Safety in Mines Research Advisory Committee

Draft Final Report

Development and testing of on-board systems for single- and double-pass continuous miners in high-seam mining conditions

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Executive Summary

Over the past few years a number of methane ignitions have been reported when mining was taking place close to dykes associated with burnt coal. The South African Department of Minerals and Energy (DME) sent out a circular stipulating that no mining with continuous miners in burnt coal will be permitted unless extra safety precautions are taken. These include the use of wet-head systems, machine-mounted active suppression systems and water-mist curtain systems. HS Design Engineering combined forces with the South African Department of Trade and Industry and Anglo Coal Ltd. to evaluate a system for seam heights up to and including 3.5 m at CSIR Mining Technology’s Kloppersbos Explosion Research Facility. This protocol testing was completed in June 2001.

Due to the dynamic nature of methane gas explosions, it is essential that these systems be re-evaluated if their operating conditions change significantly, as is the case if they are to be used in high-seam conditions, up to 5 m. SIMRAC requested CSIR Mining Technology to do protocol tests to determine whether the HS Design Engineering active suppression system would be able to satisfy the acceptance criteria as outlined by Du Plessis, J.J.L., 2001b, when used in high-seam conditions, i.e. 4.75 m.

The active suppression system was tested in the 20 m full-scale test gallery at Kloppersbos Explosion Research Facility using a single-pass Voest ABM 30 and a Joy HM 31 continuous miners, which are used to mine in these seam heights. The results of the protocol testing showed that the HS Design Engineering active suppression system was capable of suppressing ignitions of stoichiometric methane mixtures under all the conditions tested, except in the case of the double-pass (Joy HM 31) mining system.

For the double-pass high-seam mining conditions, the tests proved that the active suppression system (although capable of preventing the propagation of the burning methane flame beyond the curtain of inert material) was not able to suppress the propagating flame within the parameters of the developed protocol due to the physical expansion of the exploding methane/air mixture. The standard suppression system for a single-pass continuous miner can be used for controlling and stopping a methane/air explosion in the in-shoulder position, with a stand-alone active suppression roadway barrier system (yet to be tested) providing additional protection in the full-face and out-shoulder positions.
Acknowledgements

The author wishes to thank the staff of the Kloppersbos Explosion Research Facility for their enthusiasm and participation in the project. Voest-Alpine SA made an ABM 30 bolter miner available for the tests. SASOL Mining provided the Joy HM 31 continuous miner. Finally, thanks are due to SIMRAC for their funding of the project.
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1 Introduction

The major ignition source for methane and coal-dust explosions is the action of the cutting picks of the continuous miner on small quartz and sandstone inclusions in the coal seam. To help reduce the risk of these ignitions, the picks of the machine are cooled with water sprays, methane detectors are mounted at the face to monitor methane concentrations, and ventilation is used to prevent methane build-up at the face. Even with these and other precautions, however, ignitions do still occur, especially when mining is taking place close to dykes associated with burnt coal.

The South African Department of Minerals and Energy (DME) sent out a circular stipulating that no mining with continuous miners in burnt coal will be permitted unless extra safety precautions are taken. These might include the use of wet-head systems, machine-mounted active suppression systems and water-mist curtain systems.

The HS Design Engineering machine-mounted active suppression system is used in conjunction with ‘traditional’ methods of explosion prevention. The system detects a methane ignition and then prevents it from developing into a methane explosion, propagating down the roadway and escalating into a full coal-dust explosion. It achieves this by extinguishing the methane ignition before it reaches the position of the operator’s cab on the continuous miner.

Once an ignition has been detected, flame sensors specifically designed to respond at the frequency of the electromagnetic radiation emitted by burning methane trigger the system. Within milliseconds, the valves of the pressurised discharge bottles open, releasing the mono-ammonium phosphate powder (extinguishant) and creating an inert fire barrier, thus preventing the flame from propagating any further.

A test tunnel at the CSIR’s Kloppersbos Explosion Research Facility was slightly modified to simulate the dimensions of a high-seam coal-winning face. A Voest ABM 30 and Joy HM31 continuous miner machines were used for test purposes.

The roof of the tunnel at Kloppersbos Explosion Research Facility has a variable height, which was adjusted to 4,75 m for these tests. For the full-face conditions, the cross-sectional area was approximately 33,25 m². (Only full-face tests had been completed and the ABM 30 is a single-pass bolter miner, cutting up to 7 m wide). The single-pass mining method is selectively used in South Africa for underground coal mine development, and is also extensively used in trials of new straight-line mining methods.

This project was conducted under the auspices of SIMRAC and involved the following companies:

- CSIR Mining Technology,
- HS Design Engineering, and
- SIMRAC, representing the coal mining industry, government and labour organisations.

The main aim of this project was to qualify the HS Design Engineering system for single-pass and double-pass high-seam mining conditions, which are up to 4,75 m high and 7 m wide.

The tests were performed in accordance with a protocol developed by the CSIR Mining Technology for such testing (Moolman, 2003). This protocol drew on experience with similar protocols which had been accepted by SIMRAC for previous tests (Du Plessis et al., 1999), the medium-seam protocol (Du Plessis, 2001), as well as a protocol accepted by INERIS of France
The protocol developed by Moolman (2003) for double-pass high-seam mining conditions has also been accepted by SIMRAC.

The outcome of the project was a set of acceptance criteria in accordance with which the results of the tests would be either accepted or rejected, and the tests themselves either passed or failed, as described by Du Plessis, (2001b).

The protocol stipulates the following acceptance criteria:

- The flame should not propagate along the tunnel in line with the operator’s position – i.e. the operator should not be exposed to any direct flame.
- The temperature increase at the operator’s position should not exceed human tolerance levels (in this case 100°C for less than half a second).
- Both the dynamic and static pressures measured should be within human tolerance limits which, is less than 5 kPa for dynamic and 30 kPa for static pressures.
- There should be no false triggering of the system due to other equipment being used underground.

The system should be up and running again within 8 hours of a detonation.

2 System description

The HS Design Engineering system consists of three main components:

a- The control electronics

b- The dual-spectrum sensor units, and

c- The discharge assemblies.

Figure 2.1 shows the flameproof components. The full design, with references and certificates are available from the manufacturer.

The control electronics are connected to the peripheral sensor units and discharge assemblies, constantly monitoring the connections so that the system will always be functional when required.

The sensor units are strategically placed to monitor the entire area of the cutting drum for any methane ignition. These sensor units are specifically designed to react only to the light wavelengths associated with burning methane, thus reducing the risk of a false ignition.

The discharge assemblies are configured for the particular conditions of the machine used for mining, the cross-sectional area of the tunnel, and the method of coal extraction being applied. They are configured to ensure the correct powder distribution for successfully extinguishing the explosion. A line diagram of the system is shown in Figure 2.2.
Figure 2.1. Components of the machine-mounted system.

- **Self cleaning dual spectrum detectors** for mining applications.
  - Range 16 meters
  - Viewing angle 60 deg.
  - Reaction time 1 ms for a standard explosion at 1 m distance

- **Flame proof distribution box for detectors**

- **2 kg extinguishing container** with a 360*90 deg area sprayhead
  - Valve opening time 2 ms

- **Flame proof control unit** for 6 detectors and 6 bottles
  - LED fault indicators
    - Red: Detector fault
    - Green: Bottle pressure error
    - Orange: Bottle wiring fault
    - Red: Bottle fired

- **Test button**

- **Flame proof distribution box for bottles**

- **15 kg Extinguishing container** with dedicated pipe connections for nozzles. Up to 6 dedicated nozzles can be fitted. Valve opening time 2 ms.

- **Bottle test switches and indicators**
3 Test equipment and test procedure

A test tunnel had previously been erected at the CSIR’s Kloppersbos Explosion Research Facility for the purpose of testing machine-mounted active suppression systems. This tunnel was modified to simulate the dimensions of mine workings of high seam height. A Voest ABM 30 and Joy HM31 continuous miners were used for these tests.

3.1 Test tunnel

The Kloppersbos tunnel is 20 m long and 7 m wide, with a variable height of 2 to 6 m. It is a steel construction with a cement floor. Energy absorbing coil systems are fitted on the outside of the structure.

These systems allow the tunnel to lift up to 140 mm off its base to provide an alternative escape route for the expanding gases, when required.

For the full-face conditions, the cross-sectional area was approximately 33,25 m².

3.2 Methane supply

Methane is fed into the tunnel through a pipe network from a gas supply point. Flat spray nozzles are used at the point of application. The flow rate of the gas is controlled by quick-closing valves.

A plastic membrane is secured to the structure behind the position of the machine-mounted system to the methane/air mixture during mixing. A fan is used to ensure a uniform mixture. The cutting drum on the model rotates during ignition; this increases the reaction and speed of the flame (see Fig. 3.2 which shows this plastic membrane, which effectively forms a methane chamber, at the front of the tunnel).
3.3 Monitoring of the methane mixture

Also positioned in the front section of the tunnel is a pipe network connected to a methane sampling device. While the methane is being mixed into the contained air volume, samples of the mixture are taken continuously to monitor the methane concentration. Once the readings from the various sampling points throughout the tunnel are all at the desired concentration, the mixture can be ignited.

3.4 Infra-red sensors

In order to measure the propagation of the flame along the tunnel, infra-red sensors are placed in four rows along the walls and roof of the tunnel. These sensors are silicon photovoltaic cells which react to the infra-red light emitted during burning. They are placed as follows:

- One row along the right-hand wall,
- One row along the left-hand wall, and
- Two rows in the roof.

In each row, the first sensor is placed 1 m from the front face of the tunnel, after which each row contains a further 18 sensors, spaced 1 m apart, extending right to the back of the 20 m tunnel.

The data is given as volt readings, allowing immediate determination of the maximum intensities measured by the flame sensors along the length of the tunnel. This also allows easy determination of the length of the flame before it was completely suppressed. In this case the flame extended to a maximum of 7 m as measured by the top right-hand row of sensors.

Figure 3.2. Plastic membrane in position (from Du Plessis, 2001b).
3.4 Pressure sensors

One static pressure reading is taken at the position of the operator’s cab. A piezoelectric sensor is used to measure the absolute (\(P_{\text{atm}} + P_{\text{gauge}} = P_{\text{a}}\)) pressure at the cab.

One dynamic pressure sensor is mounted 2 m from the open end of the tunnel and this is used to measure the wind force as the pressure wave from the explosion moves through the tunnel.

3.5 Temperature sensor

A thermocouple is placed at the operator’s cab to measure the temperature rise to which the operator would be exposed. The temperature reading is measured as an increase, from ambient, with the ambient temperature being designated as 0 °C.

Although this sensor is constructed of a relatively fine bimetallic wire, there is a slight lag in the temperature measurement. For this reason, the temperatures analysed represented temperature rises rather than absolute temperature values. Moreover, unfortunately, the thermocouple also cools down rather slowly, mostly by convection with the surrounding air. It is therefore assumed that after the temperature has peaked, the surrounding temperature returns immediately to ambient, although the thermocouple takes a while to cool down. Figure 3.5 shows an example of the temperature charts compiled from the data generated from the measurements form the thermocouple.

![Temperature chart](image)

**Figure 3.5: Temperature chart.**

The figure shows that over the 2 second sampling period, the temperature at the operator’s cab position rises from around 0 to a maximum of just above 500°C (where 0 is equivalent to the ambient temperature).
3.6 Photographic record

A video camera was attached to the roof of the tunnel, 1 m from the open end, to capture a visual record of the tests.

3.7 Data-acquisition system

The data-acquisition system was custom-built and has 128 input channels, each of which samples simultaneously at a rate of 30 kHz for a period of 2 seconds. For these tests, 75 of these channels were used. The data are stored on the system’s hard drive, and are available immediately after testing.

3.8 Protocol tests

The active suppression system was tested on the two main types of continuous miners used in South Africa coal mines: the Voest ABM 30 (single-pass) bolter miner and the Joy HM 31 (double-pass) continuous miner.

3.8.1 Single-pass continuous miner

In accordance with the protocol (Du Plessis, 1998; Du Plessis, 2001b), the test sequence was carried out in order of ascending difficulty. The main position of the Voest ABM 30 machine inside the tunnel was in the full-face scenario, with variations on the placement of the boom (and thus ignition) position at various methane concentrations.

The main placement was:

1. Full face – to simulate the position of the machine during the cutting cycle (see Fig. 3.8.1).

For the main placement, the following ignition positions were used for the nine different boom positions of the machine, in the following order:

- Bottom left (BL)
- Bottom middle (BM)
- Bottom right (BR)
- Centre left (CL)
- Centre middle (CM)
- Centre right (CR)
- Top left (TL)
- Top middle (TM)
- Top right (TR).
In order of ascending difficulty, for the sub-conditions, first a less potent 7,5 per cent (methane/air concentration) explosion was carried out. Thereafter, the 9,0 per cent explosions were done for all nine sub-conditions. Finally, for the full-face machine position, a 7,0 per cent explosion was performed.

It was assumed that the ignition would have been caused by a pick on the machine striking a sandstone inclusion in the coal seam. For the purposes of these tests, 3x200 J match heads – electrically activated – were placed in the ‘shadow’ area of the drum (shielded from the ultraviolet sensors of the system). The flame would, therefore, propagate out from behind the drum before the system detected and extinguished it. After each completed test, the data were analysed to determine whether the explosion had been successfully suppressed in accordance with the protocol, or not.

### 3.8.2 Double-pass continuous miner

In accordance with the protocol (Du Plessis, 1998; Du Plessis, 2001b), the test sequence was scheduled in order of ascending difficulty. Three main positions of the Joy HM 31 continuous miner inside the tunnel were tested. Each position was tested with various placements of the boom (and thus ignition position) at various methane concentrations.

The three main placements were:
1. Full-face – to simulate the position of the machine at the beginning of the first cut (see Fig. 3.8.2a).

![Figure 3.8.2a. Full-face position.](image)

2. In-shoulder – to simulate the position in which the machine has completed the first cut but is still within the confines of the tunnel, with the shoulder adjacent to it (see Fig. 3.8.2b).

![Figure 3.8.2b. In-shoulder position.](image)
3. Out-shoulder – to simulate the position in which the machine has moved back out of the 4 m shoulder area and is preparing to start the second cut (leaving a large cavity exposed next to the shoulder in which a build-up of methane could occur) (see Fig. 3.8.3c).

![Figure 3.8.2c. Out-shoulder position.](image)

For these three main placements, the following ignition positions were used for the different boom positions of the machine (in this order):

- Bottom (BL)
- Bottom right (BR)
- Centre face (C)
- Top left (TL)
- Top right (TR).

Due to the success of the previous tests, and the perceived risk in suppressing an explosion being associated with the larger volume of gas in the out-shoulder position (see Fig. 3.8.2c), the test programme sequence was changed to descending difficulty. Ascending difficulty was maintained for the sub-conditions: first a less-potent 7.5 per cent (methane/air concentration) explosion was carried out. Thereafter, the 9.0 per cent explosions were done for all five sub-conditions. Finally, for the full-face and out-shoulder machine positions, a 12.0 per cent explosion was performed.

It was assumed that the ignition would have been caused by a pick on the machine striking a sandstone inclusion in the coal seam. For the purposes of these tests, a 200 J match head – electrically activated – was placed in the ‘shadow’ area of the drum (shielded from the ultraviolet sensors of the system). The flame would therefore propagate out from behind the drum before the system detected and extinguished it. After each completed test, the data were analysed to determine whether the explosion had been successfully suppressed in accordance with the protocol.
4 Results

The data for both the single- and double-pass continuous miners were analysed separately and the results of both data sets are summarised below.

4.1 Single-pass continuous miner

For purposes of comparison, a 7 per cent (methane/air concentration) unsuppressed test was done in an open tunnel. The risk of damage to the tunnel was perceived to be too great to do an unsuppressed test with the continuous miner present.

4.1.1 Face test results

Table 4.1.1: Full-face active suppression test results

<table>
<thead>
<tr>
<th>Test</th>
<th>CH₄/Air (%)</th>
<th>Ignition position</th>
<th>Flame length (m)</th>
<th>Dynamic pressure (mbar)</th>
<th>Temp. increase °C</th>
<th>Test: Pass/Fail</th>
<th>Test comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>7,5</td>
<td>NR*</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>9,0</td>
<td>NR*</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>9,0</td>
<td>NR*</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>9,0</td>
<td>8</td>
<td>NR*</td>
<td>NR*</td>
<td>Fail</td>
<td>1 bottle not armed, redo test</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>9,0</td>
<td>9</td>
<td>NR*</td>
<td>NR*</td>
<td>Fail</td>
<td>Fault finding, due to symmetry of test set-up, test position 7</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>9,0</td>
<td>7</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>Redo test to confirm findings</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>9,0</td>
<td>7</td>
<td>NR*</td>
<td>NR*</td>
<td>Fail</td>
<td>No video</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>9,0</td>
<td>2</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>9,0</td>
<td>1</td>
<td>10m</td>
<td>40</td>
<td>Fail</td>
<td>Investigate and correct spray pattern.</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>9,0</td>
<td>3</td>
<td>NR*</td>
<td>1</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>113</td>
<td>9,0</td>
<td>5</td>
<td>NR*</td>
<td>6</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>114</td>
<td>9,0</td>
<td>6</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>9,0</td>
<td>3</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>116</td>
<td>9,0</td>
<td>1</td>
<td>NR*</td>
<td>NR*</td>
<td>Fail</td>
<td>No video, redo test</td>
<td></td>
</tr>
<tr>
<td>117</td>
<td>9,0</td>
<td>1</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>Redone test No 116</td>
<td></td>
</tr>
<tr>
<td>118</td>
<td>7,0</td>
<td>1</td>
<td>NR*</td>
<td>NR*</td>
<td>Pass</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

* NR = no flame, pressure or temperature reading

The testing began with the 7,5 per cent methane explosion for full-face conditions (see tunnel walls – there are operator’s (driver and roof bolter) cabs on the left- and right-hand sides, as well as on top of the machine). Thereafter the remaining suppression tests were conducted on methane explosions resulting from methane/air volumes of up to 270 m³ at around 9 per cent concentration per volume. Ensuring that all tests were conducted at a 9 per cent methane/air
concentration proved challenging due to the difficulty in creating an airtight chamber in the tunnel.

During test No.105, a large number of data channels were damaged. For the remaining tests, the available channels were used to record the dynamic pressure, temperature and the propagation of the flame from the three sets of flame sensors around the operator's cab. The changed data-logging system did not put any of the tests and or test results in jeopardy as the facility for recording the relevant data, i.e. temperature and pressures, was still functional. However, it was not possible to compile the additional flame sensor data required for the temperature and flame graphs discussed earlier.

The problems initially encountered with the failed tests could be traced back to the spray pattern not closing off the surface area of the test tunnel effectively (see Fig. 4.1.1, photo taken at 360 ms, with the red circle). Once the spray pattern had been adjusted to seal the tunnel effectively, the ‘hole’ in the spray pattern disappeared and no more tests that failed due to this problem were recorded.

![Spray pattern tests, with photos taken at 40 ms, 80 ms, 160 ms and 360 ms](image)

**Figure 4.1.1: Spray pattern tests, with photos taken at 40 ms, 80 ms, 160 ms and 360 ms**

In two tests (No’s 109 and 116), the video recording equipment did not function correctly, and both tests were considered failures, irrespective of the instrumentation readings.

In all the successful tests, the pressure and temperature rises caused by the explosion were so small that they were almost zero, hence the "NR note in Table 4.1.1. For these tests, the highest temperature rise at the operator's position was approximately 0,3°C, which is negligible. The operator and the rest of the crew working at the face would therefore be safe under those conditions.
4.2 Double-pass continuous miner

In accordance with the protocol (Moolman, 2003 and, in previous tests, Du Plessis, 2001a, the test procedure should have been carried out in order of ascending difficulty. However, considering the results from previous test programmes (Du Plessis 1998; Du Plessis, 2001a), and the perceived risk in suppressing the larger volume of gas in the out-shoulder position, the decision was taken to carry out the double-pass high-seam tests in order of descending difficulty.

Previous tests had shown that of the three main placements of the machine inside the tunnel, the out-shoulder position was the most challenging.

The three main placements are:

1. Full-face – to simulate the position of the machine at the beginning of the first cut.
2. In-shoulder – to simulate the position in which the machine has completed the first cut but is still within the confines of the tunnel, with the shoulder adjacent to it.
3. Out-shoulder – to simulate the position in which the machine has moved back out of the 4,5 m shoulder area and is preparing to start the second cut (leaving a large cavity exposed next to the shoulder in which a build-up of methane could occur).

4.2.1 Face test results

Before the test commenced, a plastic membrane was placed behind the position of the machine-mounted active suppression system, with the purpose of containing the methane/air mixture during mixing. In the out-shoulder position, a 9,0 per cent methane/air mixture of up to 330 m³ (at the 11 m position) in volume was created, with up to 280 m³ in front of the active suppression system.

The tests began with the 9 per cent methane explosion for the out-shoulder position. The first test proved that the active suppression system was capable of preventing the propagation of the methane flame beyond the inert curtain of ammonium phosphate powder to the gas zone at the back of the system. However, due to the 9 per cent methane/air mixture expanding up to five times in volume when exploding and due to the corresponding pressure wave, the exploding gas/air mixture pushed the inert powder curtain over the position of the operator’s cab. This resulted in temperatures above 500ºC (thermocouple destroyed) and a maximum length of the flame extension of 18 m (the operator’s position was at 12 m for the out-shoulder tests).

This resulted in a test failure, not due to the system, but due to the test set-up and the following acceptance criteria stipulated in the protocol:

- The flame should not propagate along the tunnel in line with the operator’s position – i.e. the operator should not be exposed to any direct flame.
- The temperature increase at the operator’s position should not exceed human tolerance levels (in this case 100ºC for less than half a second).

During preparations for this particular suppression test, the abovementioned outcome was anticipated. In order to combat this, two full suppression systems were installed on the Joy HM 31 continuous miner to provide a thicker inert curtain with more back pressure. This measure was aimed at controlling the pressure wave from the explosion front and controlling the burning front, but it proved to be insufficient.
The test team was of the opinion that the active suppression system, although capable of preventing the propagation of the burning methane flame beyond the curtain of inert material, was not able to suppress the propagating flame within the parameters of the current protocol due to the physical expansion of the exploding methane/air mixture. Alternative technical options and or solutions were investigated and were presented to SIMRAC for their consideration.

The following alternative solutions/options were considered:

1. The system would be moved forward on the Joy HM 31, to just behind the cutter head, ensuring that only one system would be required. Discussions with, and an investigation by, Joy South Africa proved this option to be impractical and indeed impossible.

2. A new spray configuration was proposed, covering the corners of the tunnel and reducing the volume of ignitable methane/air. This proved to be very risky and would require two full suppression systems. Again, according to discussions with Joy, it would be both impractical and impossible to install two full systems at the desired position on the Joy HM 31 miner. Moreover, even if successful, this option would almost double the installation and operating cost of the system per Joy HM 31 miner, making it expensive and bulky for production underground.

3. It was proposed to use the standard suppression system on the Joy HM 31 miner, capable of stopping a methane/air explosion in the in-shoulder position (generally believed to be the riskiest cutting cycle of the three), with a stand-alone active suppression roadway barrier system. The machine-mounted system would provide protection during this mining cycle, with the roadway barrier providing additional protection or stand-alone support in high-risk areas and the out-shoulder position.

At the DME/mining industry workshop meetings held in mid-2003 and on 2 April 2004, changes to this test programme to include a dynamic load scenario, including the effect of a working scrubber and jet spray, was recommended. Over and above this recommendation, it was also recommended that after the completion of the high-seam active suppression tests, a dynamic load test should also be performed.

SIMRAC feedback was that the current data/results on the active suppression tests for all types of continuous miners were sufficient and that the current test programme should be terminated. The funds saved by the termination of the double-pass continuous miner test programme should be utilised for a separate test programme aimed at evaluating the active roadway barrier system.

5 Conclusions

With the completion of the tests prescribed by the protocol, the system has proved itself to be effective in detecting and suppressing explosions for the given scenario – configured and mounted on a Voest ABM 30 for a cross-section with an area of approximately 33,25 m².

Earlier testing in Germany (Faber, 1990) was confined to a single-cut scenario. The system was subsequently implemented in that country and has proved to be effective in underground applications.

Previously in South Africa the Explo-Stop® system had proved effective for low-seam mining conditions, with 9 per cent methane/air mixture concentration volumes of 80 m³ to 90 m³ being used, as well as for French mining conditions (Du Plessis and Van Dijk, 2001) in which a second mining cut resulted in 9,0 per cent methane/air mixture of up to 180 m³ in volume.
The Explo-Stop® system also proved effective for medium-seam conditions with 9 per cent methane/air mixture concentrations in a cross-sectional area of approximately 21 m², and with volumes of up to 123 m³ being recorded when the second mining cut was tested. The system was subsequently implemented in an Anglo Coal colliery and has since proved to be reliable in underground applications.

Furthermore, the Explo-Stop® system was also tested at Kloppersbos when installed on the surface auger miners that are used in South Africa (Moolman and Mthombeni, 2002). Since its installation on the augers, the system has effectively stopped a propagating methane/coal-dust explosion at an operating mine in South Africa, with mono-ammonium phosphate powder being used as the suppressing agent.

The single-pass high-seam mining condition tests, proved challenging due to the huge increase in the explosive volume of methane under these conditions. Nevertheless, the HS Design Engineering system complied effectively with all the requirements of the test protocol and is ready for commissioning in South Africa to protect workers and mines against explosions in adverse conditions.

For the double-pass high-seam mining conditions, the tests proved that the active suppression system (although capable of preventing the propagation of the burning methane flame beyond the curtain of inert material) was not able to suppress the propagating flame within the parameters of the developed protocol due to the physical expansion of the exploding methane/air mixture. The standard suppression system for a single-pass continuous miner can be used for controlling and stopping a methane/air explosion in the in-shoulder position, with a stand-alone active suppression roadway barrier system potentially providing additional protection in the full-face and out-shoulder positions.

The results of the protocol testing showed that the HS Design Engineering system was capable of suppressing ignitions of stoichiometric methane mixtures under all the conditions tested, except in the case of the double-pass high-seam mining system. This was achieved with a temperature increase of less than 100°C at the operator’s cab and without any flame being detected at this position.

6 References


