Safety In Mines Research Advisory Committee

SIMRAC

Final Report

Title: INCREASE THE USE OF THE STONE DUST BAGGED BARRIER ENHANCING ITS APPLICATION FOR DIFFERING CONDITIONS

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Executive Summary

This report summarises the results of work completed on the bagged stone dust barrier for stopping the flame propagation of a coal dust explosion in the 200-m G P Badenhorst test gallery at the Kloppersbos Research Facility. This work was completed under the auspices of SIMRAC.

The work done was based on the needs identified at a workshop held on 5 March 1997. At this workshop 14 research needs were identified by the interested parties, which included representation from the industry, unions and the DME. The four identified for further research were:

- placement and positioning of barriers
- safety factor
- criteria for a successful barrier
- lower limits of operation.

This work was then combined into three major areas of evaluation, namely:

- placement of barrier
- classic distributed barrier
- stone dust bags as a stone dust supplement.

The constraints of the 200-m gallery allowed the barrier to be evaluated only at a maximum distance of 120 m. From this work it was recommended that the last through road and not the face be used as a reference point to establish the barrier position and that the start position of the bagged stone dust barrier be extended to 120 m.

The results presented in this report should be interpreted in the context of the experimental set-up and procedure described using a round gallery of 2,5 m diameter. This report summarises the performance of various bagged stone dust barrier designs against various explosions.

The main findings of the work are:

- The concentrated and distributed barriers should not be placed further than 120 m from the last trough road in bord-and-pillar workings or from the face in the case of longwall mining.

- At 120 m, the minimum design requirements for the bagged stone dust barriers are:
  (i) concentrated barrier – 100 kg/m^2 (mass per unit area)
  (ii) distributed barrier – 1 kg/m^3 (mass per unit volume).
  It is the authors' opinion that a reduction in the above requirements cannot be warranted from the research results.

- The classic distributed barrier, positioned at 120 m and designed to 51,4 kg/m^2 , failed to inhibit flame propagation inside the 200-m test gallery when evaluated against the standard and strong explosions.

- The performance of the classic distributed barrier in the surface tests was such that its use can be recommended.

- When used as a stone dust supplement, in the context of the tests, the bags inhibited flame propagation in simulated worst-case scenarios. They successfully inhibited flame propagation for both 40 and 60-m pure coal dust zones.

List of abbreviations, symbols and terms

Abbreviations

SIMRAC	Safety in Mines Research Advisory Committee
DME	Department of Minerals and Energy
LTR	Last Through Road
COLEAG	Collieries Environmental Engineering Advisory Group
TIC	Total Incombustible Content

Symbols

m	metre
kg/m^2	kilograms per square metre
kg/m^3	kilograms per cubic metre
µm	micrometres/microns
J	joule
g	gram
m^3	cubic metre
kPa	kilopascal
m/s	metre per second
g/m^3	grams per cubic metre
M_A	mass per unit area (kg/m^2)
M_V	mass per unit volume (kg/m^3)

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1 Introduction

The bagged stone dust barrier system was developed by the CSIR at its Kloppersbos Research Facility. This passive barrier system has undergone extensive evaluation in the 200-m G P Badenhorst surface test gallery and at the DMT Tremonia underground experimental mine.

During the completion of the initial research work, under the auspices of SIMRAC, a need was expressed to identify and develop more applications for the barrier. To this end, the present project was defined with the intention of identifying industry needs and requirements.

To establish the needs and to formulate alternative user requirements, a workshop was held which was attended by representatives of the industry, unions and the DME. Subsequently the requirements identified were formulated and proposed to COLEAG.

An extensive test programme was then initiated in the 200-m test gallery at Kloppersbos to evaluate these requirements within the constraints of the gallery.

This report summarises the test work and the findings during the evaluation of the bagged barrier system.

1.1 Background

One of the control measures employed to prevent coal-dust explosions from propagating in underground workings is the passive explosion barrier. The development and evaluation of the bagged stone dust barrier system on surface at Kloppersbos (Du Plessis and Vassard, 1997) and in underground testing at the DMT Tremonia facility (Michelis et al., 1995; Margenburg, 1995; Michelis et al., 1996 and Margenburg et al., 1996) has proved that the bagged stone dust barrier can prevent the propagation of coal dust explosions.

The concentrated and distributed barrier systems per se have proved to be as effective as other barriers tested and these designs should be suitable for most mining layouts.

The accepted systems were a concentrated, minimum design of 100 kg/m^2 or a distributed design. The distributed barrier system consists of four individual barriers with a maximum allowable distance from the face of 100 m. It was also specified (at the time the project commenced) that the quantity requirement of 1 kg/m^3 be adhered to. In mines without a systematic support rule, the systems were subject to a construction constraint due to the absence of roofbolts.

To this end the evaluation of alternative barrier designs, conforming to the more classic distributed or concentrated barrier design, will aid such mines with the implementation of tailor-made designed barrier systems.

An evaluation of the stone dust concentration, relative to varying explosion strengths and distances from the face, might allow the mining industry to reduce the number of bags required and to relax the maximum distance allowed from the face. If the limits at which this system operates can be determined, more efficient alternatives can be achieved.

As enough large-scale test work has been conducted, showing reasonable correlation to the 200-m test tunnel, and as the latter is significantly less expensive, the tunnel can be used to evaluate the effect of alternative barrier configurations. In this way new barrier configurations and lower-density barriers can be tested. The end result of this work should be more efficient use of the bagged barrier system.

To facilitate the project planning and project definition, an industry workshop was held on 5 March 1997 to meet the criteria given above and as set out in the original project motivation.

2 Workshop

In order to formulate the alternative user requirements for the bagged stone dust barrier, a tri-partite group of representatives was invited to participate in the workshop. A list of delegates who attended the workshop is given in Appendix A.

The main objective of the workshop was to define the user requirements and from these to scope the work to be undertaken in the project. At the workshop the following main points were raised, discussed and listed:

1. Lower limit of operation
2. Excessive safety factor
3. What criteria indicate a successful barrier?
4. Is there a change in the requirements if all roads are protected?
5. Practicalities of current guidelines
6. Training of fundamentals
7. What is the combined effect of stone dust barriers on distance from the face to allow greater ease of use?
8. Newer innovative designs
9. Stone dust supplement principle
10. Other inert material
11. Life of bag
12. Different bags, shapes, etc.

A questionnaire was then circulated to ensure that the needs had been correctly identified and to give an opportunity to rate them in order of importance. Of the 12 research needs, the four most important issues identified for further research (in order of importance) were:

1. Placement and positioning of barriers
2. Safety factor
3. Criteria for a successful barrier
4. Lower limits of operation.

It was decided that the test work would follow the order of importance, as combined and discussed below.

Placement and positioning of barriers

The aim would be to evaluate the maximum distance at which the barrier can be placed within the constraints of the 200-m test gallery.

Safety factor and lower limits of operation

For the safety factor and lower limits of operation, it was decided that the following should be done:

a) evaluate current barriers at a lower stone dust concentration (kg/m^3)

b) evaluate a classic distributed barrier at a lower stone dust concentration

c) evaluate the stone dust supplement principle at a lower stone dust concentration.

These decisions were then reported to SIMRAC through the COLEAG sub-committee, after which the different evaluation phases of the project commenced.

The "criteria for a successful barrier" was not deemed to be of importance as a research need. The performance of any type of barrier is measured against a pass/fail criterion, where a pass requires the flame propagation of a coal dust explosion to be stopped within a certain distance, as described by Du Plessis and Vassard (1995). This research need was not pursued as a pass could also be the prevention of an explosion developing/propagating into a stronger explosion, as expressed by Cybulski (1975).

3 Explosion procedure

A coal dust explosion is an explosion in which coal dust particles smaller than 240 μm participate in an uncontrolled combustion in an underground mine environment.

A coal dust explosion can result if all the installed measures and procedures fail, or if the measures being used are inadequate at the time.

3.1 Igniter

The igniters used for various explosions are:

- a standard detonator that comprising a fuse cap (200 J) and 1,5 g barium nitrate powder,
- a fuse cap.

3.2 Ignition

The initiation of coal dust explosions for evaluating the barriers was achieved by igniting a 36 m^3 methane/air mixture. This chamber of 36 m^3 was obtained by placing a plastic membrane 7,5 m from the closed end of the gallery. This amount of methane/air mixture is needed to produce enough wind pressure to lift the coal dust into the air and to supply sufficient heat to the coal dust particles for flame propagation to take place.

3.3 Gallery description

The 200-m G P Badenhorst test gallery was used to conduct the various tests. A comprehensive description of the gallery was given by Cook (1993).

The gallery is equipped with static and dynamic pressure sensors and with flame and temperature sensors. The gallery arrangement with the instrument positions is shown in Figure 3.3.

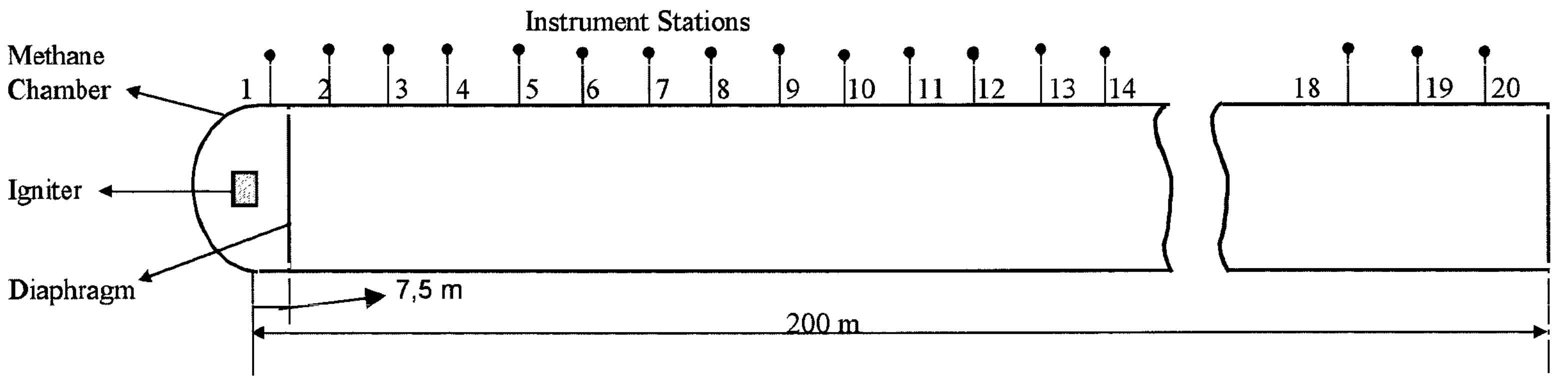
3.4 Coal dust

The coal dust used for the tests was the standard coal used for previous experiments at the Kloppersbos facility. This coal has the following average main characteristics as determined by proximate analysis on a dry ash-free basis, as shown in Table 3.4.

Table 3.4

Average standard coal characteristics

Coal characteristics	**Percentage d.a.f. (%)**
H_2O	2,36
Ash	14,28
Volatile Matter (VM)	24,88
Fix. Carbon	58,8
Total Sulphur	0,5



Notes: There is a total of 20 instrument stations.
The instrument stations are 10 m apart.
At each instrument station, static pressure and flame sensors are installed.
Dynamic pressure sensor is installed at station 8.

Figure: 3.3 Diagrammatic representation of the 200-m explosion gallery

The coal was milled to a median particle size of 20 μm ± 2 μm and a top size of 150 μm ± 10 μm as expressed on a Rösin-Rammler-Bennet size distribution graph. This is considered to be typical of explosive coal dust, representing the mean size distribution of the float dusts that are encountered in underground return airways.

4 Results

The results for the individual baseline explosions as well as the evaluation tests are described in this section.

4.1 Baseline explosions

To evaluate the performance of the barrier, a number of explosions were developed. These were:

- Standard explosion
- Weak explosion
- Medium explosion
- Strong explosion
- Supplement explosion.

4.1.1 Standard explosion

The standard explosion (Du Plessis and Vassard, 1995) is initiated by igniting a 9 % CH_4/air mixture with a volume of 36 m^3 using a standard igniter. Coal dust (144 kg) is distributed on the floor for the remaining 192,5 m of the tunnel. This results in a distributed coal dust concentration of approximately 150 g/m^3. A graphical representation of the explosion is shown in Figure 4.1.1.

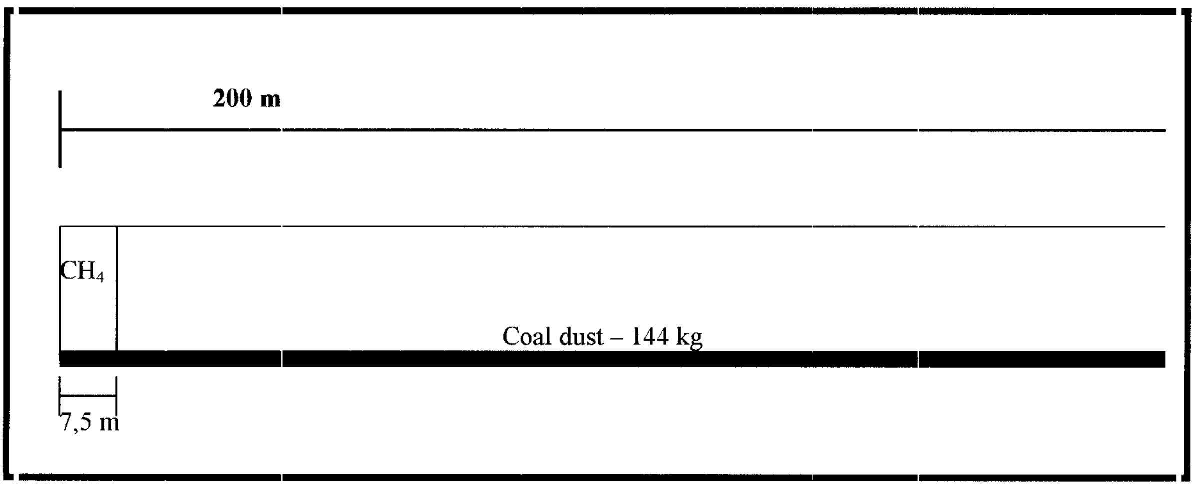


Figure 4.1.1: Test layout for the standard explosion

This explosion was designed to develop a dynamic (wind) pressure of approximately 25 kPa, with flame propagation throughout the gallery from coal dust combustion but without the production of additional pressure. The main delay time, between flame and dynamic pressure wave, for the standard explosion varied between 400 and 600 ms.

4.1.2 Weak explosion

The weak explosion (Du Plessis and Vassard, 1997) is initiated by igniting a 9 % CH_4/air mixture with a volume of 36 m^3 using a fuse cap (200 J igniter). Coal dust (144 kg) is distributed on the floor for the remaining 192,5 m of the tunnel. This results in a distributed coal dust concentration of approximately 150 g/m^3. The graphical representation of the explosion would be similar to that shown in Figure 4.1.1, as only the strength of the igniter was changed.

4.1.3 Medium explosion

The medium explosion (Du Plessis and Vassard, 1995) is initiated by igniting a 9 % CH_4/air with a volume of 36 m^3 using a fuse cap. Coal dust (192 kg) is distributed on the floor for the remaining 192,5 m of the tunnel. This results in a distributed coal dust concentration of approximately 200 g/m^3. The graphical representation of the explosion is would be similar to that shown in Figure 4.1.1.

4.1.4 Strong explosion

The strong explosion (Du Plessis and Vassard, 1997) is initiated by igniting a 9 % CH_4/air mixture with a volume of 36 m^3 using the standard detonator. Coal dust (192 kg) is distributed on the floor for the remaining 192,5 m of the tunnel. This results in a distributed coal dust concentration of approximately 200 g/m^3 (an increase of 25 % above that of the standard explosion).

The graphical representation of the explosion would be similar to that shown in Figure 4.1.1. The change in the amount of coal dust results in a propagating explosion, increasing the dynamic pressure wave, if unsuppressed, to approximately 50 kPa at the tunnel mouth.

4.1.5 Supplement explosion

The supplement explosion is initiated by igniting a 9 % CH_4/air mixture with a volume of 36 m^3 using the standard detonator. Two secondary fuel zones are used. In the first zone, pure coal dust is distributed on the floor and on the shelves. This zone simulates the distance from the face to the LTR. The length of the first fuel zone is either 40 or 60 m. The second fuel zone consists of a mixture of coal dust and stone dust, intermittently mixed to a 40 % Total Incombustible Content (TIC.) The % TIC is calculated as follows:

$$VMdaf = \frac{VM\% x 100}{(100 - \% Ash - \% Water)} \qquad (1)$$

$$\% TIC = 40\%$$

$$\% Stone\,dust = \left[\frac{(\% TIC - \% Ash - \% Water)}{1 - \frac{(\% Ash + \% Water)}{100}} \right] \qquad (2)$$

The graphical representation of the explosion is shown in Figure 4.1.5.

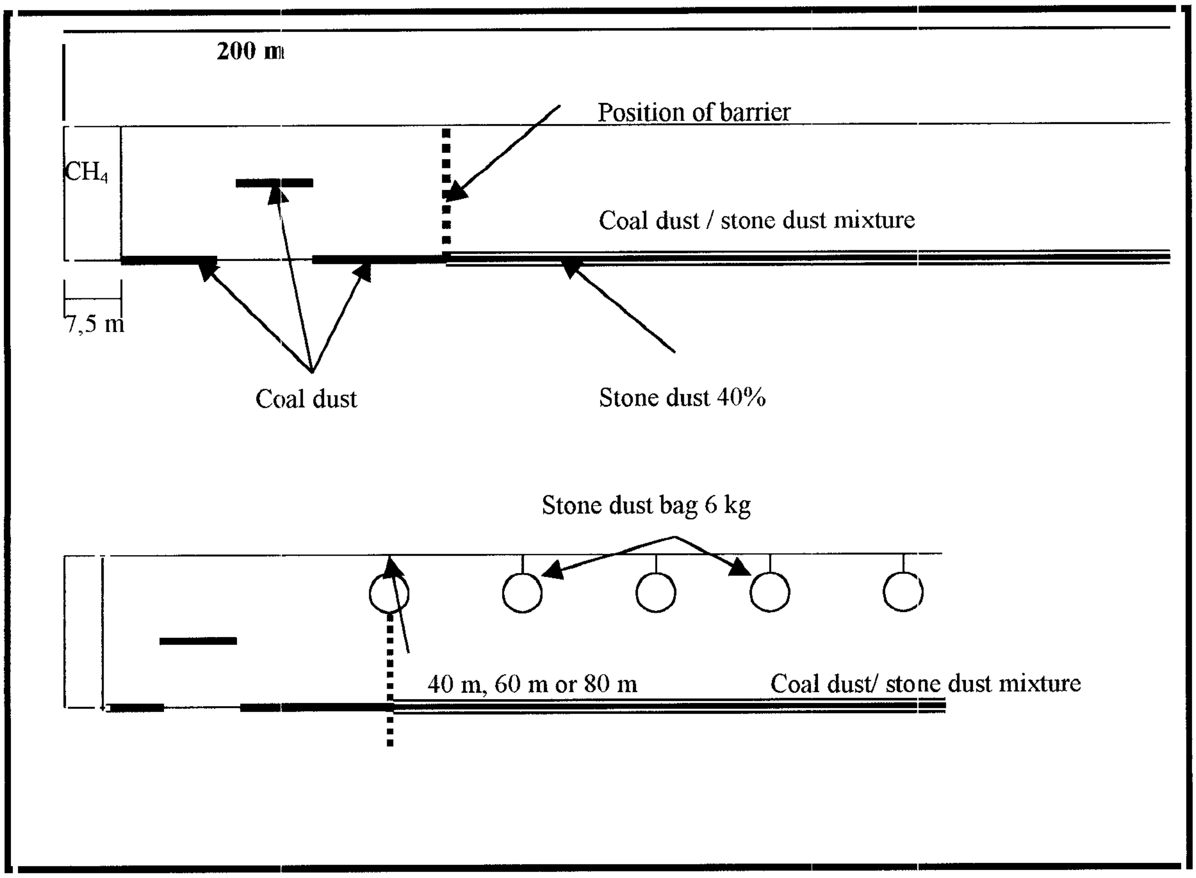


Figure 4.1.5: Test layout for the supplement explosions

The test results for the individual baseline explosions are shown in Table 4.1.5. The reported flame speed is the average measured at either 40 or 60 m respectively for the different baseline explosions.

Table 4.1.5

Baseline supplement explosion test results

Expl. No	Description	Static pressure (kPa)	Dynamic pressure (kPa)	Flame speed (m/s)	Flame length (m)
77	Baseline (40 m)	66	28,9	160,4	>200
81	Baseline (40 m)	65	26,7	171,4	>200
82	Baseline (40 m)	68	32,6	154,4	>200
93	Baseline (60 m)	64	32,3	165,2	>200
98	Baseline (60 m)	65	30,7	145,5	>200
100	Baseline (60 m)	83	40,0	174,6	>200

Note: > 200 m indicates that the flame length extended throughout the test gallery.

The baseline explosion (with a 40-m coal dust zone) has the following average characteristics:

Flame length: > 200 m
Flame speed at 40 m: 162,1 m/s
Static pressure: 66,3 kPa
Dynamic pressure at 80 m: 29,4 kPa

With the first fuel zone extending 60 m from the point of ignition, the following average characteristics are evident:

Flame length: > 200 m
Flame speed at 60 m: 161,8 m/s
Static pressure: 70,7 kPa
Dynamic pressure at 80 m: 34,3 kPa

Both the 40 and 60 m supplement explosions are defined as weak explosions (static pressure less than 1 000 kPa) but have reasonable dynamic (wind) pressures to ensure activation of the bags. In both these explosions the primary contributor to the measured dynamic pressure should be the initiating methane explosion and the coal dust distributed on the shelves.

4.2 Results: Placement and positioning of barrier

The concentrated barrier that was evaluated consisted of 80 stone dust bags of 6 kg each. The stone dust concentration was 96 kg/m^2 (mass per unit area). Seven bags were suspended every 2 m. This resulted in 13 lines of bags suspended over a distance of 24 m.

To evaluate the limit and distance of operation, it was decided to evaluate the concentrated barrier at a distance of 140 m from the ignition source. In test 26, in which the barrier was evaluated against a strong explosion, the barrier failed to arrest the flame propagation inside the tunnel. It was subsequently decided to move the barrier to 120 m as previous evaluation of this barrier at 100 m had been successful (Du Plessis and Vassard, 1997). The concentrated bagged barrier was evaluated against the standard, weak, medium and strong explosions. The results obtained, with the barrier positioned at 120 m are shown in Table 4.2.

Table 4.2

Concentrated barrier test results at 120 m

Expl. No.	Description	Static pressure (kPa)	Dynamic Pressure (kPa)	Flame speed (m/s)	Flame length (m)
28	Standard	69	31,9	151,9	170
110	Standard	65	25,5	92,1	140
31	Weak	30	16,5	148,9	180
109	Weak	46	13,6	78,3	140
30	Medium	56	18,3	147,6	160
111	Medium	52	32,3	80,8	140
27	Strong	72	29,8	202,1	> 200
29	Strong	74	35,1	199,8	170
112	Strong	61	23,4	-	150

The test results show that the concentrated barrier was effective against the standard, weak, medium and strong explosions. In explosion 27(strong explosion) the barrier failed to inhibit flame propagation.

At 120 m the barrier proved effective for the following range of pressures and flame speeds:

Static pressure:	30 to 74 kPa
Dynamic pressure:	13,6 to 35,1 kPa
Flame speed:	78,3 to 199,8 m/s

4.3 Safety and lower limits of operation

4.3.1 Lower stone dust concentrations

To evaluate the effect of a reduction in the stone dust concentration, the concentration was lowered to approximately 60 kg/m^2. This was achieved by reducing the number of bags to 50 stone dust bags of 6 kg each. Seven bags were suspended every 2 m, starting at 120 m.

As the strong explosion had proved to be the most difficult to inhibit in prior tests, it was decided to evaluate this principle against the strong explosion.

The stone dust concentration per unit area (M_A) was calculated as follows:

$$M_A = \frac{stone\,dust\,mass}{tunnel\,area} \qquad (3)$$

$$= \frac{300\,kg}{4{,}91\,m^2}$$

$$= 61{,}1\,kg/m^2$$

The test results are shown in Table 4.3.1a.

Table 4.3.1a

Reduction in stone dust concentration at 120 m (61 kg/m²)

Expl. No.	Description	Static Pressure (kPa)	Dynamic Pressure (kPa)	Flame speed (m/s)	Flame length (m)
32	Strong	69	29,3	210,7	160
33	Strong	67	24,5	178,5	> 200
113	Strong	79	37,6	183,3	> 200
114	Strong	66	27,8	143,5	160

At this concentration and barrier position it was difficult to assess the barrier's performance. It seems to operate at a lower limit that indicates both success and failure for the same design. As no safety factor was built into this design, it is clear that a reduction in the stone dust concentration leads to an increased risk with regard to the successful operation of the design. Therefore, no reduction in the stone dust concentration should be allowed for this design.

In order to prove the repeatability of these tests, two tests were conducted at 80 m and a concentration of 80 kg/m^2. The results are shown in Table 4.3.1b.

Table 4.3.1b

Concentrated barrier (80 kg/m²) results

Expl. No.	Description	Static pressure (kPa)	Dynamic Pressure (kPa)	Flame speed (m/s)	Flame length (m)
34	Strong	67	26,4	219,6	140
35	Strong	71	33,3	189,1	140

If these are compared to the results previously obtained (Du Plessis and Vassard, 1997), greater flame extension is observed. The major change in the design was that the barrier length was increased to accommodate a 2 m spacing between rows. The repeatability of the explosions and of barrier operation was good.

4.3.2 Classic distributed barrier

If the barrier start position is at 120 m, the minimum design requirement of the distributed barrier results in only two sub-barriers being positioned close enough to have any influence on flame propagation. They were therefore not evaluated at this distance per se.

Instead, it was decided to evaluate the classic distributed bagged stone dust barrier at the following design specification:

M_A = 60 kg/m^2
M_V = 0,6 kg/m^3.

The barrier design was seven rows of seven bags spaced 14 m apart (barrier length extending over 98 m distance). The stone dust concentration per unit area was calculated as shown in equation 3 and the stone dust concentration per unit volume (M_V) of the barrier was determined as follows:

$$M_V = \frac{stone\ dust\ mass}{Tunnel\ area\ x\ spacing\ distance} \qquad (4)$$

$$M_v = \frac{42\,kg}{68{,}74\,m^3}$$

$$= 0{,}61\,kg/m^3$$

where: M_v = mass per unit volume (kg/m^3)

The classic distributed barrier was evaluated at the following positions: 80, 100 and 120 m from the ignition source.

The results obtained for the tests in which the barrier start position was at 80 m are shown in Table 4.3.2a.

Table 4.3.2.a

Classic distributed barrier test results at 80 m

Expl. No.	Type of explosion	Static pressure (kPa)	Flame speed (m/s)	Flame length (m)
42	Standard	68	107	130
43	Standard	72	93	90
50	Standard	60	108	160
51	Standard	68	102	120
52	Weak	49	85	130
53	Weak	48	86	120
46	Strong	73	88	140
47	Strong	64	116	100

Note: Dynamic pressure sensor destroyed.

When the barrier was installed at 80 m, it proved effective for the following range of static pressures and flame speeds:

Static pressure : 48 to 73 kPa
Flame speed : 85 to 116 m/s

At the 80 m position, the classic distributed barrier effectively arrested the flame propagation of all the explosions against which it was evaluated.

At 100 m, 49 bags were suspended in seven rows (61 kg/m^2). The results obtained with the barrier starting at 100 m are shown in Table 4.3.2b.

Table 4.3.2b

Classic distributed barrier test results at 100 m

Expl. No.	Description	Static Pressure (kPa)	Flame speed (m/s)	Flame length (m)
54	Weak	51	50	100
55	Weak	45	42	120
56	Standard	65	70	130
57	Standard	78	140	140
60	Weak	56	69	130
62	Medium	59	71	130
63	Medium	51	56	100
66	Medium	44	68	130
65	Strong	56	158	150
67	Strong	56	126	140

Note: Dynamic pressure sensor destroyed.

At the 100 m, position the classic distributed barrier proved effective in all the tests. The maximum flame extension was observed in explosion 65 (150 m) but this was still well within the barrier. The range of explosion characteristics against which the barrier proved effective were:

Static pressure: 44 to 78 kPa
Flame speed at 100 m: 42 to 158 m/s

At 120 m, only 42 bags were suspended in six rows of seven bags. This resulted in a 51,4 kg/m^2 stone dust concentration although the mass per unit volume was kept constant at 0,61 kg/m^3.

Table 4.3.2c shows the results with the distributed barrier at 120 m.

Table 4.3.2.c

Classic distributed barrier test results at 120 m

Expl. No.	Description	Static Pressure (kPa)	Dynamic pressure (Kpa)	Flame speed (m/s)	Flame length (m)
74	Standard	66	28,4	144	> 200
75	Standard	69	33,1	151	> 200
72	Weak	45	14,9	122	140
73	Weak	48	14,7	99	150
70	Medium	49	24,4	72	170
71	Medium	63	F	66	130
68	Strong	66	F	179	> 200
69	Strong	66	F	149	> 200

With the barrier positioned at 120 m, it failed to inhibit flame propagation inside the tunnel against both the standard and strong explosions. In explosions 74 and 75, a reduction in flame speed was observed but the explosion propagated at an almost constant flame speed from 160 m, indicating insufficient inert material to arrest the explosion. Similar conclusions can be drawn for explosions 68 and 69.

4.4 Bags as a stone dust supplement

The use of stone dust bags as a stone dust supplement was initially tested and reported by Du Plessis and Vassard (1997). The principle of operation is based upon that used in the design of distributed barriers in which extended areas are protected by using lower stone dust concentrations. In all the tests, the start position of the suspended bags was where the first fuel zones ended (40 and 60 m respectively).

4.4.1 Fuel zone 40 m

Single bags of 6 kg were suspended in the following arrangements:

1) 40 bags of 6 kg spaced 4 m apart
2) 60 bags of 6 kg spaced 2,5 m apart

3) 80 bags of 6 kg spaced 2 m apart.

These arrangements resulted in the stone dust concentrations as shown in Table 4.4.1.a.

Table 4.4.1a

Stone dust concentrations

Description	M_A (kg/m^2)	M_V (kg/m^3)
40 bags	48,9	0,31
60 bags	73,3	0,49
80 bags	97,8	0,61

The results obtained for the different arrangements evaluated against the supplement stone dust explosion are shown in Table 4.4.1b.The flame speed shown was determined at 40 m and is the average speed between instrument stations 4 and 6 inside the test tunnel.

Table 4.4.1b

40 m Fuel zone test results

Expl No	Description	Static pressure (kPa)	Dynamic pressure (kPa)	Flame speed (m/s)	Flame length (m)
78	40 bags	83	38,4	141	200
95	40 bags	52	37,6	131	140
102	40 bags	49	14,8	132	140
83	60 bags	67	25,1	137	140
84	60 bags	68	30,4	164	140
85	60 bags	69	F	218	180
79	80 bags	71	26,7	160	140
80	80 bags	53	35,9	148	140
96	80 bags	58	33,0	162	130

The different stone dust bag arrangements proved effective for the following explosion conditions:

Static pressure:	49 to 71 kPa
Dynamic pressure:	14,8 to 38,4 kPa
Flame speed:	131 to 218 m/s

Whether either 40 or 60 stone dust bags were installed there was basically no difference in the flame length of the explosion. Even when the number of bags was increased to 80, the flame still reached 130 to 140 m inside the tunnel (± 100 m from the start position of the barrier). This is illustrated in Figure 4.4.1a, test 95 (40 bags) and Figure 4.4.1b, test 96 (80 bags).

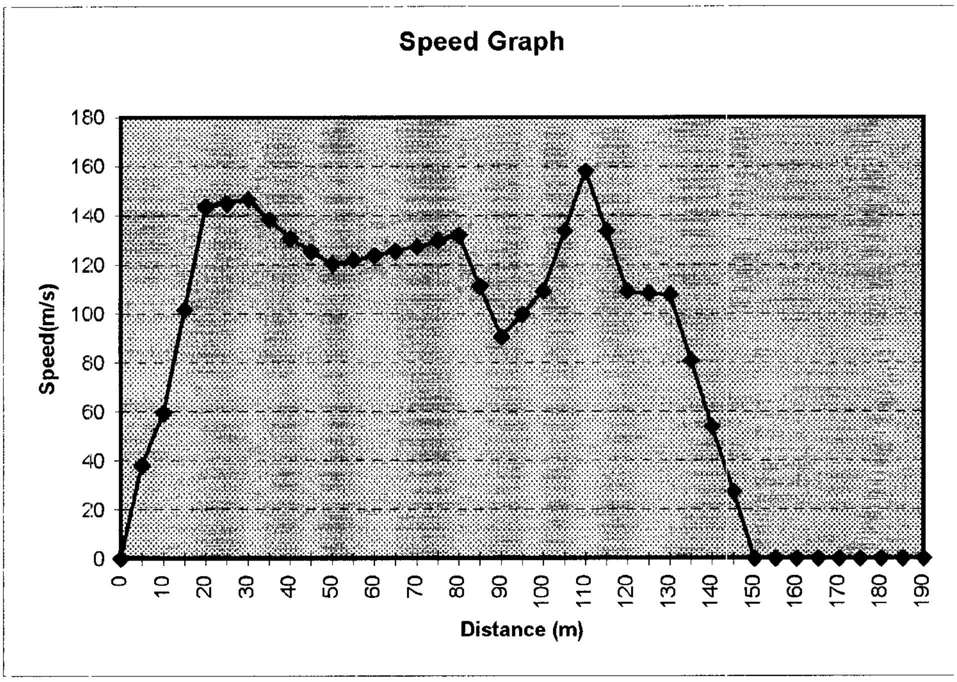


Figure 4.4.1a: Test 95: 40 bags

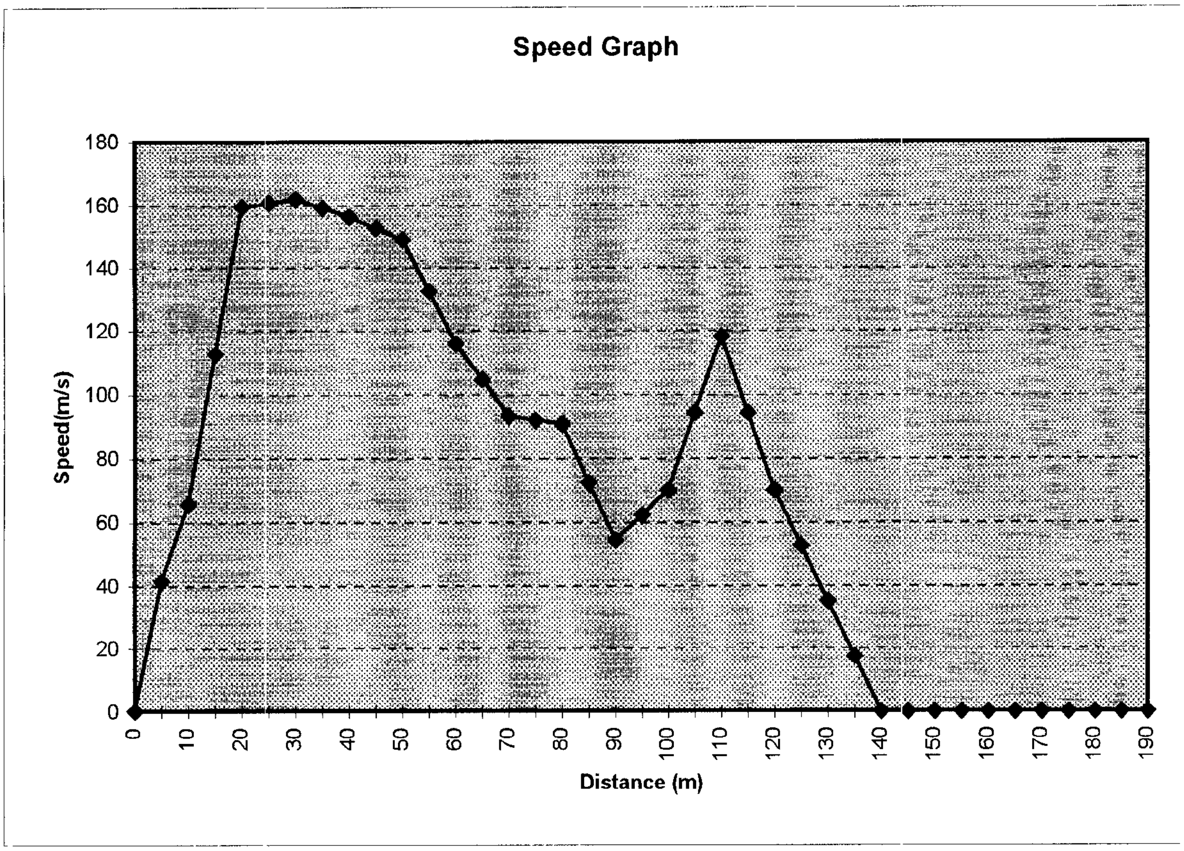


Figure 4.4.1b: Test 96: 80 bags

4.4.2 Fuel zone 60 m

In the tests in which a 60 m fuel zone was used as the first fuel zone, the number of 6 kg bags used varied from 30 to 60.

The spacing of the individual bags is given below:

- 30 bags: spaced 4 m apart
- 40 bags: spaced 2,5 m apart
- 60 bags: spaced 2 m apart

The stone dust concentrations for the individual arrangements are shown in Table 4.4.2a.

Table 4.4.2a

Stone dust concentrations

Description	M_A (kg/m^2)	M_V (kg/m^3)
30 bags	36,7	0,31
40 bags	49,0	0,49
60 bags	73,5	0,61

The results obtained for the supplement stone dust explosion are shown in Table 4.4.2b. The flame speed was calculated at 60 m and is the average between instrument stations 6 and 8.

Table 4.4.2b

60 m Fuel zone test results

Expl. No.	Description	Static pressure (kPa)	Dynamic pressure (kPa)	Flame speed (m/s)	Flame length (m)
87	30 bags	70	30,9	119	+ 200
105	40 bags	60	28,1	134	140
106	40 bags	53	25,4	142	150
86	60 bags	63	F	129	140
103	60 bags	57	25,4	138	150
104	60 bags	59	38,2	137	150

When 30 bags were installed (one every 4 m) the flame propagated throughout the gallery, as illustrated by explosion 87. When the number of bags was increased to 40 and 60 bags respectively, the propagation of the explosion was stopped. This is illustrated in Figure 4.4.2, explosion 86.

No measurable difference between these tests and the tests with the 40 m fuel zone was observed. This indicates that the use of stone dust bags as a supplement should be effective at a distance of 60 m from the ignition source if they are suspended in such a manner as to ensure M_A of 50 kg/m^2 and an M_V of 0,5 kg/m^3.

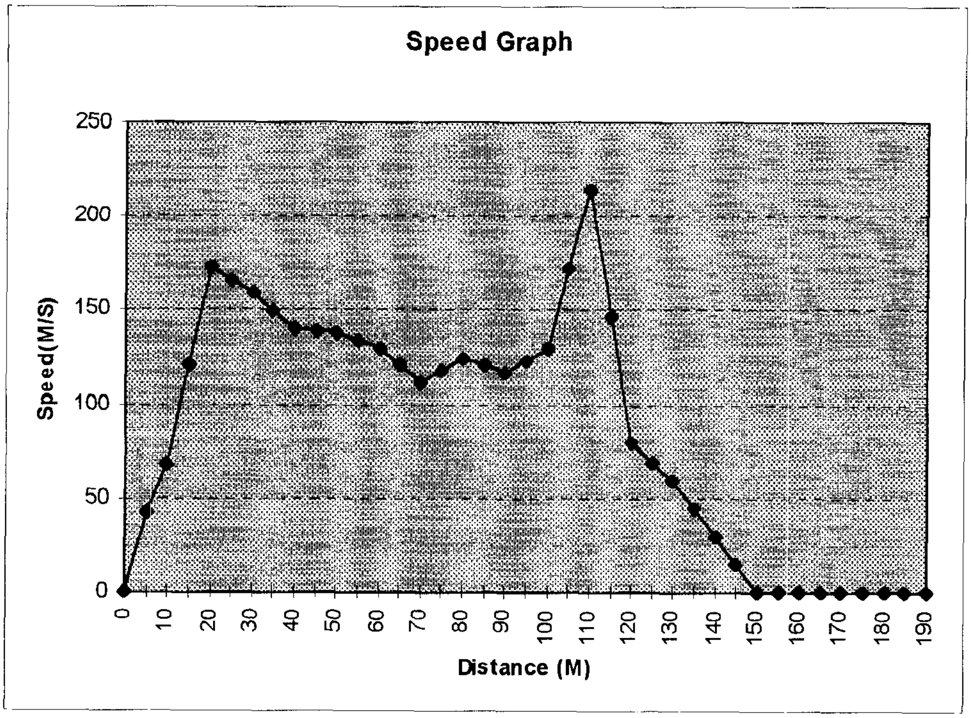


Figure 4.4.2: Explosion 86: 60 bags

5 User guidelines

5.1 Basic barrier requirements

The following requirements as set out in the Guideline for the Compilation of a Mandatory Code of Practice for the Prevention of Coal Dust Explosions in Underground Coal Mines (1997) on the construction of a bagged stone dust barrier apply:

The horizontal distance between the hooks of the bags on a plane must be not less than 0,4 m and not greater than 1,0 m when measured across the roadway width.

The actual distances are determined by the total mass of stone dust that needs to be incorporated into a barrier, which is itself determined by the roadway dimensions. To cover a range of workings heights, the following requirements apply:

- For roads in the height range of less than 3,0 m, each row must have a single level of bags suspended below the roof.

- For roads in the height range 3,0 m to 3,5 m, each row must have a single level of bags suspended not more than 0,5 m below the roof.

- For roads in the height range 3,5 m to 4,5 m, each row must have two levels of bags suspended at approximately 3,0 m and 4,0 m above floor level.

- For roads in the height range of more than 4,5 m but less than 6,0 m, each row must have three levels of bags suspended at approximately 3,0 m, 4,0 m and 5,0 m above floor level.

- The distance between the bags and the side of the pillar must be < 0,5 m.

Since no test data are available for roadways greater than 6 m in height, any Code of Practice covering such a roadway should be developed in consultation with the Chief Inspector.

The distance measured along the roadway between rows of bags within the barrier must be not less than 1,5 m and not more than 3,0 m.

The total mass of stone dust to be used in a bagged stone dust barrier is based on either the cross-sectional area of the roadway in which the barrier is to be installed, or on the total excavated volume of the road between the extremities of the full barrier.

If M_A is the mass of stone dust based on cross-sectional area and M_V is the mass based on volume, the M_A must be at least 100 kg/m^2 of the cross-sectional area and the M_V must be at least 1 kg of stone dust per cubic metre of roadway volume between the barrier extremities.

The minimum requirements with regard to the classic distributed stone dust barrier and the stone dust supplement are shown in Sections 5.2 and 5.3 respectively.

The total mass of stone dust to be used in a barrier must be based on the greater of M_A and M_V.

To ensure effectiveness, the basic requirements as set out in the Guideline, together with the requirements as set out below, should be adhered to.

5.2 Classic distributed bagged stone dust barrier

As a minimum requirement, the following barrier design criteria must be adhered to:

- The minimum barrier length must exceed the distance required to ensure the minimum stone dust requirement
- M_A must be greater than 60 kg/m^2
- M_V must be greater than 0,6 kg/m^3 .

5.3 Stone dust bags used as a supplement

The minimum user requirements cannot be stipulated per se. Each application should therefore be treated on merit and designed to the minimum requirements for that application. In this design it is assumed that an explosion is in progress and the supplementary stone dust must ensure a greater % TIC than the minimum requirement as stipulated in the DME Guideline.

As a minimum requirement, the following barrier design criteria must be adhered to:

- The minimum barrier length (stone dust bag installation length) must exceed the distance required to ensure the minimum stone dust requirement
- M_A must be greater than 50 kg/m^2
- M_V must be greater than 0,5 kg/m^3.

6 Conclusions

The results presented in this report should be interpreted in the context of the experimental set-up and procedure described using a round gallery of 2,5 m diameter. This report summarises the operation of different barrier designs against different explosions.

The altemative user requirements were combined into three major areas of evaluation as follows:

- Placement of barrier
- Evaluation of classic distributed barrier
- Evaluation of stone dust bags as a stone dust supplement.

The main conclusions drawn from the test results can be summarised as follows:

- ➢ The concentrated and distributed barriers should not be placed further than 120 m from the LTR in bord-and-pillar workings or from the face in the case of longwall mining.

- ➢ At 120 m, the minimum design requirements for the bagged stone dust barriers are:
  (i) concentrated barrier – 100 kg/m^2 (mass per unit area)
  (ii) distributed barrier – 1 kg/m^3 (mass per unit volume).
  It is the authors' opinion that a reduction in the above requirements cannot be warranted from the research results.

- ➢ The classic distributed barrier, positioned at 120 m and designed to 51,4 kg/m^2, failed to inhibit flame propagation inside the 200-m test gallery when evaluated against the standard and strong explosions.

- ➢ The performance of the classic distributed barrier in the surface test was such that its use can be recommended.

- ➢ As a minimum requirement the following design criteria, for the classic distributed stone dust barrier, must be adhered to:

- Minimum barrier length must exceed the distance required to ensure the minimum stone dust requirement
- M_A must be greater than 60 kg/m^2
- M_V must be greater than 0,6 kg/m^3

- ➢ When used as a stone dust supplement, in the context of the tests, the bags inhibited flame propagation in simulated worst-case scenarios. They successfully inhibited flame propagation for both 40 and 60-m pure coal-dust zones.
- ➢ As a minimum requirement the following design criteria, for the stone dust supplement,

must be adhered to:

- The minimum barrier length must exceed the distance required to ensure the minimum stone dust requirement
- M_A must be greater than 50 kg/m^2
- M_V must be greater than 0,5 kg/m^3.

7 Recommendations

- The current standards, as described in the Guideline for the compilation of a Mandatory Code of Practice,(1997) should be adhered to for both the concentrated and distributed barriers.

- The use of a classic or continuous distributed barrier should be included in the Guideline for the Compilation of a Mandatory Code of Practice adhering to the minimum requirements as set out in section 5.2.

- The use of stone dust bags as a supplement can be recommended and included in the Guideline for the Compilation of a Mandatory Code of Practice adhering to the minimum requirements as set out in section 5.3.

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Appendix A

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