PARACHUTE STOPPINGS FOR RAPID VENTILATION CONTROL

By

Paul F. Howlett1 and Mark Buizen2

ABSTRACT

The results of calibration trials conducted on parachute stoppers under a recently completed NERDDC grant are presented. Applications of parachute stoppers, for rapid regulation and control of ventilation networks are described including use in mine recoveries, sealing sections and rescue work.

Parachute stoppers are one of a series of non-rigid ventilation control structures specifically designed for quick installation in emergency situations, for use in high production/rapid advance areas and areas suffering roof-floor convergence.

INTRODUCTION

In 1984 Earth Resources (R & D) Pty. Limited were commissioned to undertake a review of stopping practice in Australia and overseas. The review, spanning 18 months, uncovered a number of new stopping techniques which had not been investigated in Australia. One of these was parachute stoppers.

Parachutes offered rapid, effective, low manpower deployment capabilities for controlling ventilation networks. In 1987 a NERDDC grant was awarded for a project to manufacture, trial and demonstrate the applications of parachute stoppers to the industry.

The project commenced with a series of three underground trials of parachute stoppers at Liddell Colliery and Liddell State Mine. Parachute installation procedure was examined and the sealing qualities in different mining environments was determined. Two parachute stopping configurations were trialed, one traditional hemispherical shape, and another with an airflow regulating device located in the centre of the parachute.

1. Principal Consultant,
   Earth Resources (R & D) Pty. Limited

2. Mining Engineer,
   Earth Resources (R & D) Pty. Limited

Following the initial underground trials the parachutes were calibrated under controlled conditions in an underground mine simulator.

Demonstrations were then held in the mine simulator to approximately 50 industry personnel.

Parachute stoppers are one of a series of non-rigid ventilation control structures currently being investigated. Other structures include: semi-rigid permanent stoppers, flexible overcasts, inflatable seals, sacrificial failure systems, flexible full section explosion barriers, and other reusable, low maintenance, easily transportable, rapid erection stopping systems.

BACKGROUND

In 1984 Coal & Allied Operations Pty. Limited commissioned Earth Resources (R & D) Pty. Limited to undertake a review of underground coal mine stoppings practices and research activities in Australia and overseas. The review was designed to be a desk top study and literature search to identify developmental trends and potential cost and/or efficiency savings that may be implemented in Coal & Allied mines.

Major research institutions and computer database were consulted and a substantial collection of documents and literature was collated, reviewed and reported upon. One major area of prior US and South African research that had not been investigated in Australia, was that of parachutes for rapid alterations to airflow networks.

The parachute stopping concept was first used in America by the US Bureau of Mines. They experimented with a number of parachute designs from the most simple, to other designs developed by aerospace engineers, which appeared too complex to be practical for everyday use in an Australian underground mine. One design termed the "Quick-fix Blowout Stopping" uses velcro straps to secure the stopping in place. This design is useful for overcoming the problem of airblasts associated with shot firing and coal...
falls. The Quick-fix stopping is knocked down by the airblast but the velcro straps allow it to be re-attached in a matter of seconds. The USBM experimented in laboratories with half scale model parachutes and with full scale models in underground mines. Several companies in America now manufacture parachute stoppings.

The review of products in Australia identified that parachute stoppings were being manufactured by ACM Canvas Pty. Limited, of Perth, for some major base metals mines – but no coal mine related work had been attempted in Australia.

Parachutes appeared to offer several advantages over traditional stoppages systems – primarily associated with the speed of erection. Stoppages could be effective within seconds or minutes and installed by only one or two personnel. This rapid, low manpower deployment capability also appeared to have benefits in the case of sealing off areas where multiple stoppages must often be deployed simultaneously to control ventilation and minimize secondary explosion potential. In addition parachutes appeared to offer the facility to temporarily stop air flow whilst a more permanent structure is installed.

In short, parachutes appeared to be a device that the Australian underground coal mining industry should investigate.

In 1987 a NRMA/DC grant was sought, and awarded, in the SPECIAL ROUND: COAL MINE SAFETY, for a 6 month project to manufacture, trial and demonstrate to the industry the potential applications of parachute stoppings. This project was orientated towards mine safety, recovery and rescue operations and much of the underground work was performed in conjunction with personnel from the Hunter Valley Mines Rescue Station. The project was completed in March 1988 and the report is available from NRMA/DC at the Department of Primary Industries and Energy.

---

**Fig. 1 - EMERGENCY PARACHUTE STOPPING**

**Fig. 2 - PARACHUTE STOPPING WITH REGULATOR**

**TRIALS**

Experimental work was undertaken in two phases, namely initial underground trials and subsequent detailed calibration in the Newcastle Mines Rescue Station Gallery. The initial trials were conducted at Liddell Colliery and Liddell State Mine. They helped familiarize personnel with the parachute stopping concept, determined the best methods for launching and sealing and highlighted suitability and likely problems of use in a mining environment. The experimental work at the Rescue Station Gallery was necessary to determine the minimum and maximum ventilating conditions in which deployment is practical, calculate the stopping efficiency and the degree of air flow regulation possible under controlled conditions.

Various parachute configurations were tested including parachutes with regulators which controlled air flow rather than simply blocking it off. Key factors which were tested and documented include:

- minimum pressure and velocity of air flow for launching and maintaining seals;
- effectiveness of seals;
- methods of launching and anchoring;
- degree of flow regulation possible;
- degree of personnel access through or around parachute;
- speed of deployment;
- costs associated with purchase and use;
- the ability to advance the parachute along a roadway in front of a rescue team to gain access through a smoke filled roadway.

The trials at Liddell Colliery were conducted in a development panel and in a main return airway – with each place providing markedly contrasting ventilation conditions. In the development panel it was quickly discovered that it is not the air flow which maintains the parachute fully deployed, but the continuation of a pressure differential across the parachute.
Paul F. Howlett and Mark Buizen

...after deployment. In the twin intake development end, air stopped by the parachute was quickly diverted through a nearby cut-through. Being close to the return, it was not possible to maintain sufficient pressure across the parachute, so the parachute deflated, as no auxiliary support had been used to pin the parachute to the walls, floor or roof. To work satisfactorily in such a location a number of options are possible including:

- stopping both intake roadways,
- stopping one intake roadway and several cut-throughs back-bye from the parachute,
- fixing the parachute to the roof, walls and floor with nails, pogo sticks etc.

In the main return airway the results were very spectacular and highly successful. A location out-bye of a set of double doors was selected where the pressure across the doors was of the order of 40m water gauge. The parachute was launched very rapidly on the air leakage through the doors and when the doors were opened, the net leakage across the parachute was substantially less than that across the double doors.

**TABLE 1**

**LIDDELL COLLIERY**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>2 East twin intake.</th>
<th>SECTION</th>
<th>5.05 x 2.12 = 10.7 m²</th>
<th>INITIAL VELOCITY</th>
<th>0.54 m/s</th>
<th>INITIAL QUANTITY</th>
<th>5.78 m³/s</th>
<th>SETTING TIME</th>
<th>6 minutes</th>
<th>PRESSURE DIFFERENTIAL</th>
<th>0 Pa</th>
<th>LEAKAGE RATES</th>
<th>0.10 m³/s 0.70 m³³/s</th>
<th>COMMENT</th>
<th>Parachute inflated on leakage through double doors.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Main Return</th>
<th>SECTION</th>
<th>3.80 x 1.65 = 7.0 m²</th>
<th>INITIAL VELOCITY</th>
<th>0.20 m/s</th>
<th>INITIAL QUANTITY</th>
<th>1.41 m³/s</th>
<th>SETTING TIME</th>
<th>5 minutes</th>
<th>PRESSURE DIFFERENTIAL</th>
<th>420 Pa</th>
<th>LEAKAGE RATES</th>
<th>0.01 m³/s 0.70 m³³/s</th>
<th>COMMENT</th>
<th>Parachute inflated on leakage through double doors.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Main Return</th>
<th>SECTION</th>
<th>3.80 x 1.65 = 7.0 m²</th>
<th>INITIAL VELOCITY</th>
<th>1.00 m/s</th>
<th>INITIAL QUANTITY</th>
<th>13.4 m³/s</th>
<th>SETTING TIME</th>
<th>2 minutes</th>
<th>PRESSURE DIFFERENTIAL</th>
<th>436 Pa</th>
<th>LEAKAGE RATES</th>
<th>0.04 m³/s 0.28 m³³/s</th>
<th>COMMENT</th>
<th>Quick setting with both double doors open.</th>
</tr>
</thead>
</table>

**TABLE 2**

**LIDDELL STATE MINE**

| LOCATION | No. 2 Heading | SECTION | 5.4 x 2.7 = 14.5 m² | INITIAL VELOCITY | 1.20 m/s | INITIAL QUANTITY | 17.5 m³/s | SETTING TIME | 8 minutes | LEAKAGE RATES | 0.08 m³/s 1.17 m³³/s | COMMENT | Trial area containing props and pipe. |
|----------|---------------|---------|---------------------|------------------|-----------|-----------------|-----------|-------------|-----------|-----------------|-----|--------------|-----------------|---------|--------------------------------------------------|

| LOCATION | No. 5 Heading | SECTION | 5.4 x 2.7 = 14.5 m² | INITIAL VELOCITY | 1.20 m/s | INITIAL QUANTITY | 17.5 m³/s | SETTING TIME | 2 minutes | LEAKAGE RATES | 0.34 m³/s 5.10 m³³/s | COMMENT | Trial with parachute regulator half open. |
|----------|---------------|---------|---------------------|------------------|-----------|-----------------|-----------|-------------|-----------|-----------------|-----|--------------|-----------------|---------|--------------------------------------------------|

| LOCATION | Main Gate D | SECTION | 5.5 x 2.9 = 15.9 m² | INITIAL VELOCITY | 0.42 m/s | INITIAL QUANTITY | 6.70 m³/s | SETTING TIME | 4 minutes | LEAKAGE RATES | 0.08 m³/s 1.20 m³³/s | COMMENT | No attempt to improve initial seal. |
|----------|-------------|---------|---------------------|------------------|-----------|-----------------|-----------|-------------|-----------|-----------------|-----|--------------|-----------------|---------|--------------------------------------------------|

**PARACHUTE SECURING AND ACCESS**

Ropes, or shrouds, attached to the edge of a parachute provide the means to anchor the stopping in place. These ropes can be tied to a central roof bolt, mine vehicle, central prop or other solid object to provide a quick seal. A better seal is obtained by tying each rope separately to any available structure such as props, baulks or roof bolts and keep the ropes as close and as near parallel as possible to the roadway perimeter. Once tied off, the parachute is lifted to catch the airflow, where it inflates to fill the roadway. In areas where the pressure differential is too low to support a parachute, or where a more permanent seal is required, the edge of the parachute may be nailed to the roof and rib.

Parachutes which incorporate a regulator allowed the easiest access for personnel from one side of the stopping to the other. The draw string cord of the regulator may be untied to allow easy passage through the centre of the stopping. The parachute is released by tying off the cord. Personnel access past conventional parachutes, without regulators, could be obtained by pulling the brattice way from the rib and walking around, or the stopping could be deflated for access of men and materials, and reinstalled by lifting the parachute edge and inflating the parachute from either side.

The AusIMM Illawarra Branch, 21st Century Higher Production Coal Mining Systems—Their Implications, Wollongong, NSW, April 1988

291.
Comparisons Between Stoppings

During the trials regular comparisons were discussed between parachutes and conventional brattice stoppings. Some of the relative advantages of parachutes are listed below:

- The parachute is rapidly deployed and initially held in place by the air pressure and restraining ropes, allowing miners to secure the stopping to surrounding strata, if necessary;
- The parachute can be deployed and secured by one miner;
- The parachute design and site is such that ample surplus fabric is available around the roadway perimeter for the material to be forced into the roughness of the strata effecting a superior seal;
- The parachutes can readily incorporate flow control regulators to reduce the violence of erection in high pressure areas and/or to subsequently control air flow through the stopping;
- The parachute profile, and sealing through surplus material, means personnel access past the stopping is easy and resleeving is automatic;
- The parachute is a complete self contained stopping system and can be readily transported underground by one person;
- The parachute can be reused many times in various locations around the mine.

Performance of Parachutes

Following the mine trials a series of calibration trials were completed in the underground mine simulator of the Newcastle Mines Rescue Station. Controlled experiments were conducted to determine operating characteristics and performance criteria under varying ventilation pressures and velocities. Results of these calibration trials are included in the NEEDAC report.

To simulate leakage conditions for a real mine, the parachute stoppings were calibrated in an area of the mine simulator which contained props, a hanging cable, air and water pipes and with the roof, floor and walls of the passage having a roughness of approximately 50% of an underground coal mine roadway. Each parachute stopping was installed in under five minutes and used no auxiliary support mechanisms such as nails or props to support the fabric. The shrouds from the parachute were tied back to any available structure such as roof bolts, props or cables.

Results from the calibration tests indicate a minimum practical pressure differential of 2m water gauge is required to keep an unsupported parachute inflated. If auxiliary support is used there is no minimum operating pressure. The maximum pressure differential tested was over 50m water gauge.
DEMONSTRATIONS TO INDUSTRY

The demonstrations of the parachute stoppings, held directly after the completion of the calibration tests, were attended by approximately 80 industry personnel. Four of the most adverse locations in the underground mine simulator at the Newcastle Mines Rescue Station were chosen as sites for the demonstrations.

Sites with props, baulks, roof bolts, cables, pipes, bricks, obstructions, water and rubble were chosen to simulate the worst conditions underground.

The demonstrations included:
- sealing a main roadway from a vehicle during an emergency in less than 60 seconds.
- sealing procedure for a parachute stopping in adverse conditions.
- sealing twain intake roadways simultaneously.
- operation of parachute stoppings as mine regulators.

Each demonstration was completed by two men in under five minutes.

A video was prepared to demonstrate the use of parachute stoppings to other industry personnel who were unable to attend the demonstrations. A copy of this video was incorporated in the final report to MEGHIC.

APPLICATIONS

In a high production environment the ability to rapidly and economically alter and regulate the local ventilation circuit is not only highly desirable but essential to maintain production. In development panels a quick, simple and effective temporary stopping can help ensure adequate face ventilation. Parachute stoppings are easily handled and transported, can be erected in under five minutes by one or two personnel and can reduce the labour requirements of a development crew. In a production panel a method to instantly replace failed stoppings and to isolate or regulate parts of the ventilation circuit is required to allow uninterrupted production at the face. Parachute stoppings provide the means to achieve such rapid changes and regulation to air circuits simply and efficiently.

There are several circumstances that may arise in an underground coal mine where rapid changes to the mine ventilation circuit can avert serious disaster and loss of life. Events such as gas outbursts, equipment fires, spontaneous combustion and falls of ground can create a situation where fresh air is denied to underground personnel and/or noxious gases are migrating towards underground personnel. Under such circumstances it is essential to re-route supplies of fresh air towards personnel and to divert noxious gases away from personnel and escape routes, in a rapid and efficient manner.

In areas which suffer from a high degree of roof sag or floor heave, the parachute stopping offers a means to maintain seal integrity as it relies on no rigid support mechanism which are prone to failure during convergence. Parachute stoppings also have an application in mine reclamation. Where a mine, or an area of a mine, has been left abandoned for any length of time and its ventilation circuit needs to be re-established, a series of parachute stoppings may be installed off the main intake roadway to quickly advance into an area and recirculate fresh air. The parachutes can later be removed if more permanent stoppings are required.

OTHER FLEXIBLE VENTILATION STRUCTURES

The technology review of ventilation stoppings practice for Coal & Allied identified a number of other issues, besides parachutes, which warranted further investigation. The primary factor raised was that of stopping failure mechanisms with consequent maintenance costs and reduced operating efficiencies. Failures of stoppings were recorded mainly through:
Conduction

Parachute stoppages have been identified as providing the means to achieve rapid changes and regulation in ventilation circuits simply and efficiently. Results from a recently completed NERD&DAC project highlight the speed and efficiency of parachute stoppages for emergency and daily ventilation control.

Parachute stoppages are the first of a series of non-rigid ventilation structures being researched to provide ventilation control in adverse mining conditions.

Acknowledgments

The authors would like to acknowledge the financial assistance received from NERD&DAC, Dept. of Primary Industries and Energy towards this work.

Acknowledgment is made of the prior research work completed by the USEM into parachute stoppages and prior trials with parachutes in base metal mines in Australia.

The authors would like to thank Dr. B. White, Superintendent Planning and Development, Coal & Allied Operations Pty. Limited, Mr. A. C. Eagleton, ACE Minerals Pty. Limited, Mr. H. Bird and staff, Hunter Valley Mines Rescue and Mr. J. Shoebridge and staff, Newcastle Mines Rescue for their encouragement and personal contributions to the project.

References


