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Sealing design

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ABSTRACT: Waste areas of a mine should be sealed especially if there is a risk of spontaneous combustion. Leakage through and around such seals can be problematic. Pressure balancing has been one of the favored options to prevent the ingress of air into these waste areas. Balance chambers require maintenance and monitoring to ensure that they are effective. This paper explores the use of inert gas as a means of controlling ingress of air and egress of waste gases as a means of reducing leakage around seals.

1 Introduction

All coal has the propensity the spontaneous combustion. Seams of high or medium propensity require careful management of their goaf areas to mitigate the risk of an underground fire or explosion.

Early attempts to control spontaneous combustion, involved sealing goaves using explosion-proof stoppings. This technique may work reasonably well when ventilation pressures were low and leakage therefore was minimal.

Blocks were then isolated using barrier pillars again to restrict leakage. However, barrier pillars under-utilized the coal resource and increase the size of development float that must be maintained to ensure steady production

More modern techniques have employed techniques of balancing pressures across goaf seals. These techniques have been used to balance is pressures or minimize the pressure differential that is exerted upon the goaf. Goaves in shallow workings have been controlled by providing intake air, along seals in the goaf edge, minimizing the ingress of air through cracks from the surface. Workings at depths where surface cracking no longer is a problem, the employment of a sacrificial return with a minimal flow has also been used

Modern longwall mining in Australia provides the bulk of all underground coal mined. Increasing the length of longwall panel reduces the number of production days lost with longwall moves. These increased panel lengths provide new challenges to manage the ventilation of the operating face and control the amount of leakage across the adjoining goaf. Passive pressure balancing has been employed to control the differential pressures from close to longwall face to the goaf seals on the previous panel entries. Although this technique will control ingress of air by minimizing these pressures, ingress of oxygen can occur with significant changes in the barometric pressure.

2 Sealing Techniques

2.1 Purpose of Sealing

Areas of the mine are sealed for several reasons. The most common is to exclude oxygen from the remaining coal to minimize the risk of spontaneous combustion. Sealing is also done to form a reservoir for methane gas.

As with any fire fighting technique the control of coal that is liable to spontaneously ignite is reliant on the removal of at least one of the elements of the fire triangle. The only one that it easily achieved is the exclusion of oxygen as this also will reduce the capacity to generate heat.

The utilization of seam gas, oxidation of coal and adsorption of carbon dioxide or inert gas pumped into the goaf will lower the oxygen concentration in the goaf.

Thus the purpose of sealing is to maintain this inert atmosphere and thus prevent an underground fire and possible explosion.

Failure to maintain this inert atmosphere has had disastrous consequences. Ingress of oxygen can occur through cracks from the surface, boreholes, leakage around and through seals, through porous bands of coal, through bed separation cracks in the roof and floor and by fluctuations in barometric pressure enabling the goaf to breathe.

In order to control the behavior of these goaves it is imperative that sealing is conducted and the goaf becomes inert as quickly as possible after the completion of the panel. Additionally, provision to control leakage needs to be applied and maintained. The atmosphere behind these seals needs to be monitored to ensure that sealing is still effective and that no dangerous situation is starting to form.

Various techniques to seal panels are discussed in this paper. It should be stressed that seals are placed to assist the process of risk mitigation and the reliance of such devices as the only or major control of spontaneous combustion may be insufficient protection and places both mine workers and miners at risk. The process of rating stoppings and seals can be used as an effective guide to their construction but to use that as anything more is foolhardy.

If the atmosphere behind the seals is inert and is maintained and monitored, spontaneous combustion cannot occur, and other potential ignition sources such as frictional ignition or lightning will have no effect on that goaf.

The characteristics of a good seal include:

- high resistance
- strong

- fireproof
- easily and rapidly deployed
- able to cope with convergence of strata without cracking
- insoluble
- non reactive
- have sampling points installed
- not easily blown over

2.2 Explosion Proof Stoppings or Seals

These stoppings or seals were constructed to seal off goaf areas with a view that if the goaf gases exploded then these seals would have sufficient strength to withstand the impact. Typical construction, included to substantially constructed brick walls that were buttressed, and separated by 10 to 20 m. The space between the two walls was sandbagged as shown in Figure 1. The construction of these seals was slow and labour-intensive. This placed those who were constructing the seals at risk until seals were constructed and the cement had cured.

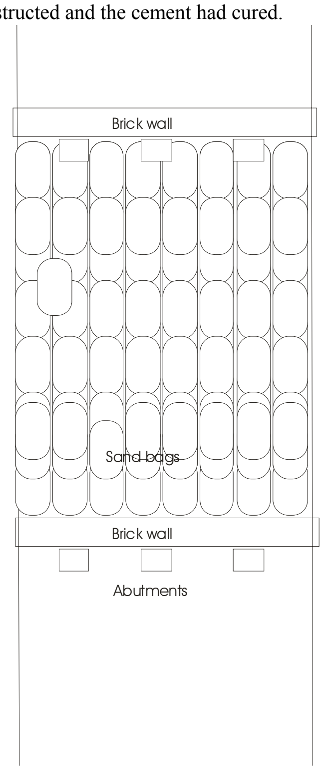

Figure 1. Explosion Proof Seal

Entries into panels were kept to a minimum so that as few seals as possible could be deployed. As with all stoppings, their effectiveness and was dependent upon the integrity of the ribs, floor and roof.

Each panel separated by a barrier pillar, which ensured that the resource would be underutilized. A typical layout shown in Figure 2

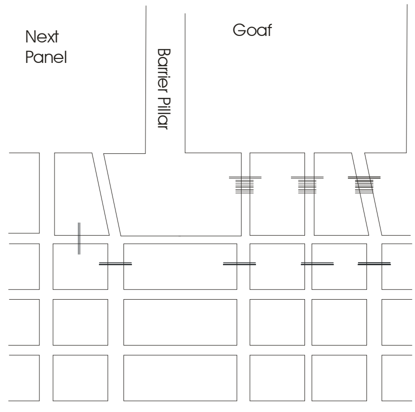

Figure 2. Typical panel layout

The major disadvantages were that these seals were:-

- time consuming to construct;
- labour intensive;
- cracked easily with floor heave or other ground movement:
- not easily breached if re entry was required.

the advantages were:-

- fire proof;
- high resistance;
- not easily blown over.

2.3 Plasterboard (dry wall)

Plasterboard seals consist of sheets of plaster nailed onto a support frame of props and wooden or steel battens and the boundaries “scrimmed” with a mix of plaster and jute fibers.

The major disadvantages were that these seals were:-

- only partially fireproof;
- low resistance;
- easily blown over.

the advantages were;

- rapidly deployed;
- cured rapidly;
- cheap;
- more flexible and able to cope with convergence.

Such seals were used as emergency seals before the widespread application of sprayed cementitous grouts.
Their low resistance would aid leakage in the longer term

2.4 Sprayed Grout

Considerable work has been done on the development and analysis of this type of seal. Physical testing has been carried out at Lake Lynn, USA and Londonderry, Australia and modeling using finite element analysis is also conducted in order that the supplier can meet a set of specifications.

Both the physical testing and the modeling give an indication as to the behavior of such devices. This has meant that their construction is more consistent and of a higher standard than previously existed.

Without a full understanding of the limitations of both the physical testing and the finite element analysis, could result in an over confidence in the ability of such devices.

The major disadvantages were that these seals were:-

- tend to shear at the boundary constraints;
- larger, thicker structures are easily compromised by rebound materials;
- can be compromised by acid waters.

the advantages were;

- rapidly deployed;
- cured rapidly;
- more flexible and able to cope with convergence;
- fireproof;
- rated;
- high resistance when properly constructed.

2.5 Summary of Seal Types

The descriptions given are by no means exhaustive. They have been included to show that merits exist for all of them and that a focus on their construction, although useful, it should highlight that the main control should lie elsewhere. Having a good seal is not enough.

3 Pressure

Pressure is the driving force of ventilation. Understanding pressures that influence sealed areas is paramount to controlling the ingress of oxygen and the egress of contaminants into the mine workings.

Pressures as little as 1000Pa (4”) have been responsible for spontaneous combustion, Liddell State Mine.

3.1 Pressures Exerted on Sealed Areas

With the practice of placing a return roadway along a row of goaf seals and cracks developing from surface, pressures approaching full fan pressure can be developed. Open boreholes can also achieve this.

Three 20,000Ns^2m^{-8} seals with 1000Pa across them would leak approximately0.7m^3/s. Although small would provide sufficient oxygen to assist spontaneous combustion.

A 3000m Longwall panel with a single return 5m x 3m would also have a pressure drop of about 1000Pa have around 38 seals to the adjoining goaf. Although not all of these seals would see the 1kPa the leakage would be significant.

Assuming the average pressure is 500Pa and the seals were 20,000Ns2m-8 then the potential leakage is 8.5m^3/s. I these seals were more substantial (80,000Ns2m-8) then the leakage would reduce to 4.2m^3/s. Clearly, these quantities are too high and spontaneous combustion would be a likely result.

This leakage would be further exacerbated by barometric and temperature variations assisting in the goaf area breathing.

4 Pressure Balancing

4.1 Passive Balancing

Passive Balancing is the standard technique that has been applied to pressure balance sealed goaves. Shallow workings can be balanced to atmosphere. By using an additional seal as shown in Figure 3 to generate a balance chamber and connecting this chamber to atmospheric pressure (pipe or borehole) the differential pressure is then exerted on the outer seal and the differential pressure on the goaf is removed.

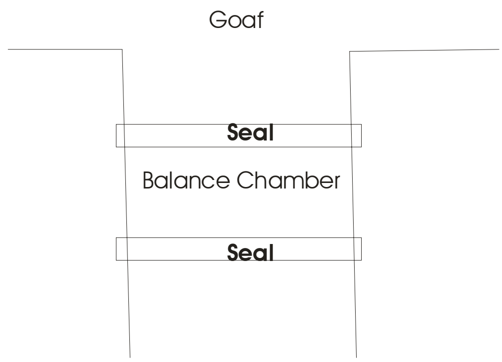

Figure 3. Balance Chamber.

Ideally, once equilibrium is achieved there is no frictional loss in the pipe or borehole as the flow would reduce to zero. In practice leakage out of the balance chamber would occur due to the differential pressure applied to the outer seal.

Longwall panels provide significant challenges.

- A decision must be made on the balance chamber pressures.
- Are balance chambers provided on all seals or only on the previous panel’s gateroad entries?
- Will the goaf naturally inert?
- Will the goaf pressurize and leak into the working panel?
- How many walls can the mine extract before an isolation barrier must be provided?

In some cases these balance chambers are connected to a pipe that is run from the longwall return to maintain the balance.

4.2 Active Balancing

With the advent of low cost, reliable pressure transducers available it is now possible to provide a pressure balancing system that can substantially reduce ingress of oxygen to the sealed goaf areas.

Active Balancing relies on leakage into the sealed area and leakage out of the pressure chamber. Balance chambers are constructed in a similar fashion as previously described. Pressure transducers are placed to sample the pressure behind the seals, in the balance chamber and in the external roadway.

Instead of the chamber being connected to a reference pressure, each chamber is connected to a supply of pressurized inert gas and a pressure relief valve to dump excessive pressures. Nitrogen being the gas of choice. The control system then pressurizes the chamber to a preset differential pressure higher than that of the goaf. 100Pa difference should be satisfactory for most cases.

Any leakage into the goaf then would be inert and any leakage out into the surrounding workings would also be inert.

The size of the chamber should be kept to a minimum so that only small quantities of gas are required to maintain pressure.

Fluctuations in external pressures would also cause the pressures in the chamber to rise, ensuring that the leakage of gas out of the balance chamber is always in the right direction.

Additionally low pressure differentials across these seals would mean that the leakage across the seal into the goaf would be minimal. As shown in Figure 4

Figure 4. Pressure variations around balance chambers.

It is debatable whether to make the inner seal more substantial than the outer or the outer more substantial than the inner. By reducing the size of one would lower the cost of these seal chambers. However, the cost of each chamber is trivial compared to the loss of production during a significant incident.

By placing the more substantial seal on the outer end would ensure that leakage from the chamber would be reduced to the workings when the differential pressure was high and minimal into the goaf. Placing the more resistive seal on the goaf edge would slow the egress of goaf gases into the balance chamber at times of sudden barometric pressure drop.

Where pressure differentials were high then three or more seals could be applied so that the pressure differential can be distributed across each seal as shown in Figure 5.

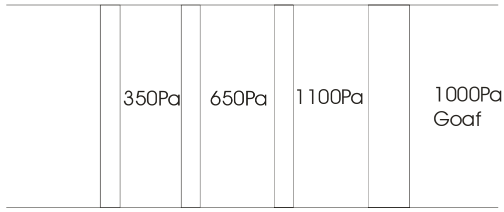

Figure 5. Pressure variations around multiple balance chambers.

At the time of writing there is one colliery applying this style of technique. A second colliery is currently investigating the possibility of using this method to control goaves. It was not possible to provide data on these trials.

5 Sources of Inert Gases

There are several sources that could be used for this process. The use of small nitrogen generation plants is ideal. The volume required per seal is minimal and the pressures required are relatively small.

For mines close to power stations, the utilization of exhaust gases from the station could be explored. The use of this source needs to be weighed against the infrastructure costs for capture and pressurization. In light of current community pressures regarding the production of greenhouse gases the utilization of the gases for inertisation of goaf areas and the use for active balancing could be further explored.

6 Summary and Conclusion

Maximizing the recovery of resources without compromising safety is essential to ensure efficient coal mines.

Seal design is an integral part of any spontaneous combustion management plan. Reliance on seal strength alone will not manage leakage and the prevention of fire and explosions from goaf areas requires careful monitoring and control.

The exclusion oxygen and the maintenance of an inert atmosphere, coupled with a means of limiting the ingress of goaf atmosphere into the mine workings must be the paramount control in managing risk.

Multiple seals required to operate longwall panels can be effectively controlled by active barriers. Having a slightly higher pressure in the seal chamber will ensure that leakage from this chamber will flow into the goaf and also into the workings.

Limiting the pressure differential across an individual seal will ensure that any leakage will only result in minute quantities flowing.

Using nitrogen as a sealing gas provides little risk to the workforce however flow monitoring on the supply line to each seal is essential to ensure the integrity of each seal and alert the ventilation officer to the possibility of an oxygen deficient atmosphere forming in the workings adjacent to the seals.

The use of carbon dioxide is a possibility however it is capable of being readily adsorbed into the coal surrounding the seals.

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