THE SPONTANEOUS COMBUSTION EXPERIENCE AT ASFORDBY MINE

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SUMMARY

This paper outlines some of the spontaneous combustion experiences associated with pillars in ladder worked roadways at Asfordby Mine, UK. Spontaneous combustion problems have been found to occur both at the development stage of ladder roadways and behind a longwall face as it retreats down these roads.

Methods of sealing ladder roadways are considered in the paper, as are the environmental monitoring systems in use at Asfordby Mine. Some of the basics of detecting and dealing with spontaneous combustion are discussed to illustrate the mistakes that were made in the past and justify the change in approach.

The lessons learnt at Asfordby clearly demonstrate the importance of fully recognising the risk of spontaneous combustion when planning the mining layout. This, it will be shown, should be backed up by proper staff training and an effective examination regime capable of giving the earliest possible warning of a spontaneous combustion heating developing.

INTRODUCTION

Asfordby Mine is a large modern underground coal mine, located some 20 kilometres South-East of the city of Nottingham in the East Midlands of England. The mine works two seams in the Leicestershire portion of the concealed East Pennine Coalfield. Both seams range in thickness from 2.5 to 3.0 metres and lie at a depth of around 550 metres.

Planning for the mine started in the mid 1970's and by 1989 shaft sinking had been completed. The first in-seam ladder roadways were driven in 1990. In 1992, in an attempt to emulate some of the success being achieved in the USA, 'place changing' was introduced to prove room and pillar methods of mining. It was found that the size of pillar required to ensure stability of roadways meant that room and pillar was not an economically viable production method and so the system was abandoned in 1993. The mine continued for a further two years to drive ladder roadways to block out for longwall retreat mining.

The first longwall unit commenced production in July 1995.

It had been identified at the planning stage that the seams of coal to be worked could pose a serious spontaneous combustion risk. The effect that working ladder roadways had on significantly increasing this risk had been greatly underestimated.

Spontaneous combustion problems started at Asfordby in 1991 and during 1992 the mine experienced an ever increasing number of very serious spontaneous combustion incidents associated with the pillars left in ladder roadways.

The problem was compounded by a fundamental lack of understanding of spontaneous combustion by those employed in key places at the mine. It was 1994 before the cost of dealing with the problem had been fully recognised by all concerned, and early in 1995 the mine plans were altered to prevent any further development that involved leaving coal pillars. By this time however, over 22000 metres of ladder roadway had been opened up.

FIRST SIGNS OF THE PROBLEM

The first spontaneous combustion heating occurred in June 1991 at the M-North ventilation overcast (**Figure 1**), approximately 13 months after this overcast had been formed. Extensive sealing and injecting work was carried out in the ribs above and below the overcast, and at first this work seemed to solve the problem. However heatings continued to flare up at this site on a regular basis. It was only much later when the ventilation was altered and the overcast breached that the problem was finally solved.

This incident was considered a one-off. There was still no perception at the mine of the spontaneous combustion problems that were to follow in ladder roadways.

SPONTANEOUS COMBUSTION WITHIN LADDER ROADWAYS

It was some eight months after the initial incident at the M-North Overcast, that the first problem within the West Parkgate ladder occurred. Activity was found in the second slit of this ladder in February 1992 (WB2 - WA2 shown in **Figure 1**). This was some twenty months after the slit had been developed. By this stage the West Parkgate ladder had been developed up to 16's slit and the

West-South Parkgate multi-entry system had started up off it.

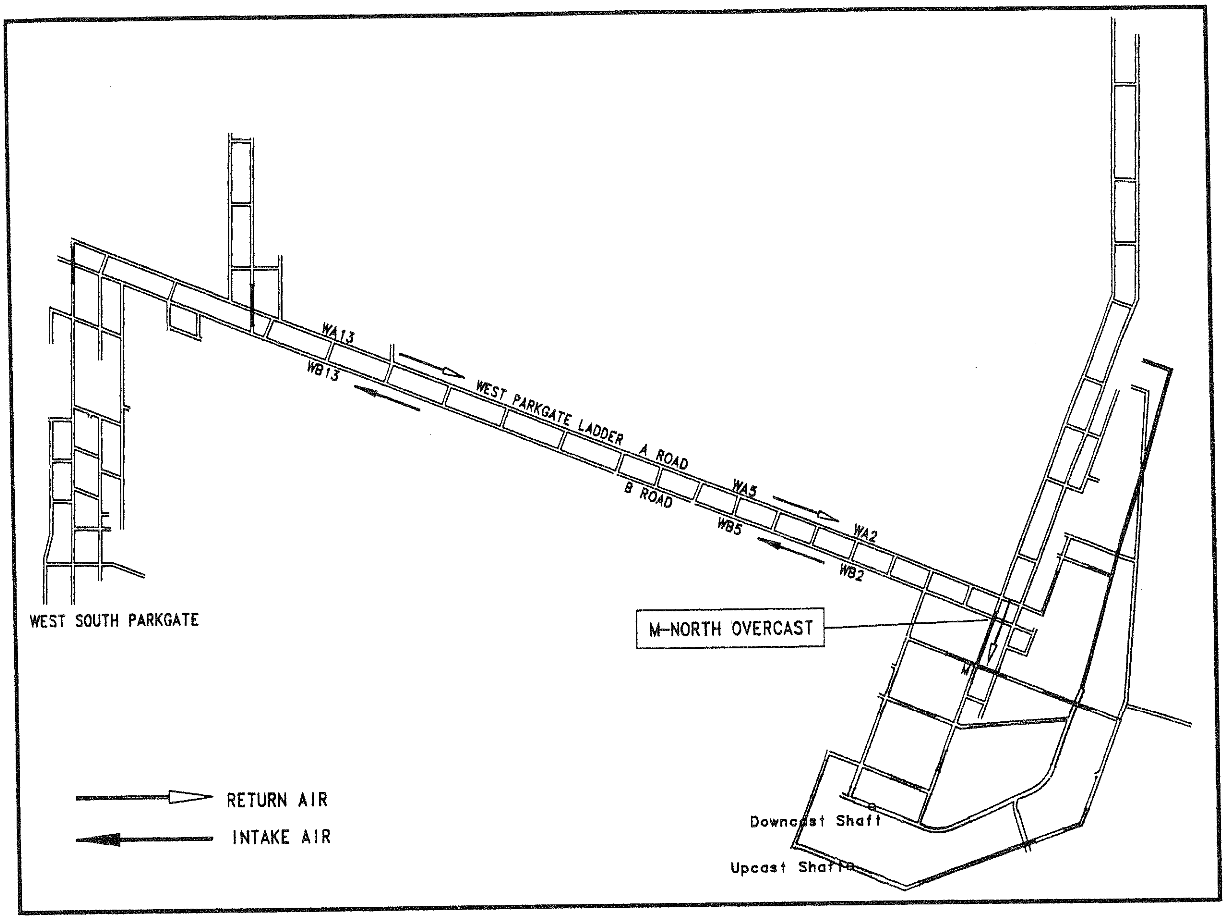

Figure 1 The Mine Layout in February 1992

The West Parkgate Ladder was ventilated utilizing the 'B' road for intake and the 'A' road for return (**Figure 1**). As the ladder developed the slits were either door or walled off depending on requirements. The method of walling off consisted of building walls at each end of the slit.

In February 1992 an increase in carbon monoxide (CO) was identified in the Control Room by a Fidesco electronic CO monitor covering the conveyor drive at WB40. On investigation the increase of CO levels were found to be across WA2 cross-slit (**Figure 1**). Injection pipes were installed through the 'A' side wall, these proved that smoke and high levels of CO were present in the slit. The cross-slit pillar corners on both the 'A' and 'B' roads were flange boarded and infilled, holes were drilled and the ribs injected. This did not cure the problem and the decision was taken to pump the complete slit solid. This operation took several days and involved pumping some 300 tonne's of cement grout from surface at cost of around £60000.

Following the experience with WA2's cross-slit it was decided to remove the walls from either end of other slits and replace them with a mid-slit stopping (**Figure 2**). This incorporated a steel ventilation duct fitted with blanking plates incorporating a 150 millimetre pipe passing through it to provide leakage ventilation in the cross-slit. This work was done to allow examination of the cross-slits.

Although it was not appreciated at the time, this new method of sealing slits would help with spontaneous combustion by discouraging leakage across the pillar edges (**Figure 2**).

Through 1992, spontaneous combustion problems became evident in other ladder pillars in the West Parkgate roadway. These were found to follow a trend based on the length of time from when they had been developed and indicated an incubation period of anything between nine and twenty months.

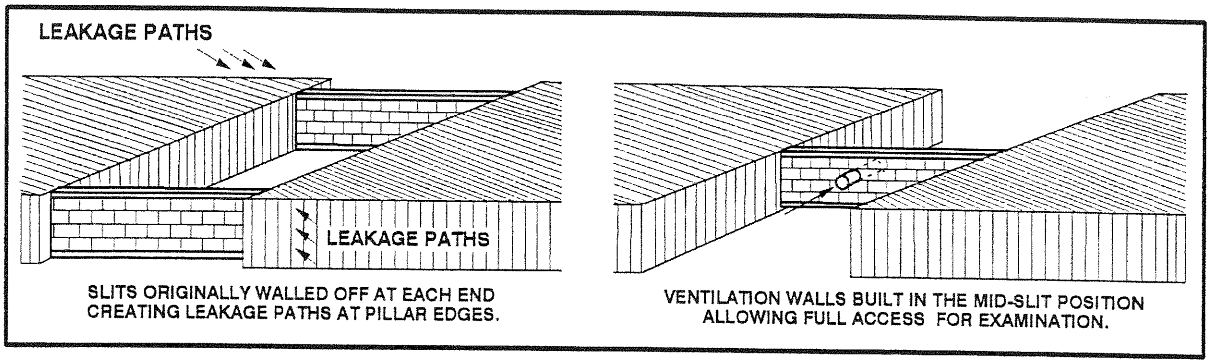

Figure 2 Ventilation Walls in Ladder-Road Cross-Slits

METHODS OF SEALING RIBS

By the end of 1992 extensive work was taking place at numerous heating sites, proving a serious drain on resources. The methods that had been adopted for sealing the ribs had to be improved.
The traditional way of treating a rib was to set wood props, nail boards to them, seal up all joints and pump cement between the boards and the roadway rib side to form an air tight seal. This method was time consuming, it would take several days to seal a 25 metre section of rib side. A new system was devised in which cement was pumped behind a simple shuttering formed out of wire mesh and 'brattice cloth' . It was now possible to cover and pump a 25 metre section in less than twenty four hours. Once the ribs had been sealed these sections could be drilled, have pipes inserted and be injected with cement. The new method was a vital step forward in the treatment and prevention of spontaneous combustion.
This system of sealing the pillar corners, coupled with going over to mid-slit ventilation walls, had a dramatic impact in reducing the frequency of spontaneous combustion heatings. It was still however expensive. In 1993 it is estimated that Asfordby Mine spent over £1.25 million in the sealing of roadway pillars.
By 1994 everyone connected with Asfordby had recognised the full extent of the spontaneous combustion problem associated with pillars and a management team was in place experienced in dealing with the situation.

CHANGE TO THE MINING PLAN

It was decided in 1995 that the increase in the risk of spontaneous combustion through driving in-seam ladder roadways at Asfordby was unacceptable. Since that date all mine plans produced for the mine fully recognise the risk of spontaneous combustion and assume that development drivage will be by 'single-entry' methods which avoid coal pillars.
To date (summer 1997), there have not been any incidents of spontaneous combustion in single-entry roadways at the mine. Between 1990 and 1995 over 22000 metres of ladder roadway had been driven. Some of these roads remain open today and pose a persisting spontaneous combustion threat which continues to require extreme vigilance.

RETREAT FACES UTILIZING TWIN LADDERS

The first longwall face at Asfordby Mine was 101's in the Deep Main Seam and came into production in 1995. The intake and return gate roads for this longwall face were developed as ladder roadways.
The outer gates of both ladders were the transport roads, the inner gates conveyor roads. The face was 250 metres long and was planned to retreat 2400 metres back down the two inner gates of these ladder roadways (**Figure 3**).
The main spontaneous combustion concern with this longwall face related to the pillars once they were behind the face. Most of the pillars had already been sealed and injected during the development stage because of heating activity. It was perceived that problems would reoccur once the longwall face past through the ladder and the pillars were behind the face.
Preventative measures were put in place designed to deal with one pillar at a time. This would be achieved by pumping seals on the 'A' and 'B' roads to form chambers for each pillar (**Figure 4**). Once the chambers were in place nitrogen would be

pumped into the chamber to reduce the oxygen levels. Prior to the face going onto production twin 77 millimetre nitrogen ranges were installed up the 'A' road. As the face retreated down the ladder roadway each pillar was sealed off and pumped with nitrogen to form an inert atmosphere within, as shown in **Figure 4**.

It was clear that the most effective way to obtain the quantities of nitrogen required was for the mine to obtain its own nitrogen plant. A pressure swing absorption (PSA) system was chosen and two plants were installed in 1994. These had a combined capacity of 310 litres per second of nitrogen at 97% purity. The PSA system works on the basis of compressed air being forced through a carbon based molecular sieve. This molecular sieve absorbs oxygen, allowing the nitrogen to pass freely through it, it can then be pumped underground. A facility is also provided to couple into an imported liquid nitrogen supply if additional capacity is required.

One serious spontaneous combustion heating did develop immediately behind the longwall face, in the intake roadway. This was brought quickly under control with the application of nitrogen. It is the belief of many at Asfordby that if nitrogen had not been available this situation could not have been resolved by other means and the longwall equipment would have been lost to protect the other areas of the mine. While this system proved effective in minimising the risk of spontaneous combustion it added considerably to the cost of production and further justifies the decision to go away from ladder drivages.

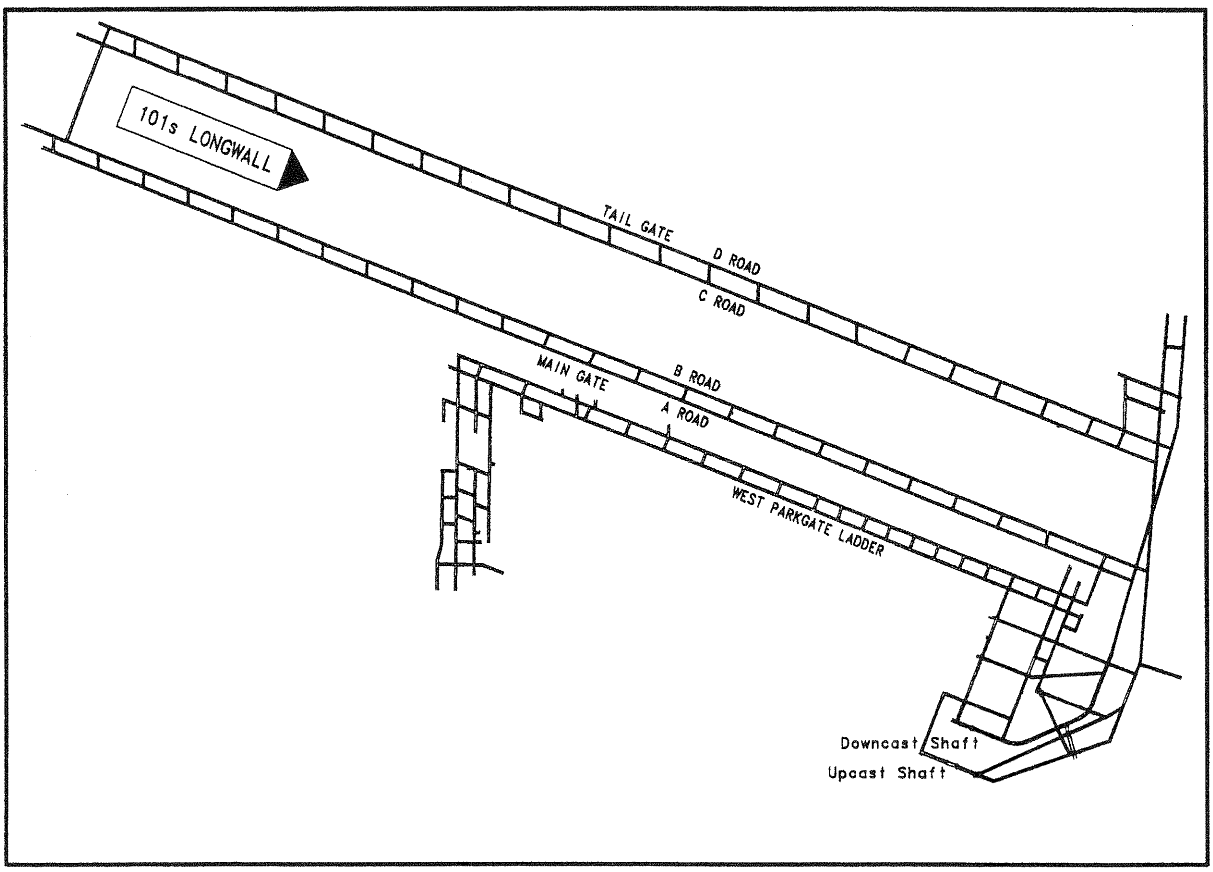

Figure 3 The layout of 101's Longwall Face

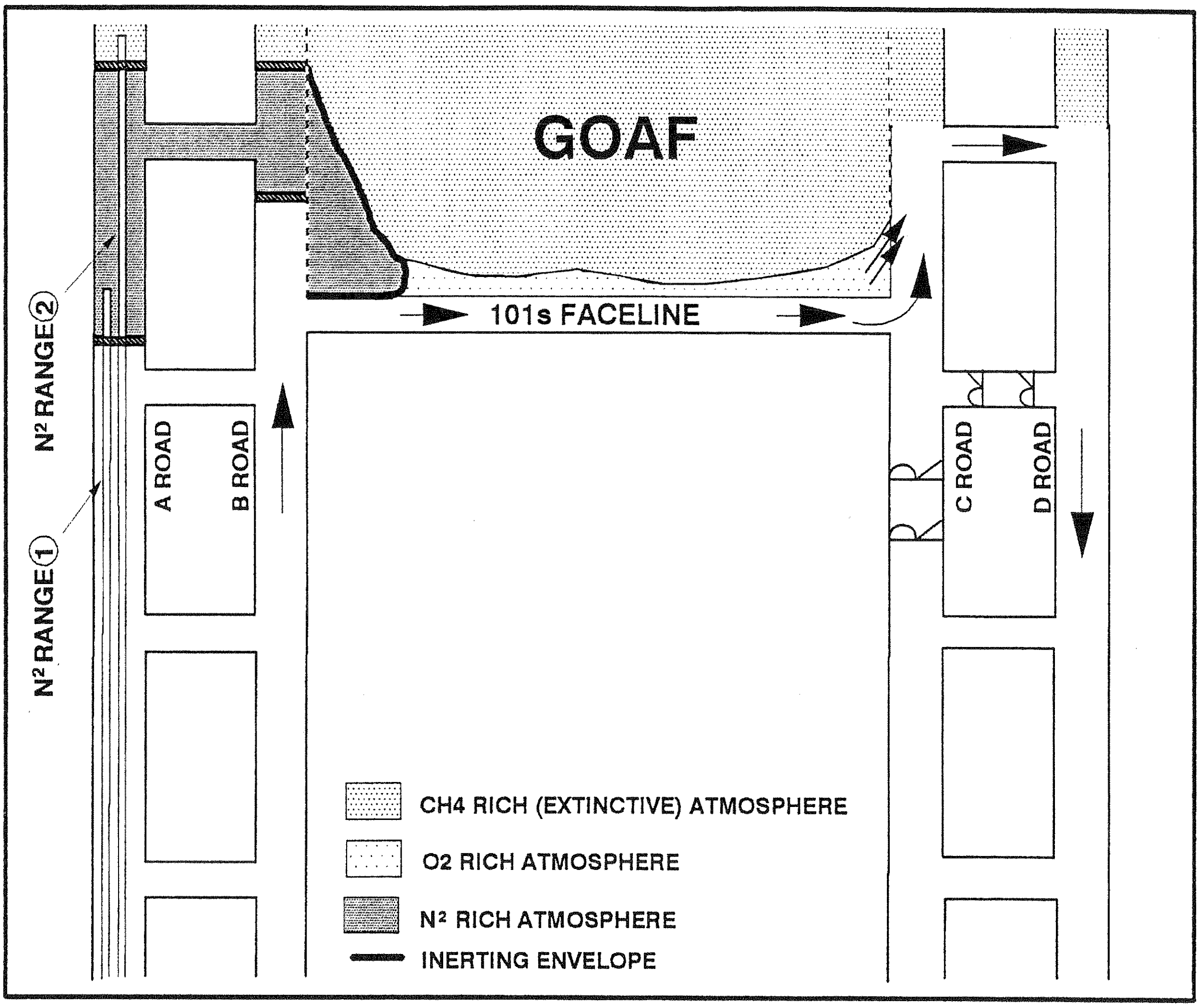

Figure 4 - *Application of Nitrogen on 101's Longwall Face*

MONITORING

The Mine, from the very start, was well equipped with environmental monitoring. Both 'tube bundle sampling' and continuous electronic CO monitoring covered all areas. These two systems were designed to be complimentary.

In the tube bundle system, samples are continuously drawn into small bore polythene tubes that run from a number of underground locations to surface where they are then automatically analysed. This system has the disadvantage of a delay from the sample entering the tube to being analysed on surface; up to 2 hours in some cases. There are however a number of important advantages with the tube bundle system, these include: the facility to continuously monitor from points deep in a district after seals have been erected, it requires no power underground, and monitors for a wide range of gases.

Electronic CO monitors give an instantaneous read-out that is continually updated. They are particularly valuable for protecting a workplace where rapid changes in conditions could occur. Their disadvantage is that they suffer from cross sensitivity with the high hydrocarbons that are present in the combustion fumes associated with spontaneous combustion and are often found to go over range once a heating is fully developed. When this occurs all knowledge of the underground environment in the affected area is lost unless it is covered by a tube bundle system. For that reason the tube bundle system is maintained at Asfordby Mine to all high risk areas. The mine is also equipped with a computer controlled 'Multi-Discriminatory Alarm System'

(MDA) that differentiates between genuine and false fire alarms. The system is designed to detect low probability events such as fires and ignore high probability events such as the higher CO levels created by diesel exhaust fumes. The computer will generate a new alarm level each month based on the statistical analysis of CO levels and time.

All electrical and tube bundle monitors are covered by the MDA system .

In the early days of spontaneous combustion, mine staff relied heavily on these environmental systems to detect spontaneous combustion heatings. By the time environmental monitors had detected a heating it had usually reached an advanced stage and become both dangerous and costly to deal with.

UNDERSTANDING SPONTANEOUS COMBUSTION

The experiences with spontaneous combustion in the early 1990's have highlighted how important it is for mine staff to have a full understanding of spontaneous combustion. It has been necessary to further train staff to be familiar with the methods of dealing with spontaneous combustion, the physical signs that indicate spontaneous combustion is taking place, and the sites where it is most likely to occur.

In the past a number of highly dangerous techniques were developed to deal with a spontaneous combustion heating. These included removing the source of the heat by digging out the hot coal, and applying water to cool the heating down. In most circumstances, the only safe and acceptable method of dealing with spontaneous combustion is to seal off the source of oxygen. This is usually achieved by pumping on a road side seal and injecting the surrounding strata with cement grout.

An important part of spontaneous combustion theory, supported by experience in the field, is the relationship between 'oxygen availability' and 'oxygen absorption' during the heating process. In the early stages of the spontaneous combustion of coal and where the air flow to it is usually very low, the rate of oxygen absorption is affected dramatically by changes in the oxygen availability. If a heating is caught at this early stage it takes only a small reduction in oxygen availability to bring it under control. When a spontaneous combustion heating becomes more developed, the heat generated will create convection currents drawing fresh air onto the heating site. In well developed heatings with a good supply of oxygen a substantial decrease is required in oxygen availability before any apparent affect is made on the incident. Dealing with an advanced spontaneous combustion heating is consequently a very much more difficult, dangerous and costly operation. The early detection of a spontaneous combustion heating is imperative.

Carbon monoxide analysis is often considered the main indicator of spontaneous combustion. Experience has shown that the physical signs of a heating can be detected by a trained person long before the most sensitive CO detectors would have picked up a change in the general body air analysis significant enough to set off alarms. Mine staff have now been trained to be particularly aware of changes in smell, signs of sweating and haze in the atmosphere. If any of these physical signs are detected then a much more detailed investigation of the effected area will take place, often using hand-held electronic CO detectors and thermal image cameras.

By training mine staff to know which areas of the underground workings are liable to spontaneous combustion they will know where to concentrate their examinations. Spontaneous combustion does not occur in solid coal. All the spontaneous combustion heatings that have occurred at Asfordby, without exception, have occurred in ladder roadways in areas of crushed coal, this is typically found in: pillar edges, faulted ground and areas of excessive floor lift.

Knowing where to look and what to look for has meant that it takes only a small team of trained people to ensure that any potential spontaneous combustion heating is found at the earliest possible stage.

CONCLUSIONS

The spontaneous combustion problems experienced at Asfordby have taught everyone associated with the mine a number of invaluable lessons, the most important of these are:

- The method of mining and the mining layout plays a major role in the susceptibility of a coal seam to spontaneous combustion.

- Wherever crushed coal is formed, (pillar-edges, faults, excessive floor-lift, longwall wastes, ventilation over-casts), there is a risk of spontaneous combustion taking place.

- In most cases, the only safe way to deal with a spontaneous combustion heating is to exclude oxygen from the heating site. Nitrogen has proved useful in dealing with spontaneous combustion problems associated with longwall retreat faces where it has been used to form an inert atmosphere in the waste.

- The physical signs of a spontaneous combustion heating taking place (smell, sweating, haze etc) will usually become apparent to trained personnel before the environmental monitoring system has detected a significant enough change in CO in the mine atmosphere to activate automatic alarms.

- Spontaneous combustion caught at an early stage is usually relatively simple to resolve. Once a heating is fully developed it becomes very much more difficult and dangerous to deal with. Any indication that spontaneous combustion is taking place should be acted upon immediately.

- Tube bundle monitoring systems are invaluable in dealing with serious spontaneous combustion incidents and continue to function after an area has been sealed off. They give a detailed analysis of the mine environment and do not suffer the cross sensitivity that occurs with electronic CO monitors.

Spontaneous combustion at Asfordby Mine is no longer the day to day problem it once was. It can be clearly demonstrated that this has been achieved through fully recognising the risk in mine planning, the proper training of mine staff and paying attention to good house keeping.