Safety and health in mines research advisory board Annual review 2013

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Introduction

The Safety and Health in Mines Research Advisory Board (SHMRAB) is one of the Health and Safety Executive's (HSE) advisory bodies. It is chaired by Her Majesty's Inspector of Mines and has members representing employers and employees in the British mining industry. Current members and others who contributed during 2013, are listed in Appendix 1[9]

Contact details for more information on the research houses and individual projects mentioned in this review can be found in Appendix 2[10].

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Fire and explosion

Minimising risk for and reducing impact of fire and explosion hazards in underground coal mines [Minfirex]
MINFIREX commenced in July 2010 and the project partners included Mines Rescue Service Ltd and UK Coal; this project was completed June 2013. It is aimed at developing strategies to prevent fires and explosions by developing innovative detection and fire fighting methods, especially for hidden fires.

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Mine environment

Development of novel technologies for predicting and combating gas outbursts and uncontrolled gas emissions in thick seam coal mining [CoGasOut]

CoGasOut commenced in July 2010 and was completed in July 2013. The objective of this project was to develop and test novel technologies for the prediction and combating of gas outbursts and uncontrollable gas emissions in coal mines which operate in thick and/or steeply dipping thick seams, primarily in Slovenia and Spain.

Low Carbon Mine Site Energy Initiatives [Lowcarb].

Lowcarb commenced in July 2010 and was completed in July 2013. The project was designed to investigate and develop modern technologies and techniques that could significantly reduce the coal mining industry's carbon footprint in terms of both emissions (CO_2, CH_4) and operational energy consumption (CO_2) whilst remaining technically and commercially competitive. Partners were Mines Rescue Service Limited and Camborne School of Mines.

Advanced tools for ventilation and methane emissions control (AVENTO)

Project partners: AITEMIN (Spain – Project co-ordinators), DMT (Germany), EMAG (Poland), GIG (Poland), Hunosa (Spain), ROMANIAN MINE SAFETY EXECUTIVE, KHWSA (Poland), University of Nottingham

The AVENTO project aims to develop advanced tools for the improved control of ventilation networks in underground coal mines for improved safety at working areas through a better control of methane emissions and climatic conditions and through the optimization of the ventilation air flow which will reduce energy and maintenance costs.

Planned work covers all aspects of the problem, including the development of new concepts in monitoring and control systems, advanced methods for the dynamic regulation of air flow as a function of actual needs, modelling activities, hardware and software development; and important experimental work in underground mines and testing facilities.

The University of Nottingham is concerned with developing computational models of the airflows within single entry drivages for when the auxiliary ventilation is either deliberately or accidentally turned off. Using a combination of 3D Computational Fluid Dynamics (CFD) modelling and 1D mine ventilation models, the gas is tracked through the drivage and then mine. A number of different auxiliary ventilation approaches are being assessed to see which results in the safest degassing strategy. Actual data from HUNOSA in Spain is being used to validate the models. The aim is to integrate the predictive tools with the mine control systems to allow real-time management of outbursts and ventilation failures.

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Ground control

COmplex Mining Exploitation: optimizing mine design and reducing the impact on the human environment (COMEX)

Project partners: INERIS (France – Project co-ordinators), GAUK, University of Nottingham (UoN), CERTH (Greece), GIG (Poland), GEOCONTROL (Spain), DMT(Germany), UK Coal.

The work of UoN focuses on modelling of the vulnerability of buildings to mining-induced subsidence. The team has identified a group of specific building types which are typical of buildings found within coal mining areas and which are vulnerable to damage from mining induced ground settlements.

The modelling work involves physical modelling using the Nottingham Centre for Geomechanics 2.0m radius geotechnical centrifuge. Centrifuge modelling allows replication of highly complex and non-linear soil-structure interactions within small-scale and economically feasible experiments. The physical modelling work includes:

- development of methods to model the shape and magnitude of mining induced ground settlements,
- fabrication of small-scale models that realistically replicate full-scale prototype building behaviour,
- evaluation of the magnitude and mechanism of transmission of strains from the ground to the buildings,
- assessment of the degree of damage to prototype buildings based on the response of the model buildings.
- assessment of the effects of mitigation techniques to reduce building damage

UoN has also begun conducting numerical modelling of mining subsidence above longwall workings using FLAC-3D in order to replicate measured subsidence events. The constitutive models adopted during this work will then be applied to the modelling of subsidence-building interactions. The physical model results will aid the validation and calibration of the numerical models. The numerical modelling allows for a more efficient means of testing a wider range of scenarios and material parameters than full-scale or model-scale experiments. As a result, the numerical models are being used to study the full group of building types identified as well as the sensitivity of results to the variation of key material parameters.

Golder Associates and UK Coal Production Ltd. are working closely together to review and progress understanding and mine layout design where seams are exploited above previously worked longwalls. The work continues that of a previous RFCS project, PRESIDENCE, and aims to review guidelines with respect to layout design and support practice in the more geotechnically challenging ground conditions encountered as a result of working within fractured and disturbed ground above previously worked longwall faces.

At Target Mine 1 the Deep Soft Seam longwall gate roadways are being driven in and around subsidence troughs created by previous undermining by longwalls in the Parkgate Seam some 35-40 m below. They are also affected by much earlier overworking in the Top Hard some 120 m above. A combination of the Guidelines developed under the previous PRESIDENCE project, careful examination of the complex mining history, results from numerical modelling and experience gained from driving a gate road directly above an underlying pillar/goaf edge, resulted in the latest 5 year plan layout and working sequence for the area to minimise interaction effects.

Four panels were shortened so that the face installation roadways were positioned a minimum distance of 30 m over Parkgate waste, (distressed ground and more favourable than over higher stressed pillar areas), and two panels were moved Eastwards so that their Supply Gates were positioned over Parkgate panel roadways below. The preliminary results show that the benefit of working over waste can still be beneficial even when the overlying roads are driven close to and even above roadways in the previously worked seam below. This indicates that for some sites the previous guidelines may be too conservative. Further monitoring data is being collected to support this.

Numerical modelling provides a powerful tool to assist with layout and support design and the project also seeks to improve modelling methodology as part of the process and the PRESIDENCE Guidelines mentioned above. One of the problems is that the existing method for prediction of stress distributions around subsided longwall panels does not always give results borne out by experience because of suitable representation of caved waste material. FLAC 2D has been used to complement MAP3D stress distributions and although has some promise it is still has limitations. As part of the work UDEC is now being considered.

At Target Mine 2 the fourth and fifth longwalls of a series of five in the Beeston Seam are being developed. These are to be over worked by panels 60m above in the Silkstone Seam. Optimising of the Beeston Seam panels as a result of faulting is leading to re-consideration of the layout of the Silkstone panels above. It is anticipated that experience from Target Mine 1 and potentially improved numerical modelling methodologies will be able to assist with optimum mine layout and support.

Geomechanics and Control of Soft Mine Floors and Sides [GEOSOFT] July 2010 to June 2013

Golder Associates (UK) Ltd as Co-Ordinator The European Partners are; UK Coal Mining Ltd., UK, Geocontrol SA, Spain, Central Mining Institute, GIG, Poland, Becker Warkop SP z o.o. Poland, Poludniowy Koncern Weglowy S.A. Poland, University of Nottingham, UK

This Project concentrates on geotechnical problems associated with soft floors and sides. The Polish partners' research concentrated on powered supports working on soft floors. The Spanish partner worked on the application and modelling of shotcrete performance for different closed support tunnel profiles. The UK Partners' activities were centred on improved control of floor and sides in longwall gate roads.

Improved instrumentation for quantifying soft ground behaviour and associated support systems was investigated. A practical and reliable means of determining rockbolt integrity and the location of bolt failure from the rib side or roof formed a major part of the instrumentation research. Radio Frequency, RF, ultrasonic, Time Domain Reflectrometry, TDR, and Acoustic methods were examined. RF remains site specific and ultrasonics limited by bolt end preparation. The feasibility of the Acoustic method was demonstrated. TDR was not effective for pre-installed bolts but proved to be a method for determining integrity and bolt failure location for pre-instrumented bolts, (subject to minor modifications to the system).

Improved materials for rib and floor control were investigated. An improved cuttable rockbolt was sought but no bolt worthy of field trail was identified. Efforts were made to develop a cuttable plastic rockbolt but excessive elongation, poor bond strength post elongation and cost meant it was not pursued past the laboratory stage.

Laboratory short encapsulation pull testing was undertaken comparing the standard biaxial test and the split cylinder test.

This has lead to an improved understanding of rotational failure of tendons in the laboratory and the potential benefits of the large split cylinder test for low confinement applications. This test is suited for comparison of axial reinforcement properties of coal mine rib tendons and should be considered for incorporation into a Standard for rib reinforcement consumables.

Testing of Australian and UK long tendon systems did not identify any products with improved properties over those already established in the UK. Consumables improvements were made with respect to the plastic rib mesh, (more reliable strength), polyurethane resin injection installation, (pressurised placement for immediate rib consolidation), a new injection product, (Geofoam), and rib webbing/strapping, (improved anchorage techniques). An up to date review indicates that there are still difficulties with respect to drilling and installing suitably bonded rockbolts into roadway floors to control movement. A trial was undertaken to investigate the use of polyurethane resin, PUR, injection for floor consolidation. The trials were successful for very site specific cases, gate ends and facelines in order to aid the stability of powered supports.

Stress distribution modelling using MAP3D forms an essential tool to determine areas of elevated stress from current and previous workings. Rib and floor movement are directly related to vertical stress levels so planning panel layout to avoid higher vertical stress should always be considered first. Through numerical exercises for cases where modelled stress had caused inaccuracies compared to measured results, a greater appreciation of stress transfer mechanics in laminated strata and the effect of goaf consolidation was gained. However no modelling packages more suitable than Map3D were identified under Geosoft. FLAC modelling can be used to determine suitable support patterns and this was undertaken for various sites.

Successful simulation of ribbing off and floor dinting was undertaken. Comparison of modelled and measured results showed that rib deformation was simulated reasonably well but floor deformation was always underestimated. Alternative, but more time consuming methodologies could be developed to resolve this problem. Simulations using current cuttable rockbolt technologies in the floor showed that if good bond strengths could be achieved even low density patterns could have significant effects on reducing floor heave.

Detailed in-situ characterisation of floor and side behaviour was completed at specific study sites at 4 UK collieries achieving improved understanding of the deformation mechanisms at each. Importantly, at Daw Mill Colliery the detrimental effects of manholes on rib stability was demonstrated.

The work was reviewed by the UK Health and Safety Executive and it was agreed, based on balance of risk to persons working in or travelling the roadway, that manhole construction should be discontinued, (alternative personnel safety measures were introduced where FSV's and other mobile plant were in use).

Floor control is managed by dinting which often has a detrimental effect on rib stability. Thus by predicting floor heave to better plan deployment of dinters, by proactive additional support of ribs before dinting, and through not over dinting in one lift both floor and rib control can be improved.

Geosoft has demonstrated that by understanding deformation mechanisms through suitable monitoring programmes and understanding the benefits of optimised support materials placement practices at the correct time, improvements in ground control can be achieved. This was borne out by the final retreat face at Daw Mill, 303's. 303's panel retreated at an acceptable rate in a difficult geotechnical environment.

Despite the quantity of repair work required to the ribs and floor they were still the best conditions achieved at Daw Mill since working of the new deeper areas commenced some 10 years previously.

European Commission Research Fund for Coal and Steel Project RFCR-CT-2013-00001 Advancing Mining Support Systems to Enhance the Control of Highly Stressed Ground, (AMSSTED) July 2013 to June 2016

The European Partners are; Central Mining Institute, GIG, Katowice, Poland, (as Co-ordinator) Geocontrol SA, Spain; Deutsch Montan Technologie GmbH, DMT, Germany; Association pour la Recherche et le Developpement des Methodes et Processus Industiels, ARMINES, (Paris School of Mines), France; The University of Nottingham, UK; OKD s.a. Czech Republic; UK Coal Production Ltd, UK; Jastrgebska Spolka Weglowa S. A., Poland

This project is aimed at improvements in roadway support techniques which need to keep pace with the demands of safer and more productive mining in ever deeper and more highly stressed mining environments. The advances in support techniques proposed address a variety of issues and cover geotechnical investigations, numerical modelling, quality and support behaviour including optimisation of bolting systems and support cost reduction. Laboratory and field trials of developed support systems are planned. Golder Associates and UK Coal Production Ltd. objective is to improve the support techniques associated with the safe recovery of powered supports from completed longwall retreat faces, commonly called face salvage in the UK.

Longwall powered support recovery is one of the most hazardous operations at a mine usually undertaken within strict time constraints and often in poor and highly stressed ground conditions. The UK industry guidance on support of face salvages was produced in 1997 and has not been reviewed since. In order to improve safety and recovery of the powered supports more economically improved support consumables and strategies, improved risk assessment techniques and alternative salvage geometries will be considered.

The work of AMSSTED has commenced by gathering data and experience of support techniques and practices world wide. Databases of New World experiences have been acquired and complementary data from current and historic UK sites has been analysed in order to compare and contrast geotechnical and support parameters.

Improved support consumable practices will take into account recent worldwide and UK experiences. Laboratory testing of improved/alternative products will be undertaken as necessary. Daw Mill's 32's face salvage made use of spiles, (a self drilling steel anchor system), for difficult ground conditions and worldwide practice has indicated the use of triple birdcaged cablebolts.

Over the last 15 years UK Coal and GAUK, (formally RMT), have been developing a risk assessment and control methodology aimed at managing the risk of falls of ground in rockbolted gate roadways. It is based on systematic, visual surveys of roadway condition combined with routinely obtained safety monitoring data. Under

AMSSTED specific consideration and adaption of risk assessment systems to face salvage is planned.

The use of pre-driven recovery roads as a strategy for face salvage will be considered. These have been applied in New World collieries at much shallower depths; the greatest depth of working recorded being 610m. Application at greater than 800m depth will require extremely careful consideration, planning and support. Work will be undertaken to investigate the benefits that numerical modelling could bring to aiding the design and support practices for these types of face salvage geometries.

Notable field work is currently being undertaken at one of UK Coal's mines where a planned conventional salvage has had to be modified. For operational reasons the powered supports on this salvage were not recovered immediately after the faceline had reached its final face stop position. During this time the original face opening had become restricted and the powered supports closed.

Risk assessment matrices were used to help determine a suitable recovery method for the powered supports, this being a novel method requiring the excavation of a pre-driven recovery road in front of the powered supports. Suitable monitoring systems were installed and to date are indicating that the chosen support system is achieving the required level of ground control facilitating powered support recovery.

In this project UoN used its rock testing and numerical modelling capabilities to support the project aims and concentrated on the variability of ground parameters at any given site and the influence of this variability upon the numerical modelling outputs. Statistical techniques were adopted that quantify uncertainty in input parameters and allow a range of results for a model output (e.g. roadway closure), each having a risk value assigned to them.

Until 2005 it was thought impracticable to use a Monte-Carlo-type approach combined with the finite difference techniques for large-scale modelling of mining applications.

However, recent improvements in hardware and the use of variance reduction techniques have made it possible, within shorter run times to analyse problems in this way. FLAC provides a very powerful built-in programming language that allows the user the control required for automatically performing the thousands of models that a Monte-Carlo analysis needs.

Before performing an uncertainty analysis, the parameters of interest must be determined by means of systematic sensitivity analysis techniques. Sensitivity analysis attempts to estimate how the uncertainty in the output of a model can be linked to different sources of uncertainty in the model inputs. The one-at-a-time (OAAT) methodology involves taking each parameter in turn, varying it across its range with all other parameters set at their nominal values. The relative sensitivity of each parameter to the corresponding output variable is then identified. The OAAT analysis allows one to determine the parameters that will be set to simple mean values and those to be systematically varied in the next stage.

After examination of all the influential parameters, the four most sensitive parameters are selected for the next stage. The output distribution obtained from the Monte-Carlo uncertainty analysis provides not only basic statistic information e.g. central tendency and variance, but also more detailed probability information such as percentiles and ranges of uncertainty.

Conventional thinking may claim that a big sample size (10,000) is necessary with Monte-Carlo in order to approach the original distribution with a very high confidence, such as 0.99. As general strata excavation stability problems in practice have no critical demand on the absolute accuracy of the results, an analysis even with a lower confidence than 0.99 has considerable value when compared to an analysis that completely ignores risk. In practice, the Latin Hypercube sampling method used reduces the number of runs required significantly. Therefore usually around 1000 models or even less are being found to be enough to provide the degree of accuracy for useful uncertainty analysis for most practical geotechnical engineering problems.

Management of minewater discharges to mitigate mining risks for the post-mining period [Manager] July 2013 to June 2016

This project aims to mitigate environmental risk associated with mine water discharges through an approach which combines; (a) identification of priority substances of concern in mine waters based on local conditions, long-term modelling predictions and forecasts, risk assessments and the objectives of the Water Framework Directive, (b) development of cost effective and sustainable passive and active treatment technologies taking into consideration the results of field tests (at pilot sites) and cost-benefit analysis, (c) identification of forward-looking technical options for mine water reuse and metals recovery, and (d) development of management approaches to mine water discharge and treatment. The research will involve pilot schemes in selected European countries which will support an assessment of the technical and economic feasibility of the proposed technologies. Replication of the approaches will be considered for the EU as a whole.

CoGAR

Project partners: GIG (Poland – project co-ordinators)), AITEMIN (Spain), DMT (Germany), INERIS (France), KHWSA (Poland), Subterra Ingeniera (Spain), TUKE (Slovakia), University of Nottingham

The Polish industry is running two UCG trials, the first at the Barbara Test Mine followed by a second test at the Wieczorek mine. This second trial is in old workings that form part of a working deep mine. The Nottingham contribution to this work is to test rock cores taken at and around the two trials, both before and after the burn has ended to assess the effects of the high temperatures generated during UCG on surrounding rock strength, and thus the extent of strata caving around the burn.

The data from this testing will provide input parameters for the numerical modelling of the geotechnical situation during and after the burn process to assess the extent and magnitude of ground movement initiated by UCG. The results obtained from this modelling will be compared with measured data obtained from the trial sites.

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Mine operations

Mine Shafts: Improving security and new tools for the evaluation of risks [MISSTER]

This project commenced in July 2010 and was completed in June 2013. The project aimed to develop cost-effective tools to enhance the understanding of hazards that may affect mine shafts and to optimise safety conditions relating to active shaft maintenance and disused shaft treatments.

European Commission Research Fund for Coal and Steel Project RFCR-CT-2012-00002 Enhanced Effectiveness and Safety of Rescuers Involved in High Risk Activities by Designing Innovative Rescue Systems (INREQ) July 2012 to June 2015

The European Partners are; *KOMAG, Poland, (as Co-ordinator);* Geocontrol SA, Spain; Central Mines Rescue Station, CSRG, Poland; DMT Deutsch Montan Technologie GmbH, Germany; Asociacio para la Investigacion y Desarrollo Industrial de los Recursos Naturales, (AITEMIN), Spain; ICOP SPA, Italy

This RFCS project is intended to directly address the safety and operational efficiency of mines rescue teams. It proposes to develop special prototype and experimental rescue equipment to increase safety, operational comfort and effectiveness. It will include a system for monitoring biometric and environmental conditions of the rescue team with data transfer via a dedicated communication system to the rescue centre and equipment to aid rescue including a lightweight rescue conveyor, lightweight support system and improved methodologies for rock cutting/disintegration. Golder Associates' role is the further development of its m-Comm rescue communications system for the biometric and environmental monitoring data transfer element.

Over the first six months GAUK concentrated on a basic specification of the system's architecture and identifying the appropriate protocols and interfaces both for data input at the rescue site and data export at the fresh air base. Discussions with project partners, CSRG and DMT, resolved many open questions regarding sensor selection and interface specification. It was agreed that the proposed data rate of 1200 baud in 300 millisecond bursts was acceptable to all. Assuming that the system will be able to transmit between 0 and 100 data bursts per minute without interference with voice communications, an update rate of once every 20 seconds should be achievable at the base station.

Documentation on the agreed specifications were then produced. CSRG specified the requirements for the environmental monitoring, namely environmental gases, oxygen, carbon dioxide, carbon monoxide and methane. DMT had originally identified that the most likely candidate for core body temperature monitoring would be a chest monitor manufactured by SEM. However further investigations indicated limitations with respect to this and work concentrated on reliable information for heat stress monitoring namely temperature, humidity and airflow. DMT are therefore designing and developing a three sensor device which is intended to interface with the Bluetooth wireless system of the m-Comm system.

The highly involved and technically challenging task of designing the m-Comm data transfer and capture system is now ongoing and progressing according to schedule. The necessary electronic hardware and firmware for the m-Comm units is now being developed. This includes biometric transponder data interfacing and initial processing to minimise data transmission requirements; data transmission through the m-Comm system to a fresh air base unit; data capture at fresh air base, storage and post-processing for generation of an appropriate graphic display, warnings and alarms, and data management for storage and archiving of measured parameters. The work has been broken into 6 stages.

Stage 1 on the hub to base communication system has been completed with a suitable printed circuit board and programmable integrated circuit processor. Work on the hardware and interface for the base to surface output as part of Stage 2 has commenced. Development and laboratory work during stage 2 has indicated where positive improvements to the system can be made. Development and progress from these two stages of the work followed by work on Stages 3-6 will facilitate the build-up of prototype equipment which will be suitable for field testing.

Mining smart electrical grids [M-SMARTGRID] July 2013 to June 2016

This project has evolved in recognition that energy consumption is a major cost component in all mining operations. Furthermore, the considerable distances underground, coupled with high power requirement impose increasing strains on the power network. In response, a number of individual system developments have been introduced over the years with an objective of decreasing the cost of energy used, mainly in the fields of mine ventilation and pumping etc. However it is increasingly recognised that if significant gains are going to be made in this area, then it is necessary to fundamentally address the grid system as a whole, applying smart grid technologies (a smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics and sustainability of the production and distribution of electricity).

The research aims to develop and implement a radical approach to mine power engineering involving smart grid system, together with the use of engineered boreholes to provide direct power supply connections from the surface. The approach will exploit current data transmission systems and wireless networks to ensure effective implementation at minimum cost, whilst additionally seeking to improve mine safety and automation.

Within this project Mines Rescue Service Limited (MRSL) is acting as subcontractor to Camborne School of Mines. The studies undertaken by Mines Rescue Service Limited are concerned with reinforcing, at a strategic scale, the underground mine power supply network by engineering and installing boreholes to provide direct point to point connections between the underground workings and the surface.

Specific objectives concern developing an effective methodology for implementing in-mine grid reinforcement schemes using boreholes, understanding the relative performance gains and net costs, and evaluating secondary applications at both operating and closed mines. The work package is structured to examine five interrelated areas; (a) borehole construction, (b) cable selection, suspension and installation, (c) borehole electrical grid system topologies, (d) scoping of additional operational benefits, and post-closure opportunities.

UK partners are Camborne School of Mines and MRSL.

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Appendix 1 – Members of SHMRAB 2013

Mr J R Leeming, HM Principal Inspector of Mines, (Chairman)
Mr T Spurry, Group Safety Engineer, UK Coal Mining Ltd;
Dr A Curran Chief Executive, Health and Safety Laboratory;
Dr R Stace, School of Civil Engineering, University of Nottingham;
Mr P Carragher, General Secretary, British Association of Colliery Management;
Dr R Quinlan, Medical Director, RPS Business Healthcare Ltd;
Mr J Wood, President, the Union of Democratic Mineworkers;
Mr R Soar, National Association of Colliery Overmen, Deputies and Shotfirers;
Dr P Holmes, British Gypsum Ltd and the Mining Association of the UK;
Mr R A Fenton, Secretary Mining Association of the UK (MAUK)
Mr R G Siddall, Past President of the Institution of Mining Engineers;
Dr B Jones, Chief Executive, Mines Rescue Services Ltd;
Mr P Shorthouse, SES Contracting Ltd;
Mr C Kitchen, National Union of Mineworkers

Others who contributed to SHMRAB meetings during 2013
Dr P Foster, Camborne School of Mines, University of Exeter;
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Mr S C Bennett, Mines Rescue Service Ltd;
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