut through.

Refrigeration of Intake Air

Refrigeration of intake air is currently being trialed at mines in the Queensland during the hotter months of the year when the intake temperature often exceeds 35°C dry bulb. The plants are not permanently installed and do not chill the total mine intake capacity.

Cooling the mine ventilation can be achieved by direct cooling of the air by chilled water sprays, indirect by cooling coils or a combination of both. Deeper coal mines have employed both methods (Hamm E, 1979). The economics of underground versus surface cooling plants depends on a number of factors however the most significant are depth and the distribution of the workings. A generalization by Ramsden and Carvahlo (1988) for gold mines was that at depths to 2000m there was no clear advantage of either system. There are however many advantages of installing a cooling plant on the surface not least of which is the dissipation of heat from the heat exchanger which would necessarily be in a return airway underground.

For the relative shallow depths of Australia's longwall mines and concentration of workings a direct cooling system using reticulated chilled water is ideal. A lower capital cost for piping, less pumping costs and an easily expanded system with mining make this method of cooling economically attractive.

Direct Cooling Systems

Over recent years the trend for the cooling of the mine climate at the larger metalliferous mines is to install bulk air refrigeration plants on the surface. This provides an advantage for plant maintenance, larger installed capacities, heat dissipation and, if required, the circulation of chilled water. In consideration of coal mines and longwall faces, bulk air cooling plants for the mine intake air is inefficient with up to 30% of the mine ventilation being lost through leakage. Alternatively piping of chilled water underground to the working areas enables the air to be cooled for maximum effect near the longwall face. Insulation of these pipes is sometimes required to avoid water temperature rises although exposed pipes does have some benefit in cooling the intake air stream.

The chilled water can be delivered anywhere in the mine and can either directly or indirectly be applied to cool the intake ventilation. An indirect method of chilled water cooling using coils allows the water to be more easily managed and re-directed to other areas without entering onto the traveling road. However, cooling efficiency is compromised requiring higher water flows and the periodic cleaning of the coils of dust.

Direct air to water contact using spray chambers provides a more efficient cooling method. Applying a spray system closer to the longwall working area will require less water and power at the refrigeration plant. The advantage of a three heading longwall panel provides a second intake airway where a series of counterflow spray chambers can be installed with appropriate water sumps and pumping equipment. The majority of the intake air can pass through the chamber by erecting vehicle doors in the parallel intake. An arrangement is shown in Figure 4. For a total longwall panel intake quantity of 60m^3/s of which 50m^3/s is directed through the spray chamber at an intake temperature of 27°C dry bulb and 26°C wet bulb a reduction to 21°C Dry bulb/Wet bulb can be readily achieved with 20 L/s of chilled water entering the chamber at 10°C. The estimated volume flow of chilled water to reduce the heat capacity in the air can be obtained by using the following energy equations balancing the water flow heat gain and the change in :sigma heat of the air current.

$Q_w = M_w \times C_w \times (t_{w2} - t_{w1})$

$Q_a = M_a \times (S_1 - S_2)$

$\eta = \Delta t_w / (t_{wbi} - t_{wi})$

Where
Q_a and Q_w = thermal energy of air and water respectively (kW)
M_a and M_w = mass flow of air and water respectively (kg/s)
C_w = specific heat of water (kJ/kg °C)
t_{w1} and t_{w2} = temperature of chilled and outgoing water respectively (°C)
S_1 , S_2 = sigma heat of air before and after the chamber (kJ/kg)
T_{wb1} = the wet bulb temperature of the incoming air (°C)

The change of thermal energy in the air is 1000 kW.
For a water efficiency (η) of 0.65 and an inlet water temperature of 10°C the outlet water temperature would be approximately 20.4°C. The ventilation pressure loss across a spray chamber will depend on the baffle or eliminator plate configuration to remove water droplets picked up by the air. For ventilation estimations approximately 250 Pa should be allowed. With this pressure loss the total fan pressure consumption around the longwall section is still below that of a twin heading development longwall of 3km length for similar face quantities.

Using a typical maximum rate of increase of 1.0°C per km for the wet bulb temperature the estimated wet bulb temperature at the last cut-through before the longwall face would be approximately 24°C. In longwall panels that are 4.5km to 5km in length the age of the initial 2km of intake roadways would be at least 6 months and have a low impact on the air temperature increase as long as they were kept reasonably dry. Wet bulb temperatures at the intake side of the longwall face are therefore estimated to not exceed 24°C.

The water collected at the spray chamber is pumped into the supply line to the face for dust suppression and motor cooling water. This provides additional cooling capacity at the face. Water consumption for dust suppression and motor cooling on high capacity faces is typically 10 to 15L/s, the majority being used by the shearer with total rated power up to 1500kW. Excess water can be either directed to other underground operations or pumped back to the surface for re-use. Float switches and PLC systems control the pumps and valves depending on demand. A schematic of the water circuit is shown in Figure 4.

Due to typical underground climates the mine cooling system will be required to operate less than five months of the year and water demand for the direct contact cooling sprays can be varied depending on daytime temperatures.

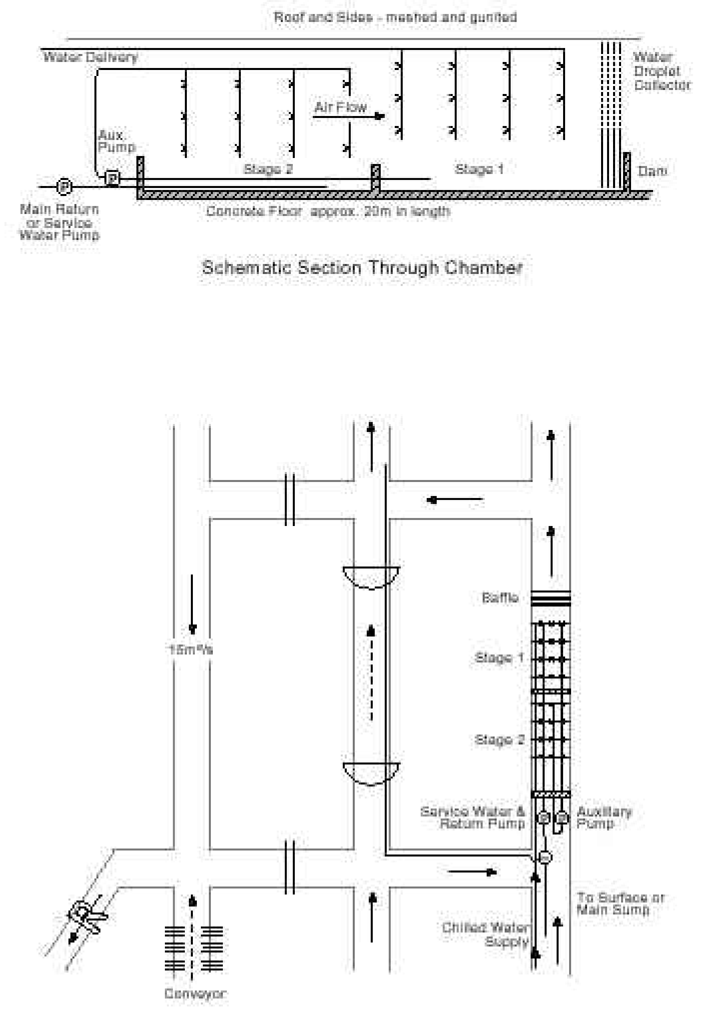

FIGURE 4
Three Heading Longwall Panel with Spray Chamber

CONCLUSION

Longer panels and hot surface climates have combined with the traditional sources of mine heat to produce uncomfortable working environments on high production longwall faces. Increasing panel air quantities and face velocities has provided respite from these conditions, however further benefits are now limited due to the already high velocities and associated pressure differentials across the face and goaf. Alternate ventilation arrangements using three heading panels to provide face and panel ventilation options with less pressures and introducing reticulated chilled water cooling systems offer a way to maintain the trend of increasing longwall productivity without discomfort to the operators.

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