OPTIMUM INERTISATION STRATEGIES

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Innovation success

The new optimum inertisation strategies developed and implemented at Newlands Colliery were highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing. During the field demonstration studies, the goaf atmosphere was inert by the time of closing the doors on the final seals, with oxygen concentration below 5 percent at all locations in the goaf.

Abstract

The main objective of the ACARP project was to develop optimum and effective strategies for inertisation during longwall sealing operations to achieve goaf inertisation within a few hours of sealing the panel.

The project has combined the detailed analysis of the performance of various inertisation field trials together with computational fluid dynamics (CFD) modelling of different inertisation operations in order to develop the optimum inertisation strategies.

The project work specifically involved review of the current inertisation practices, laboratory studies, CFD simulations, tracer gas tests, development of optimum strategies and field demonstration studies.

Analysis of the data from six review case studies showed that the traditional inertisation schemes were not effective in preventing the formation of explosive gas mixtures in three cases, and in the other three cases oxygen concentration levels were above 12 percent[for up to two days after panel sealing.

CFD modelling simulations and review studies indicated that just injecting inert gas through the MG or TG seals does not achieve the objective of quick inertisation of longwall goafs.

Based on the results of various simulations, an optimum inertisation strategy was developed taking into consideration the positive effects of various options and the field site conditions.

Field demonstration studies of the optimum strategy were conducted at Newlands Colliery. The new optimum inertisation strategies developed and implemented at Newlands Colliery were highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing.

Introduction

In underground gassy coal mines it is generally recognised that immediately after sealing a longwall panel, the atmosphere behind the seals may enter and pass through the explosive range. The duration of explosive conditions in the sealed longwall goaf ranges from a few hours to one or two days or even a few weeks, depending on the gas emission rate and goaf characteristics.

Therefore, any sealed area with methane as the seam gas has the potential to explode depending on the presence of ignition sources.

To minimise this risk of explosions, the modern practice in some of the Australian mines is to inject inert gas into the sealed goafs immediately after sealing the panel.

The specific objective of inert gas injection operations is to reduce the goaf oxygen levels below the safe limit of 8 percent or 12 percent before methane concentration reaches the lower explosive limit of 5 percent.

The traditional inertisation schemes usually involved just injecting inert gas through maingate (MG) or tailgate (TG) seals until goaf gas sampling results show that oxygen level was below 8 percent.

In many cases it was found that the goaf oxygen concentration was above 12 percent even after two to three days of inert gas injection and in some cases an explosive atmosphere was also present in the goaf during inertisation.

There was a need to optimise inertisation operations to reduce the goaf oxygen levels, thus reduce the explosion potential as quickly as possible during longwall sealing off periods.

The main objective of theACARP project was to develop optimum and effective strategies for inertisation during longwall sealing off operations to achieve goaf inertisation within a few hours of sealing the panel.

This research work was carried out under the Australian Coal Association Research Program (ACARP) project C9006, entitled 'Optimisation of Inertisation Practice.'

The project has combined the detailed analysis of the performance of various inertisation field trials together with extensive computational fluid dynamic (CFD) modelling to develop the optimum inertisation strategies.

Field demonstration studies of the optimum inertisation strategy were conducted at Newlands Colliery in Queensland. A brief summary of the project work is presented in this paper**.**

Review of traditional inertisation schemes

Longwall goaf inertisation is being carried out in some of the mines in Australia on a regular basis to reduce the potential risk of explosions during the panel sealing-off period.

Traditionally liquid N_2 and CO_2 were used in most of the fire control inertisation operations.

However, it was difficult and expensive to procure large quantities of the inert gases for routine longwall sealing applications, particularly in mines located at remote places of Australia. In 1997, the Tomlinson Boiler low-flow inertisation device and a high capacity GAG 3A jet engine system were demonstrated to the Australian mining industry as new practical tools for inertising underground mine atmospheres.

The successful demonstration of these devices has improved the availability of inert gases for routine mine applications.

While the previous inertisation projects concentrated on development of inert gas generators, this project concentrated on development of an effective and optimum inertisation strategies using the available inert gases.

Over the last few years, there have been more than 10 applications of inertisation during longwall sealing operations.

The data review phase of the study involved collection of inertisation data from previous operations and field studies to collect data from the on-going inertisation operations at a number of longwall panels.

In total, inertisation data has been collected from 6 different longwall panels. These six panels had employed different inertisation schemes and cover three different mines with different gas emission rates and panel characteristics.

A comprehensive review of the inertisation data has been carried out to analyse the effect of different inertisation designs on goaf inertisation.

The effect of mine factors such as goaf layout, ventilation systems and inert gas composition on effectiveness of inertisation was also assessed.

Analysis of the data from some of the mines showed that the inertisation schemes implemented were not effective in preventing the formation of explosive gas mixtures near the longwall finish line for up to two days after panel sealing. In one case, the goaf atmosphere near the finish line fluctuated widely and the oxygen concentration was over the 12 percent level a number of times over the two week period after sealing.

Results from another mine showed that although the inertisation schemes employed at that mine were relatively more effective when compared with results of other cases, oxygen levels in the goaf were still above 12 percent for up to two days after panel sealing. Analysis of results from one of the typical case studies is discussed below.

In the typical inertisation practice, the inert gas is injected into the goaf generally through the MG seal immediately after sealing the panel.

Recently, some mines started the practice of injecting inert gas simultaneously into both MG and TG

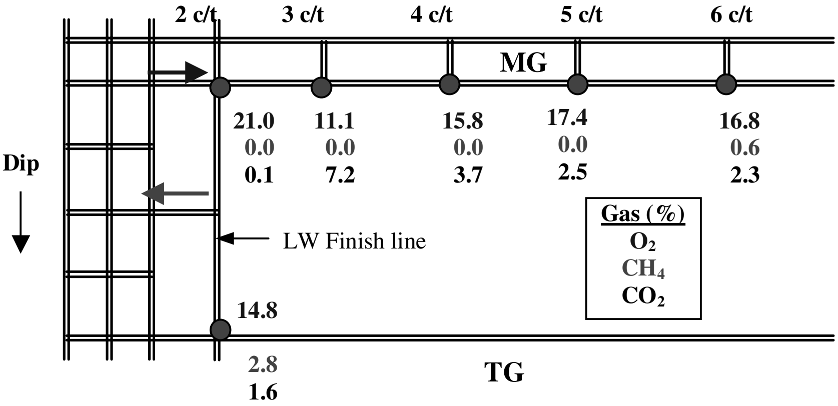

Figure 1 Gas distribution in the goaf – just before panel sealing in a typical case study

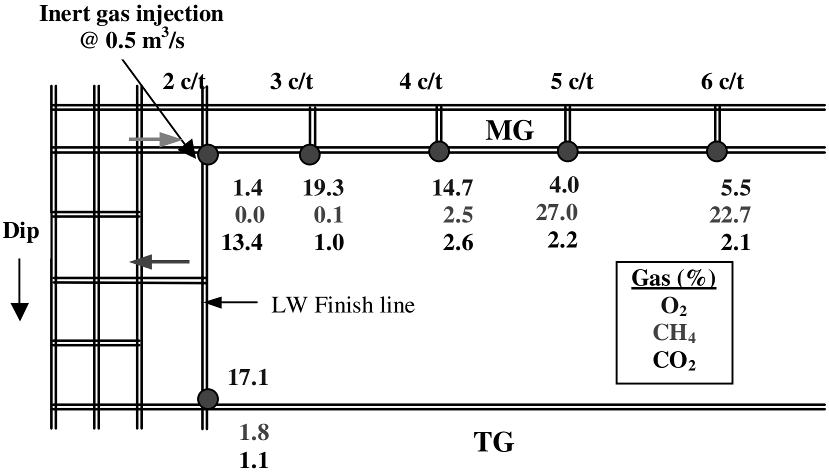

Figure 2 Gas distribution in the goaf – 6 hours after panel sealing, with traditional inertisation

seals or other seals depending on the oxygen levels at various locations around the goaf.

The inert gas generator is normally set up at a temporary surface site above the longwall and one or two 150mm diameter boreholes are drilled from the surface into the gateroads for inert gas delivery.

In the typical case study presented here, the maingate was used as an intake airway and the tailgate as return airway during longwall retreat operations.

Airflow quantity of 40 to 50 m^3/s had been maintained along the face during longwall extraction.

In this case, the panel orientation was such that the maingate intake was at a higher elevation compared with the tailgate roadway and the outbye tailgate corner was the point of lowest elevation.

Methane gas emission in the panel was relatively low at the rate of about 300 l/s. After sealing off the panel, Boiler inert gas was injected into the goaf through the MG seal for inertisation.

Goaf gas distribution at various locations around the longwall panel during the inertisation period is shown in Figures 1 to 3.

Figure 1 presents the goaf gas composition immediately before sealing off the panel and shows that the oxygen level was above the explosive nose limit of 12 percent even at 6 c/t, ie at 400m behind the finish line on maingate side.

Gas distribution in the goaf 6 hours after sealing the panel is shown in Figure 2. Comparison of Figures 1 and 2 shows that fresh air/oxygen from the face finish line area was pushed towards 3 c/t and TG areas after introduction of inert gas through the MG seal.

Figure 3 shows that the goaf O_2 level was above the safe limit of 12 percent, 12 hours after panel sealing. Results showed that the goaf became completely inert two days after panel sealing.

In another typical case study, inert gas was injected through both MG and TG seals, immediately after sealing off the panel. Gas composition in the goaf after one day of inert gas injection is shown in Figure 4.

Analysis of the results shows an increase in oxygen level to 15 percent at 3 c/t seal, which indicates that high O_2 concentration pockets were still present in the goaf even when inert gas was injected through both MG and TG seals.

The results from the review studies indicate that just injecting inert gas through MG or TG seals does not achieve the objective of quick inertisation of longwall goafs.

Analysis of results indicated that the effect of inert gas injection through the MG/ TG seals on gas composition at inbye locations of the goaf was negligible for up to two days after sealing. It was also noted that development of positive pressure in the goaf alone, even at 500 Pa, does not indicate goaf inertisation.

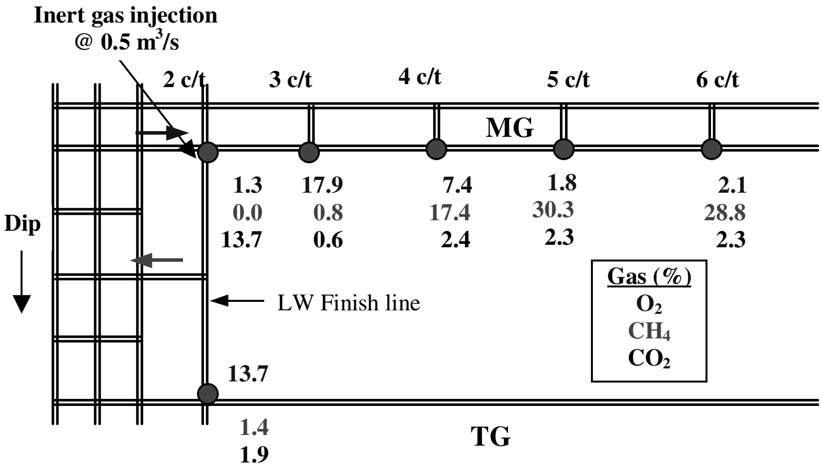

Figure 3 Gas distribution in the goaf – 12 hours after panel sealing, with traditional inertisation

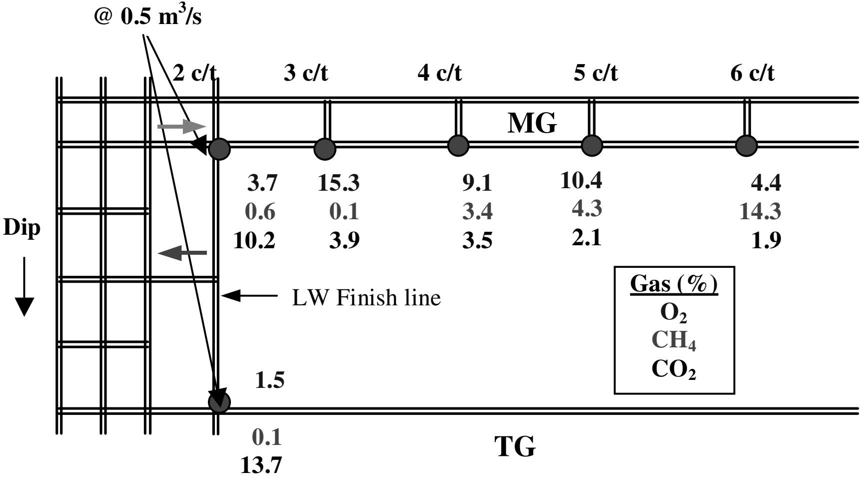

Figure 4 Gas distribution in the goaf – 1 day after panel sealing, with traditional inertisation

These review studies indicated that there is a need for optimisation of inertisation strategies to achieve the desired objective of goaf inertisation within a few hours of sealing.

Development of optimum strategies requires a detailed understanding of inert gas dispersion patterns in the goaf and their effect on goaf gas distribution.

A brief summary of the modelling studies carried out to improve our understanding of the effect of inertisation is presented in the following section.

Cfd modelling studies

The focus of the modelling exercise was to obtain a better understanding of the inert gas flow patterns in the goaf and qualitative analysis of the various factors involved in inertisation operations, in order to establish a scientific basis for design of optimum strategies.

Computational fluid dynamics (CFD) techniques have been used to develop the goaf models to study the inert gas flow mechanics in sealed longwall panels.

The modelling of the inertisation process in longwall goafs consists of a number of stages, including:

- field studies to obtain the basic information on panel,
- goaf geometries and other parameters
- construction of 3D finite element model of the longwall goaf
- setting up flow models and boundary conditions through user-defined subroutines
- base case model simulations
- model calibration and validation using field measured data
- extensive parametric studies and development of optimum inertisation strategies.

Base model simulations

Field studies were conducted in the beginning of the project to obtain the basic information on geometry of the longwall goaf, gas emissions, ventilation system, caving characteristics and inertisation practices and system details.

These initial studies also involved a detailed monitoring of the gas distribution changes in the goaf during standard inertisation operations in order to collect field data for base-case model calibration and validation purposes.

Information obtained from the above field studies was used to construct the base-case longwall inertisation model. The base model for the longwall inertisation studies was 1km in length along the panel, 205m in width and 50m in height to cover the immediate high porosity caving regions in the goaf.

The seam and roadways were 4m high and all roadways were 5m wide. Goaf gas emission was varied between 100 l/s and 600 l/s to represent typical longwall panels in highly critical low gas environments.

This was also equal to the gas emission rates of the panels used for model calibration and validation.

The maingate inlet was set at an elevation 20m higher than the tailgate return to represent the field case scenario.

A 'U' ventilation system was used in the base-case models, with the maingate as intake and tailgate as return roadway.

The distribution of goaf porosity was derived from results of typical longwall geomechanics models.

Pressure, flow rate and gas distribution in a typical longwall goaf were used to calibrate the initial models and further refine the distribution of goaf permeability.

The permeability distribution in the goaf ranged from 10^{-4} m^2 to 10^{-10} m^2. A standard two equation k-e model was used to estimate the turbulent transport through the flow region.

Flow through goaf was handled using custom written subroutines, which were added to the 'flow through porous media' modules of the basic code.

A number of subroutines were written to represent the goaf gas emissions and inertisation scenarios, which were then combined with the main FLUENT program to carry out the simulations.

Initial simulations were carried out using the base-case longwall inertisation model.

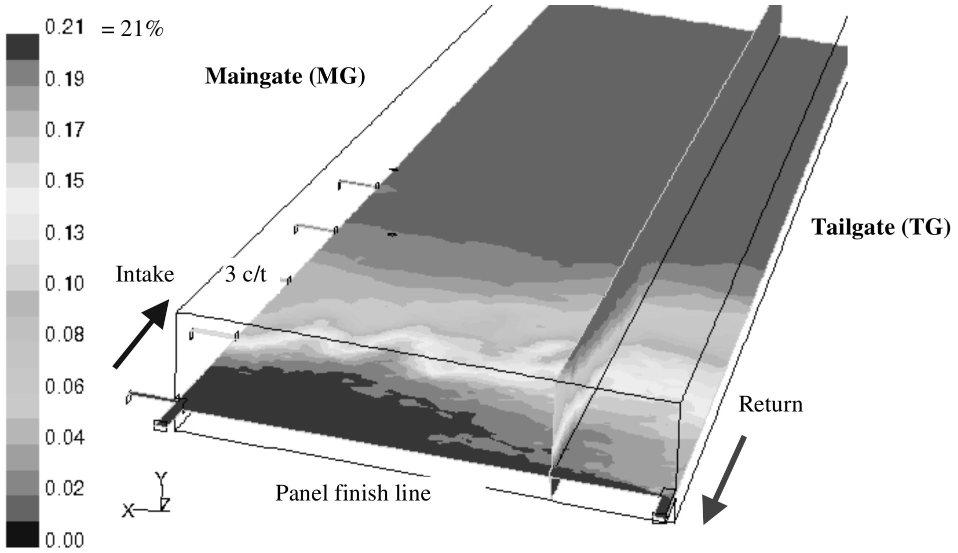

Figure 5 Oxygen gas distribution in the longwall goaf near the finish line – with 50 m^3/s airflow

Two sets of base-case simulations were carried out to represent the conditions during face bolting and panel sealing-off periods.

The intake airflow rate through the maingate was kept at 50 m^3/s in the first base case set, which represents goaf environmental conditions during face bolting period. In the second base case, intake airflow was reduced to 10 m^3/s to represent goaf conditions just before sealing off the panel.

These base-case simulations were carried out under different gas emission flow rates. Steady state modelling was carried out to simulate goaf conditions before the sealing off period and transient modelling techniques were used to simulate the sealed goaf atmosphere at regular time intervals after panel sealing.

The results of the base-case simulations in 3D view are presented in Figures 5 and 6, showing the oxygen gas distribution in the goaf under different airflow conditions.

The 3D view figures show two slices along the longwall panel. The horizontal slice is midway through the seam and the vertical slice is 50m from the tailgate rib.

In the colour coding scale of the figures, 0.21 represents 21 percent oxygen, ie fresh air composition.

Figure 5 shows the oxygen distribution in the goaf with first base case simulations, ie, with 50 m^3/s airflow and 0.6 m^3/s methane goaf gas emissions.

Results show that oxygen ingress into the goaf was more on the maingate intake side compared with tailgate return side.

For example, the oxygen level was around 20 percent on the maingate side and 16 percent on the tailgate side of the goaf at 60m behind the face.

Other important points to be noted from the results presented in Figure 5 are:

- The vertical section in the figure clearly shows the air/gas layering in the goaf with higher oxygen concentration near the lower working seam level. However, Figure 5 also shows that even though tailgate return was at lower elevation, the oxygen levels were higher in the maingate area. This indicates that during longwall retreat operations, ventilation pressures and gas emissions had a major influence on goaf gas distribution at working seam level near the face, compared to the effect of methane gas buoyancy forces.
- It is also to be noted that although the oxygen concentration levels were lower near the tailgate area, air penetration distance into the goaf was higher on tailgate side with 10 percent oxygen at 200m behind the face.
- Oxygen levels presented in the figure represents only goaf gas distribution near the bolted-up area of the panel near the finish line, but not a standard goaf gas distribution under normal caving conditions. (In normal caving zones, high oxygen concentration zone penetration distance into the goaf will be significantly less due to higher consolidation of the goaf material at the centre part of the panel).

In the second base case simulations, airflow in the panel was reduced to 10 m^3/s to represent goaf conditions just before sealing off the panel. Results of simulations are shown in shown in Figure 6.

Oxygen distribution presented in the Figure 6 shows that oxygen concentration levels and penetration distance were higher on the tailgate return side of the goaf.

Oxygen penetration distance extended up to 300m on the tailgate side of the goaf. This is in contrast to the oxygen distribution for first base case, presented in Figure 5, where oxygen concentration levels were higher on the maingate intake side.

Comparison of the results presented in Figures 5 and 6, shows that intake airflow rate and the consequent air velocity and ventilation pressures have a major influence on gas distribution in the goaf.

Reducing the intake airflow in the panel during chock recovery operations has considerably reduced the oxygen penetration on the intake side of the goaf and drastically changed the goaf gas distribution pattern.

In addition, reducing the intake airflow also resulted in extension of buoyancy force effect down to working

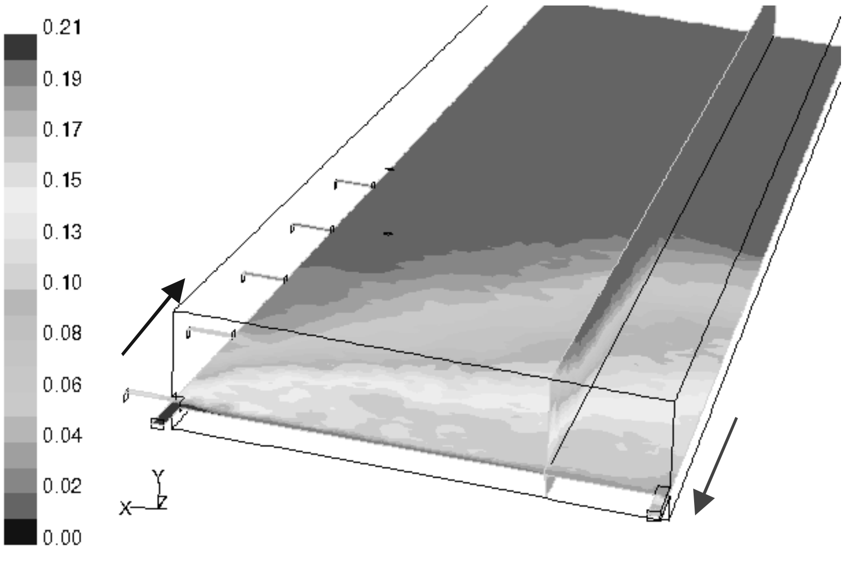

Figure 6 Oxygen gas distribution in the longwall goaf near the finish line – with 10 m^3/s airflow

seam level in the goaf.

Parametric studies

The base case CFD models were calibrated and validated based on the information obtained from previous inertisation studies and goaf gas monitoring. The validated models were then used for extensive parametric studies involving changes in inert gas injection locations, inert gas flow rates, seam gradients, and different inertisation strategies to investigate their effect on goaf inertisation.

Parametric studies were conducted under both steady state and transient conditions. Goaf conditions were simulated for up to five days after sealing of the longwall panel with various inertisation strategies.

Results from two typical parametric studies are presented in this paper.

(a) Effect of inert gas composition: The effects of two different inert gases on goaf inertisation were investigated in these parametric studies. In the first model, boiler exhaust gas was used as inert gas, whereas in the second model nitrogen gas was used for goaf inertisation. In both the models inert gas was injected through the MG seal at the flow rate of 1.0m^3/s. In both the models, seam gradient was set at 1 in 10 dipping towards the tailgate side. All other parameters were the same in both models. These modelling studies were carried out with transient parameters to simulate the goaf conditions immediately after sealing of the panel. Results of the simulations are presented in Figures 7 and 8. Results show that there were no major differences in goaf gas distribution between the two cases under the modelled parameters. In both cases the oxygen level was reduced to only 14 percent after 24 hours of inert gas injection.

Results show that there was no major difference in effectiveness of boiler gas or nitrogen on goaf inertisation. These results indicate that although inert gas composition might have an effect on goaf inertisation under certain conditions, it is not the major factor that would make an inertisation process a success or a failure, particularly under sealed goaf conditions.

(*b*) Effect of inert gas injection location: The effect of two different inert gas injection locations on goaf inertisation was studied in separate models with transient parameters to simulate goaf conditions after panel sealing. In the first model inert gas was injected through the MG seal and in the second model inert gas was injected at 200 m behind the face (through 3 c/t seal) on the maingate side. Inert gas was injected at the rate of 0.5 m^3/s in both the models. All other conditions and parameters were the same in both cases. Oxygen distribution in the goaf for both models after 24 hours of inert gas injection is presented in Figures 9 and 10

Results show that different inert gas injection locations resulted in entirely different goaf gas distribution for the two cases.

Figure 9 shows that injection of inert gas through MG seal resulted in a reduction of oxygen concentration only near the point of injection, ie near maingate area.

The oxygen concentration level in this area reduced down to 8 to 10 percent.

However, oxygen level near the tailgate area was very high at 15 to 17 percent even after 24 hours of inert gas injection.

Results presented in Figure 10 shows that inert gas injection through 3c/t on the maingate side resulted in a reduction of oxygen concentration levels down to 10 to 12 percent over a wider area near the finish line.

Further simulations showed that when inert gas was injected through the MG seal, the oxygen concentration was above 14 percent over a wider area even after two days of inert gas injection.

In the second case with inert gas injection through 3 c/t, oxygen concentration was below 12 percent across the entire goaf.

Analysis of the figures indicate that the strategy of inert gas injection through the MG seal was not as effective as the alternative strategy of inert gas injection at 200m behind the face (ie through 3c/t).

Results also indicated that inert gas injection through the MG seal results in pushing the fresh air zone towards the goaf and consequently requires a longer time for goaf inertisation.

It is to be noted that open goaf simulation results also indicated that inert gas injection from the maingate side at 100 to 200m behind the face reduces the oxygen level in the high sponcom risk area of the goaf and helps in sponcom control during face retreat.

Analysis of the various simulation results also

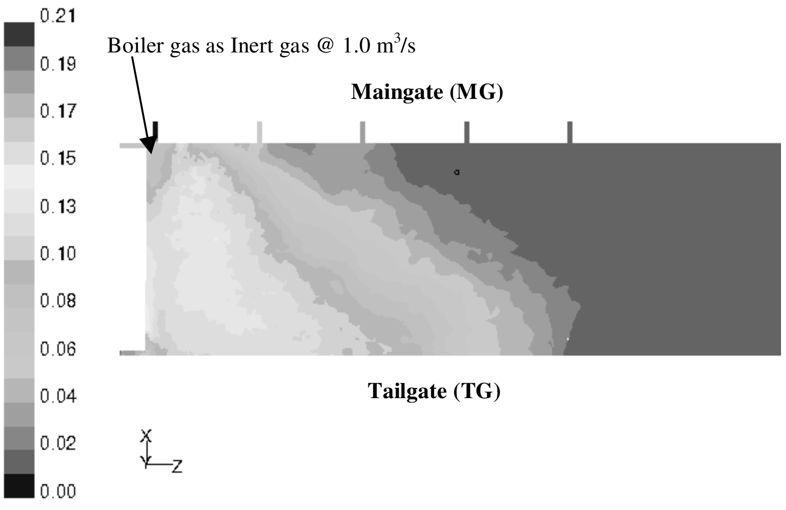

Figure 7 Oxygen distribution in the goaf – 1 day after sealing, with Boiler exhaust as inert gas

indicated that longwall panel geometry, goaf characteristics, gateroad conditions in the goaf, goaf gas emission rates and composition, ventilation during panel sealing off period, chock withdrawal and panel sealing sequence would also have a significant influence on goaf gas distribution and inertisation.

Optimisation studies

CFD modelling simulations with field site geometry and conditions showed that the strategy of inert gas injection through the TG seal only, would not be effective for goaf inertisation.

Simulations with inert gas injection through the MG showed that although this inertisation scheme resulted in better goaf inertisation compared with the previous scheme, it did not achieve the objective of goaf inertisation within a few hours of panel sealing.

Based on the results of various simulations, an optimum inertisation strategy was developed taking into consideration the positive effects of various inertisation schemes and the field site conditions.

The optimum strategy developed basically involved the following three steps:

(i) inert gas injection (@ 0.5 m^3/s) through the TG for two days before panel sealing

(ii) inert gas injection through 3 c/t for one day with door on chute road seal open

(iii) panel sealing and continuation of inert gas injection through 3 c/t.

This inertisation strategy was implemented in the transient CFD modelling simulations to study its effect on goaf gas distribution, particularly oxygen concentration levels in the goaf.

Inert gas was injected at the rate of 0.5 m^3**/s** through the TG seal initially and then through 3 c/t seal on the maingate side, as outlined above. Modelling simulated the goaf gas conditions for three more days after panel sealing.

Results of the simulations showing oxygen distribution in the goaf just before final sealing (ie just after step (ii) in the above optimum inertisation

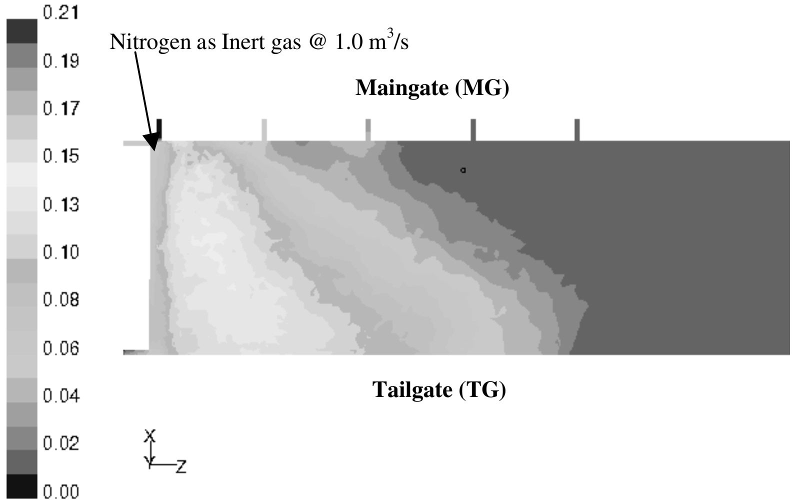

Figure 8 Oxygen distribution in the goaf – 1 day after sealing, with Nitrogen as inert gas

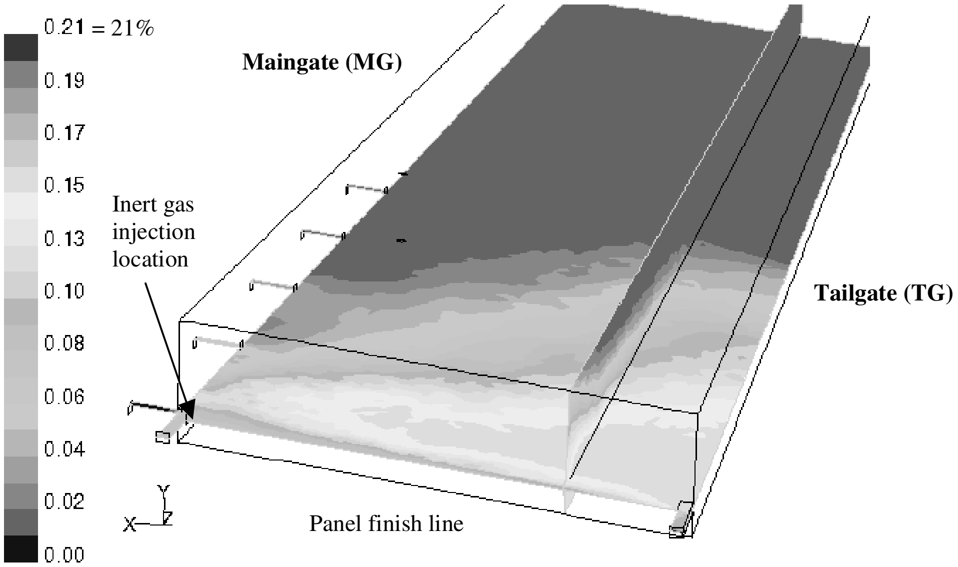

Figure 9 Oxygen distribution in the goaf – 1 day after sealing, with inert gas through MG seal

strategy) are shown in Figure 11.

Results show that the oxygen level was below 12 percent at all locations in the longwall goaf. Further simulations and analysis of the results showed that the optimum inertisation strategy developed during the course of investigations had achieved goaf inertisation within a few hours of panel sealing.

Simulation results showed that the optimum strategy effectively reduced the oxygen concentration at all locations in the goaf to below 12% levels even before panel sealing.

Field demonstration studies

The field demonstration studies were carried out at Newlands Colliery in the northern Bowen Basin of Queensland.

The mine is located near Glenden township, which is at about 180km west of Mackay. The mine operates a single longwall face employing two leg high reach 1000T capacity chocks and produced about 5.5Mt in 2000.

The mine extracts the upper Newlands seam, which averages 6m in thickness in that region. The longwall mining height is about 4.8m. The width of the longwall panels was about 250m and the length ranged from 1600m to 2500m.

Newlands Colliery is one of the less gassy mines in Australia, with goaf gas emissions in the range of 100l/s to 500l/s.

It is to be noted that effective inertisation of a sealed goaf may take a longer time in less gassy mines.

Therefore, Newlands Colliery presented one of the difficult conditions for goaf inertisation, which was ideal for field demonstration studies.

Over the years, Newlands has made significant

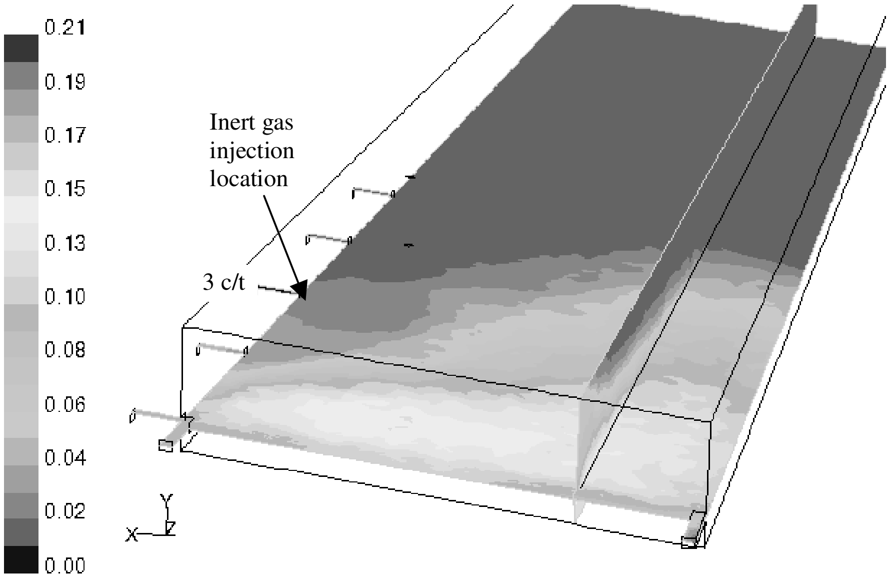

Figure 10 Oxygen distribution in the goaf – 1 day after sealing, with inert gas through 3 c/t seal

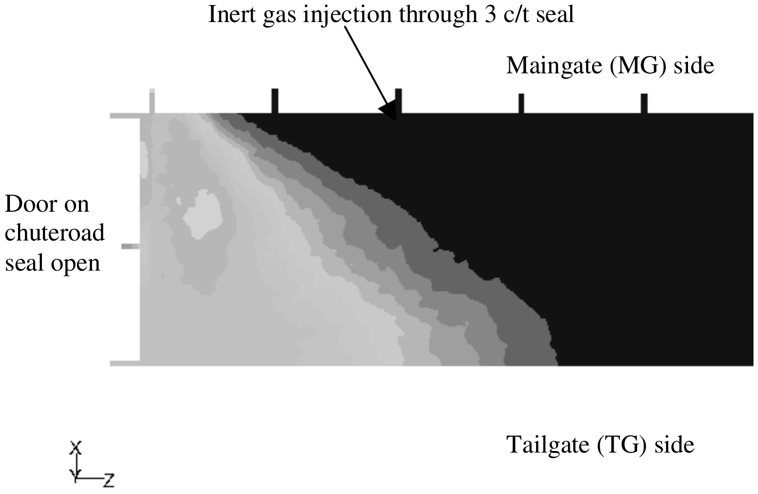

Figure 11 Oxygen distribution in the goaf – inert gas injection through 3 c/t with return doors open

improvement in the inertisation schemes and was able to reduce the goaf inertisation time down to two days, a good result compared with other mines. However, there was a need to optimise the inertisation operations to ensure complete inertisation of the goaf and to further reduce the inertisation period.

Field demonstration studies of the optimum inertisation strategy were conducted in N4B LW panel of the Newlands Colliery.

This panel was the first panel in the sequence of longwall extraction on the north side. The layout of the N4B panel and the ventilation system are presented in Figure 12.

The orientation of the panel was such that the outbye tailgate corner was the point of lowest elevation in the panel. In this panel a ‘U’ ventilation system was employed with the top maingate as intake and the bottom tailgate as return roadway.

Goaf gas emission flow rate in the panel was about 300 l/s (0.3m^3/s). Approximately 50m^3/s of airflow was supplied to the panel during panel extraction and the airflow was reduced to about 10m^3/s during the face recovery operations.

A chute-roadway was driven near the finish line of the panel to simplify the chock withdrawal process.

During face recovery operations this chute roadway was used as a return roadway after collapse of the face line near the TG. It is also to be noted that the face finish line was at two cut-through (c/t) in this panel.

Gas composition distribution at various locations around the goaf during the chock recovery in the panel is shown in Figure 13. Results show that oxygen ingress distance on the maingate intake side was about 300m and about 200m on tailgate side.

Readings indicate that gas distribution in the goaf during the chock recovery stage still depended largely on the panel ventilation system.

Conversely, the buoyancy effect of methane gas emissions in the goaf was not significant at the working seam level. The high oxygen concentration zone was spread over a wide area in the goaf.

Based on the results and analysis of the review studies and modelling investigations, an optimum inertisation strategy had been developed for Newlands Colliery to achieve the project objective of reducing oxygen concentration in the goaf to below 8 percent within a few hours of sealing the panel.

The new strategy developed during the course of the project has been implemented in the field studies.

Tracer gas studies were also carried out to map the inert gas dispersion patterns in the goaf. An extensive underground gas monitoring system was installed around the N4B panel involving 9 monitoring tubes installed on both sides of the goaf.

Three surface boreholes were also drilled into the goaf specifically for these demonstration studies to monitor the gas concentration levels deep inside the

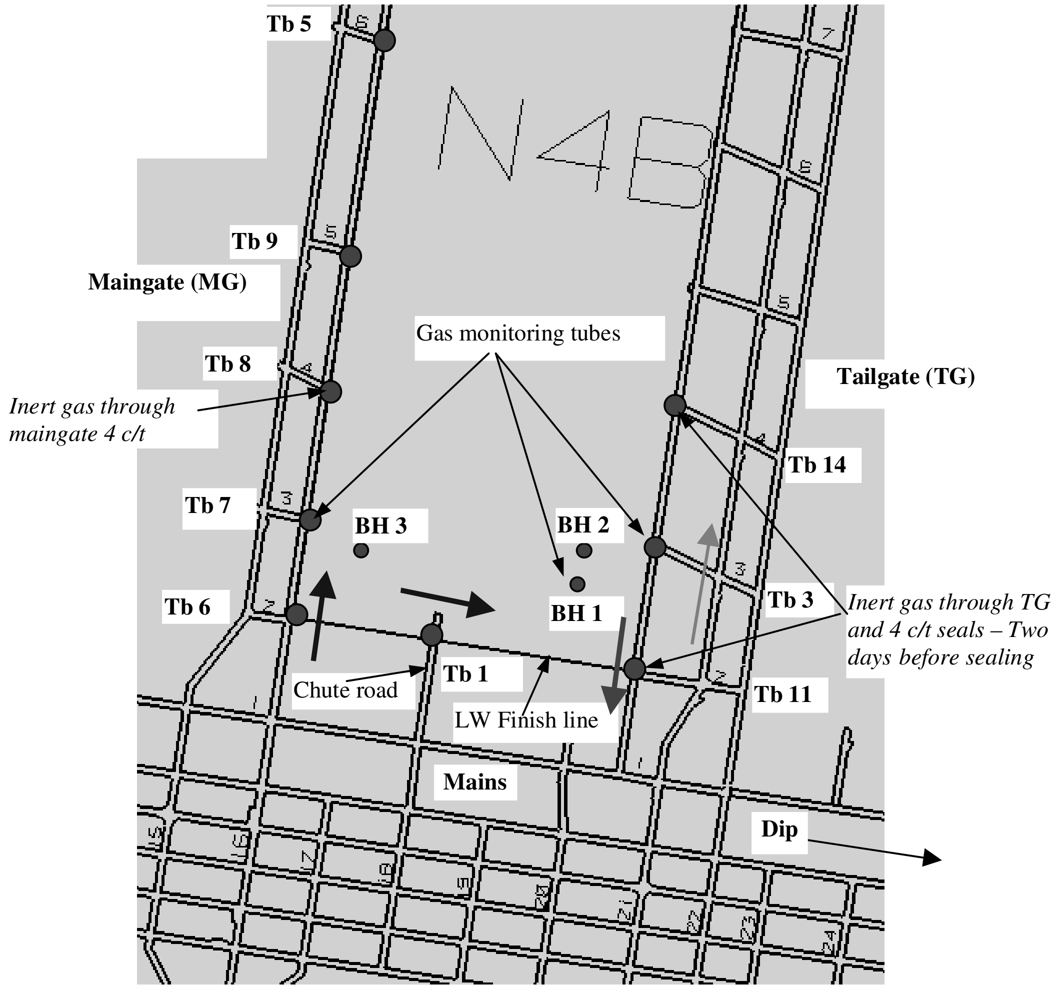

Figure 12 Longwall panel layout and location of gas monitoring tubes at the field site

goaf during sealing off and inertisation operations. Newlands Colliery and project collaborator SIMTARS have also been extensively involved in these field studies.

The optimum inertisation strategy developed during the course of the project for Newlands Colliery site conditions basically involved:

(i) inert gas injection through tailgate 4c/t and TG seals for two days before sealing

(ii) inert gas flow rate at 0.5m³/s **(Boiler gas)**

(iii) inert gas injection through maingate 4c/t (ie at 200m behind the face finish line) for one day with door on chute road seal still open

(iv) panel sealing and continuation of inert gas injection through maingate 4c/t until oxygen levels in the goaf reduced below 8 percent.

Goaf gas conditions were monitored continuously at 30 minute intervals during the field demonstration studies to study the changes in goaf gas distribution during the inertisation process.

The results of the field demonstration studies illustrating the effect of the optimum inertisation strategy on N4B panel goaf inertisation are presented in this section.

The changes in gas concentration levels at chute road seal during inertisation and longwall sealing off periods are shown in Figure 14 It is to be noted that

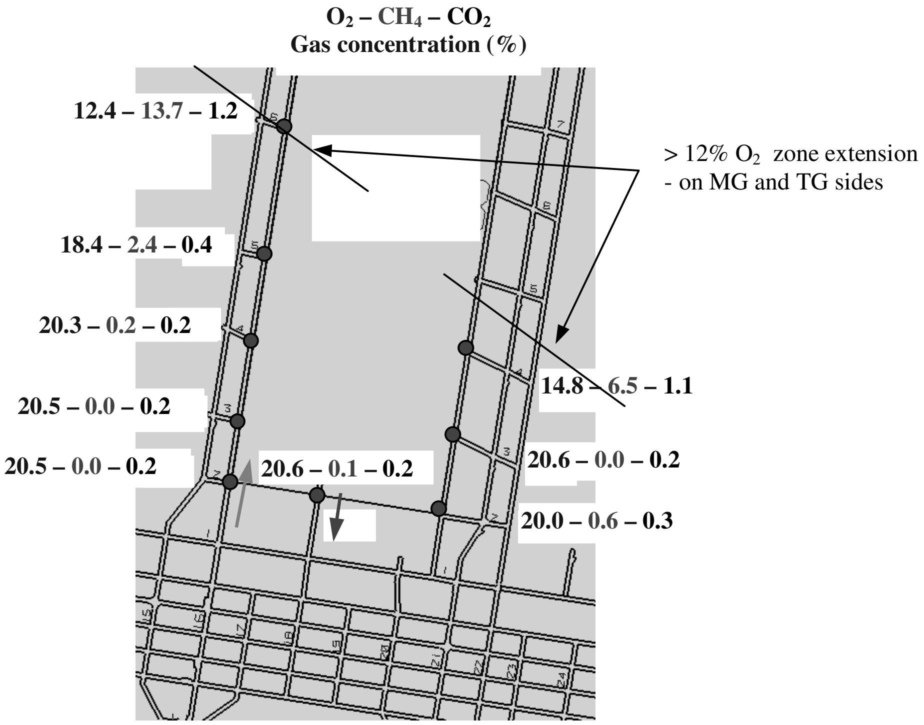

Figure 13 Gas distribution in the goaf – just after chocks recovery at the field site

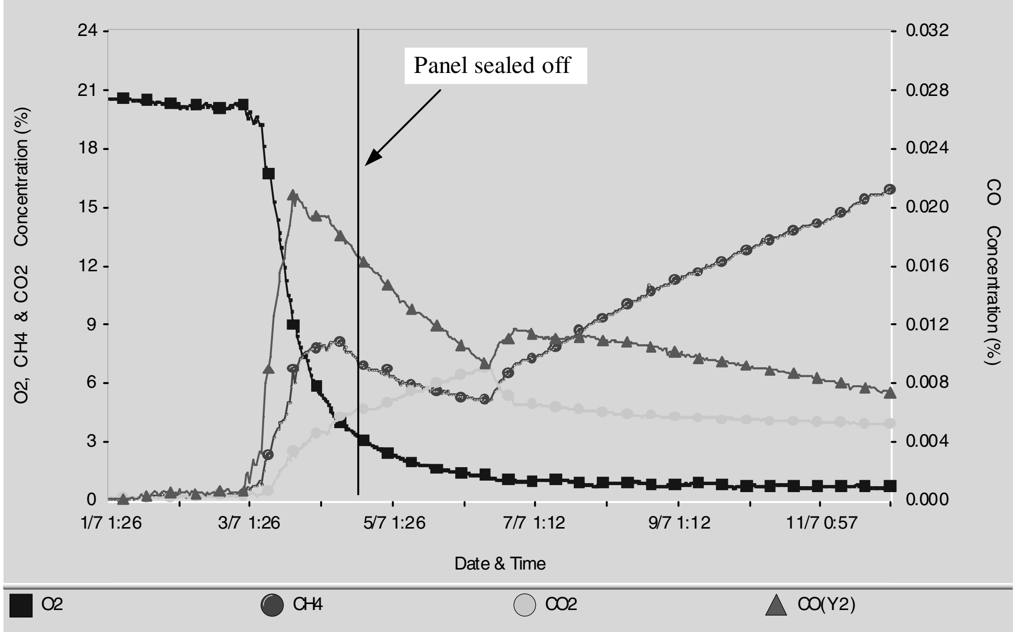

Figure 14 Gas concentration profiles at Chute road seal (Tube 1) during inertisation period

inert gas was not injected through this seal. Results show that the oxygen concentration level at this location reduced rapidly to below 8 ppercent levels within a few hours of inert gas introduction through 4c/t on the maingate side.

A similar trend was observed at the MG seal also. By the time the panel was sealed off at 10:20 hours on 4-7-01, the oxygen concentration level at both the MG and chute road seals was below 5 percent.

Gas distribution in the longwall goaf within one hour of panel sealing is shown in Figure 15.

Gas readings show that oxygen gas concentration was below 5 percent at all locations in the panel. In fact, the goaf atmosphere was completely inert and safe by the time of panel sealing.

Gas levels across the goaf were continuously monitored for another one week after stoppage of inertisation to check the effectiveness of goaf inertisation.

Monitoring results showed that oxygen concentration levels continued to fall and there were no signs of high oxygen concentration zones in the goaf. Results showed that oxygen gas levels remained low at around 2 to 3 percent and the goaf was completely inert.

Analysis of the results also indicate that boiler gas dispersion in the goaf was not just confined to a narrow zone in the collapsed maingate, but extended to a wider area in the goaf and resulted in faster and complete goaf inertisation. These results indicated that in the case of the optimum inertisation strategy, inert gas works in combination with goaf gas emissions and would achieve faster goaf inertisation. This is in contrast to the results presented in review case studies with the standard inertisation practice of inert gas injection through the MG seal. Traditional inertisation practice review studies indicated that in the case of the standard inertisation system, inert gas works against goaf gas emissions and hence take a longer time for inertising the goaf.

Field demonstration study results show that the optimum inertisation strategy implemented at the field site was highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing.

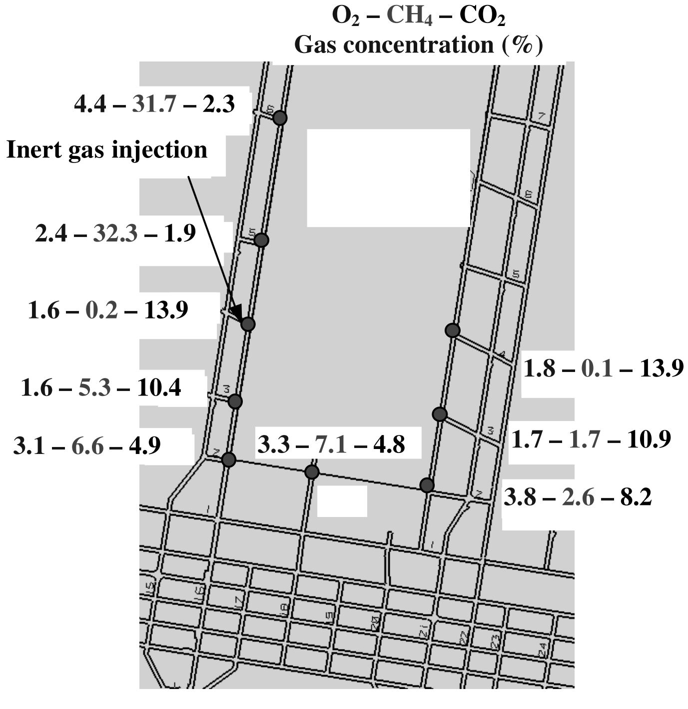

Figure 15 Gas distribution in the goaf – 1 hour after sealing, with optimum inertisation strategy

During these demonstration studies, results show that the goaf atmosphere was completely inert with oxygen concentration below 5.0 percent at all locations in the goaf by the time of closing the doors on the final seals.

Results also showed that oxygen levels in the goaf did not rise after stopping the inert gas injection, confirming the success of goaf inertisation.

Conclusions and recommendations

The main conclusions and recommendations from the research are:

(1) During longwall retreat operations, the panel ventilation system and goaf gas emission flow rates would have a major influence on goaf gas distribution at working seam level when compared with the effects of goaf gas buoyancy pressures.

(2) During panel sealing off operations, when panel airflows are restricted, goaf gas composition and buoyancy pressure plays a major role on gas distribution in the goaf.

(3) Coal seam gradient, panel geometry, caving characteristics, chock withdrawal and panel sealing sequence also play a significant role in goaf gas distribution and needs to be considered during development of inertisation operations.

(4) Development of an inertisation strategy should take into consideration the effect of all the above site parameters on goaf gas distribution. The most important design parameters for goaf inertisation during longwall sealing operations are (in the order of influence):
    a location of inert gas injection points
    b inertisation strategy – leakage paths, timing, etc
    c flow rate of inert gas injection
    d inert gas composition.

(5) In many cases, the standard practice of inert gas injection through MG or TG seals immediately after panel sealing would not be effective for goaf inertisation. In addition, it may increase the inertisation time because it acts against the goaf gas emissions. The optimum inertisation strategy should work in combination with goaf gas emissions to achieve faster goaf inertisation.

(6) Inert gas injection through the 2nd or 3rd cut throughs behind the face, i.e. at 100 to 200 m behind the face finish line, would result in effective goaf inertisation at a faster rate, compared with inert gas injection through TG or MG seals.

(7) Inert gas flow rate of 1.0 m^3/s is recommended under less gassy conditions. Inert gas flow rate of 0.5m^3/s would be sufficient under moderately gassy conditions, if optimum inertisation strategies are implemented.

(8) The recommended guidelines for optimum inertisation strategy are:
    a inert gas should be injected

into the goaf at around 200m behind the face finish line, ie, at an inbye location with respect to explosive fringe in the goaf.

b inert gas should be injected on the intake side of the goaf OR on both sides of the goaf.

c inert gas injection should start at least one or twodays before panel sealing, with minimum ventilation flow and doors on return seal still open.

d inert gas flow rate of 0.5 to $1.0m^3/s$ is recommended, subject to implementation of all these optimum strategies.

e inert gas injection to be continued after sealing until O_2 levels are below 8 percent.

In summary, the field demonstration study results showed that the optimum inertisation strategy implemented at the mine was highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing.

In fact, during the field demonstration studies, the goaf atmosphere was inert by the time of closing the doors on the final seals, with the oxygen concentration below 5 percent at all locations in the goaf.

This represents a major improvement to mine safety compared to typical inertisation practices that were able to achieve goaf inertisation within two to four days after sealing.

The project studies have greatly improved the fundamental understanding of the various site parameters and inertisation schemes on goaf inertisation.

This new understanding has been used to develop the optimum inertisation strategies for site conditions, which have proved to be highly successful in goaf inertisation.

This project demonstrated that it is feasible to completely inertise the longwall goafs within a few hours of sealing the panel by implementing optimum inertisation strategies.

The fundamental understanding of inert gas flow patterns and optimum inertisation guidelines developed during the course of the project greatly enhance the safety of coal mines.

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