ANNUAL REPORT

COMRO

1992

Cover: Some of COMRO's achievements over the past 30 years. *Front left to right from top:* Self-contained self-rescuers for the protection of workers in the event of a fire or explosion underground; the portable gold analyser which measures ore grades instantaneously and in-situ at the stope face; the water-powered rockdrill offers drilling rates more than double those of pneumatic drills; impact mining, a non-explosive rock-breaking system which makes continuous mining possible; ENVIRON, one of a range of computer programs for the design and optimization of mine ventilation and cooling systems; and the hydraulic prop which, installed 1 m from the face, provides protection to workers from rockfalls.

Back left to right from top: Distribution of heavy minerals deposited in flume experiments to simulate the fluvial conditions responsible for the formation of Witwatersrand reefs; water jet assisted cleaning, made more practical with the introduction of hydro-power; ice as a primary coolant for deep mines; pyschometric tests for the improved selection of workers; the portable underground radio; and stress relieved slots, cut into a tarred road, which is being undermined, as a preventative measure to reduce damage to the road as a result of subsidence.

This publication is printed on Dukuza. At least 60 per cent of the paper's fibrous content is bagasse, a by-product of sugar cane-farming, much of which was previously burnt as waste.

COMRO is an applied research and development organization serving, primarily, the gold and coal mining industries of South Africa.

COMRO's mission is to provide a research and development service of high quality which delivers timeous solutions to its customers' pressing and crucial mining problems.

For the past 30 years, COMRO has worked closely with the gold and coal mining industry to solve the most crucial problems that threaten the health, safety and well-being of its workforce, and the productivity of the mining operation, through the development of knowledge and technology. COMRO also undertakes research and development on a contract basis for a wide range of customers (throughout all sectors of the mining industry and in related areas), offering services in the areas of improving the underground environment, strata control, reducing the hazardous effects of rock pressure in mining operations and increasing productivity through improved mining systems and equipment. These services range from fundamental research, through technology development to general advice and assistance, and feature:

- *Specialist expertise in a wide variety of mining-related fields acquired over many years, particularly concentrating on areas where such expertise is not available elsewhere.*
- *Comprehensive on and off site test facilities for conducting mining related research, the scale of which ensures that all tests provide meaningful results for mining conditions.*
- *Worldwide collaborator network with manufacturers and other research bodies - giving it access to a vast resource of knowledge.*
- *Extensive experience of managing research and development projects.*

COMRO

INNOVATION IN MINING

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FOREWORD

Following consideration of current and likely future circumstances in the mining industry, it was decided towards the end of last year that the possibility of merging COMRO with the CSIR, the largest scientific and technological research and development organization in Africa, should be investigated as such a merger could well best serve the long-term interests of both Chamber members and COMRO staff. The envisaged merger would enable the Industry to conserve and effectively utilize the unique source of specialist mining research and development skills and resources that has been developed within COMRO over the years, and would also provide it with ready access to the broader based expertise of the CSIR. Additionally, the merger would result in an organization well poised to continue finding solutions to the problems of the Chamber of Mines member mines, as well as providing it with a springboard from which to expand the scope of its operations. For the CSIR, the merger would provide it with an important base in the mining industry, while overall, such a step would be a logical consolidation of research and development activities within South Africa.

This annual report also marks an important change to the 30 year old arrangements for undertaking R&D for Chamber members. Over the past two years an increasing proportion of COMRO's activity has been based on contract research and from 1993 all of COMRO's R&D activities will be based on commercial contract research arrangements, on a project by project basis. These new arrangements were to a large extent necessitated by the increasingly differing requirements of the individual mines and mining Houses. It is however important to note that they include the facility for projects for Chamber members to be undertaken jointly by two or more mining Houses on an elective basis, or on an individual contract basis for both Chamber and non-Chamber members. Also, from 1993 a significant portion of COMRO's safety research activities will be conducted under contract to the newly established Safety in Mines Research Advisory Committee - SIMRAC. Together, these changes will in some ways mark the beginning of a new era of mining R&D in South Africa.

While COMRO is looking forward to a challenging future, at this time it is perhaps fitting for this report to reflect some of the achievements made over the past 30 years through the Chamber's co-operatively sponsored programme. A brief account of these achievements is thus included, and includes items such as:

* MINSIM D for the design of mine layouts
* guidelines for ameliorating the hazards of rockbursts and rockfalls
* rapid yielding support systems
* portable seismic system
* technology for backfill systems
* mine cooling with chilled service water
* recirculation of ventilation air
* computer software for mine cooling system design
* heat acclimatization procedures
* Heat Stress Management
* microclimate cooling systems
* self-contained self-rescuers
* hydro-power
* water-powered rockdrills
* continuous scraper
* impact mining system
* blast design guidelines
* gold analyser
* guidelines for shaft steelwork
* underground radio
* pyschometric tests for the selection of workers
* coal mine design procedures
* computer software for optimizing coal production
* coal cutting technology

Turning to 1992, despite it being a year of some uncertainty for COMRO, research and development activities have continued to make good progress . Within the rock engineering area, the development of rockburst control methods and regional support systems reached important milestones. Preconditioning, through controlled longhole blasting ahead of and parallel to the face to create a stable zone of stress-relieved rock, is showing considerable potential as a production tool for rockburst control in the stopes, while a start was also made with the placement of concrete pillars for regional support in place of reef pillars. An important aspect of work in the underground environment area was assisting with and monitoring the implementation of new systems and technologies. In particular, by the end of 1992, a new holistic approach of optimal 'heat stress management' had been introduced on two-thirds of 'hot' mines. With regard to the work on assisting the Industry with the implementation of a cost-effective method of radiation protection, a newly developed radiation spectrometer for environmental monitoring was made commercially available using a basic technique of spectral analysis. New techniques of spectral analysis are being validated internationally to further improve the effectiveness of the instrument. During 1992 the gold analyser reached full production trial stage, with considerable work devoted during the year to identifying optimum sampling strategies and assessing the economics of the system. In the area of coal mining, considerable advances were made in the development of an in-section central monitoring and analysis system to improve the control of continuous miners and to maintain control of coal production and coal transportation.

COMRO's contract R&D activities continued to grow as an active and wide ranging area. The impact mining system reached production trial stage and the four machines completed at the end of 1992 will be installed early in 1993. In the application of geophysical techniques, mine-worthy radiowave tomography equipment was successfully developed and has been applied in the base metal, gold and coal mining environments, both locally and abroad, for the delineation of ore bodies. A highlight of work in the area of the prediction of gold grade distribution was the opening of the new flume facility. Work using this facility will provide an enhanced knowledge of the mechanisms of gold concentration in Witwatersrand deposits as an aid to predicting gold distribution.

As COMRO enters into a new era, I believe that the organization will continue contributing significantly to the future of the South African mining industry, and thus to the country, since the future exploitation of South Africa's mineral wealth will to a large extent depend on the development of improved lower cost mining methods. Finally, I would like to thank all COMRO staff for their support and continued hard work over the past year.

J M Stewart
Research Adviser, and General Manager,
COMRO

SUMMARY OF MAJOR R&D OUTPUTS IN 1992

GOLD ANALYSER

The portable gold analyser, developed to scan an entire exposed reef thus increasing precision of both stope face valuation and ore reserve evaluation, has reached the stage where mines may purchase the instrument for use in production trials. The analyser's ability to produce unbiased grade readings on Witwatersrand reefs, relative to chip sampling, has been established, and a training course has been drawn up for operators and samplers. As the gold analyser is able, in most situations, to provide rapid and more reliable information than is possible with chip sampling, this should enable mines to increase the grade of ore mined as a result of improved selection of mining faces. (Page 22)

SOFTWARE FOR PREDICTING GOLD DISTRIBUTION

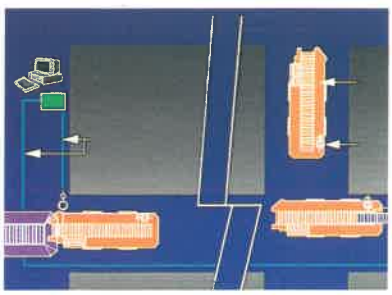
The MIDAS (mechanistic sediment transport model) computer program, which simulates multiple size density sorting, was evaluated against borehole data sets for its applicability in predicting grade distribution in unmined areas. The program is available for use on a consultancy basis and provides a powerful tool suitable for a number of applications relating to exploration targets and to unmined portions of reef within existing lease areas. (Page 31)

RADIATION MONITORING EQUIPMENT

Development of improved, low cost instrumentation for monitoring exposure to radiation reached the stage where certification of the instrumentation for use on South African mines is being sought. With regard to environmental monitoring, the established Rolle technique for measuring radiation levels is used in the newly developed radiation spectrometer to allow its immediate application while further, more sophisticated operating modes are being developed and internationally validated. Calibration and verification of the track etch radiation monitoring system, which can be fully integrated with personal gravimetric dust monitoring systems employed on mines, were completed during 1992. This instrumentation provides the Industry with a basis for devising cost effective strategies for dose limitation suited to South African gold mines. (Page 13)

BACKFILL PIPELINE SYSTEM DESIGN

Three computer programs for designing and optimizing hydraulic transportation systems were finalized. The programs include HYDTRANS for predicting and comparing slurry transport properties; HSD, which uses the output from HYDTRANS or any slurry transport parameters to predict the hydro-transport behaviour of a piping network; and BACKSIM, a combination of the above for limited slurry behaviour prediction. These IBM PC-compatible programs enable mines to carry out the design, analysis and optimization of systems in-house and help to identify restrictions and unsafe operating conditions, resulting in a more cost-effective transport of backfill. (Page 30)



CONTINUOUS MINER CONTROL SYSTEMS

A horizon control system for incorporation on continuous miners successfully underwent field trials in a variety of applications and is now available to the Industry. The system enables continuous miner operators to move the cutting head quickly and accurately to roof and floor horizons, thus reducing time lost to trimming and eliminating uneven floor conditions, a major cause of maintenance and operational problems. This device is one component of an overall system currently under development for improving the control of various activities in continuous miner sections. (Page 27)

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COMRO P O Box 91230,
Auckland Park 2006, South Africa
Telephone (011) 726 2030
Fax (011) 726 5405; 482 1214
Telex 4-26070

INTRODUCTION

The complexity of the problem areas which comprise the research and development programmes for gold and coal mining requires expertise drawn from a variety of disciplines. To address these areas, COMRO is structured into four divisions, Underground Environment, Rock Engineering, Coal Mining and Special Projects. Co-operatively sponsored research for gold mining was directed during 1992 by the Technical and Research Advisory Committee, and for coal mining by the Collieries Technical and Research Advisory Committee. The representatives on these committees for 1992 (as at December 3) are listed below.

Technical and Research Advisory Committee

MUNRO, A H, Gold Fields of South Africa Limited (Chairman) (Portfolio Holder for Research)

VAN GESSEL, K A, SCHMID, E, Anglo American Corporation of South Africa Limited.

DIXON, J R, SPINDLER, T V, Anglovaal Limited.

LEE, G S, FIELD, A J, General Mining, Metals & Minerals, Limited.

LOMBARD, H E, KAMP, N, Gold Fields of South Africa Limited.

MORRIS, R, LOURENS, M J, Johannesburg Consolidated Investment Company Limited.

VOS, P, MILELLA, D, Randgold and Exploration Limited.

STEWART, J M, Research Adviser, and General Manager, COMRO.

GREEFF, J C, Manager, Safety and Technical Services, Chamber of Mines.

Collieries Technical and Research Advisory Committee

FAUCONNIER, C J, Johannesburg Consolidated Investment Co Ltd (Collieries Committee Research Portfolio Holder)

VAN ZYL, H C, WIGGETT, C H, Anglo American Coal Corporation Limited.

SPENCER, K C, LOMBARD, H E, Gold Fields of South Africa Limited.

WATSON, D S, VAN NIEKERK, D J, Iscor Limited.

FOURIE, G A, SCHAFFLER, H A, Johannesburg Consolidated Investment Company Limited.

PALM, J G, Kangra Group (Pty) Limited.

BARTHOLOMEW, G D, MCNEICE, K, Lonhro South Africa Limited.

MICHAEL, D C, RORKE, E, Randcoal Ltd.

VILJOEN, J C, VAN DER MERWE, H G, Trans-Natal Coal Corporation Limited.

STEWART, J M, Research Adviser, and General Manager, COMRO.

GREEFF, J C, Manager, Safety and Technical Services, Chamber of Mines.

While the four divisions also individually undertook contract work during 1992; the bulk of the contract work was conducted by the Special Projects division. Details of the contract research service are given on page 28.

COMRO: A HISTORY

"Important changes have been made in the central co-ordinating body within the industry.... One of these was the decision to establish a Mining Research Division. This division will provide a central headquarters for research on underground mining problems ... Its activities are aimed at improving the health and safety of workers and at reducing working costs and improving profitability. It is therefore a most important factor in the industry's struggle to ensure the fullest possible exploitation of marginally payable ores."....read the Chamber of Mines Annual Report for 1963, announcing the formal establishment of what was then known as the Chamber of Mines Research Organization.

Research activities had in fact been carried out by the South African mining industry almost since mining operations had begun on the Witwatersrand, and had already yielded some notable developments - the first acclimatization procedures amongst others. However, these activities were largely reactive to specific problems as they arose and were thus conducted on an ad hoc basis; by the mid 20th century, with increasing mining depths and ever worsening conditions, the need for a co-ordinated and systematic research programme was becoming more and more urgent for the mining industry to successfully face the challenges of the future. Following an in-depth review of the industry's research needs by, amongst others, Sir Basil Schonland, an eminent scientist from the UK, the first Research Adviser to the mining industry was appointed in 1962, and shortly after the Research Organization was born.

In the years that followed, the organization, building on past research activities and resources, built up a unique source of expertise and testing facilities which has established it as a leader in the field of deep level mining research. Funded until recently on a co-operative basis by the six major mining houses in South Africa, COMRO's research programme has over the past 30 years addressed a wide range of mining-related problems, covering both the gold and coal sectors, including rock engineering, the underground environment, human resources, stoping technology and gold exploitation - and has yielded many practical solutions to the problems facing the mining industry.

IMPROVING THE ENVIRONMENT

The development of methods to provide a comfortable, healthy and safe working environment has constituted a major research effort - particularly with the hot, humid conditions encountered in South African gold mines. This research has taken a two-pronged approach: first, tackling and modifying the environment so that man can work safely within it, and second, adapting man to and protecting him from the environment.

From this research, a considerable body of knowledge into the mechanisms of heat flow and cooling in deep mines has been assembled, enabling the development of a variety of innovative techniques and technologies which make it possible to mine at depths at which environmental conditions would previously have been prohibitive.

The concept of ***chilling the vast quantities of service water*** routinely used to control dust and assist in stoping operations as a means of cooling underground workings was first put into practice in 1979, and has subsequently been implemented on all deep gold mines. Since then, the feasibility of using ***ice as a primary coolant*** has been demonstrated, providing the mining industry with a cost effective means of distributing refrigeration in deep gold mines. The technical and economic feasibility of ***recirculating ventilation air*** to provide the higher quantities of air required for distributing refrigeration air within working areas, without the need for higher quantities of downcast air, has also been established, and safe practices and ancillary safety technology for its implementation developed.

Reducing the heat load at source will also assist in considerably reducing ventilation and cooling costs, and in this regard the benefits of ***insulating mine airways*** to reduce heat flow into mines were determined in the 1980s. These results provided the necessary impetus for manufacturers to investigate the development of suitable insulating materials.

Spray chambers for the bulk cooling of ventilation air were first tested in the field towards the end of the 1970s, and rapidly supplanted other types of air coolers - growing from 158 MW of refrigeration capacity to 254 MW in 1984 and 560 MW in 1987 - saving the Industry many millions of rands as a result of the lesser need for capital equipment. The air cooler industry has also benefited significantly from this research. Design assistance and testing facilities have been provided in the development of ***closed circuit cooling cars*** and ***direct contact cooling cars***, while a ***stope entrainment cooler***, developed as a low cost method of providing spot cooling at the face, was introduced in 1986.

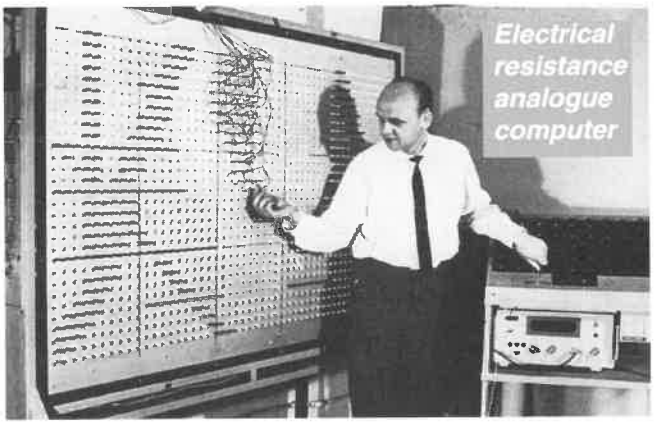
Providing a framework to guide this research, a ***three phase strategy for distributing cooling*** was developed in the 1970s: firstly, all the water normally used in mining is chilled, secondly, for greater depths, all the ventilation air is cooled in bulk on surface and/or underground so as to counteract the effects of autocompression; and thirdly, for deep mines, where the ventilation air requires recooling, smaller secondary coolers are used.

More recently, this vast source of knowledge of heat loads and cooling has been made directly available to the mining industry through the development of a suite of ***computer programs which assist the mines in the improved design of cooling and ventilation systems.*** These programs include ENVIRON, released in 1989, for the full thermodynamic analysis of a mine, CHILLER, released in 1987, a computer program for simulating the performance of refrigeration installations, and STRIPPER, released in 1991 for assessing

the effectiveness of insulating chilled water pipes on a site specific basis.

PROTECTING THE WORKER

Research into the science of human heat stress dates back to as early as the 1920s when, as mining operations reached depths at which wet bulb temperatures exceeded 30 °C, the first human heat stress fatality was recorded. Over the years, significant steps were made in the introduction of acclimatization procedures with new knowledge yielding incremental improvements. Initially ***two-stage acclimatization,*** in which workers spent six days in a cool production stope, followed by six days in a hot production stope, was introduced in 1953. This was followed by ***surface acclimatization*** in 1965, which enabled acclimatization to be achieved on surface within eight days; and later ***Vitamin C assisted acclimatization*** which reduced the time spent on acclimatization to five days. A further development was ***Microclimate Acclimatization,*** introduced in 1981, which allows a worker to acclimatize while working in hot conditions underground, but with the protection of a specially-designed jacket containing dry ice blocks.



In addition, ***limits defining safe thermal conditions*** for workers working in hot environmental conditions underground were defined in the 1970s, specifically for South African gold mining conditions and labour force, and, because the ability to maintain a safe body temperature is determined by a number of interacting factors, the concept of ***cooling power*** was established. This concept takes into account, amongst others, metabolic heat production and environmental factors such as humidity, temperature and air movement. These limits have formed the basis of currently used selection and acclimatization procedures and thus have contributed significantly to overcoming the threat of heat stroke in the gold mining industry.

Concurrently with the development of acclimatization procedures were the advances made in labour selection. The ***physical selection test*** was first introduced in the 1970s to identify the physical work capacity of workers destined to work in strenuous or hot work categories. This was followed by one of the most important developments in the field of labour selection - the Heat Tolerance Test (HTT), which was first applied on a South African gold mine in 1983. Soon finding industry-wide acceptance, the HTT identifies those workers who do not need to be acclimatized before entering a hot underground environment and this has resulted in a significant reduction in both the time spent on formal acclimatization in climatic chambers and in heat stroke incidents.

Recently, another important milestone was achieved in the field of controlling human heat stress with the introduction of a holistic approach to ***heat stress management.*** This programme, which was finalized last year, obviates the limitations and arduousness of conventional acclimatization procedures by incorporating a short duration screening test, to identify the grossly heat intolerant, and then involves natural acclimatization underground with special precautions.

Worldwide, a variety of self-rescuers are used underground to protect workers from noxious fumes produced by fire underground, but, after an extensive in-depth survey of all self-rescuers available, it was concluded that none were applicable to South African conditions. Specifications were therefore developed, and finalized in 1986, for ***belt-worn self-contained self-rescuers (ResQpacs)*** which would not only provide protection to workers against the noxious fumes produced by an underground fire, but would also provide them with life sustaining support in the form of an oxygen supply. These self-rescuers form the basis of an ***escape and rescue strategy,*** drawn up by COMRO, which includes elements such as escape routes, back-up facilities, and hazard detection and communication.

Intensive research efforts have also centred on reducing the risk of fire underground, and a comprehensive ***database on the combustion characteristics of materials*** commonly used underground has been established using an underground fire test facility, established in 1986, and a subsequent surface fire test facility. The database enables mines to select materials on the basis of their combustion characteristics and provides guidance for their safe use underground.

While COMRO's research into the problem of human heat stress is perhaps one of the areas that have received worldwide recognition, its research into the protection of workers against the deleterious effects of the environment has been wide ranging over the years. With increasing recognition of the need to protect workers against excessive noise exposure, a ***hearing conservation programme,*** together with guidelines for its implementation, were finalized in the mid 1980s. This programme is specific to the South African mining industry and comprises three elements: engineering control, to eliminate or reduce noise at source; administrative control, to limit workers exposure to noise; and personal protection, to reduce effective exposure to noise.

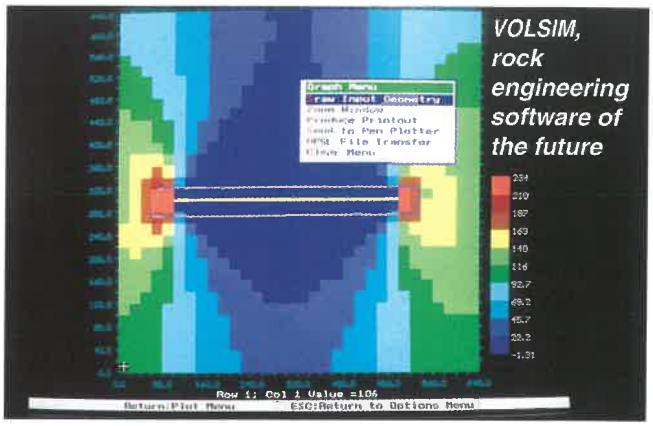
Dust research has yielded the Witwatersrand konimeter (introduced in 1967) and the "R" type konimeter (1978), an adaptation of the Kotze konimeter, ***spot dust sampling instruments*** which provide a measure of respirable dust concentration in mines and have contributed to the reduction in pneumoconiosis. More recently, Industry specifications for ***personal gravimetric samplers*** were finalized, together with sampling strategies, based on statistical techniques, for the effective use of the instrument. The instrument samples a worker's exposure to dust throughout an entire shift, thus providing a more realistic assessment which will enable a

more equitable risk formula for levy purposes. Illumination was also a concern of COMRO's early research with SABS specifications for ***cap lamps*** being drawn up, based on COMRO recommendations. These lamps have reduced maintenance costs and have improved safety underground.

ROCK ENGINEERING

With rockbursts and rockfalls posing the major hazard to the safety of workers underground, much research has been directed at accumulating a considerable body of knowledge on the behaviour of the rockmass to enable the design of mine layouts and support systems that assist in safe, productive mining, particularly of highly stressed areas.

This knowledge has enabled the formulation of ***design methodology and criteria for the layout of working faces, the design of regional support, the siting of shafts and shaft pillars and the optimal placement of haulages for more stable, safe and productive mining layouts***. This information was first made available in the latter part of the 1960s through the development of the ***electrical resistance analogue computer*** for determining stress concentrations, convergences and energy release in tabular mine excavations. It is now utilized routinely by mine personnel, most notably through the application of the computer program *MINSIM* and its derivatives for the design of mine layouts and rational stoping sequences. The most recent development, MINSIM-D, a sophisticated user-friendly program, allows rock mechanics practitioners on mines to handle the most complex situations involving non-parallel and faulted multiple reefs. Additional numerical models, such as *VOLSIM* and *WAVE* are under investigation to provide greater insight into the physics of rockmass behaviour and the interactive nature of deformation mechanisms.



A milestone in the science of rock engineering was the publication of ***Guidelines for Ameliorating the Hazards of Rockfalls and Rockbursts*** (first published in 1977 and revised in 1988), incorporating the state of the art in terms of rock engineering to provide practical advice on methods of reducing rock-related accidents. In addition to widespread distribution in the mining industry, the publication is also used as a university textbook.

A better understanding of the properties of the fractured rock surrounding underground excavations has enabled the development of a range of support systems, both for tunnels and stopes - the most significant of which is probably the ***rapid-yielding hydraulic prop.***

The development of this prop in fact underlines the need for technology developed specifically for South African gold mining conditions. In the 1960s, with the increasing mining depths resulting in an increasing incidence of rockbursts and rockfalls, hydraulic props, utilized in overseas mines, were applied on a number of gold mines. However, within months of their introduction, these props were withdrawn as they proved incapable of accommodating the rapid closure which occurs during a rockburst in the highly stressed mining conditions of South African gold mines.

An intensive research effort was thus initiated into the development of hydraulic props suitable for South African conditions and, by 1975, trials of a 400 kN prop which was able to yield at 1 m/s were complete. A ***second generation of hydraulic props***, incorporating the rock engineering knowledge gained over the past two decades, is now being introduced into the mining industry for the control of both rockbursts and rockfalls. These props are sufficiently robust to withstand a blast and thus can be installed within 1 m of the stope face, and incorporate elongate headboards which provide good areal coverage of the hangingwall. They thus provide effective support of the working area between the stope face and the first line of permanent support where 50 per cent of all rock related accidents occur. In addition, the props are sufficiently lightweight to be easily handled in the restricted confines of a stope.

With regard to tunnel support, a new generation of ***grouted rock tendons*** consisting of energy absorbing yielding tendons called cone bolts was developed. These units provide effective support in regions prone to high stress changes or seismic events and are capable of significantly reducing damage due to rockbursts and large quasi-static rock deformations. Cone bolts can yield up to 1 m at displacement rates varying from slow to over 3,0 m/s, while maintaining the designed support forces of up to 200 kN.

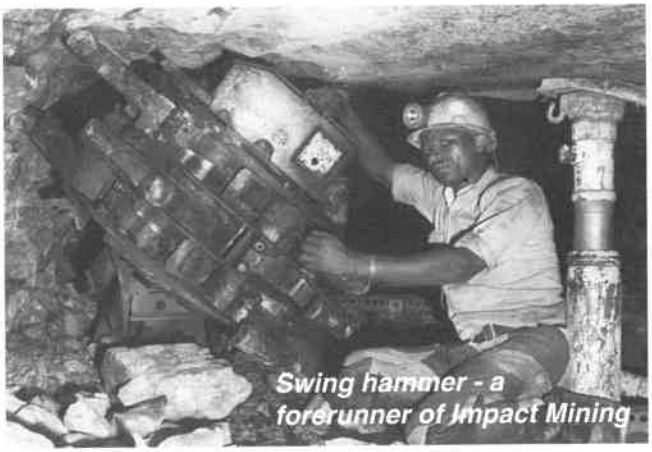
The significant benefits of ***backfill*** in terms of both support and environmental control have been quantified in recent years, with the results providing a guide to the mining industry in terms of the application of backfill. This information can assist the mining industry in achieving the effective use of backfill to reduce rockfall accident rates by up to 30 per cent, while also indicating how to avoid accidents rising from poorly placed fill. In terms of environmental control, large scale backfilling can reduce the overall mine heat load by up to 25 per cent, and potentially reduce the quantity of air at the stope face by up to 35 per cent. With regard to ***backfill systems design***, the fundamental knowledge gained since the mid 1980s has been incorporated in a systematic design approach which can be adapted for the cost-effective design of new systems and for the evaluation of existing ones.

Concurrently with the development of support systems, equipment to test the suitability of support systems and elements, and the properties of rock samples, has been developed; the machines for the ***rapid testing of all types of support elements*** are in constant use for evaluating the performance of all new support elements, including hydraulic props, pack and stick supports and rock tendons, and other support units for tunnels and service excavations.

Seismic research to establish the origins of seismic activi-

ty, and the association between seismic activity, rockbursts and rockfalls and the various geological structures encountered underground, was first initiated in the 1960s leading to the establishment of a number of regional and microseismic networks purely for research purposes. By the 1970s, the potential of seismic networks to assist in the prediction of rockbursts and the need for mines to run their own networks, and analyse and interpret the data, had become apparent, initiating the development of the ***portable seismic system.*** The system's many advantages include its portability enabling it to be moved easily to new sites; its ability to offer stope- to mine-wide coverage; its user friendly and comprehensive software; and its flexibility, making it suitable for a wide variety of mining applications.

Complementary to the seismicity research, COMRO is well into developing ***active rockburst control techniques,*** with one in particular, preconditioning, showing considerable potential as a production tool. Preconditioning the rockmass involves controlled blasting three to four metres ahead of the face to relieve potentially unstable rock stresses.


Swing hammer - a forerunner of Impact Mining

STOPING

The stoping operation accounts for approximately half of mining costs and therefore any improvement in the productivity of this operation could have an important impact on the productivity of the mining operation as a whole. Research into improving the labour intensive stoping activities - in an effort both to increase the cost-effectiveness of the mining operation and to reduce the number of workers exposed to hazardous conditions underground - has yielded a number of innovative technologies.

Every year, the gold and coal mining industries consume in the order of R0,5 billion in explosives - a field that has seen considerable improvements starting with the development and application of ammonium nitrate blasting agents to gold mining in the late 1950s. In the 1960s and 1970s a sound knowledge of the fundamental mechanics of rockbreaking using explosives was established and led to the development, in collaboration with a manufacturer, of a range of new, ***improved fuses, cords and stope sets***; the compilation of Industry guidelines on the safe and effective application of blasting agents, such as ANFO, slurry explosives and emulsion explosives; and the development of guidelines for improving the reliability of initiation systems. More recently ***"Blast Design Guidelines"***, incorporating considerable research into characterizing the blasting process in narrow stopes, were produced.

Despite these advances, the productivity of the stoping operation is still inhibited by the cyclical nature imposed upon it by the blasting process. Considerable efforts were therefore devoted to developing a mechanical method of mining and in the process COMRO developed a fundamental understanding of the mechanics of breaking rock non-explosively. From the investigations into all known methods of breaking rock, ***impact ripping***, which involves breaking the rock with the use of a hydraulically operated hammer, was identified as the most promising for the fractured rock conditions in deep South African mines. The development of an ***impact mining system*** is now at production trial stage, supported by a major South African mining Group, and the system has shown itself, in extensive underground trials, to be capable of achieving rockbreaking rates more than double those of conventional drill and blast operations.

The slowest of the component activities that make up a conventional stoping operation is that of rockhandling and considerable efforts have been made over the years into gaining an understanding on how to load and move broken rock. Important developments include the ***reciprocating flight conveyor*** used successfully in the impact mining system, specifications to improve the efficiency of ***water jetting*** guns, and the adaptation of an overseas technology for gully cleaning, the ***continuous scraper,*** to local conditions. Testing of this first continuous rock conveying device to be applied in South African gold mines began in 1983 and it was soon shown to have conveying rates of more than 150 tons per hour (more than five to ten times that of conventional scrapers) and the ability to convey rock both up- and down-dip. With its potential to reduce development and operating costs and to increase productivity, the continuous scraper has considerable potential in the Industry.

While the pneumatic rockdrill has served the Industry faithfully for the better part of the twentieth century, the increasingly fractured nature of the rock at greater depths has detracted seriously from its efficiency. A programme to develop an alternative drilling technology more suited to these conditions identified ***hydraulic drilling*** as being able to provide the extra torque required without increasing the size of the drill. Finalized towards the end of 1991, the ***water-powered rockdrill*** offers drilling rates approximately twice those of pneumatic drills and significantly reduced operating costs.

Although the individual benefits of the new technologies have been demonstrated, the full synergistic effect of combining these technologies can only be exploited if they are combined effectively in a stoping system. Therefore, an ***integrated stoping system*** to maximize the benefits of newly developed stoping equipment was designed towards the end of the 1980s. The system is based on the use of hydraulic rockdrills, blast-on hydraulic props, diagonal blast barricades, water jet assisted face cleaning and continuous scrapers.

With the introduction of chilled service water and with widespread mining at depths in excess of 1 500 m, the concept of utilizing the resulting hydro-static head of this chilled water to power underground equipment becomes

feasible. COMRO pioneered the development of this technology, now known as ***hydro-power***, to the point of full-scale implementation. By 1991, the first large-scale hydro-power system was implemented with the commissioning of the Northam platinum mine in the north-western Transvaal. This system, developed to provide cooling and powering from one energy source, that of high pressure water, was tested extensively on a pilot scale during the 1980s, during which time the system design and components were fully developed and verified. In addition to water-powered rock-drills, a full range of ancillary equipment, including water jetting guns, ***water driven scraper winches, blasthole cleaners and watering down guns***, is now available for use with hydro-power.

GOLD EXPLOITATION

Another component of COMRO's programme has been research into the spatial distribution and values of gold in unmined ground to assist in the optimal exploitation of gold bearing reef. Through these efforts, considerable progress has been made into gaining a fundamental understanding of the geochemistry of the reef and the mechanisms controlling the original sedimentological processes. This increased understanding has enabled geologists on mines to improve their interpretation of exposed reef and to predict more accurately the grade content ahead of the reef. This knowledge has also been utilized in the development of ***geotechnical techniques and criteria*** to delineate different placer facies as a means of improving mine planning decisions, and in ***software for predicting gold distribution*** which, when released, will provide mining geologists with a powerful tool. Known as ***MIDAS*** (mechanistic sediment transport model), the computer program simulates multiple size/density sorting to predict grade distribution in unmined areas.


Impact mining

A major development in the valuation of the exposed reef was the application of the fundamental theory of X-ray fluorescence to determine gold grades in situ in placer deposits. The resultant development of a ***portable gold analyser***, designed to scan an exposed reef thus increasing precision of both stope face valuation and ore reserve evaluation, has reached the stage of production trials. As the gold analyser is able, in most situations, to provide rapid and more reliable information than is possible with chip sampling, this should enable mines to increase the grade of ore mined as a result of improved selection of mining faces.

SPECIAL NEEDS

Over the years, COMRO also addressed specific needs which did not fall within the above major categories of work. Important contributions arising from this work included the compilation of ***design guidelines for the dynamic performance of shaft steelwork and conveyances*** released in 1991 and which provided, for the first time, a comprehensive basis for the design of shaft steelwork based on the predicted dynamic behaviour of the shaft steelwork. In addition, portable ***underground radios*** for rescue and production purposes were introduced into the mining industry in the 1970s, with a second version being made available in the late 1980s. The system provides short range two-way communication through the rock for rescue teams, but has also proved successful as a general mine communications system.

Research into geophysical surveying techniques has made good progress with the development of tools for assisting in short term mining decisions and for overall mine planning having reached an advanced stage. ***Ground Penetrating Radar*** has proved ideally suited to providing high resolution maps of geological features over relatively short ranges, while ***Radiowave Tomography*** has proved effective in the broad scale mapping of geological features.

HUMAN RESOURCES

Research into Human Resource issues, first initiated in 1960s, was accelerated in the 1970s as a result of growing industrial unrest in the mining industry and contributed a variety of solutions to the development of effective manpower strategies and the maintenance of industrial peace. Amongst these were important contributions to the development and validation of ***psychometric tests***, culminating in the Industrial Test Battery (introduced in 1986) which measures cognitive ability, language proficiency, numeracy skills and general 'trainability' of recruits. Also, in the early 1970s, the in depth understanding gained into the use of safety symbols and signs in the mining industry and of their perception by miners facilitated the introduction of effective ***safety signage*** throughout the Industry.

In the late 1980s, a ***non-racial merit based manning*** programme assisted mine management in ensuring the successful movement of formerly excluded race groups into 'competent' job categories, while a ***leadership training*** guide for stope production team leaders covered a wide range of leadership skills from problem solving to the development of interpersonal and communications skills. In addition, a practical ***communications strategy for mine management***, introduced in 1987, assisted management in retaining the attention and trust of employees.

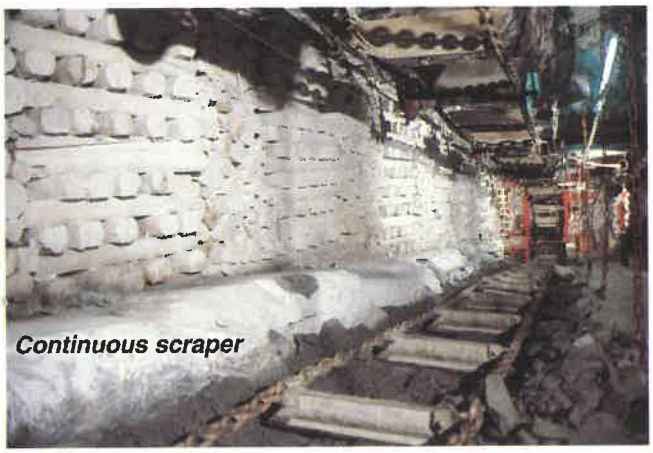
The understanding gained through this research into the resolution of labour-related problems in the mining industry was also made available on an individual basis to mines through a range of consultancy services which included the examination of management and employee attitudes towards greater participation in work situations, an industrial relations climate survey, and advice on psychometric test batteries.

COAL MINING

The South African coal mining industry has been more

fortunate than the gold mining industry in being able to draw from much of the technology and practices used abroad. However, there are unique problems specific to local conditions and COMRO's role in this area, while smaller in scale than in gold mining, has therefore been both to adapt proven technology to local conditions, and also to develop innovative technology and procedures where strategically necessary. For example, the extensive knowledge of the science of ***coal cutting*** gathered in the late 1970s and 1980s was used to enhance the applicability of continuous miners to South African coal mines while innovative contributions have also been made in the development of ***pillar design formulae*** which have maintained the safety of the workings whilst optimizing extraction of coal reserves.

The first pillar design formula, the Salamon and Munro formula, was introduced in 1967 as a result of research initiated following the Coalbrook Colliery disaster of 1960. This formula, which has been used successfully throughout the Industry in subsequent years, was modified in the late 1980s to take into account changed mining conditions, in particular the changed strength behaviour of pillars with high width-to-height ratios. Known as the ***squat pillar formula***, the formula enables collieries to design stable pillars to smaller dimensions than was previously possible, thus increasing percentage extraction.



Continuous scraper

In the 1970s, the years of intensive research in the area of rock mechanics resulted in the distribution of a handbook ***"Rock Mechanics in Coal Mining"*** which facilitated access to the first soundly based principles available for the design of workings in collieries. More recently, this research has yielded ***MULTI-SEAM***, a program for designing stable multi-seam bord and pillar workings, and the ***critical span formula*** for the design of total extraction workings beneath dolerite sills, taking into account the depth below surface and the thickness of the sill as well as the thickness and nature of the parting between the sill and the coal seam.

The effects of the vertical and horizontal movement above total extraction panels on a variety of surface structures has also been determined through long term ***subsidence*** monitoring during the 1970s and 1980s. This knowledge enables collieries to gauge the potential effect of total extraction on surface structures such as railway lines, power pylons, farm buildings, and tar and gravel roads.

Much of the knowledge gained through investigations into equipment and operating techniques in the South African coal mining industry has also been made available directly to collieries through the development of computer software. Programs released in the latter part of the 1980s include the ***COMSIM PC*** program for optimizing production by conventional drill and blast methods in bord and pillar mining, as well as by continuous miners in bord and pillar developments, and pillar and rib pillar extractions; ***BELTSIM*** for simulating the flow of coal on conveyors from the working section to surface, to determine where bottlenecks exist in established networks or where a planned conveyor network might create a problem; and ***CUTSIM***, offered on a consultancy basis to assist mines and manufacturers in achieving optimum efficiency and effectiveness of their cutter drums.

In addition, a ***stooping manual***, published in 1990, incorporates the results of detailed investigations into stooping practices in South African collieries and includes guidelines for pillar and rib pillar extraction. These guidelines provide coal mines with a number of options to cost-effectively increase extraction of reserves, while maintaining the safety of the underground workings.

Environmental research into coal mining has also contributed significantly to safeguarding the health and safety of colliery workers . Guidelines for ***environmental protection at continuous miners*** were released in 1988 to indicate how airborne dust concentrations could be reduced in continuous miner sections. ResQpacs, discussed earlier, were first developed for application on collieries, while a ***post disaster surveillance probe***, fitted with a visual and audio communication system, was finalized in the late 1980s. The complete system is housed in a mobile caravan which is easily transported to the site of the disaster, and enables mines to search for and establish contact with survivors trapped underground.

THE FUTURE

With the changing needs of the South African gold and coal mining industry, COMRO has moved away from conducting research and development exclusively on a co-operative basis on behalf of the major mining Houses, and is now providing its full spectrum of research activities on a contract basis to individual mines and mining Houses. In addition, since much of its expertise is applicable to other mining sectors, manufacturers and related industries, the market for its services is increasingly reaching beyond the gold and coal mining industries of South Africa, with work now being done for the local platinum industry and for other mines internationally.

As it enters into this new era of operation, COMRO can look back on more than a quarter of a century of innovative service to the gold and coal members of the Chamber of Mines of South Africa, in the process of which it has helped make the South African gold mining industry a technological world leader.

And for the future - given the time spans that are required for new developments to evolve, COMRO is looking now for solutions to the mining problems of the year 2000. Already a range of novel and innovative technology that will assist in assuring the continued viability of deep level gold mining, with its unique and challenging problems, is nearing full development.

WORK SPONSORED BY GOLD PRODUCERS

The lightweight 3 m/s rockburst prop and load spreader installed within a metre of the face in a deep gold mine. Note that the support comprises an integrated system of props, matching extension pieces and load spreader to ensure maximum coverage of geological and stress induced fractures, thus providing workers with maximum protection in the event of a fall of ground.

Areas addressed by the co-operative research programme conducted on behalf of the gold mining industry during 1992 were concerned primarily with health and safety and thus focused on Rock Pressure and the Environment, but also included certain projects, impacting mainly on productivity, but considered crucial in the short term.

ENVIRONMENT

The creation of underground environments that are conducive to health, safety and worker satisfaction, and hence improved productivity, is a crucial concern of the gold mining industry. With mining activities continuing at great working depths and hence high virgin rock temperatures, the control of heat released into the environment remains critical, while the provision of cooling and ventilation is becoming ever more costly. There is thus scope for improving the utilization of existing cooling and ventilation systems and for the incorporation of new technology.

Mines also need to control the quality of the air in the underground environment in terms of dust, ionizing radiation and other pollutants, while, on surface, the Industry is coming under increasing pressure to reduce the negative impacts of the mining operation on the environment.

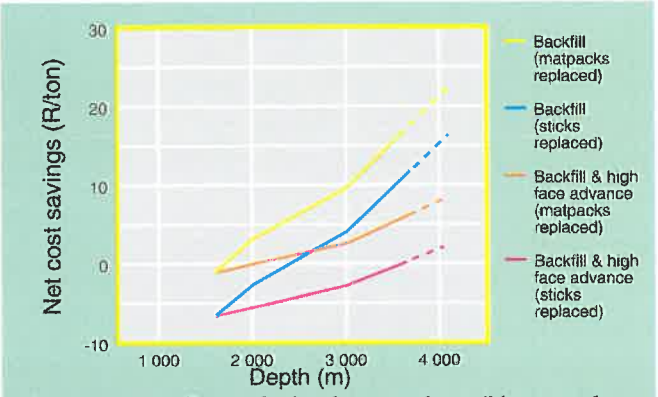
Current research into cheaper and more efficient methods of ventilating and cooling mines is concerned with developing user friendly software for improved heat load analysis, identifying and evaluating, quantitatively, methods for reducing mine cooling requirements, and evaluating the technical and economic feasibility of novel cooling systems. To assist the Industry in meeting environmental legislation, research is also being conducted on methods of ameliorating the effects of mining operations on the water environment. The protection of workers is approached through the development of cost-effective strategies for air quality monitoring, evaluation and risk assessment, and the development of a system for radiation dose limitation and control, appropriate to the needs of the gold mining industry. In addition, assistance is provided with the application of new, more acceptable heat stress management procedures, and monitoring has continued of the implementation of self-contained self-rescuers for the protection of workers in the event of a fire or explosion underground.

MINE VENTILATION AND COOLING SYSTEMS

The considerable advances made in recent years in addressing the heat problem in deep mines have enabled the technical feasibility of cooling mines to depths of 4 000 m to be established and demonstrated. However, the costs associated with providing this cooling are a major part of the total cost of mining. Work in this area is therefore directed at assisting the Industry in reducing the costs and improving the effectiveness of mine ventilation and cooling systems, by identifying and quantifying technical problems common to the Industry in general, and developing and applying improved diagnostic and problem-solving computerized tools to assist mine staff in taking corrective action.

Progress

During 1992 the main emphasis was directed at improving existing and producing new computer software to provide better tools for mine ventilation departments to reduce operating and capital costs, whilst simultaneously gaining tighter control over underground environmental conditions. The improvements relate to more powerful features in the programs and to experimental validation of some of the more recent programs. This resulted in the release of ENVIRON 2.0, an updated version of ENVIRON, used extensively in the Industry to simulate mine ventilation and cooling systems. The new version includes major improvements, introduced in close collaboration with users, to provide the capability for "what-if" studies.



The diagram indicates the breakeven and possible cost reduction in Rands per ton for new mines, when backfill is used for replacing either pipe sticks or matpacks. Two cases are shown, one a more conventional face advance rate of 7 m/month, and another for a high face advance rate of 20 m/month. (The latter case does not take into account the significant cost reductions achievable from changing to higher face advance rates.)

COOLFLOW, a program for the simulation and optimization of cooling water distribution systems, was updated, following its original release, based on user-feedback and on an underground experimental verification exercise. CYCHEAT, a new generation program was validated for the assessments of dynamic effects in ventilation and cooling systems, such as the influence of diurnal temperature changes on surface, or sudden changes caused by system failures or planned temporary shutdowns. This program has important applications for determining cost saving potentials from interrupting cooling over weekends and for assessing safety aspects in emergencies. The program STRIPPER, used for the analysis of insulation strategies for cooling water pipes, was also experimentally validated. Extensive assistance was also provided to program users for modelling increasingly more complex and larger networks, encompassing entire mines. These important developments allow significant improvements in the benefits which can be derived from modelling, both from a cost reduction and safety point of view.

Investigations to identify and quantify, on a general Industry-wide basis, opportunities for improving the effectiveness and reducing the costs of existing systems continued during 1992 with a major study on the effect of replacing conventional support with backfill on ventilation and cooling costs. The investigation, conducted as an inducement to mine specific studies, made use of the program ENVIRON and simulated an entire mine over a full range of mining depths, to assess potential cost reductions. The results showed that backfilling can result in significant net cost savings, taking into account the savings in ventilation and cooling costs versus the cost of the support medium.

NOVEL COOLING SYSTEMS

As the depth of mining increases, the costs of providing and distributing chilled water for cooling the workings become unacceptably high. While means of increasing the effectiveness and reducing the costs of existing systems are being investigated, new cooling system technologies are becoming available, some of which are already being implemented on a limited scale. In the light of this, and other factors affecting the future operation of water chilling installations (such as the Montreal Protocol), there is a need to assess the potential benefits of new cooling technologies that do not make use of chilled water.

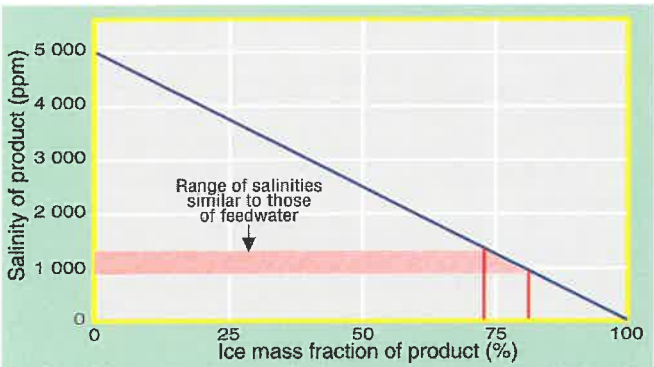
Work in this area is thus aimed at providing a means to evaluate new technologies on a comparative basis for any mining situation, taking into account technical, economic and future legislative factors.

Progress

During 1992 many of the uncertainties regarding slurry ice were addressed and the problems highlighted in 1991 were solved. For example, the original four tubed slurry ice concentrator was identified as being unstable and susceptible to blockages. A modified single tube concentrator was therefore designed, commissioned and found to operate in a satisfactory manner. Typically, the ice mass fraction of the product is in excess of 75 per cent with a salinity as low as 900 ppm - 10 per cent less than that of the feed water.

Slurry ice with a high mass fraction was also successfully conveyed, pneumatically, from surface to underground in tests. An evaluation of the performance of the key components in the distribution systems, such as rotary valves, pipes, bends and diverter valves, was completed, and the results are being used in the preparation of guidelines for the design of distribution systems for complete mine cooling systems based on the use of slurry ice.

A feasibility study on the performance and costs of different cooling systems, including refrigeration plants using refrigerants R22 and R134a and water vapour, was carried out. The effect of seasonal variations on the energy requirements of the complete cooling systems was optimized for typical variations in ambient temperatures. Other parameters influencing the choice of system, such as ease of maintenance and available technology, were also covered.



The relationship between the ice mass fraction and salinity of the ice product is shown together with typical operating measurements. The new concentrator with additional drainage facilities enabled an ice product with a lower salinity than the feed water to be produced on a continuous basis.

AIR QUALITY CONTROL

Personal gravimetric sampling has been introduced on mines to monitor worker exposure levels to airborne particulate contaminants. With this method of sampling, worker exposure over a full shift is quantifiable and it is also possible to identify and evaluate concentrations of pollutants other than the primary pollutant, quartz, where analytical techniques have been developed.

Major objectives of this project are to compile and interpret information on personal gravimetric dust sampling results and international literature on diesel emissions, and to establish cost-effective sampling and analysis techniques for an extended list of airborne pollutants.

Progress

Progress was made with the compilation of literature on diesel emissions with nearly 300 papers referencing several aspects of the operation of diesel powered equipment in underground mines having been collected and analysed.

As part of the objectives to reduce costs and efforts in implementing the Department of Mineral and Energy Affairs' dust sampling programme, work continued with techniques for recombining the respirable and coarse fractions of the collected dust samples, once quartz analysis has been performed. Whereas quartz analysis is performed on the respirable fraction of the dust sample, analysis for other pollutants is done on Total dust. The collection of only Total dust samples, a technique not yet proven satisfactory, would exclude the possibility of any quartz analysis and implies the necessity to duplicate sampling efforts and thereby increase sampling costs. A promising approach to re-combine the two dust samples has been identified; this involves placing a suitable thimble in the catchpot of the separating cyclone to trap the non-respirable fraction of the airborne dust. Once the respirable fraction has been analysed for quartz content, the two fractions can be redeposited together for further analysis. Currently attention is being directed at refining the design of the necessary hardware.

A simple technique has been developed for determining the soot component - Respirable Combustible Dust (RCD) - of airborne dust samples for mines operating diesel powered vehicles underground. The technique focuses on the use of ultra-lightweight crucibles to obtain improved accuracy in successive weighting of samples and was submitted in 1992 to the SABS for approval.

RADIATION PROTECTION

Radiation protection techniques in use by mines overseas tend to be based heavily on personal monitoring techniques, making them inappropriate for South African gold mines with their large labour forces. The aim of work in this area is to develop a system for radiation dose limitation more closely suited to the South African mining industry, thereby assisting the Industry in minimizing the cost of radiation protection on its mines while maintaining levels of health and safety acceptable to the regulatory authorities. This work comprises firstly the provision of direct support in establishing, for the Industry as a whole, data on the distribution of radiation doses underground and on surface, data on radioactive wastes, and the cost impact of radiation protection measures which might become necessary. This

information will assist in influencing international recommendations and standards concerning radiation protection on mines, and in establishing the scope for reducing the radiation problem at source. It will also guide the development of appropriate engineering and mining methods for reducing the problem, and will provide the basis for establishing appropriate protection strategies.

Secondly, instrumentation, techniques, special knowledge and strategies for selecting optimal approaches to the problem of radiation protection in mines are being developed. The development of improved, low cost instrumentation and modelling techniques will form the basis for devising cost-effective strategies for radiation monitoring and dose limitation suited to South African gold mines, while the quantification of key factors fundamental to the determining of exposure limits will provide a basis for modifying broad international norms to take account of local circumstances.

Progress

An Industry-wide radiation survey, under the auspices of the Chamber Standing Committee on Radiation and co-ordinated by COMRO, commenced in 1992 to provide information for assessing the impact of radiation in mines on workers, and the potential economic and social implications of instituting radiation protection according to new international recommendations. This information was also requested by the International Atomic Energy Agency to assist in deriving, during 1993, appropriate international guidelines on safety standards for the implementation of radiation protection in mines. In this regard, a preliminary assessment of the risks associated with radiation from South African mines was presented at an International Conference on Radiation Safety in Uranium Mining.

Certain key factors such as lung ventilation rate, hours worked per annum, working life and the relative toxicity of radionuclides underground, used to convert radiation exposure assessments to radiation dose (the basis used internationally to establish acceptable radiation exposure and health risk limits), were investigated for application in a radiation protection system specific to South African mines.

Needs identified during deliberations between the mining industry and the regulatory authority are being addressed by appropriate Chamber working groups, with some of the areas covered by these groups being addressed by COMRO. For example, the working group on radiation surveys, chaired by COMRO, compiled interim guidelines for screening surveys required for compliance with Council for Nuclear Safety licensing conditions. A computer program (RADBASE) for the collation and reporting of radiation measurements was also developed. COMRO is also actively involved in the Waste Management Working Group activities to establish the type and extent of radioactive waste in the mining industry in order to provide the information needed to establish appropriate strategies for the management and disposal of radioactive waste from mines.

The development of a system for environmental monitoring is focused on developing a mineworthy radiation spectrometer for efficient measurement of radiation levels underground. Since international validation of the new radiation measuring techniques, as required by the local regulatory authority for use in South African mines, is expected to take some time, a basic technique for measuring radiation levels has been programmed into the radiation spectrometer in order to make it commercially available in the meantime. This technique was developed by COMRO and employed and validated internationally for many years. The spectrometer will therefore be made available in progressive stages of development; updates towards full capability will only require replacement of personal computer downloading and data analysis programs.

The radiation spectrometer for environmental monitoring. The instrument has been designed to measure all types of radiation underground and to log all relevant information. This information is retrieved and analysed using computer software being specifically developed for the purpose.

Development of a personal gravimetric track-etch radiation monitoring system reached an advanced stage with verification and calibration being completed during 1992. The system can be fully integrated with the gravimetric dust monitoring system being employed on mines and will eliminate the need for establishing a separate infrastructure for personal radiation monitoring. Certification of this technique for use in South African mines is being sought from the regulatory authority prior to it being made available commercially.

HEAT STRESS MANAGEMENT

A comprehensive Heat Stress Management programme has been developed which gives practical effect to the knowledge of human heat stress developed over the past 40 years. By eliminating heat intolerance from the work force and designing appropriate precautionary measures, it has been possible through this programme to provide procedures which are more readily acceptable to management and the workforce and which are more cost-effective than previous procedures.

Heat Stress Management consists of a short duration screening procedure to detect gross heat intolerance; and a period of natural acclimatization in the actual workplace underground, under special supervision and with precautions, especially where work can be classified as hard.

Work in this area is directed at assisting the Industry in implementing and monitoring the conversion from conventional selection and heat acclimatization procedures to Heat Stress Management, particularly in view of the major new responsibilities placed on mine management

Progress

More than 60 per cent of 'hot' mines in the mining industry have implemented Heat Stress Management since its introduction to the Industry at the end of 1991. Based on the results of tests conducted on these mines, approximately two per cent of the work force was classified as heat intolerant, or being unable to develop the requisite degree of heat tolerance and would therefore always be at risk of developing heat stroke and should not be permitted to work in thermal environments where the wet-bulb temperature equals or exceeds 27,5 °C.

Close monitoring of the implementation of Heat Stress Management commenced and feedback from mines using Heat Stress Management, as well as those planning to introduce the new procedure in future, revealed that the provision of drinking water, mandatory water breaks during the shift and the daily recording of environmental temperatures where workers are undergoing natural acclimatization were sometimes viewed as logistical problems. Through close interaction with the mines concerned, most of the above problems were addressed.

WATER QUALITY MANAGEMENT

The Industry is facing increasing pressure to address potential negative impacts of the mining operation on the environment, with, in particular, the introduction of the concept of an Environmental Management Programme Report, which contains a legally binding Environmental Management Programme, for defining and managing environmental problems. This has led to a need to define technically and economically viable procedures which can be practically implemented to ameliorate any negative impacts on the environment.

Thus the aim of research in this area, which is partially funded by the Water Research Commission, is to identify those ameliorating procedures that will reduce the costs of implementing Environmental Management Programmes (EMPRs). Guidelines will also be produced containing procedures and techniques which can be used in carrying out environmental impact assessments and audits. These guidelines will contain all the methods and procedures which were developed during the project and will be of specific benefit to the Industry in preparing EMPRs and subsequent updates, and implementing compliance auditing programmes.

Progress

Two mines on the Witwatersrand and West Wits regions respectively were identified as study sites to clarify and characterize the biophysical impacts attributable to mining operations. Also assessed are the impact and significance of operational and disused slimes dams, rock dumps and effluents from underground stopes and metallurgical plants on water quality and quantity, as well as on aquatic biota.

Monitoring at the Witwatersrand site commenced and important water pollution sources were identified. The significant impacts are being quantified in relation to a control site unaffected by mining operations. Initial assessments of various ameliorating procedures were initiated with a view to developing an integrated environmental management plan applicable to Witwatersrand mines.

The monitoring schedule for the West Wits site was finalized and sampling commenced, using the same parameters as the Witwatersrand site.

SELF-CONTAINED SELF-RESCUERS

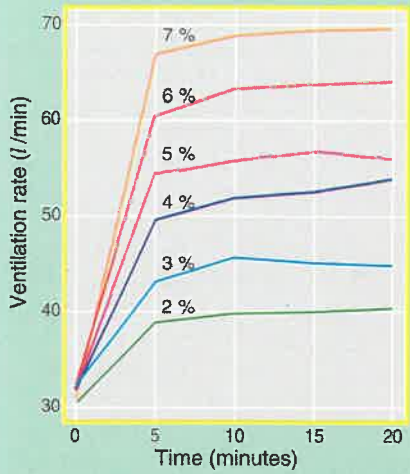
Body worn self-contained self-rescuers (SCSR's) were first introduced into the South African mining industry in the late 1980s as a proven but novel concept of providing protection to mine workers in the event of a fire or explosion. A considerable amount of research was therefore required to address various issues associated with the implementation of novel technology, including the need to ensure that SCSRs deployed on a daily basis on mines remain functional, and ready for instant use during an emergency. For this purpose, a pilot scale monitoring programme, funded by the National Energy Council (NEC), was initiated by COMRO on collieries. Although the merit of the monitoring programme was demonstrated at an early stage when adverse performance trends were detected in one of the units deployed on the collieries, the programme nevertheless suffered a number of weaknesses. A revision of the original programme was proposed to cover more fully the needs of the mining industry, with funding by the NEC.

Work in this area is thus aimed at the introduction of an effective programme for the South African mining industry.

Progress

Since the formulation of appropriate rejection criteria for SCSRs in daily use and an in-depth evaluation of logistics associated with the implementation of the revised programme were believed to be a prerequisite, research efforts during 1992 were directed primarily towards these issues.

Work to define rejection criteria reached an advanced stage. Physiological limits for inhalation of carbon dioxide were established, whilst experimental work to define limits for breathing resistance was also completed. Research to establish unacceptable inhalation air temperatures made good progress and it is envisaged that guidelines on rejection limits for SCSRs will be available at the beginning of 1993. The logistics associated with the implementation of the revised monitoring programme were investigated and a comprehensive instruction (guidance) manual which would cover, inter alia, the relevant sampling strategy and programme, a minimum mine record keeping system and reporting facilities reached finalization. Only a limited number of self-rescuers were withdrawn for testing from mines during 1992 but this will escalate during 1993.



The effect of increased carbon dioxide loads on ventilation rate during simula-ted escapes. Ineffective scrubbing of metabolic carbon dioxide in SCSRs could result in toxic carbon dioxide loads which could jeopardize the chances of escape during an emergency. Research suggests that a TLV-C (Threshold Limit Value - Ceiling) of 5 per cent could be adopted as a rejection limit for self-contained self-rescuers.

ROCK PRESSURE

The high rock pressures encountered in deep gold mines cause extensive and sometimes violent fracturing of the rock surrounding excavations and in combination with the aggravating effect of geological structures, can lead to rockfalls and rockbursts. These hazards are responsible for a large proportion of all injuries, and more than 50 per cent of fatalities and often cause serious production losses. Thus the major need for the mining industry, from the rock engineering point of view, is to ensure the safety of mine employees while promoting maximum profitable extraction methods to exploit the gold bearing reefs. Improved mine design and rock support methods are necessary to implement safer and more productive mining methods and layouts.

The Industry's rock pressure programme carried out through COMRO is therefore aimed at developing methods for achieving solutions to the problems resulting from extreme rock pressures. This includes improving mine layout design to minimize the effects of high stresses; improving support techniques to avoid the occurrence of falls of ground and rockburst damage; and reducing dilution.

However, the major effort is concentrated on the development and evaluation of rockburst control techniques using seismic management and engineering techniques to reduce the incidence and severity of the rockburst hazard. To facilitate these developments, fundamental research into the behaviour of the highly stressed fractured rockmass is essential.

ROCKMASS BEHAVIOUR

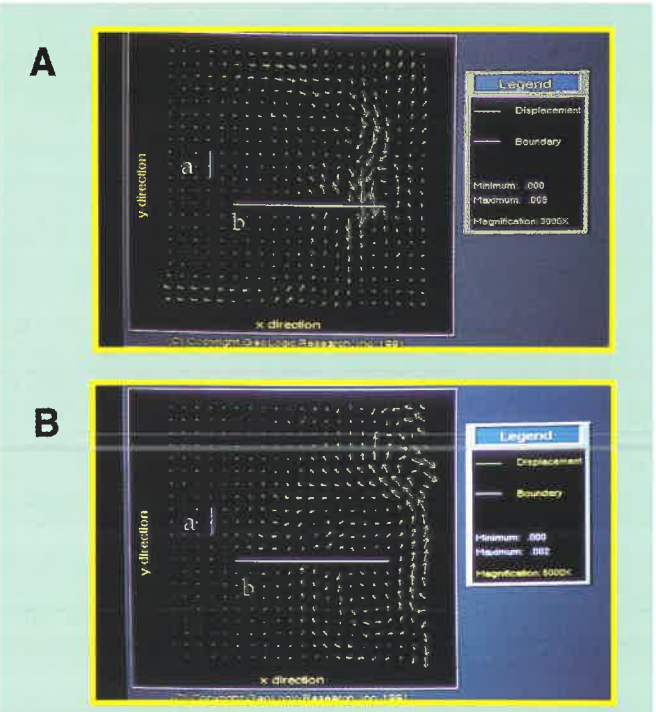
With a significant percentage of mining taking place between depths of 2 000 m and 3 000 m, the rockburst and rockfall problem presents the greatest threat to the safety of the workforce. This project investigates the fundamental nature of rock deformation mechanisms occurring in deep mines so that improved strategies for safer gold mining methods and layouts can be developed. The research in this area aims to provide an understanding of energy release processes in the stope fracture zone and the origin and propagation of hazardous fault slip seismic events and burst fracturing. Although essentially of a fundamental, long term nature, the work is so structured that, as sections of the project are completed, they can be incorporated into modelling and mine design programs and made available to the Industry.

Progress

Work during 1992 concentrated on three main areas: laboratory modelling, numerical model development and the application of models to understand stope deformation mechanisms.

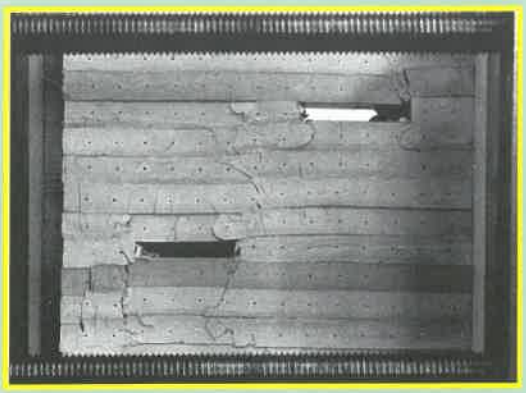
Physical laboratory modelling was carried out in-house and externally, in collaboration with a university. A particular theme of the experimental work was the effect of pre-existing discontinuities on the initiation and growth of fractures. The way in which the fracture zone around an opening is formed affects the stability of the zone and this knowledge makes an important contribution to the design of support. In one series of experiments, fracture initiation was studied using Brazilian Test specimens in which an existing discontinuity was introduced by combining two machined halves of each specimen or by pre-splitting an initially intact specimen. The load deformation curves for an intact specimen and a specimen containing a pre-existing discontinuity were compared, and demonstrated that the discontinuity facilitated the formation of additional fracturing and reduced the peak load. This type of result is of great importance in characterizing the deformation and stability features of the rock ahead of the stope face. Fracturing generated by numerical simulations using the DIGS computer code has demonstrated encouraging correspondence in the fracture patterns. Satisfactory agreement was also achieved between laboratory modelling and DIGS numerical simulations of fracture growth near openings in layered materials.

Various computer codes have been developed or are in the process of development to represent dynamic movements in the rockmass. The elastodynamic finite difference code, WAVE, was presented to Industry rock mechanics practitioners at a workshop and a user manual prepared and issued. A number of enhancements were incorporated into WAVE to allow sliding faults to be simulated and to enable initial stresses to be specified. The results of this work demonstrate that the transient elastodynamic state is not predictable from any static analysis and also emphasize the current need to develop elastodynamic design criteria and powerful graphic representations of dynamic movements.

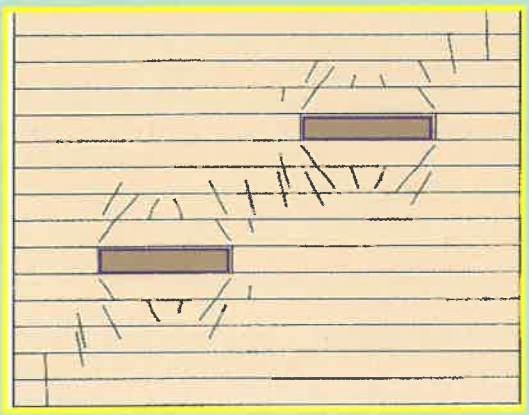


Interaction between seismic waves released by a vertical shear source (a) and a horizontal stope (b). (Photograph A) Snapshots in time of the particle velocity, plotted on a vertical window, highlight the current positions of the P- and S-waves (P-waves being compression waves and S-waves being shear waves). In photograph B, a diffracted P- and S- wave combination, which is reflected off the right hand stope face, is visible. The results are computed using the boundary element code TWO 4D developed by COMRO.

A



B



Additional laboratory modelling has been carried out to study fracture growth near openings in layered plaster-of-paris and cement material (A). The layers are confined laterally and loaded in a vertical direction. The corresponding numerical simulation (B), using DIGS, shows extension fractures which have been allowed to initiate from the layer interfaces at fixed seed positions. The agreement in the fracture patterns confirms the extensional nature of the initial fracturing.

Boundary element elastodynamic solution methods, which are complementary to the finite difference approach, have also been developed to allow increased flexibility in the representation of crack or tabular stope problems and to allow three-dimensional cavity problems to be solved. These analysis techniques provide insights into the relative motions (tangential and perpendicular) of the stope hanging- and footwall, which are crucial for effective design of stope support and for controlling the stability of excavations in rockburst conditions.

ROCKBURST CONTROL

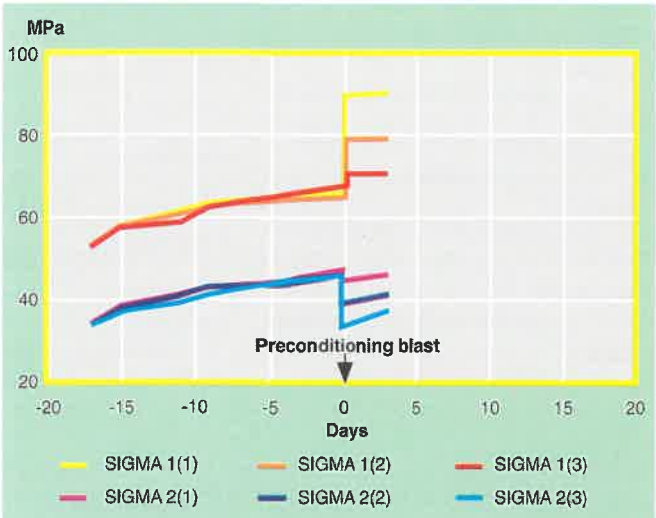
As mining depths increase and the proportion of South African gold mines which experience high rates of seismicity and associated rockbursts rises, a major goal of the research programme is to provide practical engineering and mining techniques for controlling the release of this seismic energy and thus minimize the number of accidents and the amount of damage caused by rockbursts. A fundamental contribution to this aim is the work on the understanding of rock-mass behaviour and source mechanisms of seismic events which cause rockbursts.

Two rockburst control mechanisms are being investigated; the one aims to control the seismicity which can cause face bursts and the other addresses the problem of seismicity generated by shear type failures associated with fault planes. A preconditioning technique, using controlled blasting three or four metres ahead of the face to create a zone of fractured, stress relieved rock, is being evaluated to address the problem of controlling the seismicity which can cause face bursts. For seismicity associated with fault planes, a fluid injection technique is being evaluated, whereby water is pumped into the fault to initiate controlled slip and thus relax stresses on the fault plane.

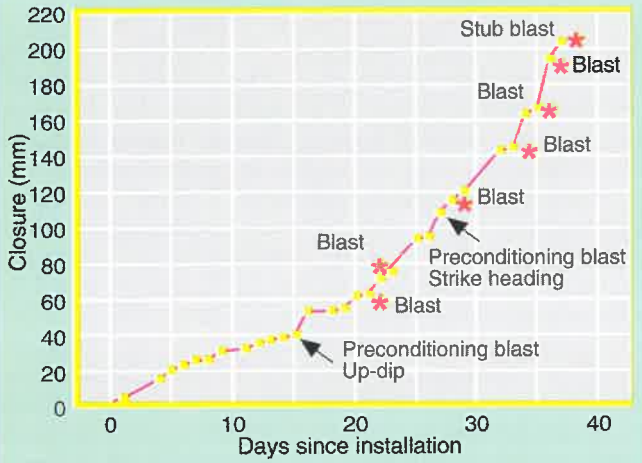
Progress

Invaluable experience was gained over the past year at the two mines where the preconditioning technique is being evaluated, particularly with regard to the capture and interpretation of data associated with preconditioning blasts. In 1992, changes made to the mining layout of the stope where the preconditioning technique is being investigated, allowed the preconditioning holes to be drilled on dip parallel to the advancing stope face. This enabled holes to be drilled quickly, equidistant from the face along their length, resulting in uniform preconditioning and minimal damage around the collar of the preconditioning hole. Considerable experimentation with different stemming types for the preconditioning holes contributed to the limited damage now being experienced around the collars of the hole. Attempts to achieve events of relatively large magnitude were successful; one of the blasts resulted in a 0,9 magnitude event. Closure measurements showed the effect of both preconditioning and production blasts on stope closures and confirm the localized influence of preconditioning blasts. Progress was made towards developing a seismic risk analysis using seismic data, closure measurements and ride movements.

Preconditioning blasting ahead of a development end at a



Stresses obtained from strain gauges installed close to the preconditioning hole at a development end. Assuming initial Sigma 1 and Sigma 2 values of 55 and 35 MPa respectively, there was a steady increase in stress until the preconditioning blast. Immediately following the preconditioning blast, the stresses increased by a maximum of 30 MPa and decreased by a maximum of 20 MPa for Sigma 1 and 2 respectively.



Plot of stope closure against time which shows localized effect of preconditioning blasts on closure. For example, the blast 15 days after installation was close to the closure station and significant closure was measured. However, the blast 27 days after installation was approximately 40 m from the closure station and no anomalous closure was recorded.

mine on the West Rand was carried out on three occasions using ANFO explosives for two blasts and emulsion type explosives for the other. The velocities of detonation and accelerations in the rock were measured using blast monitoring instrumentation. The effect of the explosives on the rockmass was evaluated by documenting fractures caused by the blast using stereo photography as the tunnel was developed through the preconditioned rock by normal production blasts. Techniques used for this evaluation included recording strain changes in the rock surrounding the preconditioning hole and quantifying the core recovery from boreholes drilled into the face after the preconditioning blast and through laboratory tests. Stress and Rock Quality Designation (RQD) changes before and after the preconditioning blast helped determine the stemming lengths, the spacing of preconditioning holes and the influence of different explosive types.

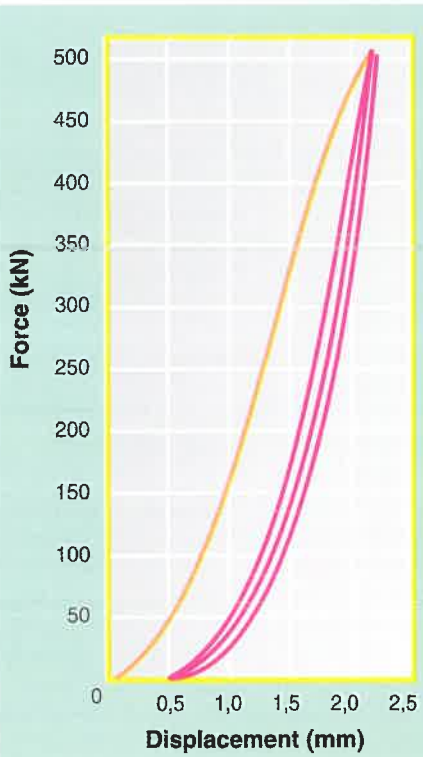
Work on the controlled fault slip project was continued at a mine in the Klerksdorp area. At this site, water is pumped into a fault at pressures of up to 30 MPa so as to initiate slip on the fault and thus release the build-up of stresses. The system, which is operated remotely for safety reasons, was successfully implemented during 1992 and more than a dozen full pumping exercises were carried out over the past year. During most of these trials, no seismic activity was recorded by the portable seismic system (PSS) network covering the site which could be directly associated with the fluid injection process. However, during a recent test, in which two holes, which intersected a fault loss approximately 10 m from each other, were pumped simultaneously, two seismic events of magnitude -0,9 and -0,8 were recorded by the PSS shortly after pumping began. The flow onto the fault was less than 10 litres per minute from each hole and the pressures were in the order of 26 MPa. The locations of the events were within metres of the intersections of the faults and boreholes. Seismicity records and extensive numerical modelling were applied in this work area to gain fresh insights into the problems of rockburst control and the application of appropriate techniques.

STOPE, GULLY AND TUNNEL SUPPORT

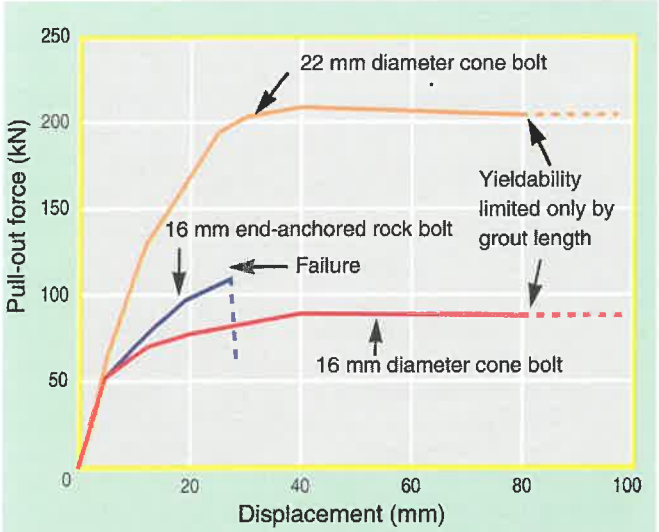
The need for support systems which are able to prevent rockfall accidents and minimize rockburst damage has long been recognized as an urgent priority by the gold mining industry. Thus the purpose of the project is primarily to improve worker safety with the concomitant aim of increasing productivity by developing cost effective support systems which are both practical and effective. Specific objectives are to control damage and increase safety in the stope face area, where the majority of accidents occur, with particular emphasis on the development of lightweight rockburst hydraulic props and elongate headboards and on the development of energy absorbing support units for tunnels in rockburst prone mines.

Progress

The first prototype lightweight 3 m/s rockburst hydraulic props were produced in 1991 in collaboration with manufacturers and in 1992, in the light of laboratory test results, a considerable amount of redesign, principally of valves and the prop shell, as well as certain other accessories, was undertaken. These props, with a mass of approximately 30 kg which is about 17 kg less than the currently used rockburst props, are set to yield at below 20 tons during normal operations. However, should a rockburst occur and the stope close rapidly, the props are able to yield at between 40 and 50 tons at a rate of up to 3 m/s, absorbing large amounts of energy in the process. Four hundred of these prototype props were used in underground evaluation trials which



The force displacement curve of a rockburst prop load spreader up to 500 kN (50 tons). Note that after the initial deflection of 0,5 mm, repeated cyclic loadings of up to 50 tons do not result in further deformation of the loadspreader.



A force displacement curve illustrating the high yield force of a 22 mm diameter cone bolt compared to a 16 mm diameter cone bolt. The limited ability to yield of the conventional rock bolt is shown for comparison.

revealed the need for further design changes. Currently, the props produced by one of the three manufacturers who collaborated with COMRO on this work have proved satisfactory, and it is anticipated that the props being produced by the other two manufacturers will be proved mineworthy shortly.

Load spreaders are considered an essential component of the hydraulic prop support system and the prototype load spreaders developed in 1991 were refined in 1992 with the main emphasis on a further reduction of mass. A steel cast version with a mass of 14 kg was developed and it is believed that this low mass will encourage extensive use of the units. The design was patented and the load spreaders proved satisfactory in extensive field trials.

The development of a stope gully pack, which is able to accommodate extensive deformation without generating increasingly high forces, was undertaken with a collaborator. The use of these packs to support gullies will reduce sidewall damage resulting from high pack forces. This damage, which causes foundation failure, can result in the conventional gully pack support collapsing into the gully during a rockburst. Laboratory tests yielded promising results and the packs are being evaluated underground.

With regard to tunnel support, implementation of the energy absorbing cone bolt yielding tendon continued during 1992 and to date almost 15 000 units have been installed. In addition, alternatives to the original 16 mm cone bolts were produced; a 22 mm diameter cone bolt which has double the energy absorbing ability of the conventional 16 mm cone bolt and a cable cone bolt designed with the ability to resist shear by fractured rock more effectively than the solid bar cone bolt. It is envisaged that these flexible cone bolts will be used as yielding cable support up to 6 m long in areas prone to large deformations.

REGIONAL SUPPORT SYSTEMS

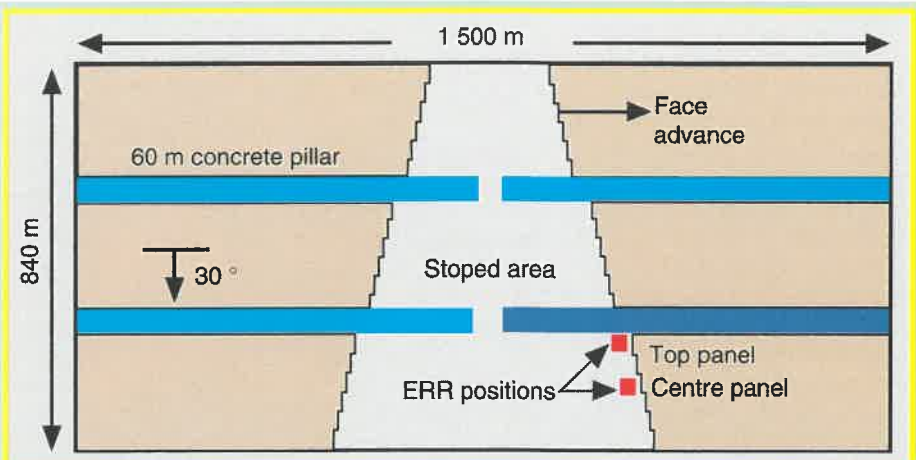
The gold mining industry needs design criteria and guidelines for improved regional support systems to reduce the frequency of damaging seismic events. The project aims to supply Industry with better methods for the routine modelling of large-scale elastic and inelastic deformations around deep level workings to enable rock engineers to design safer mine layouts based on a realistic assessment of geological conditions. Specific attention is being given to problems such as the effectiveness of backfill as a regional support, pillar foundation failure associated with current stabilizing pillar layouts and the potential benefits of replacing reef pillars with concrete pillars.

Progress

A new version of MINSIM-D with pre- and post-processor extensions was released in 1992. In addition, two-dimensional versions of the non-linear programs,VOLSIM and HYBRID, were also made available to rock engineering practitioners from the mining industry and four courses were held during the year to train rock engineers from the mines in the use of the programs.

The effectiveness of backfill as regional support for reducing the number and magnitude of seismic events was reassessed. However, data from mines where backfill is being placed on a mine-wide basis for extended periods will provide conclusive information on the effects of backfill on regional seismicity.

Ground motion measurements to determine the influence



Typical 60 m wide concrete strike stabilizing pillars placed in advance headings. Regional stability using concrete pillars can be achieved provided that the concrete placement occurs in low closure environments to allow sufficient time for cementitious bond strength to develop prior to stoping. The mining sequences would therefore consist of the establishment and ledging of a raise connection to overstope access crosscuts; concurrent mining and filling with concrete of advance headings; and then the stoping of interpillar areas. Average pillar stress and energy release rate calculations were concentrated on the pillar shaded in dark blue.

of backfill on the response of underground excavations during large seismic events were completed. Analysis of these large seismic events with magnitudes between 0,5 and 3,2 revealed that backfill reduces both peak ground velocities and accelerations and that there is a reduction in the differential movements between the hangingwall and footwall of backfilled stopes.

The in situ and laboratory performance of cemented backfill was determined with good correlation observed between the two sets of results. Vertical backfill stresses of up to 6 MPa were measured in stopes after about nine per cent strain, where the stoping widths varied by between three and four metres. The shrinkage was negligible and this contributed significantly to the success of the cemented backfill used at the mine.

At two different mines in the Carletonville area, the in situ behaviour of stabilizing pillars is being observed and the seismicity associated with these pillars is being monitored using portable seismic systems. Preliminary ground penetrating radar readings showed a 5 m to 6 m fracture zone at the sides of the pillars. Doorstopper and closure measurements also commenced in the vicinity of the pillars.

An investigation into the use of concrete pillars placed in advance headings for deep level regional support indicated that the system is both technically and economically viable. Detailed cost and rock mechanics analyses were carried out for a longwall layout at 3 000 m. These show that existing reef stabilizing pillars could be replaced with concrete material of 10 GPa stiffness, with increases in face energy release rates of 10 per cent to 25 per cent, depending on the effectiveness of the concrete placement. However, the use of concrete in place of pillars would also reduce the seismicity likely to occur due to stabilizing pillar foundation failure. The use of concrete pillars has the potential to increase the life of the mine by 15 per cent to 20 per cent.

GROUND PENETRATING RADAR

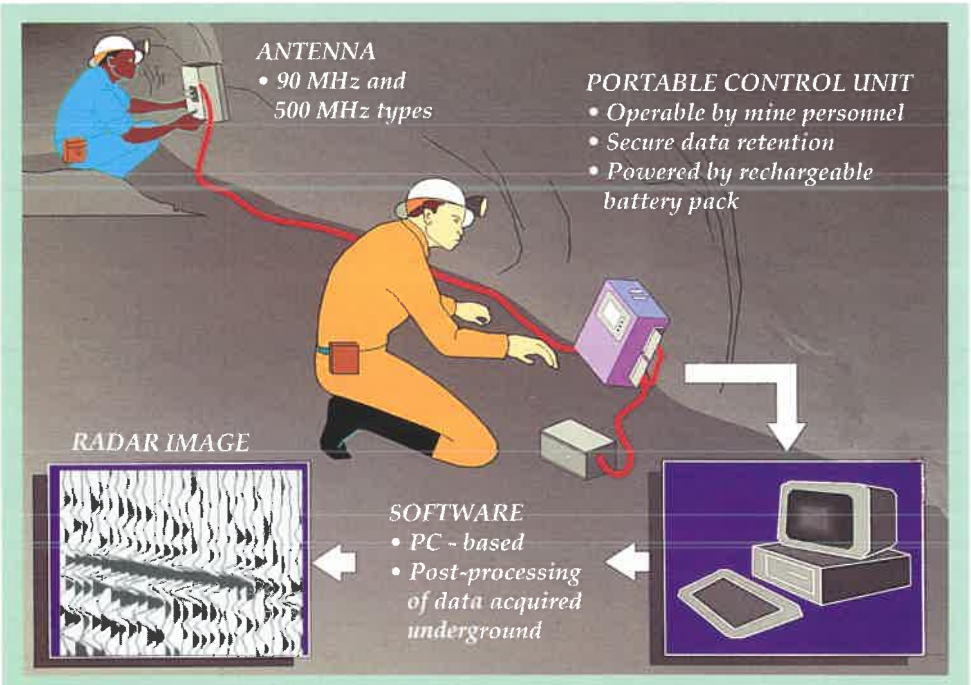
The mining industry requires cost effective methods for detecting hazardous conditions in advance of mining, such as the presence of geological structures, and the depth and extent of fracturing around excavations. The purpose of this project is therefore to develop ground penetrating radar equipment as a viable tool for mapping faults, dykes, fractures and other rockmass features within a few metres of an excavation.

Progress

Previous work using commercial ground penetrating radar equipment highlighted a number of mining applications where this technology satisfied important Industry requirements. However, it was established that a development programme was required before equipment and software could be provided that is able to withstand the harsh underground environment and can be operated as a routine tool in the mines. Accordingly, a functional specification for a mineworthy ground penetrating radar system was prepared, and equipment suppliers with the necessary technological and manufacturing capabilities were approached.

During 1992, a commercial manufacturer of ground penetrating radar equipment was contacted to develop this system, which comprises a portable control and data acquisition unit, two types of radar antenna, and software for processing mining radar data on a PC. Detailed specifications and designs were completed, combining proven technologies or updates thereof, to meet the requirements of mining applications. A feature of the instrument is an automated data acquisition function; this will allow data to be efficiently collected in confined spaces by mining geologists or rock engineers with relatively little exposure to geophysics. To meet the physical requirements of the mining environment, the instrument has been designed for low battery power consumption in a lightweight package of robust construction that is intrinsically safe. Sub-systems of this design have been built and successfully tested as part of the process of constructing a full prototype for field evaluation.

Application work performed during the year included establishing a routine radar measurement procedure for investigating the change in fracture patterns before and after preconditioning blasting conducted in stopes and development ends (see page 31). A simulation test site was built for the purpose of quantitatively assessing the response of ground penetrating radar to different configurations of rock fracturing. The information generated from this site is of great importance for the interpretation of radar fracture data acquired underground.



Mineworthy ground penetrating radar system

SPECIAL PROJECTS

Certain projects, not directly concerned with health and safety, were included within the co-operative programme on the basis that they were nearing completion or were considered crucial in the short term. This work was concerned primarily with the development of cheaper, safer and more efficient mining methods and technologies.

METALLURGY

A study to assess the effect of feed size distribution on autogenous mill performance and thereby optimize the milling operation, enhancing recovery and reducing the cost of processing, was completed by a contractor utilizing a fully instrumented test facility. The results showed that, as the amount of coarse material in the feed was reduced, the mill throughput was reduced but the grind achieved was finer. However, the energy efficiency of the operation was poorer mainly because of the build-up of intermediate sizes.

WINDER ROPES

Current regulations on the selection of winder ropes are based on the maximum static load, while the discard criteria are based on the deterioration in the strength of the ropes. Due to an incomplete understanding of the rope deterioration mechanism and the dynamic loads in the ropes, it is not possible to determine the true reserve or real factor of safety in a hoisting system. Proposed regulations are being drafted which are aimed at limiting both the deterioration of the ropes as well as the dynamic loads imposed upon them. This will allow the use of higher static load factors, enabling the rope strength to be exploited more fully, while maintaining a known and adequate safety reserve.

The objectives of research in this area is thus the development of improved rope selection criteria. This will enable an increase in the load carrying capacity of current conventional shaft winding systems, and the depth of hoisting for future systems. This work will not only reduce costs in shallow mines, but in future deep level mines will also enable the orebody to be accessed without the need for a sub-vertical shaft, and also reduce the time for workers to reach the face.

Progress

A study of the dynamic rope forces exerted on winder ropes, involving the measurement and analysis of drum dynamics, was completed on 20 winders providing quantitative input for the proposed changes in rope safety regulations. As part of the study existing software to calculate rope dynamic forces was modified, and used together with rope stiffness measurements of new and used ropes to verify the relevant factors in the proposals. Additional work on the effect of emergency braking on peak rope loads was also completed, and confirmed that it will be possible to limit dynamic loads by appropriate specification of static factors and maximum conveyance acceleration.

Regarding recommendations for amendments to the Factor of Safety regulations, a final draft of "Proposed Changes to Rope Safety Regulations" was completed and presented to the Department of Mineral and Energy Affairs (DMEA). This document proposes Phase I changes to the regulations by addressing dynamic loads. The development of a Code of Practice for non-destructive Rope Condition Assessment was assigned a high priority, as this Code will be used in Phase II as a basis for seeking dispensation for winder operation at lower static factors, on the premise that early fault detection will lead to safer winding. A final draft of the Code was completed for consideration by the DMEA, and addressed rope discard criteria, non-destructive testing (NDT) equipment and procedures for ropes.

Work on identifying rope deterioration mechanisms was aimed at providing input to the feasibility study on a rope testing facility, and providing support for changes to the rope safety regulations. Work on the mathematical modelling of rope wear was completed, based on analysis of a set of discarded ropes. An investigation into the strength of rope terminations showed that splice efficiency is very dependent on rigger skill, indicating the need for further research to establish the performance of other types of terminations and to identify safe rope terminations, less dependent on artisan skill. Monitoring of new rope designs continued with a manufacturer completing, in conjunction with a mine, a field trial of non-spin ropes to assess in-service performance.

SHAFT STEELWORK AND CONVEYANCES

Design guidelines for the dynamic performance of shaft steelwork and skips have been published, but need to be enhanced by attention to such issues as sustained slamming, different guide stiffness in one compartment, and the applicability of the guidelines to cages. In particular, misalignment of the shaft guides remains a major cause of slamming of the conveyance, leading to guide roller tyre failure and fatigue damage to the conveyance and shaft steelwork.

Research is directed at developing design methods for shaft steelwork and conveyance guidance systems that account for dynamic behaviour and facilitate reliable high speed winding. This is being pursued through developing an accurate and economic means of measuring shaft steelwork misalignment to facilitate maintenance, and compiling guidelines for the design and selection of guide rollers.

Progress

Investigations to date on the design and selection of guide rollers have shown that guide roller systems should be custom designed in each conveyance/steelwork configuration to account for system dynamics. Draft design guidelines, developed during 1991 to facilitate this process, were used to design optimal guide roller systems for three different configurations, with the results being verified on a dynamics test facility. They were also used to design optimized guide rollers, using commonly available solid tyres, for a 22 ton skip on a mine. In the field trial at this mine, a variety of spring and damper settings were evaluated to verify the new design approach, and to provide data for the verification of simulation models in the future. A prototype guide misalignment measuring device was optimized and work was also conducted on enhancing the existing steelwork design guidelines by investigating and reporting on sustained slamming, different guide stiffnesses in one compartment, and applicability of the guidelines to cages. Efforts commenced to establish whether the approach adopted in the shaft steelwork design guidelines is adequate to avoid sustained slamming. The development of a suitable analytical model for this purpose was completed towards the end of the year.

Analysis and testing of the more promising solutions to the problem of loading and unloading conveyances in deep shafts were completed with a specific cage holding system being identified as a viable solution to rope stretch problems. This device, developed over a period of 20 years, uses friction clamps to hold the conveyance during loading and unloading. Over the past 18 months significant advances have been made in controlling the release rate of the clamps. Previous maintenance problems have also received attention and the device is now almost maintenance free. Tests by a mining House have confirmed that controlled release of the conveyance after loading/unloading leads to significantly reduced dynamic rope loads, and field trials of the device have been initiated by the manufacturer, with assistance from the mining Groups.

GOLD ANALYSER

Reef valuation in gold mines is currently performed by the chip sampling and fire assay method. This technique provides a relatively imprecise valuation as a result of the low sampling density, and significant time delays are incurred before the results are available. Work in this area has therefore been aimed at developing a portable instrument, the gold analyser, which scans the entire exposed reef thus increasing the precision of both stope face valuation and ore reserve evaluation. In most situations the gold analyser is able to provide rapid and more reliable information and this should enable mines to increase the grade of ore mined as a result of improved selection of mining faces.

Development of the gold analyser has reached the stage where a complete system for sampling and mine valuation has been designed and work is now focused on the initiation of production trials to establish it as a production tool.

Progress

Work followed two main routes: first, underground trials to identify the most appropriate methods of use for the instrument in a production mode and to establish the financial benefits and costs to be expected through routine valuation; and second, studies to facilitate the establishment of routine manufacturing and support facilities.

An underground field trial was conducted at Kinross gold mine during most of 1992 to identify the operational performance and the quality of ore valuation which could be achieved through use of different sampling strategies. This work involved the selection of different sampling intervals and durations for individual gold analyser scans. The instrument was used throughout the trial to conduct 1 m long scans of the face. A further trial was initiated at Vaal Reefs gold mine to obtain comparative information on a different reef and in different mining circumstances.

As a result of the experience gained and the data collected through this trial, it is now possible to advise mines more realistically on the operational and economic implications of selecting sampling strategies. However, further experience to be gained through scheduled full production trials will be required to facilitate a more comprehensive assessment.

Detailed preparations were also made to enable manufacture of production model instruments. A comprehensive costing study was undertaken to identify instrument capital costs and manufacturing schedules. This work included a review of the capabilities of suppliers of certain specialized components required for the gold analyser. In addition, improved estimates of maintenance and operating costs were generated.

STOPE BLASTING CONTROL

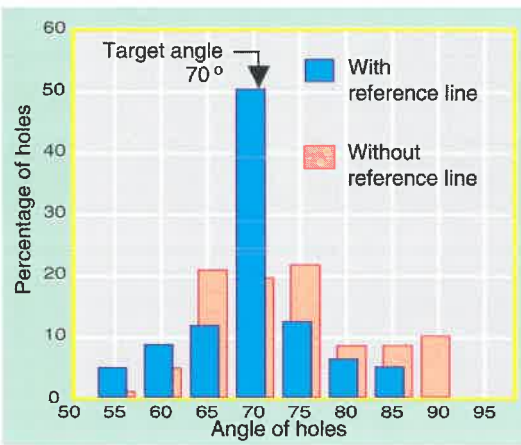
Improved blasting control has the potential to lower working costs by reducing the amount of explosive used, enhance the grade of ore transported and hoisted by reducing hangingwall and footwall waste production, and provide safer working conditions in the stope through improved hangingwall conditions. Control of the rockbreaking process may be achieved through ensuring that the correct amount of the appropriate explosive is placed in an accurately drilled hole and fired using a reliable and correctly sequenced initiation system. While the positional requirements and tolerances of the various explosives are known, these are not achievable with current blasthole drilling methods and thus a more accurate method of drilling is required.

The objective is thus to develop a drill guide and implement an intensive training programme which, together with previous blast design work and current work by manufacturers on initiation systems, will bring about the control of the rockbreaking process and maximize blasting efficiency.

Progress

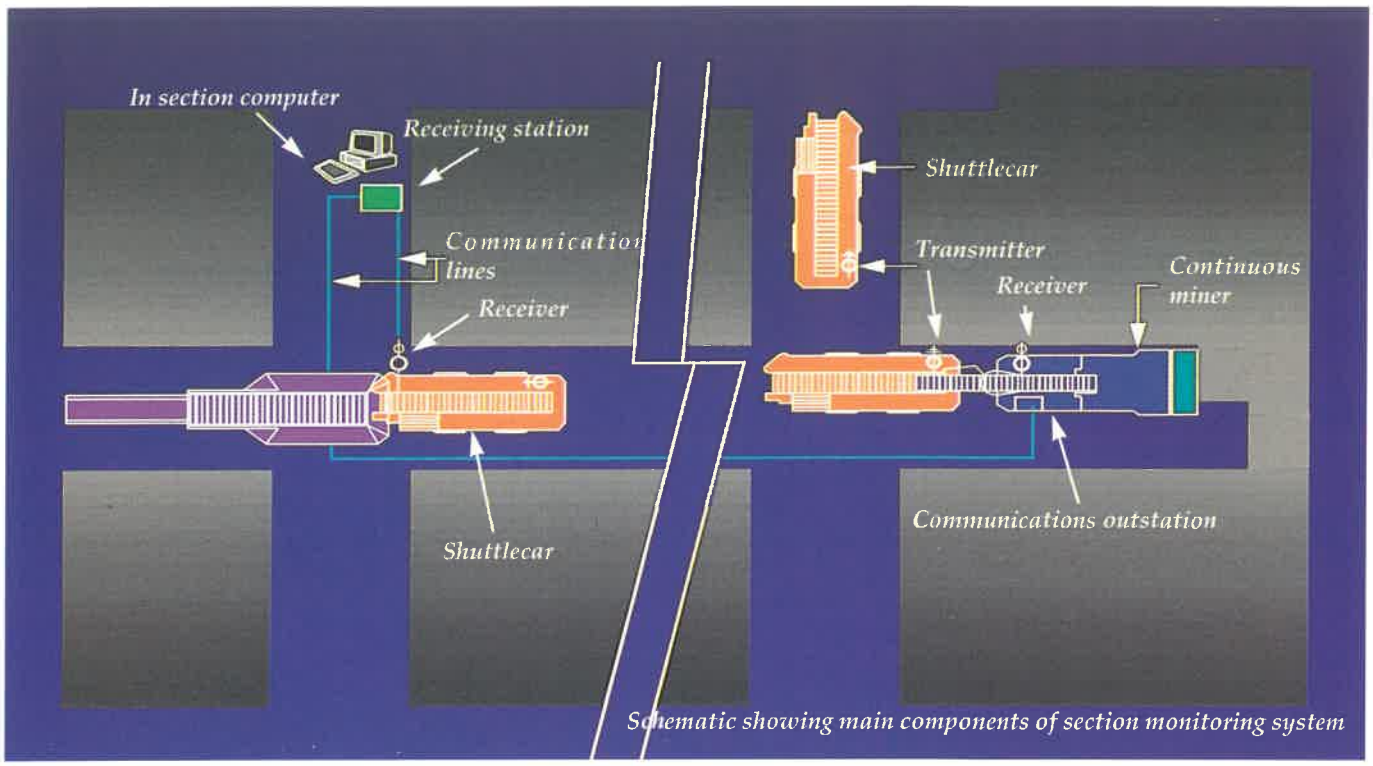
A variety of different methods to improve the accuracy of blasthole drilling have been pursued in the past with little success, and therefore investigations were first conducted to identify the causes and factors which detract from drilling accuracy. This information could then be applied in the development of operator training, drilling methods and/or equipment to facilitate accurate drilling. An assessment of training practices at mines revealed that, while a combination of supervision and training improved drilling results, further improvement could be gained by the provision of datums by which both the miner and the drill operator may assess drilling angles.

A device to determine the spatial position of a blasthole relative to a defined reference line was successfully developed, providing a method of quantifying the current accuracy of drilling. The measuring device is currently being used to gather data on drilling accuracy for correlation with drilling factors such as drilling method, operator training and experience.



The data in the figure demonstrate the improvement in drilling accuracy following the provision of a reference direction which in this particular case was established by installing support members parallel to the required drilling direction.

WORK SPONSORED BY COAL PRODUCERS



Schematic showing main components of section monitoring system

As much overseas experience and technology have been found to be suitable for application in the South African coal mining industry, the co-operative programme of research in this area has concentrated on those problems caused by conditions unique to South Africa. It is important that the recovery of coal reserves be maximized, that standards of health and safety be continually improved and that overseas technology and equipment be adapted to suit local mining conditions. Research in coal mining is thus conducted in three main technological areas: environment, mining methods and equipment and strata control. These three areas are presently covered by five projects, two of which address specific technological problems, namely, maximizing the underground extraction of coal and minimizing air-borne dust in colliery workings.

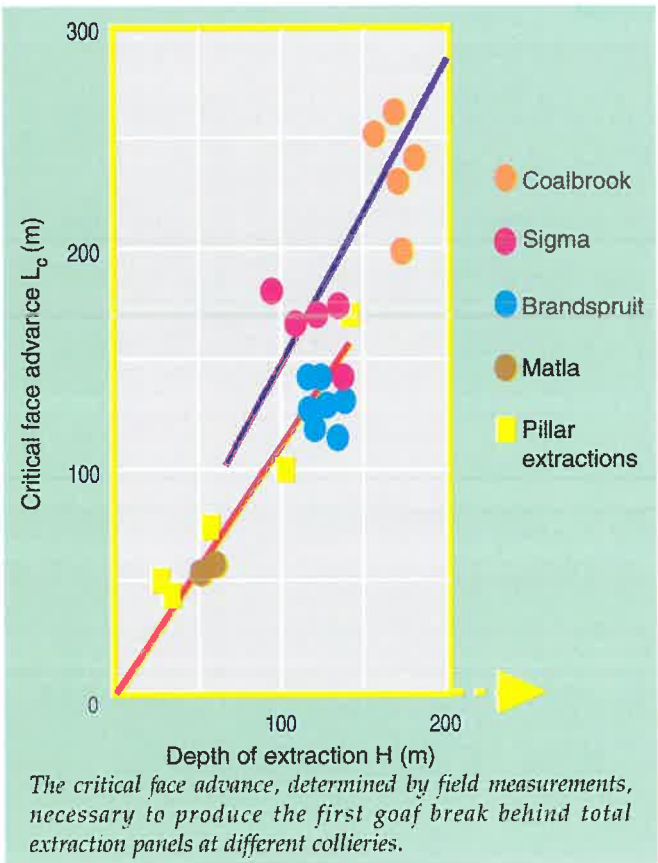
MAXIMIZING UNDERGROUND EXTRACTION

As the current reserves in many coal mines are approaching depletion, it is important to investigate all viable mining methods for safe extraction of the reserves currently locked up in the pillars of old workings. This project is concerned with the identification and development of mining methods and systems, suitable to South African mining conditions, for increasing the safety and productivity of high extraction mining. In addition, it also addresses the evaluation, prediction and effects of subsidence and strata behaviour above these high extraction panels.

Progress

During the past year, efforts concentrated on adapting existing methods used locally and overseas, or designing new methods for specific application on certain collieries. These include the extraction of small pillars of varying dimensions at shallow depth, extracting large pillars or virgin reserves at depth and increasing extraction where the surface strata need to be protected. A method of extracting alternative rows of pillars, employed on three collieries in Australia, has also been adapted for local collieries. A similar method was used successfully at a local colliery where five panels were extracted in a checker board fashion instead of in a straight line. The remaining pillars appear stable and surface subsidence above the panels is negligible.

The final version of the first part of the subsidence guidelines, taking the comments and recommendations of Industry into consideration, is in progress. General empirical norms of typical strata behaviour due to caving and surface subsidence behind total extraction mining operations were established. Deviations from the norm can be detected by observing the deflection and ultimate break of a dolerite sill or a competent sandstone layer, and thus concurrently assess the operational risk to and safety of advancing longwalls or pillar extraction panels.



The critical face advance, determined by field measurements, necessary to produce the first goaf break behind total extraction panels at different collieries.

Field results of the investigations into subsidence above interpanel pillars with the aim of reviewing the D/2,7 rule were completed and a report issued to the Industry for comment.

Five boreholes across a crush pillar between two longwall panels were monitored during the extraction of both panels. The influence on the final subsidence over the previous panel and the behaviour of the strata above the crush pillar were determined. The dimensions of the crush pillar at this colliery proved very effective as the surface subsidence above the crush pillar was only 100 mm less than the subsidence in the centre of the panels. This resulted in an even subsidence of the topography instead of the humps normally experienced above interpanel pillars. A monitoring programme is currently underway to determine the behaviour of strata above subcritical panels and nine boreholes have already been instrumented in the three adjacent shortwall panels separated by competent interpanel pillars.

STRATA CONTROL

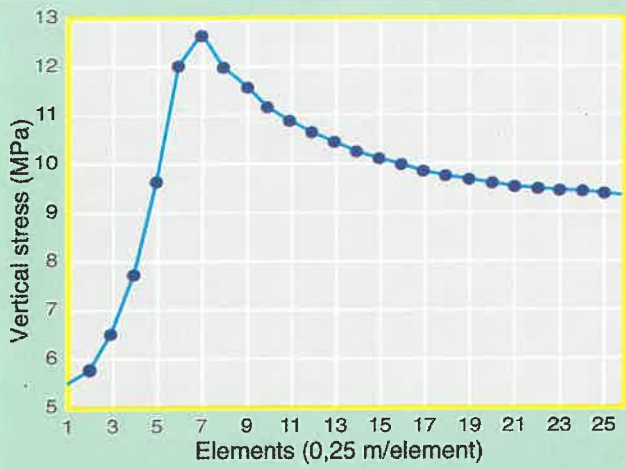
The need within the coal mining industry to increase the safety of underground workings, increase the percentage extraction and decrease the cost of support systems has necessitated a detailed investigation into improved mine design and support systems. Thus this project is involved in assessing pillars designed to new criteria; the effect of the macro environment, including floor heave, on the stability of pillars; the factors affecting multi-seam operations; and support systems and requirements for underground roadways and intersections.

Progress

Studies carried out into the strength of rectangular pillars showed that the depth of fractured zones is not dependent upon the pillar width but influenced by the pillar height and mining depth. In general, the knowledge gained through these investigations on pillar behaviour is presently being used to estimate pillar strength when designing rectangular pillars. A site investigation into the behaviour of surrounding strata in a stooping section was carried out at a Natal colliery. Floor heave and the behaviour of the immediate roof were observed and the results of the investigation together with 3-D numerical simulations are being compiled in a report. An underground study, as well as numerical simulations, was carried out to determine the most suitable mining methods for increasing the percentage extraction at a depth of 450 m to 500 m. This work is very site specific although some aspects can be applied to other mining situations.

Investigations at a number of collieries in Natal, where mining has been taking place over goafs, were completed. The findings indicated that the feasibility of mining over goafs is dependent on the ratio of the parting thickness to the lower seam mining height.

Numerical modelling was carried out to determine the effect of the barrier pillars in bord and pillar layouts in



Vertical stress distribution and the fractured zone using FLAC. These simulations confirmed observations that the fractured zone extended approximately 1,5 m into the pillar sides. (Depth = 252 m, pillar width = 32 m, mining height = 2,5 m).

multiseam configurations. It was determined that there is a relationship between the limiting distance (ie the distance above or below the seam where the stresses return to virgin stress) and the ratio of the barrier pillar width to panel pillar width. The current guideline recommending superimposition of barrier pillars if the parting is less than 1,5 C (C = centre distance of panel pillars) is only valid if the width of the barrier pillar is more than twice that of the panel pillars. If the barrier pillar is the same width as the panel pillar, superimposition will only be necessary if the parting is less than 0,9 C. Work is currently being carried out in the Eastern Transvaal to determine the effect of high extraction in the lower seam, on the upper seams. Alternative mining methods to maximize extraction in the lower seam without sterilizing the upper seams will also be investigated.

Preliminary investigations were conducted to measure load distributions along roofbolts. The tests, carried out with a locally manufactured strain gauged roofbolt, were successful and the first bolts were installed at a colliery in the Eastern Transvaal . Roof deflection during the development and pillar extraction of a number of sites was monitored and led to a better understanding of roof behaviour in local coal mines. Computer simulations were carried out at all the sites to determine the correlation between the actual measurements and computer simulations and in most cases the correlations proved very satisfactory.

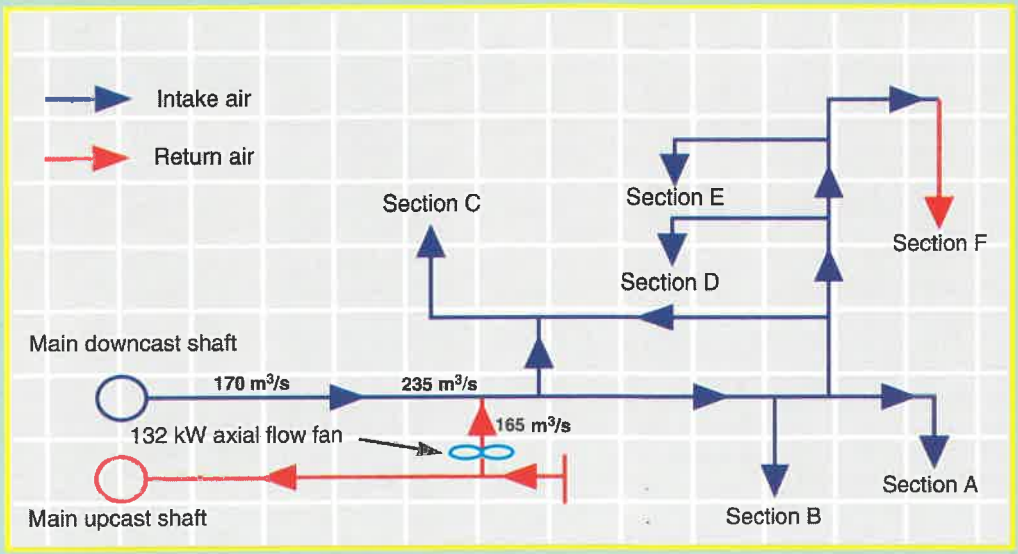
ENVIRONMENT

The improvement of underground working conditions with regard to safety and health, as well as the productivity of the workforce, is of primary concern to the coal mining industry. Work in this area, therefore, is of a medium to long term nature and is aimed at the development of procedures, systems and equipment which will contribute to improving conditions underground in collieries. Of particular importance in this regard is the development of techniques to reduce the methane hazard in the workings, to detect and control underground fires and to increase the efficiency of ventilation systems to control pollutants. In addition, the monitoring of self-rescuers and the development of rejection criteria, and studies of the effects of coal mining on the surface environment have been undertaken.

Progress

Work towards the development of a methane prediction model continued on schedule and most of the local coal seams have been analysed for sorption potential, diffusion characteristics and fracture network sizing. A two-dimensional model, capable of predicting the methane emission potential of a longwall face, was developed. This model will be expanded to include the prediction of methane flow from more complex situations, such as bord and pillar headings, and boreholes. A technique was developed to determine the distance at which holes should be drilled for methane drainage purposes. The adsorption and desorption potential of burnt coal was determined and it was found that such areas are prone to accumulate methane more readily than unburnt coal because of their increased sorption potential. In situ, burnt coal is also more porous and friable than unburnt coals and thus the available surface area for methane adsorption is increased. This confirms previous observations that high methane emission is encountered in the vicinity of areas of burnt coal.

A self-cleaning device for the sampling heads of pellister-type continuous methane monitors used on continuous



Layout of a ventilation district during a recirculation trial

miners was developed. Coal dust, deposited on the sampling heads of methanometers, tends to generate false alarms and repeated false alarms cause the reliability of the instrument to be questioned. In some cases the instruments are removed and other means of gas detection used. The self cleaning device removes the dust out of the air stream before it comes into contact with the sampling head and improves the reliability of the instrument.

Work on the recirculation of air within a ventilation district of a coal mine revealed that when up to one third of the available air is recirculated, no detrimental effects, particularly with regard to gas and airborne dust build-up, were recorded.

In cases of fire, the rescue and mine fire teams in local coal mines appear to favour the USBM explosibility diagram, although other ratios, such as Young's, Graham's and Trickett's are also used to identify the prevailing conditions within areas under fire. However, investigations revealed that none of these methods are entirely successful for all situations; for instance, it was found that the Coward's triangle is more accurate than the USBM diagram in the lower explosive spectrum. As a result of these studies, it became clear that the ideal tool for fire incidents would be a single computer software package which would provide a print-out of all the diagrams and ratios on a single sheet. This would enable all the information to be assessed at a glance and any inaccuracies would be immediately obvious. A set of guidelines on fire control procedures for coal mines is being prepared and should be available early in 1993. A short study at five selected mines of the contribution of underground coal mining operations towards global warming was launched. The study will include aspects such as the quantities of methane emitted from upcast shafts and an assessment of all gases being released from coal and waste dumps.

A brief study on two coal mines was also completed to determine radioactivity levels. Coal samples from two different seams were analysed in the laboratory and exposure levels of the employees working in the seams were monitored. Final results are still awaited but the preliminary indication is that the level of radioactivity is well below recommended exposure levels.

MINIMIZING AIRBORNE DUST

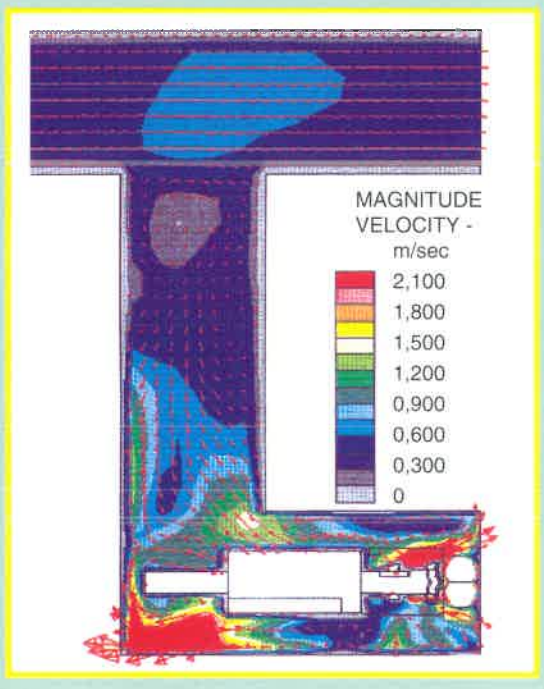
The levels of respirable dust to which underground colliery workers are exposed still give rise to considerable concern despite the efforts of the coal mining industry and manufacturers of equipment to institute effective dust allaying systems. A reduction in dust in underground workings is not only necessary to improve the health and safety of the workers but would also improve productivity through the provision of a better working environment. During 1992, work in this area mainly focused on determining the levels of awareness regarding dust in the Industry and developing integrated methods to suppress dust in the vicinity of continuous miners, which have been identified as the major source of unacceptable levels of dust.

Progress

A study was undertaken at a colliery to measure the degree of awareness of dust as a health hazard and to determine the levels of existing knowledge regarding the methods used to suppress respirable dust. The survey targeted mine employees from labourers to first line supervision and results indicated that although there was a lack of knowledge regarding the nature of dust and the ways of combating it, there is nevertheless a strong commitment to reducing the amount of dust. To assist mines, a trial dust awareness programme was implemented on the mine to disseminate information on the properties of dust, the effects of dust on health and safety, dust sampling, the prevention of generated dust and the suppression and control methods. The effectiveness of the programme was determined by a follow-up survey and this modified dust awareness programme will be made available to Industry early in 1993.

Computational fluid dynamics (CFD), which provides a rapid, accurate and cost effective simulation of the physical flow of air in and around a continuous miner in a heading, was used successfully to evaluate the various ventilation configurations around continuous miners and roadheaders and to assess the effects of these configurations on dust removal.

The use of spray fans was investigated to move the air in and around the cutting drum of a continuous miner, working on the principle that specific water spray nozzles have the ability to move air like small fans. The system consists of several manifolds with the sprays at predetermined angles, strategically placed on the continuous miner. The sprays redirect the main ventilation flow to the face, sweeping cont-



Computational Fluid Dynamics results produced as horizontal and vertical slices taken through a 3-D mining situation, each slice showing velocity contours or flow tracks of individually released particles of dust. Airflow in the vicinity of a roadheader which has been fitted with a scrubber and sprays is shown in a global view, with the roadheader positioned in the split. Also shown are the flow vectors and contours which delineate the effects of the scrubber and sprays.

aminants across the drum and into the main return airstream. The system also fulfills the roles of existing spray systems of dust suppression, pick lubrication and cooling. The use of wetting agents to increase the efficiency of dust allaying systems was tested with positive results. The use of agents form part of the whole dust allaying strategy and it is intended to test them on an on-going basis.

As a result of the diversity of dust suppression systems now becoming available, a standardized test procedure was developed which will allow a system to be evaluated in such a way that the effects of the various components can be quantified.

MINING SYSTEMS

Productivity and the containment of operating costs continue to be of great concern to the coal mining industry, both in terms of supplying local markets and remaining competitive internationally. Past research has established that in some cases as little as 15 per cent of the theoretical maximum production levels are achieved in practice. These production losses are caused by a combination of incorrect operating procedures and inappropriate selection of equipment and equipment design. Production shortfalls are often only identified once the total shift production is calculated and thus machine operators and section supervisors have little or no indication of how effectively they are performing during the shift. Corrective measures tend to be remedial rather than preventative and are generally aimed at standards of performance that fall far below what could be achieved.

Thus the work in this area has concentrated on developing systems to improve the control of continuous miners and to communicate information, regarding the activities of coal production and in-section coal transportation equipment, to a central monitoring and analysis unit. This would enable the section supervisor to be aware of the existence and nature of problems, as and when they occur, so that actions can be taken to eliminate the causes of production losses at source.

Progress

Following the completion of the continuous miner horizon control system in 1991, the application of the system was evaluated in a broader range of operational conditions and plans to modify or customize the system for particular site requirements were established. Further field trials confirmed that the system significantly improves the operator's ability to move quickly and accurately to the prescribed roof and floor horizons, reducing time lost to trimming and eliminating uneven floor conditions that cause maintenance and operational problems with all mobile equipment.

The development of an advance control system for the continuous miner, to work in conjunction with the horizon control, continued during 1992. Construction of the modified processing and display unit was completed and tests using a prototype advance measuring system were conducted. The advance was measured through the rotation of a specially designed wheel fitted to the continuous miner boom and held in contact with the roof during sumping. Although this system at present appears to offer the best solution, the evaluation of alternative devices which operate without contact continued. However, it appears that the complexity of these devices and the extensive development required would render them impractical at present.

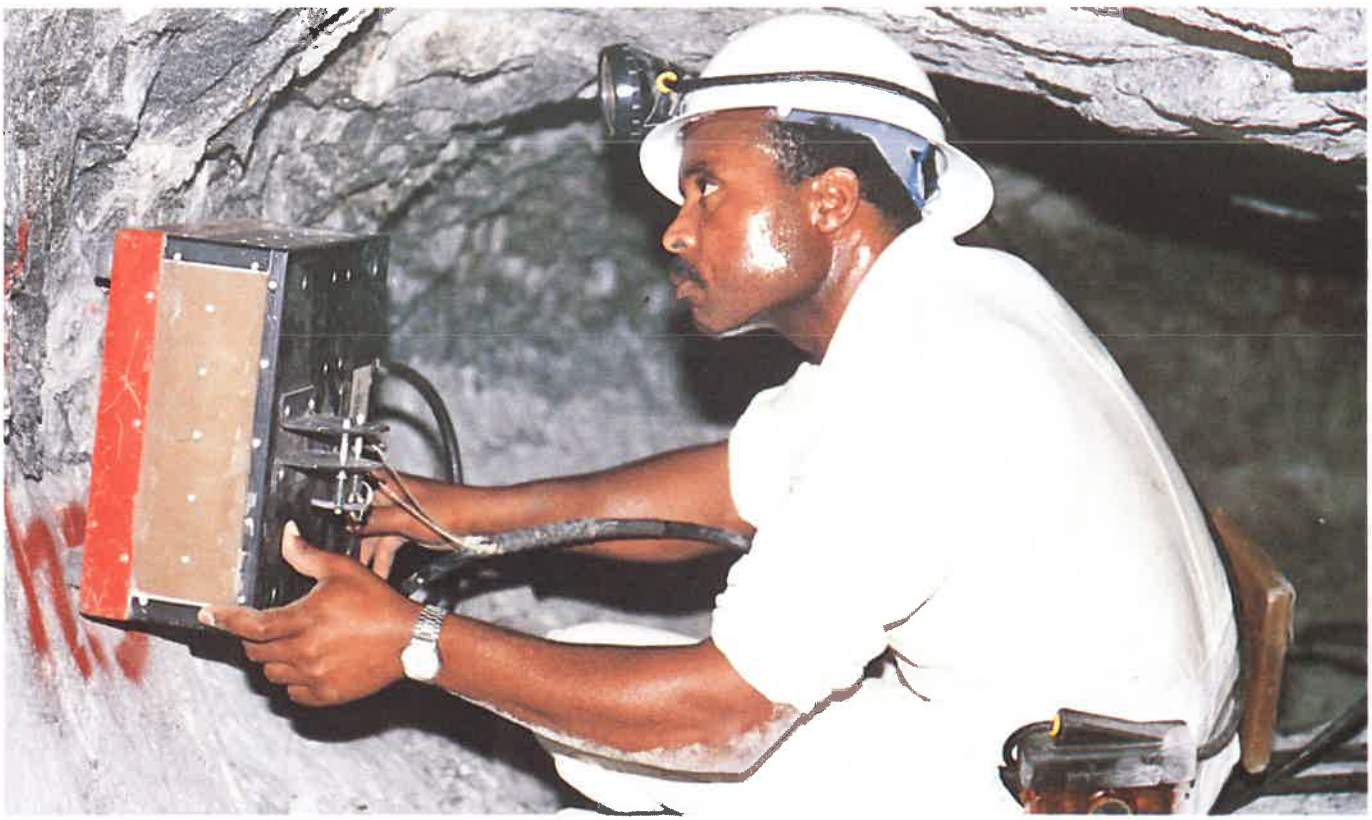
The development and testing of two radio frequency tagging systems with different signal and operating characteristics were completed during 1992. Together with the continuous miner advance and horizon control systems, these units are designed to form part of the system which provides for the monitoring and synchronization of section activities. Radio frequency tagging devices, attached to shuttle car tipping points and continuous miners, relay signals relating to the movement and performance of the vehicles to an underground computer that can be accessed by the section supervisor. By timing the duration of each shuttle car's presence at the continuous miner or the tip, it is possible to deduce tramming times and thereby determine the overall efficiency of the in-section transportation system.

The design and development of ancillary sensors to enable more detailed diagnoses of equipment activities, and communications systems and software to provide for the analysis of the data collected, was also completed. This will allow section supervisors to be alerted to slow sumping, shearing and tramming rates, track slip conditions and various other related problems. The data collected during the shift can be called up in graphic form or as current status reports and the system can also be used to generate shift end reports. To facilitate research into alternative configurations, as well as information gathering and analysis on a mine-wide basis, and to provide the Industry with a more capable and user-friendly version of the package, the COMSIM suite of programs was rewritten and several additional modules are being prepared. The package now caters for section advances of up to seven roads; provides for single heading cutting sequences to be duplicated into other roads and full cycles duplicated for successive cycles (thereby simplifying and speeding up the configuration process); enables more user-friendly access through simple explanatory graphic prompts and "Help " notes; and provides on-screen reporting. These improvements should minimize the need to use the manual and eliminate the need to print all results after each run.

Studies into methods of transporting coal within the section, which reviewed the uses of shuttle cars, LHDs, continuous haulages and bunker cars, were completed. The results indicated that LHDs could be more cost effective than shuttle cars in a broader range than currently recognized. Continuous haulages were found to offer production advantages of between five per cent and 18 per cent, but at a substantially higher cost and with increased complexity and reduced flexibility. Bunker cars were found to offer production benefits in excess of 30 per cent over normal shuttle car arrangements.

A study into the effects of increased cutter jib length on productivity was also completed. This work confirmed the anticipated trend towards increased productivity with longer jibs and also quantified the effects of different interactions between the various operational components within the section. Both the in-section transportation studies and the cutter jib study confirmed the importance of careful analysis and optimization of equipment combinations and section layouts, as well as confirming the value of analytical tools such as COMSIM.

CONTRACT & CONSULTANCY SERVICES



Ground Penetrating Radar

COMRO's extensive experience in mining research and its multidisciplinary expertise and facilities have enabled it to offer a wide range of contract services to mining and related industries.

These services, which range from the development of techniques, guidelines and equipment to general advice and assistance, include:

Underground Environment:
- *Ventilation and Cooling
- * Selection and Acclimatization
- * Air Quality Control
- * Radiation Protection
- * Water Quality Management
- * Fire Engineering and Escape Strategies
- * Hearing Conservation
- * Montreal Protocol

Rock Engineering
- * Regional Support Systems
- * Stope, Tunnel and Gully Support
- * Rockmass Behaviour
- * Rockburst Control Methods
- * Mine Layout
- * Laboratory Testing
- * Training

Coal Mining
- * Dust
- * Environment
- * High Extraction Mining
- * Mining Systems
- * Strata Control

Mining Equipment and Systems:
- * Hydro-power
- * Backfill
- * Rockbreaking
- * Stoping

Orebody Information
- * Gold Distribution Prediction
- * Geophysical Applications
- * Sedimentological Research

1992 CONTRACT WORK

Underground Environment

General Environmental Engineering: Consultancy work on ventilation and cooling involved a field trial for a platinum mine to measure heat flow in working stopes, evaluation of ventilation ducting and dust scrubbers, and measurements of the thermal properties of insulation for pipes.

Fire Engineering: The fire tunnel was used to evaluate the combustion characteristics of a wide range of materials, equipment and systems under simulated mining conditions.

General Industrial Hygiene, Hearing and Vision, and Protection against Acute Respiratory Hazards: Air quality investigations were conducted for a number of mines and mining group laboratories on sampling techniques and analyses. In addition, assistance was provided with the calibration and servicing of environmental control instrumentation, the training of personnel and the assessment of acclimatization centres and hearing test centres. The assessment of body-worn, self-contained self-rescuers and other aspects of escape strategies was also undertaken, while assistance was also available on radiation dose limitation, conducting of surveys for the assessment of radiological hazards in underground mines and in surface facilities, and biological analysis for radiological protection in uranium plants.

Water: Consultancy work covered mine water quality, management and treatment; analysis of water samples and the chemical and radiological properties of a variety of liquids; pilot plant investigations into all aspects of mine water treatment; and technical support to the industry on mine water quality management issues.

Rock Engineering

The major consultancies in the area of rock engineering involved recommendations for mine layouts, mining sequences and support, and assistance to support manufacturers in the testing and evaluation of new support units. In the area of mine layouts, linear and non-linear modelling for mine layouts, strata control and backfill applications were undertaken, and the design and evaluation of pillar systems for shallow mining were carried out using the new program, BEPIL (Boundary Element Pillars). Certain projects were undertaken with regard to mining sequences, namely, the design of a mining sequence for a large remnant in the vicinity of a shaft pillar of weak rock, together with an assessment of the benefits of backfilling in this situation. Reports from mines on strata control and shaft pillar stability were evaluated on request.

In the area of support, a considerable amount of quality assurance testing for the new design rockburst props and accessories was undertaken and assistance was given with the introduction of the hydraulic prop support system at a new mine. Problem areas were identified for a number of mines by analysing accident records and recommendations were made to overcome the problems. Also, new prototype support units were tested and evaluated for manufacturers and recommendations were made in terms of modification and further development. Work was undertaken to evaluate the influence of backfill on rockmass behaviour and to assess the effectiveness of cemented backfill versus uncemented backfill. Using a new triaxial cell, high pressure testing of backfill materials for various mines was carried out to provide input parameters for numerical modelling of layouts incorporating backfill. In addition, the effect of backfill on the stabilization of bord and pillar workings for a coal mine was investigated.

Suites of rock tests were carried out for a variety of organizations and, in some cases, the input parameters required for non-linear modelling were computed from test results for the requesting client.

Coal Mining

Services included advice and recommendations on pillar design, methods of roadway support, mining layouts, ventilation practice and productivity simulations. Examples of specific consultancies carried out were production simulations using the COMSIM computer program; open cast overmining of bord and pillar workings; undermining of various surface structures; assessments of mine designs to maximize extraction; rock testing; assessments of dust reduction methods for mining machines; and the determination of in situ methane pressures in geologically disturbed ground ahead of planned mining areas.

Mining Equipment and Systems

Water Hydraulic Rockdrills: Water powered hydraulic rockdrills, which offer significant improvements in drilling rates over pneumatic drills as well as environmental benefits, were commercially available for the first time in 1992 and, in their first year on the market, more than 550 units were sold, bringing the total number of hydraulically powered hand-held rockdrills in use in the mining industry to close to 1000. The drills are currently being powered by hydro-power, electro-hydraulic pumps or combinations thereof and it is notable that, even under such diverse operating conditions, the performance and operating costs determined by COMRO during the development of the drills are being substantiated in routine production use.

Other notable developments during 1992 in the field of water-powered equipment include completion of the development and commercialization of a range of water hydraulic motors by a COMRO collaborator. These compact motors can provide output powers of between 6 and 44 kW at 1500 RPM at a power to mass ratio of 0,5 kW/kg, which is five times higher than the 0,1 kW/kg of electric motors. These motors are currently being used for fire fighting applications in Europe and are being evaluated by COMRO for their suitability for hydro-power and general mining applications.

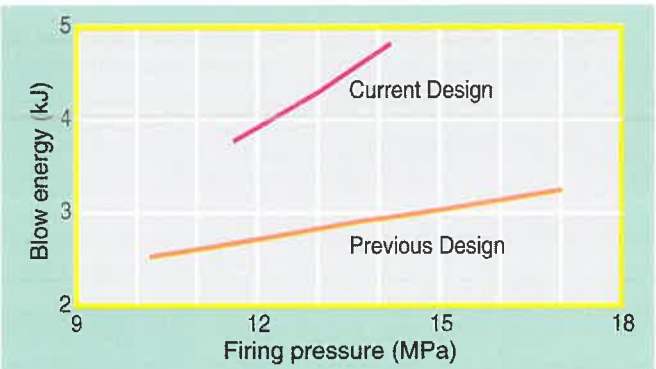
A dewatering pump capable of discharging up to 120 *l*/min was also successfully developed by COMRO and commercialized during 1992. This unit is based on the jet-pump principle and consequently has no moving parts; as it has been designed for operation from high pressure water, it may be powered directly from hydro-power. A standard commercial pneumatic powered diaphragm pump was also successfully converted to high pressure water operation and evaluated successfully by COMRO.

The increasing acceptance of hydro-power as a cost effective method of powering for deep level mines led, in 1992, to increased demands for assistance in the design and cost

analysis of system proposals. Furthermore, the increased requirement for hydro-power and ancillary equipment resulted in a concomitant increase in the demand for testing and evaluation of such equipment and COMRO therefore established facilities for the evaluation, testing and verification of water hydraulic equipment for use with hydro-power. Furthermore, proposals for the establishment of additional underground facilities for the hydraulic testing of safety-critical hydro-power components were submitted to a major mining House for consideration.

Impact Mining: The development of a mechanized system for mining stopes without the use of explosives offers major benefits including the possibility of mining continuously and therefore the potential for high rates of face advance. Continuous mining also allows equipment to be well utilized and shifts to be staggered, while other advantages of mechanized mining include increased labour productivity and concentrated mining. In addition, waste rock can be sorted and packed in the back area enabling an effective reduction in stoping width to be achieved. Extensive research has identified impact ripping as being the method best suited to mechanically mine the stress fractured rock which prevails in deep South African gold mines and the development of an impact mining system has reached full scale production trial stage.

Field trials on both narrow and wide reefs have demonstrated the ability of the system to significantly increase profits through improved labour productivity, reduced dilution, increased safety and improved working conditions. Based on the performance achieved to date, it was decided to initiate a major production trial using four impact mining systems installed in a mini longwall, operating on a multi shift per day basis. These systems, which incorporate extensive design modifications to improve reliability and facilitate maintenance, were manufactured during 1992 and are now ready for installation.



It was established early in the impact mining development programme that, for the achievement of acceptable mining rates, the blow energy of the hammer should ideally be in the region of 4 000 J. Through an increased understanding of the hammer's operating characteristics, it has been possible to increase the blow energy to 5 000 J at a firing pressure of 14,5 MPa. Since the impact mining system has operated reliably for sustained periods at this blow energy and firing pressure, the new systems will incorporate hammers designed to these specifications.

Advanced Stoping Systems and Application of New Mining Technologies: Work performed on the optimization of the safety and productivity benefits obtainable from the use of advanced stoping systems, incorporating newly available technology, continued during 1992 with a number of consultancies being undertaken for mines to advise on the correct selection and use of the equipment. These systems enable the full synergistic effect of combining new technologies efficiently in a stoping system to be realised. During the year there was a steady increase in the number of mines employing water-jet assisted stope cleaning systems coupled with diagonal blast barricades.

Consultancies were also undertaken to assist mines with the placement of backfill and to manufacturers of high pressure water-powered equipment seeking to introduce their equipment to the mines. Also during the year, full scale underground tests of an electronic blast initiation system were conducted which demonstrated the reliability of the units and the productivity benefits that stem from sequential blasting.

Materials Transport: Theoretical studies into the application of the continuous loader in several widely differing mining situations were completed, machine designs prepared and system layouts proposed. The prototype loader that was built in 1991 was evaluated at COMRO's surface test site in a number of configurations and using a variety of flight designs; the unit was shown to be capable of loading a range of materials at a rate in excess of 100 tons per hour. This work highlighted the need for a variety of flight designs to suit the different size ranges of materials to be encountered. An evaluation was also carried out at a gold mine where the continuous loader was used for dump reclamation. In this situation, though the prototype machine was not of the optimum design for the application, the loader confirmed its ability to load rock from a pile in a production situation. The material handled at this site, rocks up to 500 mm on their longest side, were larger than anticipated and did on occasion cause the unit to choke up; notwithstanding this, mine personnel involved with the evaluation reported that the unit loaded at rates in excess of 200 tons per hour.

Backfill: Two contract research projects were undertaken: firstly, a project to identify alternative, cost-effective cementitious binders for cemented backfill which resulted in very much cheaper binder components being made available. Binders largely overcome the problem of excessive solid losses in the form of fines, and water drainage which exists on several mines practicing backfilling, however, the previously high cost of commercially available binders inhibited their use. The cheaper binders identified offer a significant advantage to the mining industry as cementitious binders are necessary components for high strength backfills, and are imperative for stiff materials required for the provision of safe support in deep level mines. Secondly, PC software for the analysis of backfill distribution systems was developed. This software is the first available specifically for analysing the transport behaviour of high relative density slurries. The software can use, as input, either experimentally determined slurry transport data, or the output from one of several pre-

dictive models.

Other contract research and consultancy in the backfill area addressed all system engineering aspects including the design of backfill systems, auditing of operating backfill installations, implementation of backfill in conjunction with advanced mining equipment and characterization of backfill properties. An important development during 1992 was the diversification of these activities into high strength concrete for the rehabilitation of waste and orepass systems. With regard to pipe wear, monitoring of complete backfill distribution systems on several shafts using different liner materials and distribution conditions continued during 1992; the benefits of full flow distribution, originally proposed by COMRO in 1988, were again highlighted in practical applications. Application of a wear monitoring device, patented in 1991, showed its benefits in terms of a full understanding of the status of backfill distribution piping during routine service.

Work for overseas organizations included evaluating materials' properties and assessing their suitability for backfilling applications on two mines in Canada; both were completed during 1992. Involvement with the coal mining industry on ashfilling concerned the hydraulic transportation of PFA for use as a fill material, mainly in old mined out areas. Close involvement continued with equipment suppliers, with work concerning pump evaluations, testing of geotextiles, and development of wear resistant materials.

Orebody Information

Prediction of Gold Distribution: A contract research programme was conducted under sponsorship from four mining Groups at the newly re-constructed COMRO flume facility. This work involved the simulation of degradational and aggradational sedimentary environments with the major objective being to identify the mechanisms for development of different lithology types and the sorting of heavy minerals under controlled flow conditions. In addition, these studies provided useful information with which to verify whether the mechanistic model of sediment transport and sorting, MIDAS, reliably simulates natural sedimentary processes.

COMRO also continued to co-ordinate and facilitate the activities of the Regional Ventersdorp Contact Reef (VCR) Working Group during 1992 on behalf of the mines involved in mining VCR. The major activities involved drawing up regional plans of VCR features, compilation of a library of representative reference samples, establishment of regional features of the VCR, holding open sessions to disseminate topics of technical value and preparation of a confidential communication for the sponsors summarizing the major technical findings of the VCR group.

Geophysical Applications: Work on Ground Penetrating Radar (GPR) concentrated on projects dealing with the determination of rock fracture conditions in hazardous areas in deep level mines. The technique was particularly used to investigate the change in fracturing before and after preconditioning blasting experiments conducted in stopes and development ends. As a result the methodology of data acquisition procedures was optimized and a routine measurement procedure was established. Improvements were also achieved in data presentation comprising the comparison of fracture patterns before and after preconditioning blasting by upgrades of the data processing software. Other underground investigations were related to the delineation of faulted and duplicated reef and the mapping of dykes. Another application where GPR proved to be a rapid, accurate and cost-effective method is concerned with the location of off-line boxholes, blind holes, raise boreholes and drain holes. These types of in-mine infrastructure can be detected with GPR providing the measurement access conditions are favourable. Further contractual work was undertaken for mapping diamondiferous gravels in various geological settings in the Western Transvaal.

During 1992, the progress of the Radiowave Tomography project (RT) followed a "concurrent engineering" approach, whereby development of a production worthy RT system was undertaken simultaneously with the implementation of the technology. Funding for a production worthy RT system was secured from a mining House on the basis of successful trials conducted in 1991. This system, which was completed successfully in 1992, scans the area between adjacent exploration boreholes and can be used both from surface or from underground (the system is not currently suitable for use in fiery mines). At present the system can operate down to a borehole depth of 1 000 metres, and can also be applied in vertically inclined in-mine boreholes. In parallel, the RT technology was tested in the base metal, gold and coal mining environments, both locally and abroad.

The most "mature" application at this stage is characterizing the geometry and grades of base metal deposits, with trials having been conducted both in Southern Africa and the USA. It was shown during field trials that in favourable geological environments the technique could map base metal mineralization with an accuracy of a few metres, over ranges between 100 and 200 metres. A highly promising trial in a South African gold mine proved that RT has the potential to map out geological disruptions on the VCR. Further trials were planned, with the switch to production work being envisaged early in 1993. Preliminary investigations also indicated the potential of RT to delineate high grade/low grade boundaries in areas where the gold is associated with pyrite.

Trials in the coal mining environment indicated that RT can be used to scan the continuity of coal seams between boreholes, and potentially to detect disruptions such as burnt coal, geological faults or sandstone washouts. It may also be possible to assess coal quality to some extent. This would offer geologists a rapid, cost-effective tool for establishing coal reserves and planning mining strategies. A highly successful seismic tomography survey was conducted to map coal seams and indications are that the technique will be a valuable complement to RT, and will extend the range of problems which COMRO's Geophysics Programme can solve. Close collaboration continued in 1992 on projects which incorporated both Ground Penetrating Radar and Radiowave Tomography technology: a specific example being the monitoring of rehabilitated sinkholes as well as the monitoring of blockages and voids in ore passes.

REFERENCE SECTION

COMMUNICATIONS IN 1992

The various channels used by COMRO during 1992 to communicate research results and new developments include:

Newsletters

R & D News informs the mining industry of progress made in research, current developments, and consultancy and contract services.

Leaflets

* Lightweight, blast-on hydraulic props as stope face support
* Summary of major R & D outputs to Industry
* Services and facilities profile

Seminars

Six seminars and workshops were held by COMRO in 1992 and were attended by over 500 delegates.

* Static and dynamic modelling of the rockmass surrounding deep excavations
* Mine ventilation and cooling software seminar
* Backfill as regional and local support
* Rockbursts: effects, mechanisms and control
* Gold analyser: a major contribution to ore valuation and mine planning
* Workshop on headboards for props

Visits

During 1992, more than 24 visits to COMRO were arranged for various groups, including overseas delegations and associations. Of particular interest were the high level delegations from China and Australia, as well as a series of presentations and demonstrations at COMRO to the Gold Producer's and Executive Committees, various Sub-Committees, the senior management of certain mines and local and overseas delegates to the 5th International Mine Ventilation Society Congress.

Reference Reports

Close on 20 reference reports were produced detailing work conducted in the co-operative research programme.

Papers

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GOLD MINING

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BAILEY-MCEWAN, M, ROMAN, W N. Assessment of Performance of Conventional Water Chilling Machines using Thorp Method and Machine Modelling. Journal of the Mine Ventilation Society, V.45(5), May 1992, p.74-91.

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INFORMATION CENTRE

The COMRO Information Centre specializes in technical information relating to COMRO services to the mining industry. A bi-annual list of new accessions and a subject index of COMRO reports and papers are sent to mining house libraries. A thesaurus consisting of more than 4 000 keywords relating to the South African mining industry has been compiled by the Information Centre. It is updated regularly and is available for use by all interested parties.

The Information Centre has rendered an extensive Inter-Library Loan service during 1992. Items were both supplied to other libraries and requested on behalf of COMRO researchers. COMRO's very large collection of technical information is available through the external Inter-Library Loan service.

The Information Centre is also mainly responsible for producing CoMIC, a monthly current awareness bulletin comprising abstracts of mining related articles. Articles are drawn from both South African and international publications that are received regularly by the Information Centre. More than 10000 requests for reprints from CoMIC were received during 1992.

FINANCIAL ANALYSIS
(unaudited)

Expenditure 1992 (R million)

Co-operative Research

	Total	Gold	Coal
Gross costs	31,372	26,080	5,292
Recoverable Service Costs	4,401	2,877	1,524
Nett Costs/ (provisions)	26,971	23,203	3,768

Expenditure breakdown

	Total	Direct COMRO Costs	External Collaborators
Coal	**3,768**	**3,681**	**0,087**
Gold	**23,203**	**19,949**	**3,254**
Underground Environment	7,177	6,896	0,281
Rock Engineering	9,630	8,094	1,536
Special Projects	6,396	4,959	1,437

ANNUAL REPORT