

CONTROL DRAINAGE GAS QUALITY AND QUANTITY FROM UNDERGROUND COAL MINES TO ENHANCE ITS UTILISATION OPTIONS

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ABSTRACT

Gas drainage has been practised in gassy underground coal mines to control a high gas emission and minimise the risk of outbursts of a gas, or gas and coal in mining operations. To reduce the greenhouse impact of fugitive methane, utilisation options of the methane being drained are investigated. The quality and quantity of gas drained determine the possible gas utilisation options. This paper presents the flow and concentration variation profile of gas drainage in Australian gassy mines, the factors contributing the variation, and a number of options to control the variability.

1.0 MINE DRAINAGE GAS QUALITY AND QUANTITY

In gassy underground coal mines, the gas from coal seams has to be partially drained to prevent outburst of coal and gas and to control gas emission during coal extraction. Mine operators use both pre-drainage and post-drainage techniques to drain the gas from coal seams. More recently, the mine operators have been encouraged to shoulder the responsibility of exploring the utilisation options of the drained gas to mitigate the greenhouse gas impact. There are about 17 underground coal mines with active gas drainage systems in Australia. The amount of gas captured from the drainage systems is around 350 Mm³. Most of the captured gas is vented into the atmosphere.

One of the major difficulties in effective utilisation of the drained gas is the variability in supply and concentration. Table 1 shows the flow rate and purity of drainage gas, which shows some significant variation in both flow rate and composition. Gas flow from pre-drainage is controlled mainly by seam permeability, in some cases a gas flow rate of 3000 l/s is achieved. Gas purity from pre-drainage can vary from 60 to 90%, and the methane concentration can reach as high as 97% if surface well technique is employed. Gas flow and purity from post-drainage depend upon many factors including: gas content and composition in the coal seams and surrounding strata, gas drainage designs and techniques, and site-specific geological and mining parameters. A gas flow rate of 4000 l/s has achieved from the post-drainage in an Australian mine, though the gas flow ranges from 500 to 2000 l/s. The methane concentration from post-drainage ranges from 20 to 80%, and up to 90% methane can be achieved in some cases.

The amount of gas captured from drainage depends on site specific conditions including: gas content and permeability of the coal seams and surrounding

strata, drainage time, amount of negative pressure applied, and other variables of the geological and drainage systems.

Table 1 Quality and quantity of drainage gas

Drainage techniques	Gas quality	Gas quantity
In-seam drainage (pre-drainage)	High quality 60-90% CH ₄	Up to 100 l/s per hole Up to 3000 l/s per mine has been achieved in Australia
Vertical wells (pre-drainage)	Above 90% CH ₄	Production varies 100 to 1000 l/s per well
In-mine boreholes (post-drainage)	20 to 80% CH ₄	10 to 70 l/s per hole Up to 700 l/s per LW district has been achieved in Australia
Surface goaf holes (post-drainage)	20 to 80% CH ₄ Up to 90% CH ₄ in a totally sealed goaf	100 to 1000 l/s per hole Up to 5000 l/s per mine has been achieved in Australia

Methane percentage in the gas captured in drainage depends upon many factors such as gas composition in the coal seams and surrounding strata, gas drainage techniques and site-specific geological and mining parameters. Though methane is the predominantly seam gas in most coal seams, there are some cases where seam gas consists of substantial carbon dioxide, such as the coal seams in Tahmoor and Dartbrook mines of Australia. Pre-drainage techniques normally yield higher quality gas than post drainage techniques. Other factors affecting the methane percentage in drainage gas include caving characteristics, mining layout, mine ventilation design and goaf sealing sequences.

In a mine-scale gas drainage system, the fluctuation in gas flow rate and composition can be very significant. Figures 1 & 2 show the hourly flow rate and composition variations from a pre-drainage system in a gassy Australian coal mine. Figure 1 shows a significant variation in gas flow rate, and even within a fairly short period of time (one day), gas flow rate can vary by as much as 1.5 m³/s. In terms of the methane percentage in the gas captured using the pre-drainage system, it hovers between 60 to 90% in most time, though it can also drop to less than 60% very quickly for several days. The degree and extent of variation in flow rate and composition of the gas from drainage system obviously hinder the effective utilisation of the gas.

A number of measures could be taken to control the quality and quantity of gas captured from drainage system to enhance possible utilisation options. These measures are discussed in the following sections.

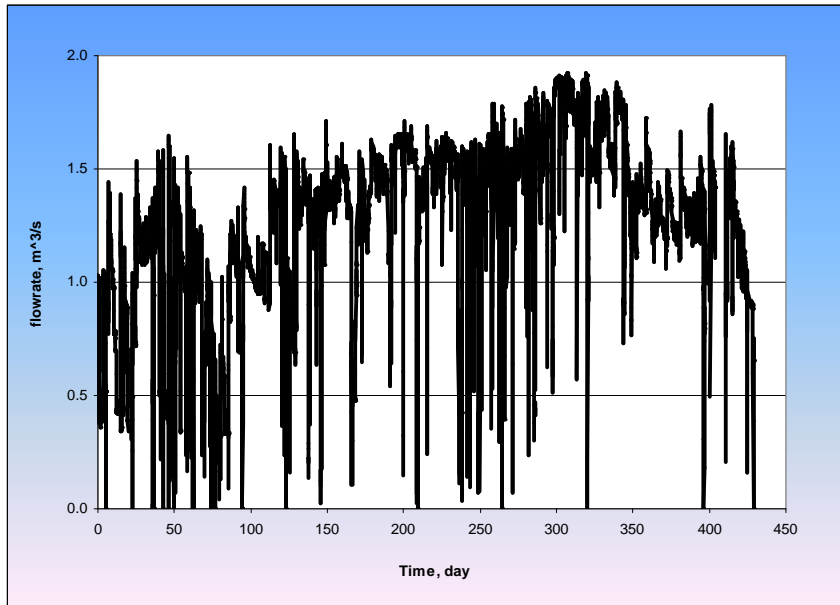


Figure 1 Gas flow rate variation from pre-drainage system

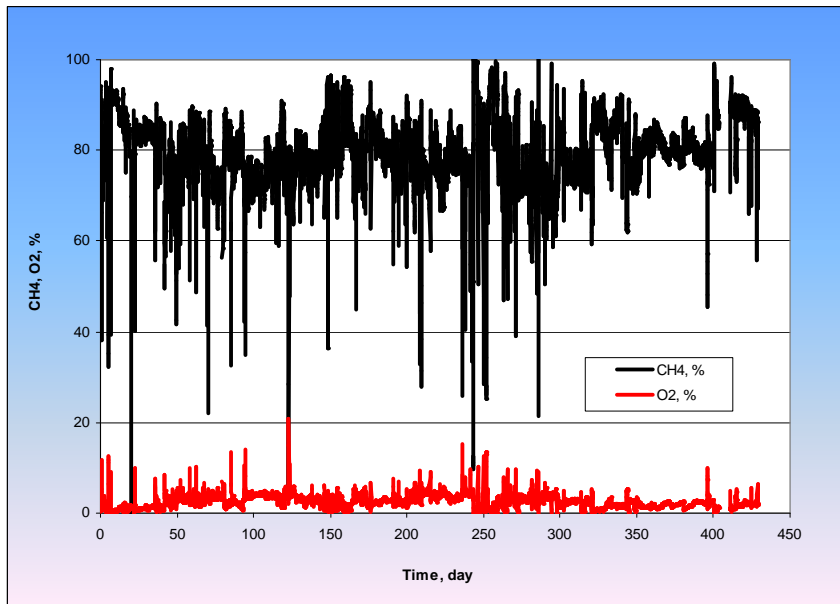


Figure 2 Gas composition variation from pre-drainage system

2.0 INTEGRATED COALBED METHANE AND MINING OPERATIONS

Coalbed Methane (CBM) could be integrated with mining operations. CBM could be carried out several years ahead of mining operations so that the mining area is pre-drained. In addition to meeting safety standards for mining, the drained gas of high quality can be utilised. With recent development in

medium radius drilling (MRD) and tight radius drilling (TRD) technologies, this option of draining gas ahead of mining becomes quite attractive. However a number of issues need to be addressed such as an appropriate arrangement of mining and/or petroleum leases and integrated planning of CBM and mining operations.

3.0 INTEGRATED MINING AND IN-MINE DRAINAGE PRACTICE

Existing methane drainage systems have been installed to meet safe operating requirements of mines. If the methane is to be used the methane supply is critical to the technologies that can be applied and this changes the attitude to drainage practice. Different utilisation technologies require different methane feed supplies, and goals of methane supply modification can include:

- Increasing the percentage of methane captured in drainage systems rather than emitted into mine ventilation air, i.e. optimising the ratio of pre-drainage and post-drainage gas captures to satisfy both coal mining and gas utilisation requirements.
- Optimising drainage.
- Reducing the fluctuations in methane supplies.

These improvements have not been systematically investigated other than in the context of improving gas removal. There has not been significant work directed to controlling the methane flows to tight specifications.

Methane supplies come as drainage from underground, surface drainage, and mine ventilation air, and each of these has individual requirements.

3.1 UNDERGROUND DRAINAGE

In operations it is sometimes difficult to balance all of the factors affecting the gas flow, as detailed data on the various gas inputs are often not collected. All gas collected is usually put into the same pipes, and it may be extremely difficult to determine what is responsible for variations with time.

Underground drainage is affected by many factors and some of the more important of these are discussed below. In most cases the technologies required to manage gas quality and flow already exist, but they have not been assembled into a complete system and demonstrated.

3.1.1 DRAINAGE TARGETS

Design of borehole patterns requires a good understanding of coal seam permeability, gas content, geological anomalies, and the site and timing of induced permeability as deformation occurs about the mine workings. The gas characteristics of the coal seam will control the borehole layout and schedule to effectively drain the gas. In tapping fracture zones in underlying or overlying seams, the location of boreholes must be continuously adjusted to changes in the fracture locations.

3.1.2 BOREHOLES

These boreholes are placed in the coal or rock surrounding the mine to drain gas from specific sources of gas. These can be in situ virgin gas or induced permeability sites where gas flows into the mine originate. The effectiveness of drainage relates to the design of the drainage pattern, correct positioning of the boreholes, and maintenance of the open boreholes for the life of required drainage. Drill guidance tools are now available which provide adequate accuracy for most conditions.

Drilling technology and practice has advanced rapidly in recent years, and down hole motor drills are capable of precise drilling when drill location monitoring is used. Rotary hole drilling is much more difficult to control and is used mainly for short holes and non-critical locations.

3.1.3 PIPEWORK

Gas is extracted under suction, and the flow of gas is controlled by pipework design, and must ensure the gas getting into the boreholes is efficiently extracted from the mine, and appropriate suction pressures are applied at the borehole. The capacity of piping systems must match anticipated flows to optimise the quality and quantity of methane delivered. Leakage of air into pipes dilutes gas supplied, and this can be minimised by regular maintenance of systems and careful connection to boreholes and installation of borehole collars. Safety devices have been developed to shut down the system in the case of mine accidents.

3.1.4 MONITORING

It is now possible to monitor gas flows and quality in real time, and to remotely manage the whole system. Installation of this monitoring will be essential to operate a system to manage the gas quality and quantity produced. A simple device is one that switches a borehole off if its gas concentration falls below a specified level.

3.2 SURFACE DRAINAGE

Pre-drainage from surface holes is essentially similar to commercial production of coal seam methane with no direct link to mining. The methane recovered is of high purity, and production follows a typical cycle for each hole. Overall sequencing well development and dewatering can even out production from the field. Surface pre-drainage holes are not generally used in Australian mines.

Most surface drainage in mines is post-drainage drawing from goafs of longwalls. A primary purpose is to limit the intrusion of gas from the goaf into the working longwall face. The gas make into goafs can come from a number of sources. The obvious source is the worked seam itself which borders the goaf and if not completely extracted partially remains in the goaf. In some mines large amounts of gas come from overlying and underlying seams that are disrupted by deformations associated with the longwall, and reach the goaf through mining induced permeable zones. There is also connection between the current longwall and previous longwalls that act as a reservoir. Issues that influence the methane in goaf drainage include:

3.2.1 CAVING AND INDUCED PERMEABILITY

A goaf drainage hole must be placed so it penetrates the permeable zones in the goaf and allows gas to drain into the hole from the goaf. While it is difficult to know precisely what is happening with caving in a goaf, experiments have shown that edges of the goaf have higher permeability and the central area is more compacted where the load is greatest. Loading and loss of permeability is not symmetrical, and is distorted by adjacent longwalls.

The nature of caving impacts on the areas of goaf that can be managed either using a single drainage hole or a number of holes at the required spacing to drain the whole goaf. The spacing varies from one hole only per longwall at Teralba, to 100 m spacing of holes at Central Colliery, with others at intermediate spacing. This is controlled in the strata separation zone above the caving. Where there is a continuous separation of strata along the length of the longwall, it allows a single bore to drain the whole goaf.

3.2.2 GOAF HOLE COMPLETION DESIGN

The depth at which the hole is terminated or perforated is critical to the mix of gases that are extracted. Within the goaf the various gases that can be present are to some extent differentiated by their density, and so the type of gas obtained is related to the gases found at the level of the bottom of the well.

3.2.3 GAS FLOW DYNAMICS IN GOAF

The gases in the goaf come from either the coal, or from the mine ventilation air on the longwall face. A poorly placed hole could pull air off the face into the goaf and dilute the seam gas extracted. A hole too far removed from the face induces greater flow of gas from the seam into the drainage hole, but does not decrease or control the flow of seam gas onto the face. Ventilation pressures, the suction applied to the hole, and gas pressure within the seam all interact to affect gas flow in the goaf.

3.2.4 MODELLING AND DESIGN

Computational Fluid Dynamics models have been applied to goaf gas flow, and techniques developed to predict gas extraction and design the position of goaf holes and the suction pressures required to achieve desired outcomes. To date these techniques have been used to manage the flow of goaf gas into the working face, they are equally valid in determining the nature of the gas extracted.

3.3 CONTROLLING FLUCTUATIONS IN METHANE SUPPLIES

All the methane streams fluctuate significantly in response to gas distribution in the coal, mining activity, the mix of drainage methods employed, and external factors. As there can be many causes to the fluctuations, it requires a case-by-case study to determine what can be done to condition the methane supply to specific requirements. Some of the causes of variation can be addressed but many of them are inherent to the mining method or natural conditions. Some of the major causes of fluctuations are:

3.3.1 COAL CUTTING AND MINING CYCLE

Cutting coal increases gas flows both from the cut coal and the disturbance created in the surrounding strata. Examples are the cycle associated with a complete longwall. Gas flows are minimal at changeover before mining begins. Gas release builds through the life of the longwall and then declines again. In a daily cycle, gas make follows the most active coal cutting periods and drops in non-working shifts.

3.3.2 VARIATIONS IN GAS CONTENT

There are significant variations in gas content and gas type of coal seams at the scale of a single longwall. This can be quite dramatic for an operation if mining shifts to a new area of the lease with different gas. Gas control techniques successfully applied in one part of the mine may no longer be applicable.

3.3.3 DRAINAGE EFFECTIVENESS

The effectiveness of drainage systems is dependent on the drainage holes being placed in their design positions, and the correct prediction of the drainage site. Design and operation of methane drainage networks are influenced by variations in geology and mining practice. An attentive and watchful drainage engineer who keeps his drainage system “tuned” can have a profound effect on its performance. If drainage holes miss their target, gas flows decrease.

3.3.4 PRESSURE EFFECTS

Gas flows are sensitive to pressure changes. These can come from regular diurnal changes in the temperature, occasional exceptional weather events such as storms, changes to ventilation design and drainage practice, and variations in gas pressures in the coal. While some of these are imposed on the situation, they can be handled by managing the mine ventilation and drainage suction to compensate for their effects.

4.0 CONCLUSIONS

There are some significant variations in quantity (flow rate and duration) and quality (methane concentration) of the gas captured from the pre-drainage and post drainage systems in Australian gassy coal mines. These variations present some challenges to effective utilisation of the captured gas. This paper reveals a number of measures that could be taken to control and manage the variations.