Chamber of Mines of South Africa

Research and Development Annual Report 1977

A Chamber of Mines of South Africa Publication
P.R.D. Series No. 223

Cover
Rock being broken from a stope face by means of a ripper hammer.

Chamber of Mines of South Africa

Research and Development Annual Report 1977

CONTENTS

Introduction

During 1977 the activities of the Research Organization have continued to progress under the guidance of the Research Advisory Committee and the Collieries Research Advisory Committee on behalf of the gold and coal producers, respectively.

Work to improve environmental conditions underground by the use of chilled service water matured rapidly and there has been wide acceptance of the underlying principles. Cooling systems based on the concept are being introduced into several mines. The scale of interest in this development is illustrated by the participation of some 250 delegates in a joint symposium on the cooling of deep mines organized during 1977 by the South African Institution of Mechanical Engineers, the South African Institute of Mining and Metallurgy and the Mine Ventilation Society of South Africa. The work of the Director of the Environmental Engineering Laboratory, Dr. Austin Whillier, in developing this system of cooling of deep mines was recognized by the award to him of the Associated Scientific and Technical Societies' gold medal, which is the premier national award for scientific and engineering achievement.

During the course of the year various approaches to mechanization in stoping were evaluated and work on several rockbreaking devices such as the swing hammer miner, the reef borer and the percussive slotter was discontinued.

It has become clear that the rockcutter is a reliable means for breaking rock. Unfortunately the mining system into which it has been incorporated is such that the productivity obtained has not been acceptable and, in particular, difficulty has been experienced in handling the rock broken by the rockcutter. For this and other reasons it has been decided to direct efforts towards the development of more efficient mining systems and to advance the development of impact rippers to the stage at which they can be used as mining machines.

The Coal Mining Laboratory was established at the beginning of 1977 under the directorship of Mr. P. King and with the recruitment of a nucleus of staff is steadily increasing the scope of its investigations. At the same time the research and development programme being conducted on behalf of coal producers is becoming more clearly defined.

In conjunction with the preparation of the research and development programme for 1978, attention has been given to the evaluation of major projects in financial terms. The value of future benefits, which are expected to accrue to the industry as a direct result of research and development, has been estimated and compared with the expected costs. The evaluations have provided useful indications of the directions in which future work should proceed, but the methods used require further refinement to ensure the reliability of the assessments.

As usual, there was close collaboration between the Research Organization and the mining industry, and a notable result of such collaboration was the publication of "An Industry Guide to the Amelioration of the Hazards of Rockbursts and Rockfalls". This guide was compiled by the High-Level Committee on Rockbursts and Rockfalls which consisted of rock mechanics experts drawn from the industry and the Research Organization. The document has been distributed widely in the industry and it is expected that it will have far-reaching effects on rock excavation practice in the industry.

The departure to an overseas university post of Dr. N. G. W. Cook (Research and Development Consultant) and the retirement of Dr. C. H. Wyndham (Assistant Research Adviser — Medical) during the course of 1977 have required changes in the management of the Research Organization. Dr. A. C. Lawrence, previously Director of the Human Resources Laboratory, and Dr. N. C. Joughin, previously Director of the Mining Technology Laboratory, have been appointed as Assistant Research Advisers. A director for the Mining Technology Laboratory has yet to be appointed and Dr. Joughin continues to act in that capacity, while Dr. N. L. Robertson has been appointed as Director of the Human Resources Laboratory.

Human Resources Laboratory

When the Human Resources Laboratory was established in 1974, three principal objectives were formulated, first, to monitor the demand for, supply of, and utilization of people so as to provide information for better action by the mining industry, second, to assist with the solution of particular human problems and, third, to assist with the implementation of research findings in this field of activity and with training for new methods of mining.

During 1977, the same set of objectives has been pursued in order to take full advantage of the sound base laid in the previous two years. The Laboratory has an establishment of 52 posts, 38 of which are professional. Considerable progress has been made towards meeting the objectives of the Laboratory. More than 20 research reports and 43 monitoring documents have been issued and a monthly bulletin providing comment on information gathered routinely during monitoring activities has been introduced. Another new feature has been seminars to individual mining houses and industry representatives on various aspects of the work of the Laboratory.

Monitoring

As in the two previous years, monitoring activities have been concentrated on three principal areas: the collection and analysis on a routine basis of personnel-related data from various sources, the routine interviewing of mineworkers on a continuous basis, and a series of short-term investigations into specific matters relating to mine labour. The principal aim underlying monitoring activities is to produce a reasonably current and progressive picture of labour-related matters in the industry in order to provide early warning of emerging trends. Much progress has been made in 1977 in the establishment of procedures to attain this aim and it is expected that the benefits of these procedures will emerge in 1978.

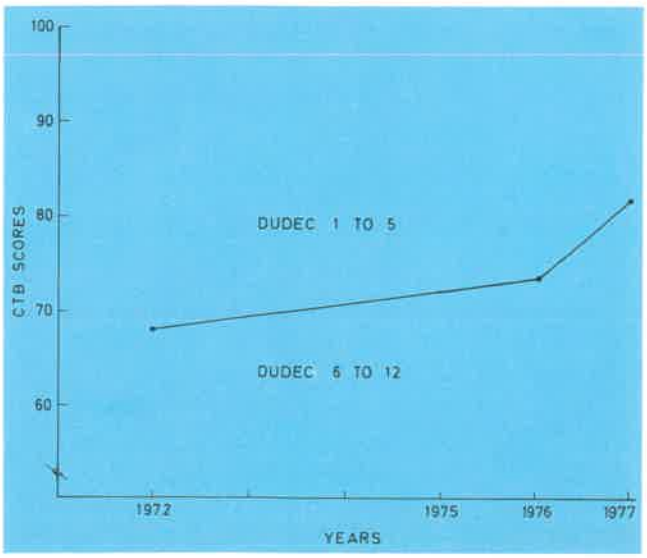
There have been some important developments in the collection and analysis of data. The monitoring of the administration of the Classification Test Battery at Aptitude Test Centres continued during 1977, and a record number of approximately 300 000 men were tested. It would appear that the administration of the tests is, in general, being done effectively, but the problem of men being retested persists, although it is apparent that centres are making concerted efforts to avoid unnecessary retesting. Monthly analyses of biographical data of men being tested, including age, level of education, region of origin and test scores, have pointed to progressively improving performance on the battery of tests as shown in the accompanying graph. This suggests that the test is becoming too easy with the result that mines are finding it increasingly difficult to differentiate among men with high scores. Although there is no immediate problem, it would seem that the Classification Test Battery is likely to outgrow its usefulness in the foreseeable future. It is, therefore, intended that in 1978 suitable alternatives to the Classification Test Battery will be investigated.

In 1977, a standard form for biographical information was introduced. This was used routinely with every mineworker who participated in any laboratory investigation. Data on 21 variables, including the usual personal attributes such as age, number of dependants, previous occupational history, length of last home stay, length of last mining tour, ownership of livestock, access to ploughing land, and so on, were collected and analyzed. Information on over 2 000 men has been gathered in this manner, and this has proved to be a rich source of information and has provided the Laboratory with its first real access to the "moving picture" concept of monitoring. During the year, considerable effort was devoted to the development of computerized techniques for analyses of these data. Not only do these techniques permit the identification of emerging trends but they also allow the examination of the relationships which exist among the variables themselves, as well as of the opinions of Black mineworkers expressed during the routine monitoring of attitudes. These techniques permit analyses of information never investigated previously in the industry. Arising directly from this study has been the introduction of a monthly monitoring bulletin in which interpretations are made upon the trends identified. This bulletin has replaced the 'Human Resources Monitor' which has provided monitoring information for the past three years.

A pilot study was conducted in seven hostels in order to establish the usefulness of gathering data as a means for identifying potential areas of conflict. Although problems of definition, lack of standardization in methods of collection, and administrative overload were identified, the usefulness of this type of information-gathering was established. As a result, it is expected that this activity will continue in 1978 and will consist of a limited number of variables on mines which will participate on a voluntary basis.

The procedure used in the second of the monitoring activities, that is, the routine interviewing of mineworkers on a continuous basis, has also undergone changes during the

Shifts in norms of the Classification Test Battery illustrating the improved performance by men new to the industry.



year. Whereas, previously, interviews have been conducted on an open-ended basis, only on matters of immediate concern to the men, use was made in 1977 of the interviews to gather wider and more in-depth information on topics other than those the men had chosen to discuss. This meant that the 1 203 mineworkers on 17 gold mines and four collieries who participated voluntarily in this exercise not only provided information in their own language to trained interviewers about such matters as novices' expectations of mining, returnees' reasons for length of stay on a mine and at home, and likes and dislikes of mine and hostel life, but also gave responses to structured questions concerning safety, promotion, urbanization, food and accommodation. These smaller, structured, studies demonstrated their usefulness by providing more detailed information on trends previously identified in routine open-ended interviewing, as well as by confirming or validating claims made by men.

Short-term investigations, the third of the monitoring activities, were carried out from time to time during the year. These studies have included such topics as mineworkers' perceptions of acclimatization procedures, factors affecting the popularity of mines, and the analysis of the skill requirements of Blacks' mechanized mining jobs.

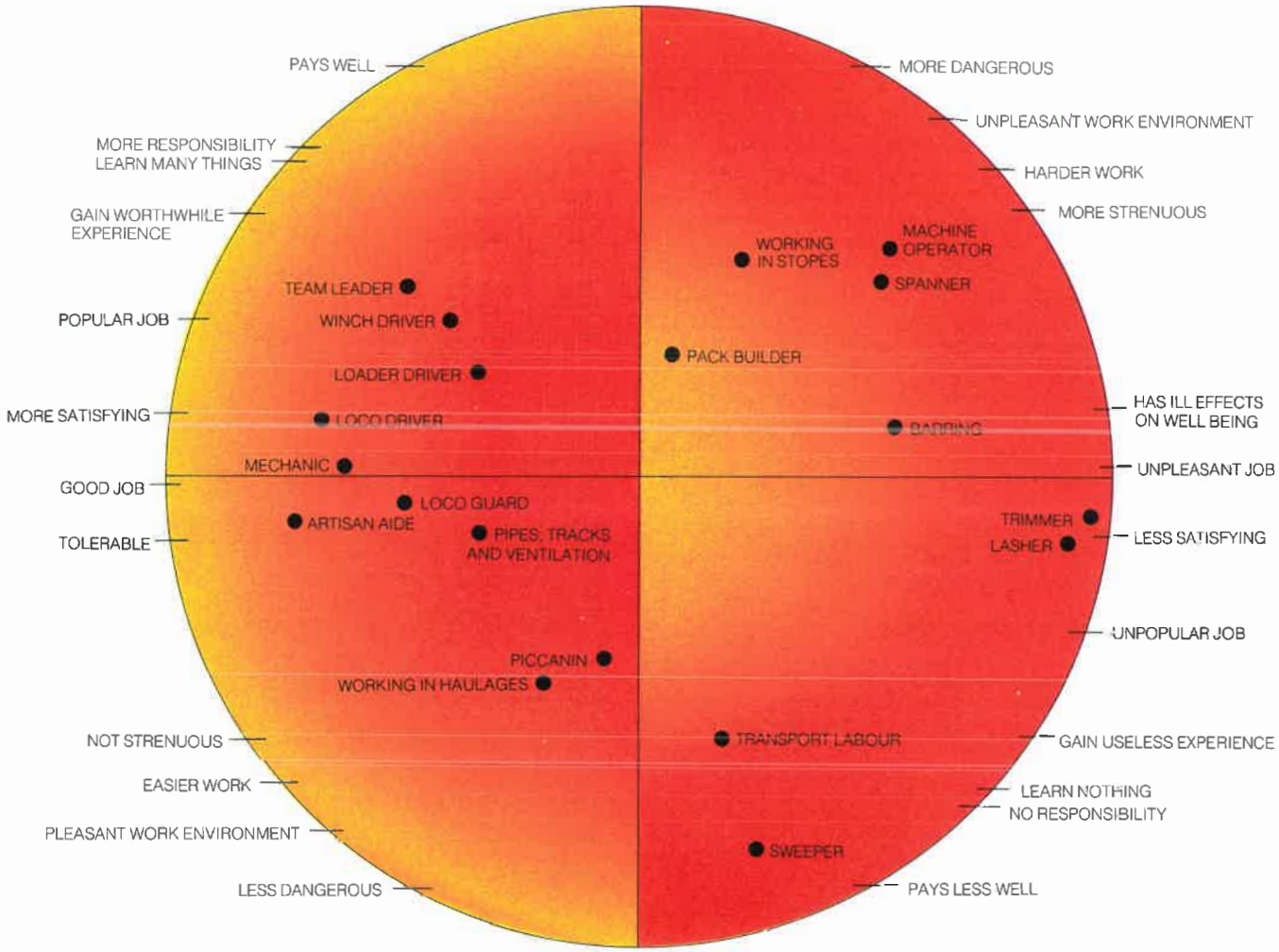
Specific human problems

A number of research projects, wider in scope and greater in depth than those which normally fall under the monitoring

Mineworkers' perceptions of various jobs.

The vertical axis divides the circle into two sections, that to the left representing the favourable or positive pole of a construct (perception) and that to the right, the negative or unfavourable pole.

Jobs located near the origin or centre of the circle are perceived to be neutral by mineworkers. The closer a job is located towards the circumference, the stronger the perceptions held by workers with greatest emphasis upon the constructs to which it is closest.



JOB AND CONSTRUCT LOADINGS BELOW 0,3 ARE NOT INCLUDED IN THE DIAGRAM

objective, were completed in 1977. In 1975 contracts were negotiated with the Institute for Social Research at the University of Natal, the Institute of Social and Economic Research at Rhodes University, and Market and Opinion Surveys (Pty) Limited to examine the likely future availability to the mining industry of unskilled or semi-skilled labour, particularly of South African origin. These contractors have examined various factors and problems facing men who migrate from different areas in search of employment. Final reports on Lebowa and Bophuthatswana have been received and work on Transkei, the Ciskei and Kwa-Zulu is nearing completion. Closely related to these studies has been work conducted under contract by the Department of Economics at the University of Southern Illinois. This investigation has resulted in the development of a mathematical model to explain the relationship between the different factors which result in a man's economic decision to seek employment in the mining industry. The work emerging from these contracts has provided the Laboratory with a most useful information base on the subject of migrant labour, as well as adding new and useful insights.

Research within the Laboratory has been restricted to the industry's likely future demand for labour in terms of numbers and skills. The results of investigations into the past, present and future trends of a number of selected Black and White occupations in gold mining have been reported. It is expected that in 1978 these results will form the basis of a Delphi exercise conducted by a group of experts who will examine the influence of present and future technologies upon future demand for labour.

Work on the extent to which human factors contribute towards safety underground has been continued. Studies have been concentrated on the perceptual behaviour of men at the work face, with particular emphasis upon strategies of search and of detection of loose rock. The results of two investigations completed in 1977 show promise that training directed at developing these skills in new mineworkers could make these men less vulnerable in their early days underground. In one study, four groups, one of experienced men and three consisting of novices, were subjected to different experimental treatments. The men were required to differentiate between "safe" and "unsafe" conditions portrayed in a series of 120 stereoscopic photographs depicting loose rock underground of various degrees of danger. The experienced group and a novice group which had received special "skills" training scored significantly higher, statistically speaking, than did the other two novice groups, one of which had been "warned" of hazards and the other which had received no instructions prior to the task.

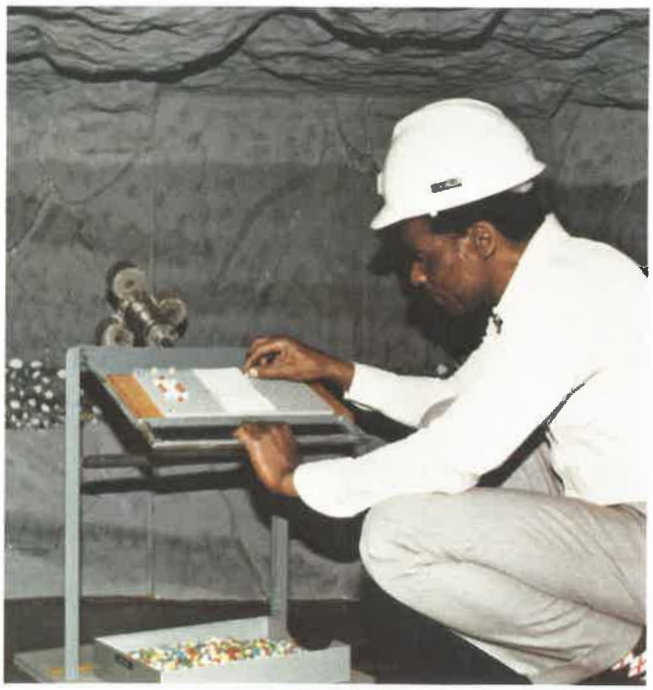
In a second experiment, utilizing a simulated stope, it was demonstrated that the "skills"-trained novices performed as well as experienced men. These two groups scored significantly higher in perceiving loose pieces of rock and taking appropriate action than did other novices who had either been "warned" or had received no prior instructions. Further work, using the simulator, is planned for 1978 and will include the effects of environmental factors such as heat, noise and illumination.

Other work completed in 1977 included investigating the skill demands of three kinds of artisan aides, namely, boilermaker, fitter and electrician. The demands of these skills were shown to be very similar.

A second investigation involved the identification of the skills required by five mechanized gold mining jobs and by seven jobs performed on collieries. The pattern of skills was similar for all driving jobs, but certain jobs required higher levels of skill than did others. On the other hand, there was no consistency in the pattern of skills demanded by the non-driving jobs. It was concluded that the mechanized gold mining jobs of jumbo drill operator, rockcutter operator, and hydraulic prop operator, did not make higher skill demands than the driving jobs on collieries. The jobs of Wagner loader operator and raise borer operator were shown to be more skilled than colliery driving jobs. In another study an examination was made of the skills, technical knowledge, training and other qualifications required by personnel responsible for the supervision, operation and maintenance of an integrated development system on gold mines.

The first phase of work examining the effects of mental stress on underground work adjustment and work performance is nearing completion. A number of stressors or strains have been identified and instruments to measure these are currently being validated. One investigation was aimed at

The simulated stope used for the study of visual search for detecting hazardous conditions. The subject is using a weighted tilting table and filling in a peg board. This performance task simulates many of the features required in drilling. While carrying out this task the subject is required to search for "loose-rock" occurrences and to take the necessary action when needed.



identifying those underground jobs which were perceived by Black mineworkers to be the most stressful. This study also sought to establish some of the characteristics common to a group of stressful jobs.

Studies were completed during 1977 of the communication roles of various employees, namely, hostel manager, *induna, isibonda* and personnel assistant. In addition, attention was given to social groups in mine hostels and a model was developed to aid the interpretation of conflict situations that could develop in gold mines.

Implementation of findings and training

Activities under this objective fell into three main categories. First, a team has been intimately and continuously associated with the mechanization activities of the Mining Technology Laboratory, involving the personnel-related problems associated with field trials of mechanized mining systems. Second, assistance to the industry with the introduction of hydraulic props has made good progress. Audio- and video-tape programmes have been developed to ensure adequate expertise and the correct attitudes towards hydraulic props at all employee levels on a mine. The third form of implementation activity concerned the synthesis of previous findings of the Laboratory and of related research. Syntheses in four main areas (safety, selection, attractiveness of mining, communication) were completed.

*Research reports

An investigation into the length of service of multiple-contract migrant mineworkers. A. M. Pace and A. C. Lawrence. *Research Report No. 4/77.*

The development of a method to train mineworkers in the detection of loose rock: a laboratory study. C. J. H. Blignaut. *Research Report No. 9/77.*

The tribal representative system on gold mines. A. Momberg and J. K. McNamara. *Research Report No. 10/77.*

How certificated ventilation personnel view their jobs. A. M. Pace. *Research Report No. 11/77.*

Past and present trends in Black and White occupations in gold mining. M. H. Steen. *Research Report No. 12/77.*

The skill demands of artisan-aide jobs. J. B. Wolfaardt and R. T. Phetha. *Research Report No. 13/77.*

Projections of trends in Black and White occupations in gold mining. L. M. Robertson and M. H. Steen. *Research Report No. 16/77.*

Selection and placement of men in the gold mining industry. L. Melamed. *Research Report No. 18/77.*

An evaluation of the monitoring of observable behaviour in gold mine hostels. H. P. Connoway. *Research Report No. 19/77.*

The perception of hazardous conditions: A synthesis. A. C. Lawrence and C. J. H. Blignaut. *Research Report No. 25/77.*

An analysis of the skill requirements of Black mechanized mining jobs. S. T. Lederman. *Research Report No. 31/77.*

The supervisory skill requirements of mechanized mining systems. (Part 1: Integrated development systems.) D. H. White and M. H. Steen. *Research Report No. 32/77.*

Arrangements for the allocation of Black mineworkers to underground jobs. D. MacArthur and P. de Bruyn. *Research Report No. 36/77.*

Black mineworkers' attitudes towards underground jobs. E. Rodenwoldt. *Research Report No. 37/77.*

The choice of mining and metallurgical engineering as careers. A. N. Pace and A. Momberg. *Research Report No. 40/77.*

How attractive is gold mining to Black mineworkers? A synthesis of research findings up to September 1977. J. A. Parsons. *Research Report No. 42/77.*

The effectiveness of the acclimatization induction programme. J. Radise and C. J. H. Blignaut. *Research Report No. 53/77.*

The contribution of visual search skills to hazard perception: A laboratory study. C. J. H. Blignaut. *Research Report No. 56/77.*

Communications in the gold mining industry: A synthesis. P. S. de Bruyn. *Research Report No. 57/77.*

Popularity of mines. D. MacArthur, J. B. Godfrey, K. McNamara and O. F. Thomas. *Research Report No. 58/77.*

Publications

The perception of dangerous rock analysed by means of the theory of signal detection. C. J. H. Blignaut. *Chamber of Mines Research Review,* 1976/77.

Learning the meaning of signs in work situations: an experimental test. L. Melamed and T. R. Phetha. *Chamber of Mines Research Review,* 1976/77.

Manpower needs for the future — projections, issues and strategies. J. A. Parsons. *South African Journal of African Affairs.* Vol. 7 (2). Pretoria: Africa Institute, 1977.

Accident prevention: new approach could lead to breakthrough. N. L. Robertson. *Coal, Gold and Base Minerals of Southern Africa.* Vol. 25 (11). Johannesburg, 1977.

*These are available normally only to members of the Chamber of Mines.

Environmental Engineering Laboratory

The work at this Laboratory is directed at the improvement of the underground thermal environment in deep mines, and at the prevention of fires in mines. The staff numbers 21 posts of which 13 are professional.

The thermal environment underground

The heat encountered in deep mines is one of the factors which limits the depths at which mining can take place. Hot environmental conditions have an adverse effect on productivity and safety; they also affect the morale and effectiveness of workmen and play an adverse role in the recruitment of staff. One of the major objectives of the work of this Laboratory is to evolve methods for providing ordinarily acceptable temperatures in deep mines.

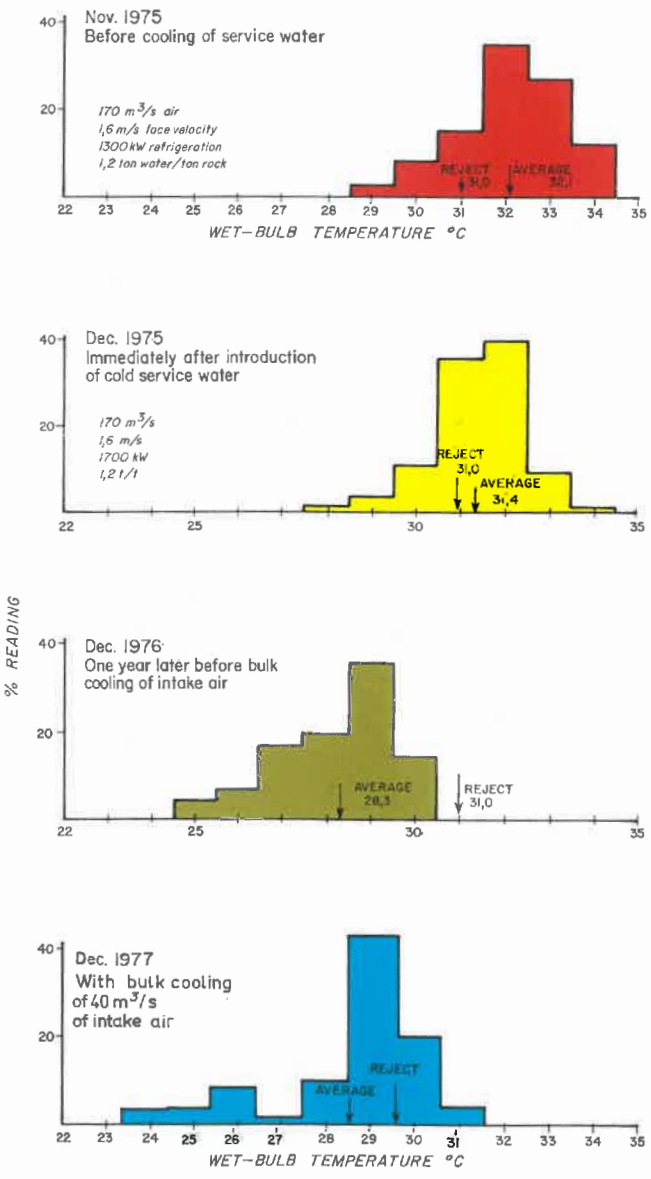
The primary parameter that determines the suitability of the thermal environment in mines is the wet-bulb temperature of the air. The velocity of the air is also important, but with so many men having to work in places where air speeds are below 0,5 m/s, it is important that wet-bulb temperatures must be kept low enough for men to be able to work safely even under still-air conditions. Under such conditions the risk of heat stroke in unacclimatized men working hard becomes serious if wet-bulb temperatures exceed 27 or 28°C. It is essential that men must be acclimatized if they have to work hard in environments hotter than this.

Research over the past few years has confirmed that the two main reasons for high air temperatures in deep mines are the high rock temperatures, and autocompression of the downcast air. Autocompression causes the temperature of the ventilation air to rise as the air goes down the shaft. The wet-bulb temperature increases by about 4°C per 1 000 m of depth, so that by the time the air has travelled about 1 500 m down the shaft, that is, when the air has reached a depth corresponding to sea level, the wet-bulb temperature of the air during the summer months will already have reached 25°C. A further rise in temperature occurs because of heat pick-up from machinery used underground, and as a result of heat from the rock in the intake airway tunnels. The net result of all these effects is that the ventilation air reaching stopes located at depths below sea level is invariably at a wet-bulb temperature exceeding 27°C or 28°C. Clearly this air is not capable of removing heat from the working stopes if the latter are also at 27°C or 28°C, and refrigeration becomes necessary to cool the incoming air.

Experience has confirmed that the distribution of refrigeration to the distant work places is perhaps the most troublesome and expensive of all operations involved in the cooling of mines. However, the difficulties encountered in distributing refrigeration have been alleviated considerably since the adoption by the mining industry of the concept of cooling the mine service water. Several large-scale field trials have been carried out on mines by the Laboratory to evaluate the benefits that can arise when the service water is cooled. One of these trials is being conducted at the No. 4 Shaft of the Hartebeestfontein gold mine, where cold service water was introduced during December 1975 in a section of the mine located at a depth of about 2 050 m, where the rock temperature is 45°C. Production from this section of the mine is about 9 400 m² (38 000 t) of reef per month.

The improved conditions that have been obtained by this mine are illustrated in the figure, which shows that stope wet-bulb temperatures which prior to the experiment had practically all been greater than 30°C, with some above 34°C, are now substantially all less than 30°C. Measurements made during December 1977 in the main production stope itself, involving faces on both sides of the original 800 m-long raise, indicated that nowhere in working stopes were wet-bulb temperatures above 30°C. The amount of refrigeration being used at this time was a little less than 3 000 kW.

Measured wet-bulb temperatures in working stopes at No. 4 shaft, Hartebeestfontein gold mine.



The cost of refrigeration to achieve this improvement in working conditions, although high, is not excessive when viewed in relation to the revenue derived from the mining, being a little less than 60 cents per ton of reef mined. This includes an allowance of 20 per cent on the capital cost of the cooling facilities, in addition to operating costs. Of far greater importance at this stage is the fact that the mine has demonstrated that conditions underground need not necessarily be unpleasantly hot as an inevitable consequence of mining at depth.

The distribution of refrigeration in mines

Perhaps the most difficult problem in cooling mines is that of distributing the refrigeration efficiently to the places where it is needed, and this reduces to the problem of distributing the cold water from the refrigeration plants. A considerable amount of work has been devoted to the solution of this problem and recommendations have been formulated for the guidance of mines.

A first step in planning the distribution of refrigeration is to predict the magnitude of the heat loads, and where in the mine these loads are likely to be generated during the lifetime of the mining operations. A method has been evolved for predicting the amount of heat that can be removed by the pre-cooled service water, and also the amount of refrigeration that has to be introduced into the ventilation air.

The philosophy of mine cooling that has been evolved from this work is that when refrigeration becomes necessary because the desired environment in working places cannot be obtained using ventilation air alone, cooling of the service water should be introduced as a first step, before any other method for distributing the refrigeration is considered. Data have been obtained which suggest that when mining is done in rock which is cooler than about 40°C, it will not be necessary to refrigerate the air itself, provided that the service water can be delivered to the stope cross-cuts at temperatures of 8 to 12°C and provided that the ventilation air reaches the stopes at wet-bulb temperatures less than about 25°C.

There is a limit to the amount of refrigeration that can be distributed by the service water, and provision should be made for bulk cooling of the incoming ventilation air when it appears that cooling of the service water alone will not be sufficient. The results of investigations suggest that this method of distributing refrigeration, that is, cooling the service water and cooling the *incoming* ventilation air, will be sufficient in mines in which rock temperatures range up to 45°C and possibly 50°C, depending upon the highest wet-bulb temperatures that can be tolerated in the stopes.

Only when rock temperatures exceed about 45°C is it necessary to consider the third phase of cooling, which involves the installation of air-cooling arrangements in or adjacent to the stopes themselves. At the present time in South Africa there are only six gold mines in which the rock is so hot that this third phase of cooling is unavoidable if ordinarily acceptable environmental conditions are to be achieved in work places.

Spray chambers for cooling the incoming ventilation air

One of the most effective methods for cooling the incoming ventilation air in order to counteract the effects of autocompression is to pass the air through cold water sprays before it enters the workings. Tentative recommendations have been formulated for the design of these spray chambers, and tests will be conducted during 1978 to determine the extent to which the spray chambers can be made more compact without reducing performance.

The operation of these spray chambers can be completely automatic, with the incoming water flow rate being regulated by a simple thermostatically-controlled valve so as to maintain the air leaving the chamber at a constant pre-set temperature. The water is re-sprayed once or twice in the spray chamber, using suitable pumps, so as to achieve a partial counterflow effect, and in this way the water that finally leaves the spray chamber for return to the refrigeration plant for re-cooling has a comparatively high temperature of 22 to 25°C.

It is expected that this type of spray chamber will find increasing use on all mines in which refrigeration is used.

Mine fires

The most troublesome and costly fires on mines are those that spread into the timber that is used for roof support. Research over the past few years into methods for protecting timber against fire has shown that there are several methods that can be very effective in preventing fires from getting out of control.

In controlling underground fires perhaps the most critical factor is *time*. Early detection followed by effective action in extinguishing fires before they can grow or spread significantly is of primary importance. It is essential, therefore, for mines to adopt a fire-protection strategy that will retard sufficiently the rate of burning of the timber so that, regardless of how or where a fire starts, it will be located while it is still burning slowly and will be extinguished by means of water before it can grow into an uncontrollable conflagration.

Electronic fire detection systems play an important role in the early detection of fires, and tests have continued at the Kloof gold mine on the evaluation of such systems.

Fires in unprotected timber grow in intensity very rapidly, and tend to burn reasonably fiercely within 15 minutes if the timber is dry, or in 30 to 40 minutes if the timber is wet.

Flames from a single burning pack will engulf adjacent packs within minutes and these adjacent packs will themselves burn out completely in about 90 minutes. A stream of very hot gases flowing immediately beneath the hangingwall spreads from such a conflagration, enabling the fire to propagate rapidly and widely by igniting the upper timber layers in packs along the flow path of the hot gases. Such fires *in unprotected timber* spread so rapidly that it is usually impracticable to take effective action before they become virtually uncontrollable, and sealing-off of the area is necessary to cause the fire to burn itself out slowly.

Tests have shown that the growth time of timber fires can be slowed from minutes to hours by a number of methods, such as by impregnating all the timber with a salt solution before the timber is sent underground, by wrapping or plastering so as to protect the timber from the heat of the fire and hindering the access of air, and by reducing the concentration and amount of timber, such as by using concrete sandwich packs. Protection is of particular importance whenever the skin-to-skin spacing of the packs is less than 2 or 2,5 m.

One of the uncertain factors with timber that is impregnated with salt solutions is the extent to which the daily wetting-down of the timber for purposes of dust control will leach out the salts and hence render the impregnation treatment ineffective. Experiments are being designed now to provide answers to this question.

The distribution of water in mines

South African mines often experience significant losses in production because of recurring shortages of water at work places as the result of underground dams having run dry. Similar shortages have occurred during fire-fighting operations, and now, with the use of cold service water to aid in the cooling of mines, it is even more necessary that such shortages should be prevented.

Investigations have pinpointed the causes of such water shortages, and recommendations have been made for the design of gravity-fed water-supply systems so as to avoid them. The problem is invariably that the sizes of pipes leading out through the walls of dams to the shaft are too small, with the result that air is drawn into the pipes. In one mine where the recommendations were implemented a single, low-pressure 150 mm pipeline is now carrying water 1 500 m down the main shaft at a rate of 220 l/s; the water flows at terminal velocity.

*Research reports

The practical measurement of heat stress in the gold mining industry. J. M. Stewart and A. Whillier. *Research Report No. 6/77.*

Annual ventilation report for the period October 1975-September 1976. A. Yaxoglou. *Research Report No. 15/77.*

Heat pick-up from the rock in gold mines: The water-rock thermal balance and the thermal efficiency of production. J. van der Walt and A. Whillier. *Research Report No. 27/77.*

Prediction of the refrigeration requirements for cooling the service water and the ventilation air in South African gold mines. J. van der Walt and A. Whillier. *Research Report No. 28/77.*

Considerations in the design of chilled water reticulation and chilled service water distribution systems for South African gold mines. J. van der Walt and A. Whillier. *Research Report No. 30/77.*

The cooling experiment at the Hartebeestfontein gold mine. J. van der Walt and A. Whillier. *Research Report No. 59/77.*

The design of spray chambers for bulk cooling of air in mines. S. J. Bluhm, J. van der Walt and A. Whillier. *Research Report No. 62/77.*

Publications

Predicting the performance of forced-draught cooling towers. A. Whillier. *Journal of the Mine Ventilation Society of South Africa,* vol. 30 (1), (1977), p. 2-25.

Water services for fighting fires in mines. A. Whillier. *Mine Fires Symposium.* Association of Mine Managers of South Africa, Johannesburg, April 1977.

Protection of timber packs against fire. A. Whillier, T. A. Burger and F. J. McClement. *Mine Fires Symposium,* Johannesburg. Association of Mine Managers of South Africa, April 1977.

Recovery of energy from the water going down mine shafts. A. Whillier. *Journal of the South African Institute of Mining and Metallurgy,* vol. 77 (9), April 1977, p. 183-186.

Gravity-fed water systems in mines. A. Whillier and J. van der Walt. *Journal of the South African Institute of Mining and Metallurgy,* vol. 77 (9), April 1977, p. 187-192.

Fire protection in gold mine stopes. A. Whillier. *Chamber of Mines of South Africa Research Review 1976/1977,* p. 73-85.

The use of diesel engines underground in South African mines. A. Whillier. *National Institute of Safety and Health (NIOSH) Conference,* Morgantown, Sept. 1977.

Prediction of performance of solar collectors. A. Whillier. In R. C. Jordan and B. Y. Liu (Eds.). *Applications of solar energy for heating and cooling of buildings.* ASHRAE 1977.

*These are available normally only to members of the Chamber of Mines.

Mining Technology Laboratory

The Mining Technology Laboratory has as its primary objective the development of new stoping methods and machinery for gold mining which present potential improvements in productivity, profitability and working conditions. Investigations into different technical aspects associated with this objective are provided for by organization of the laboratory into divisions concerned specifically with geological engineering, geochemistry, rockhandling, rockbreaking, machine design, hydraulic power, electrical engineering, field studies and field trials. The laboratory has a staff of 120 of which 52 posts are professional.

Fundamental studies of the physical properties of reefs and the distribution of gold in them

At an early stage in the research programme on mechanized mining methods for application in gold mines, it was recognized that a quantitative knowledge of the geological and physical characteristics of the gold-bearing reefs and of the adjacent strata was of prime importance for the design of practical stoping machines. Studies into these aspects have continued and have resulted in steady advances in this direction.

Perhaps the most far-reaching progress has been the increase in understanding of the way in which the rock around stope faces becomes fractured by stress and the manner in which geological features affect the fracture pattern.

Two years ago it was known only that the rock was fractured to a depth of about 0,5 m ahead of the face and that at times the face could be solid and at other times so intensely fractured that the rock had the consistency of gravel. It is now known that the fracturing is far more extensive than this and that while it can be exploited very advantageously by some types of machine it can be a serious obstacle to others.

The formation of fractures around stope faces is being observed wherever mining experiments with mechanized rockbreaking are being carried out and where it is possible to observe the stress-induced fractures without the confusion caused by the effects of blasting. Observations have now been made over a wide range of circumstances extending from shallow unstressed conditions to very deep and highly-stressed conditions.

In a mining situation where the energy release rate was about 0,5 MJ/ca the fracture zone extended a few hundred millimetres into the rock. Observations where the energy release rate was about 10 MJ/ca revealed that new fractures formed about 2 m ahead of the face; these fractures were typically 50 mm to 500 mm apart. Where the energy release rate was 30 MJ/ca the fractures formed about 5 m ahead of the face and were typically 10 mm to 100 mm apart. Where the energy release rate was about 100 MJ/ca, it was possible to make observations up to 7 m ahead of the face and the rock was shown to be intensely fractured for this entire distance.

The fracture pattern at any particular energy release rate is regular and systematic and usually occurs without any accompanying significant seismic activity. This pattern is disturbed, however, by geological features; for example, it is quite common to find more intense fracturing on one side of a fault than on the other. Where a geological discontinuity such as a near-vertical fault is inclined at a small angle to the face, it may interrupt the normal development of the fracture pattern and the rock at the face could be relatively solid. Such conditions are associated frequently with violent rock fracture.

Horizontal discontinuities such as parting planes also affect the fracture pattern markedly, with fractures tending to terminate at parting planes. The existence, orientation and separation of parting planes therefore have a great bearing on the ease or difficulty with which rock may be broken from the stope face. This has important implications for all methods of

Fractures ahead of a stope face being mined non-explosively by machines. The photograph was taken from inside a heading mined into the stope face.

The highly fractured condition of a stope face seen after a slot had been cut by mechanical means.

mechanized rockbreaking as well as for mining by blasting, where effective stope cleaning depends on the ability to define a reasonably smooth footwall. This is particularly so where conveyors are used for face cleaning. Mapping of the reef shapes and of geological features associated with them has continued and has indicated that a high proportion of all narrow reefs appears to be suitable for some form of mechanized breaking or cleaning.

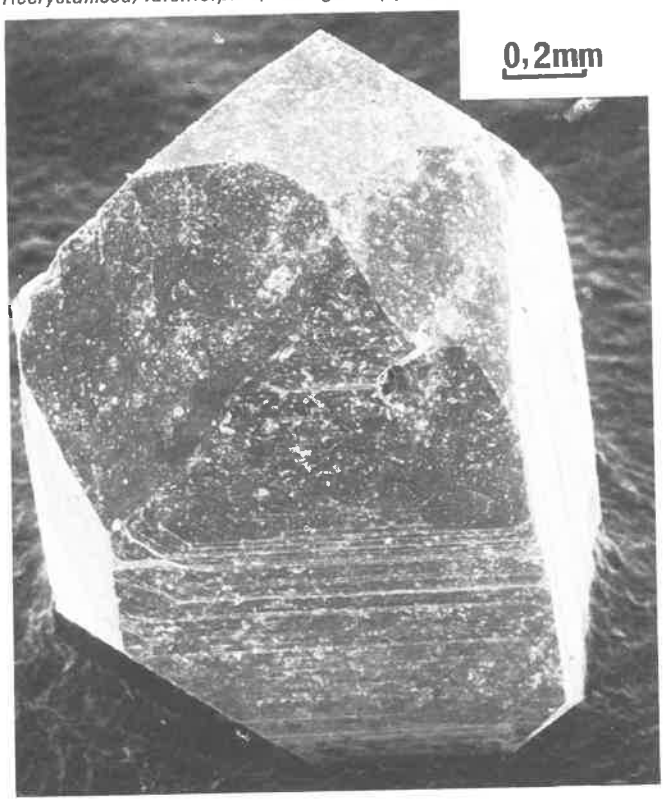
Investigations have continued into seismic activity around the longwall face of the experimental mechanized stoping site at a depth of 2 600 m in Doornfontein gold mine. Because this face is being mined entirely by mechanized methods, it has been possible to examine the locations, magnitudes and frequencies of seismic events caused by geological and mining layout conditions alone, without the complications introduced by the effects of blasting. The majority of seismic events has been shown to occur within 10 m of the face, but only over that section of the total face length where geological complications of faults and old fractures exist. Over the remainder of the face, which is geologically simple, little or no seismic activity has been detected. This work is of great value in investigations into the causes of, and possible methods of reducing the effects of, rockburst phenomena.

In the past, mineralogical studies of the various minerals in the gold reefs relied on classical methods of microscopy, using thin sections and polished sections of rock for observation in two dimensions of the mineral grains. The scanning electron microscope, used in combination with hydrofluoric acid treatment to produce concentrates of undamaged grains of many ore minerals, represents a considerable advance and has provided the means for furthering the knowledge of geological processes which led to the formation of the Witwatersrand reefs and other deposits.

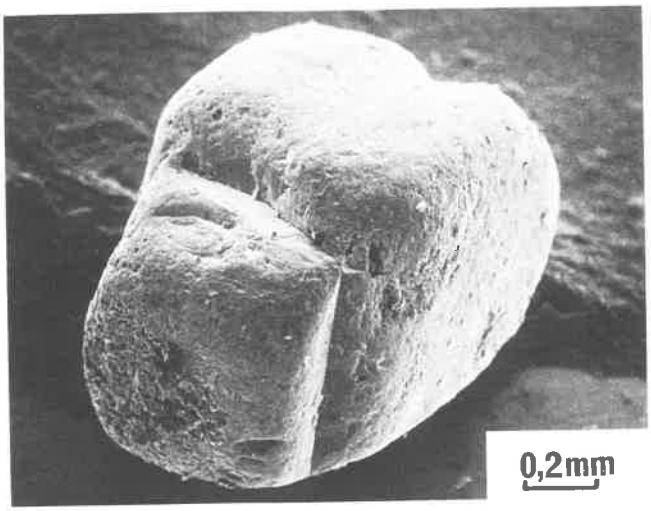
It has been reported previously that the carbonaceous matter in reefs is recognizable as the fossilized remains of organisms,

Classification of the three types of pyrite according to their morphologies.

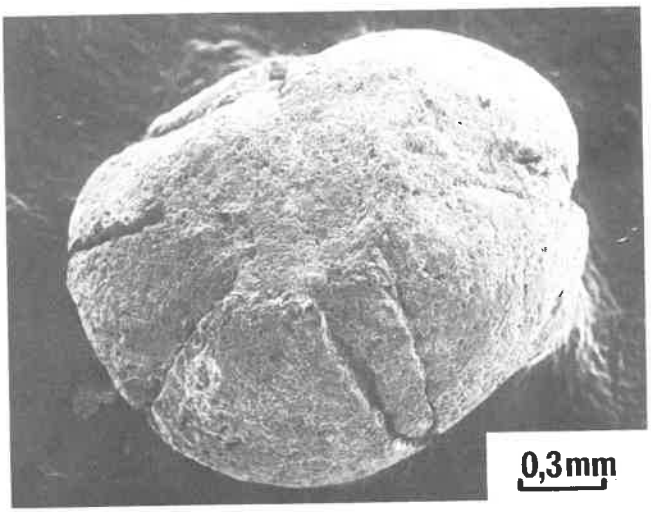
Type I.
Recrystallised, idiomorphic, authigenic pyrite.



Type II.
Rounded compact detrital pyrite with outlines of the crystal faces still visible despite abrasion during transport.



Type III.
Rounded, porous, allogenic "mudball" pyrite with indentation on top and radial cracks.



and preliminary work has dated these at about 2 700 million years by examination of the radioactive decay products of biologically-concentrated uranium. The morphology and chemical composition of gold particles reflect some of the geological processes which led to the formation of the Witwatersrand deposits. The proportions of silver contained in gold particles from the various reefs show that fineness of the gold is distinctly different in different reefs, and has permitted the identification of separate facies arising from different inflows within the same goldfield. The wide spread of fineness values for gold of the Ventersdorp Contact Reef in the Klerksdorp district reflects the reworking of older reef horizons now incorporated in this reef. The narrow spreads of fineness values in horizons such as the Basal Reef (Steyn facies), Carbon Leader Reef, and Ventersdorp Contact Reef (Far West Rand) point to primary sources and to the absence from these reefs of detritus from reworked older horizons.

Three-dimensional examination by means of the scanning electron microscope of pyrite particles from the Witwatersrand System has shown that the range of pyrite described in the past can be classified into three distinct types, a classification which has been confirmed by trace-element analysis by atomic absorption spectrophotometry. Consideration of the genesis of each of these types has revealed new evidence concerning the environment and mechanisms of deposition at the time of formation of the reefs.

Development of equipment to be used in conjunction with blasting

The primary object of mechanization with blasting is the improvement of labour productivity and such improvement is coupled inevitably with faster mining rates. Most of the basic operations in conventional stoping are either slow or labour-intensive. Achieving a major improvement requires improvement in all the basic operations and particularly those concerned with rockhandling, drilling, support, and barricades.

The basis of mechanizing these operations is the introduction of a continuous articulated reference rail parallel to the face. To this rail the various items of equipment associated with each operation are attached. The rail makes it possible to apply more force or power in each operation and facilitates the movement and control of equipment. The control and steering of the reference rail are of great importance and a tendency for such a reference rail to slip down-dip has to be controlled without hindering its advance; techniques have been developed to achieve this. The reference rail could be integral with other equipment such as a reciprocating flight conveyor.

Systems incorporating reciprocating flight conveyors for face cleaning have received considerable attention. Trials of the second prototype conveyor at Blyvooruitzicht gold mine were concluded in 1977. This prototype was used largely to gain knowledge regarding operation under conditions of faulting and of moving the conveyor over a rough footwall, as well as steering it on a dipping face. A much better understanding has been obtained both of the techniques required for control and steering of the conveyor system and of the changes in design needed for the successful application of those techniques.

Trials of a third and considerably more complex conveyor system continued at Vaal Reefs gold mine throughout 1977, with emphasis on the development of the drilling system, the blast barricade, the self-advancing supports, the method of advancing the conveyor to maintain the footwall horizon, and the co-ordination of all these into a viable mining system. Operation of the conveyor itself, as a stope-cleaning device, was quite satisfactory and many of the problems which arose could be attributed to the first-prototype nature of much of the conveyor ancillary equipment. The reference rail facilitates the mounting of drills on carriages which makes it possible to use much more powerful drills than can be used in conventional stoping.

Rough footwall resulting from the absence of favourable parting planes in a stope mined by blasting. This footwall was negotiated by a reciprocating flight conveyor.

Smooth footwall resulting from the presence of favourable parting planes in a stope mined by blasting. The stope was cleaned using the reciprocating flight conveyor.

Underground tests of hydraulic drilling jumbos with 5 kW rockdrills having the ability to drill at a rate of 1 m/min were commenced. The main problem has been the removal of the jumbo from the reference rail for storage in a special parking carriage located behind the reference rail away from the blast. It has been found that transfer of the jumbo from the parking carriage to the reference rail is very time-consuming and several alternative approaches are under investigation.

The trials of the third prototype reciprocating flight conveyor provided the opportunity for substantial development towards effective systems of self-advancing chocks and blast barricade erection. The self-advancing chocks serve the dual purpose of providing roof support and the means for controlled movement of a conveyor with significant reductions in labour requirements. The conveyors have been developed to a stage where they can be regarded as viable mining machines, but a fully co-ordinated mining system has yet to be developed. However, the favourable prospects of attaining this objective, coupled with work study predictions of appreciable improvements in labour productivity, to levels exceeding 40 ca/worker/month, fully justify the continuation of this work.

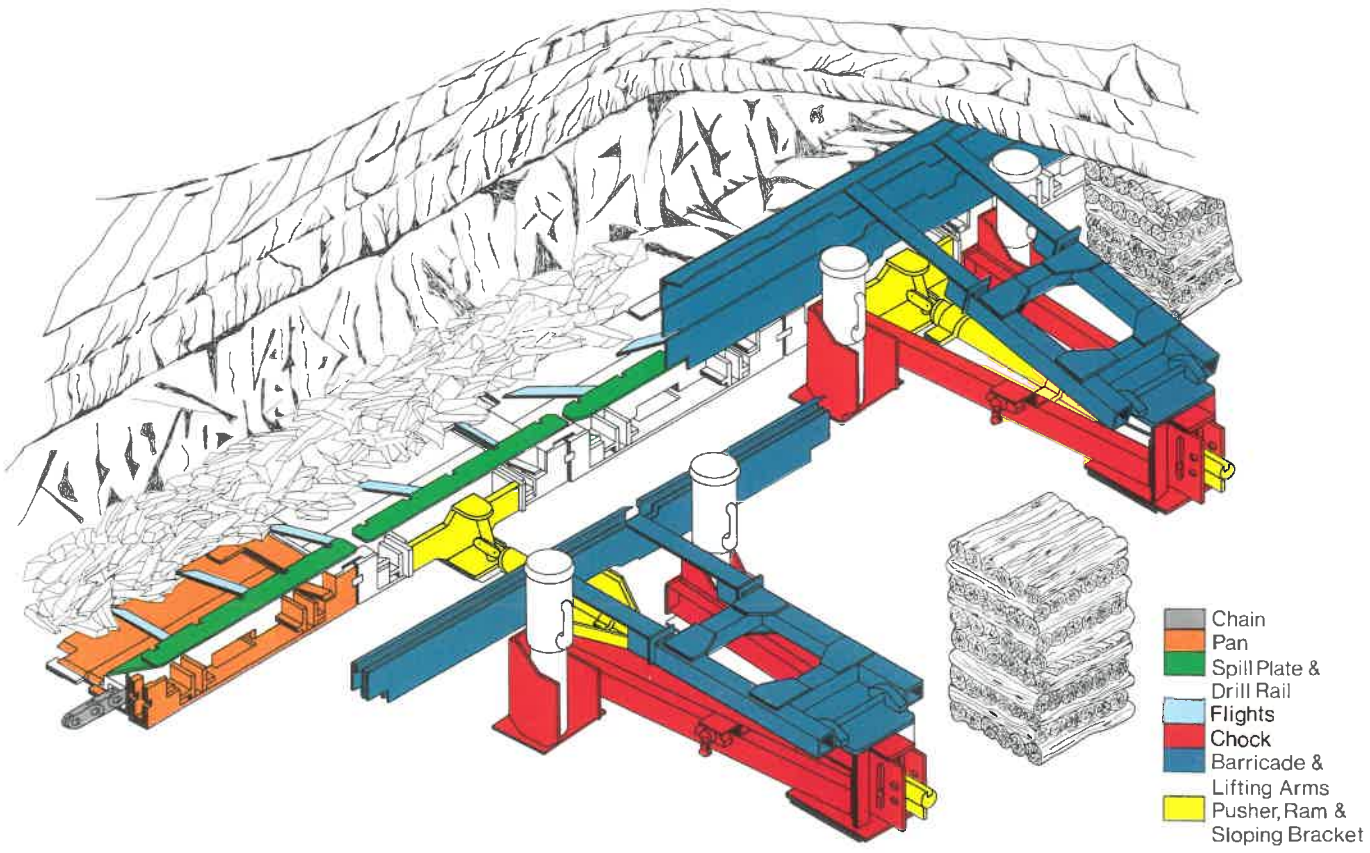
In addition to the development of equipment designed specifically for use with reciprocating flight conveyors, effort has been directed to other aspects of mechanizing the operations associated with roof support and the erection of blast barricades. Development has started on a combined system of self-advancing roof support and blast barricades using a reference rail only, which is designed to function in stopes having angles of dip of up to 30° and which should be suitable for use at all except the most severely faulted faces.

Progress has been made in developing hydraulic rockdrills for stoping which operate on water-based fluids. Tests have commenced on low-powered drills suitable for hand drilling or mounting on light rigs; these drills have improved torque characteristics and a mass of 20 kg. High-powered drills will be tested underground during 1978.

Development of non-explosive rockbreaking methods

Mining systems based on mechanized rockbreaking offer the advantage of selective mining. As little rock as possible is removed from the stope with the barren rock sorted from the reef being left in the stope as a waste pack to provide a measure of control of closure and additional roof support.

A general view of the reciprocating flight conveyor showing the disposition in the stope of the various system components.



The main field of application of systems based on rockcutting would be for mining deep, narrow reefs where their use could lead to increased profits and improved working conditions. The total area mined in rockcutting experiments is now 55 000 ca. The development effort during the last few years has been directed at achieving a mining rate of at least 5 ca per shift and a labour productivity equivalent to that attained in conventional mining. Although to be economically viable it is not necessary for rockcutting to achieve these performance figures, a rate of mining and a labour productivity less than those achieved in conventional mining would make it unattractive.

During the last two years several successful features have been built into rockcutting systems. These are high-pressure water jets which make it possible to cut the hardest quartzites at acceptable rates, mounting of the cutter on a guide rail which permits faster machine movement, an inverted machine configuration which avoids the obstruction caused by rock falling off the face during cutting, a ram haulage which eliminates the interference between different operations caused by the haulage chain, and a machine configuration which eliminates the need to drill finishing holes at the end of the slot. Techniques for cutting against the hangingwall which decrease the effort involved in face preparation have been introduced as well. Two different mining systems incorporating these improvements were evaluated with the object of investigating rockhandling problems and improving labour productivity.

There were two essential differences between the systems. In one a rockcutter was mounted over a reciprocating flight conveyor close to the face and hand-held pneumatic picks were used for secondary rockbreaking. In the other the rockcutter was mounted on a simple guide rail with a shaker conveyor behind the first row of hydraulic props and parallel to the face; a secondary rockbreaking device mounted on the same guide rail followed the rockcutter. In each system, the rockcutter functioned quite satisfactorily. In both systems the rockhandling and secondary rockbreaking equipment was unable to keep up with the rockcutters, and this incompatibility resulted in much idle time so that the actual labour productivities were less than the targets. However, work studies showed that the work content was within the limits for the achievement of an acceptable labour productivity.

While rockcutters could be developed further to achieve even higher rates of mining, present designs are such that production rates acceptable in a practical mining machine can be attained. The main obstacle to the finalization of a mining system based on rockcutting does not appear to lie in the machine itself but in the development of a device which will remove rock from the face and transfer it into a conveyor lying along the face.

With rockbreaking by impacting it is feasible to obtain rapid rates of mining combined with good labour productivity. In addition, when narrow reefs are so mined, it is possible to sort and pack waste in the stope. Two types of device have been investigated, namely, the swing hammer miner and impact rippers. A little more than 1 000 ca have been mined with these devices.

Experiments with the remaining swing hammer miner at Hartebeestfontein gold mine were concluded in the middle of 1977. In the sense that the machine actually broke rock at rates approaching those predicted and that it loaded the rock onto the conveyor most effectively, it was successful. However, there are several features inherent in the machine which make it unattractive. First, the angle of attack of the hammers is poor. When the hammers encounter a hard patch of rock which does not break readily, inclined fracture surfaces are formed. The configuration of the machine is such that the angle of attack becomes worse in relation to the inclined surfaces. Thus, the ability of the hammers to break rock deteriorates precisely when the rock is most difficult to break. Second, the poor angle of attack results in a very short bit life an order of magnitude less than that which could be acceptable. Third, the machine is mechanically complex and unreliable. Fourth, it is not possible to increase the blow energy much without causing severe mechanical problems. Nevertheless, much useful knowledge was gained from this work regarding the effects of impact on rock faces and this is being applied to the development of impact ripping machines.

A basic advantage of an impact mining system using impact rippers is that the potential exists for delivering blows of

Rockhandling in a multi-purpose diagonal gully in a mechanized stope. The hydraulically-powered shaker conveyor has a total length of 100 m and receives rock from the strike gully discharge point as shown and conveys this rock to the main level.

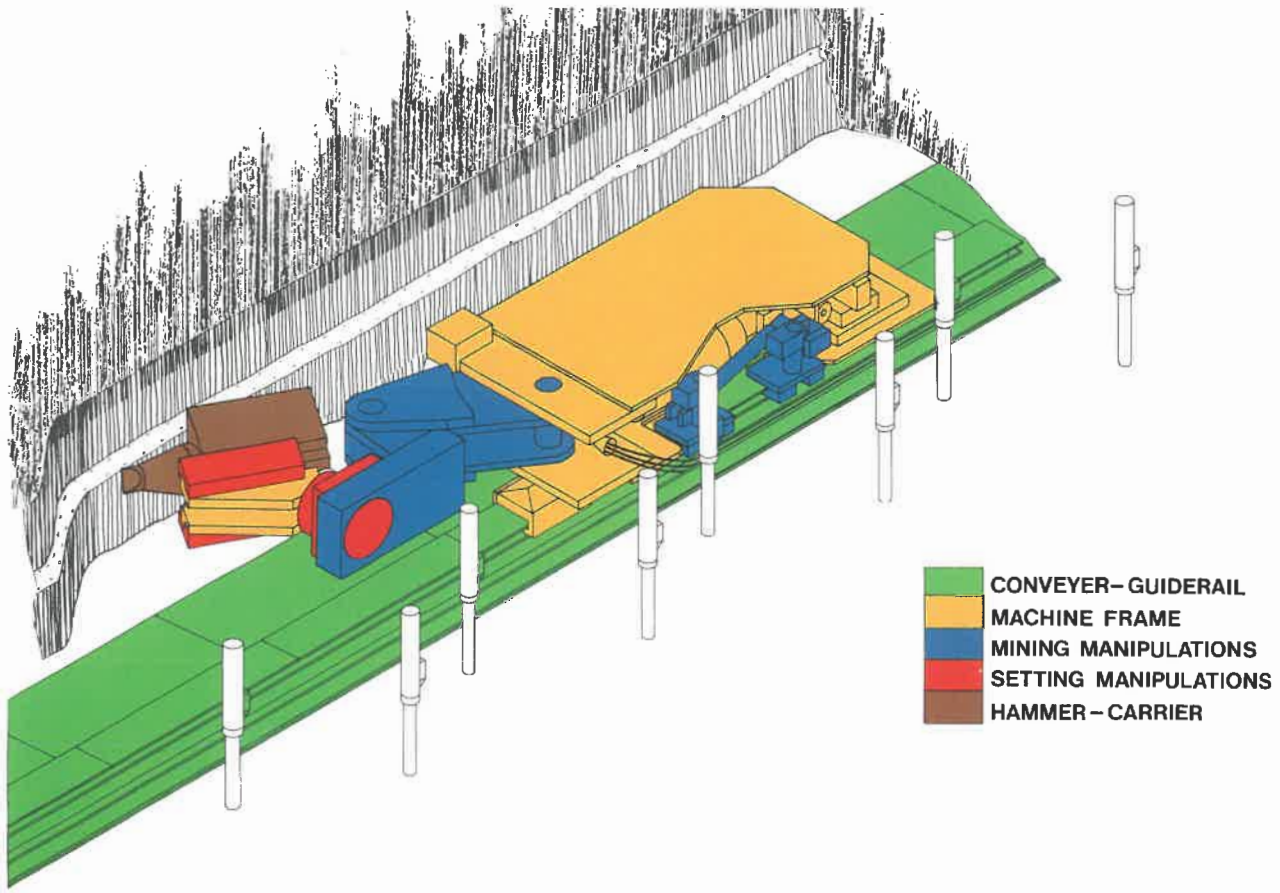
much higher energy more reliably and at more favourable angles of attack than is possible with the swing hammer miner. Several experiments have been carried out with impactors having blow energies of up to 2 000 J. Experience has shown that where fractures exist in the rock and these can be used to proper advantage by the impacting machine, greatly increased rockbreaking rates can be achieved. Currently, most mining is carried out in rock in which energy release rates exceed 10 MJ/ca. At rates of 10 MJ/ca fractures are spaced typically from 50 mm to 500 mm apart. To cope with most rock conditions, therefore, it is necessary for impactors to be capable of breaking through 500 mm slabs of solid rock. To accomplish this a blow of about 5 000 J energy is indicated.

The evolving of practical mining systems for impact rippers will require much investigation. There may be considerable difficulty in breaking beyond parting planes where the rock is intensely fractured on one side and relatively solid on the other, and under such conditions it is necessary to manipulate the hammer to attack the rock at appropriate angles. Provision of comprehensive hammer manipulation leads to mechanical complexity of the ripping machine and a practical balance has to be reached between this complexity and the degree of manipulation provided.

Ripping machines may be designed to mine down-dip or up-dip, and while the former method has the potential for achieving the higher mining rate, rockhandling techniques must be capable of clearing the rock from the path of the machine rapidly enough to prevent obstruction. The latter method has the disadvantage of requiring more comprehensive hammer manipulations as well as having a lower mining rate. Again it is apparent that the main limitation to production is likely to be in the area of rockhandling.

One machine, installed underground for testing early in 1977, has a highly manipulable impactor with seven different movements. The articulation of the manipulator is such that the machine can dig gullies behind the reciprocating flight conveyor on which it is mounted. Although numerous mechanical difficulties have arisen which prevented the attainment of consistent and acceptable mining rates, this machine has achieved an instantaneous breaking rate better than the predicted 4 ca/h. It has demonstrated the viability of this method of primary rockbreaking and much valuable knowledge has been gained regarding requirements for future ripping systems.

Sketch showing a ripping machine operating on a guiderail in a stope.



Development of electric and hydraulic power systems and other back-up systems for mechanized mining

Machines and equipment for use in gold mine stopes are subjected to extremely harsh environmental conditions and very severe space constraints. These factors require specific consideration during the design of such underground equipment.

It has been necessary to develop an electric power system which permits frequent disconnection of machines, which provides an independent supply to each machine, which allows control devices to be incorporated, and which is safe for workers in the wet stopes. The system consists of a compact rail-mounted 200 kVA transformer which supplies stope gully boxes by means of plug-in cables. There is a gully box for each machine and power is supplied to the machine by means of plug-in trailing cables. Each gully box contains earth-leakage protection and control circuits. Special features of the system are that all electrical equipment can be disconnected or reconnected and defective equipment replaced by unskilled workers. If a fault develops on a machine only the supply to the faulty machine will be interrupted. The system is safe for personnel because of the earth-leakage protection and a control circuit which disconnects the supply if a circuit is opened. It is less likely to cause fires than conventional mine power supplies. Any number of control devices, such as temperature and level controls, can be incorporated readily.

The plug-in electric power system has continued to operate very satisfactorily throughout 1977 at a number of experimental sites and has now been developed to the extent where it is sufficiently reliable to be used in production.

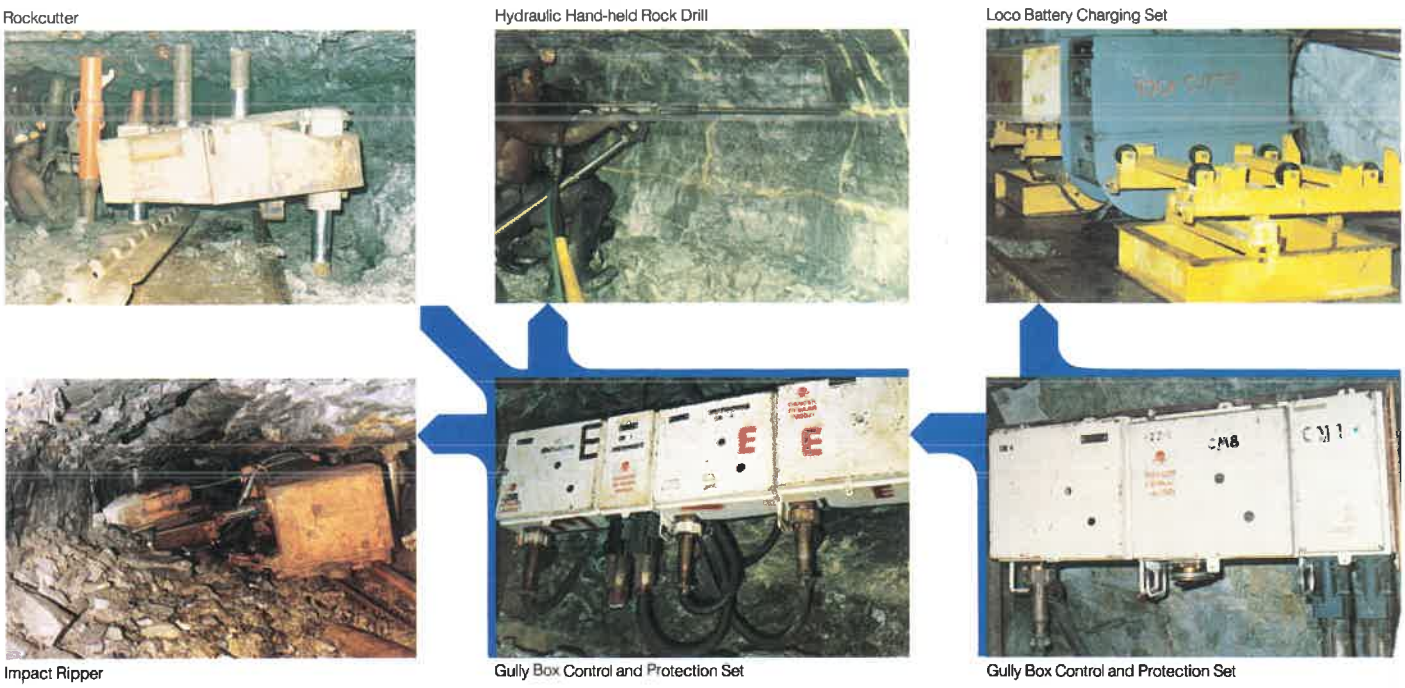
Following the success of the application of remote radio control to monorail transport systems, the technique has been used to control rockcutter electro-hydraulic power packs and gulley conveyors.

A compact arc welder has been developed for use in gold mining stopes.

Water-based hydraulic power systems are being developed for economy, safety and for preventing pollution of the workings. Very good progress has been made in developing equipment for use with a 5 per cent soluble oil-in-water emulsion. In collaboration with manufacturers, variable-delivery pumps have been developed which have good lives and efficiencies when operating at a pressure of 15 MPa. Evaluation of hydraulic valves in operations underground has indicated the need for much investigation in this area and laboratory testing of valves has commenced with the object of improving designs.

A variety of impacting devices operating with 5 per cent oil-in-water emulsion has been developed and tested with encouraging results. Low-power rockdrills for hand drilling, high-power rockdrills for rig mounting, and high-blow energy impactors have been tested. Progress has been achieved by attention to seal friction in the small devices, the selection of materials such as plastic bearings, surface treatment of materials, and careful geometrical design to avoid cavitation which is more prevalent in the large devices.

Diagramatic representation of the plug-in electrical distribution system showing typical applications.



A serious problem in using oil-in-water emulsion in mines is the difficulty in maintaining a stable emulsion because of the poor quality of mine water. There are many grades of soluble oil, but analyses of mine waters indicated that the high concentrations of calcium and magnesium salts are such that on many mines a stable emulsion could not be formed with any of the grades of oil. However, from laboratory tests it appears that filtering to remove the suspended solids and softening to remove some of the harmful dissolved salts would make virtually any mine water suitable to form stable emulsions.

Progress has also been made in the use of mine water alone for powering machines and it has been possible to operate a rockcutter underground by means of filtered mine water treated with a corrosion inhibitor.

Research into the utilisation of labour for mechanized mining methods is of prime importance in the attainment of labour productivity levels which will enable those methods to be accepted as practical mining techniques. During 1977 one particularly successful result of this work was the development of a fault diagnosis training programme for rockcutter operators which has enabled unsophisticated personnel to keep their machines in working order, and the early type of rockcutters still in service at the Doornfontein experimental site have been maintained in this way for some four months.

*Research reports

Morphology and geochemistry of the different types of pyrites from the Upper Witwatersrand System of the Klerksdorp goldfields. T. Utter. *Research Report No. 8/77.*

A study of methods to improve the performance of drag bits used to cut hard rock. M. Hood. *Research Report No. 35/77.* Doctoral Thesis, University of the Witwatersrand.

A local gold distribution pattern in the Precambrian Kimberley reef placer: a case study at the Marievale gold mine, East Rand goldfield. W. Hirdes. *Research Report No. 41/77.*

The morphology and fineness of gold from the Upper Witwatersrand and Ventersdorp System of the Klerksdorp goldfields, South Africa. T. Utter. *Research Report No. 40/77.*

Trials with the TEX 35 HSA hand-held hydraulic pick for secondary rock breaking. Z. J. Walczak. *Research Report No. 54/77.*

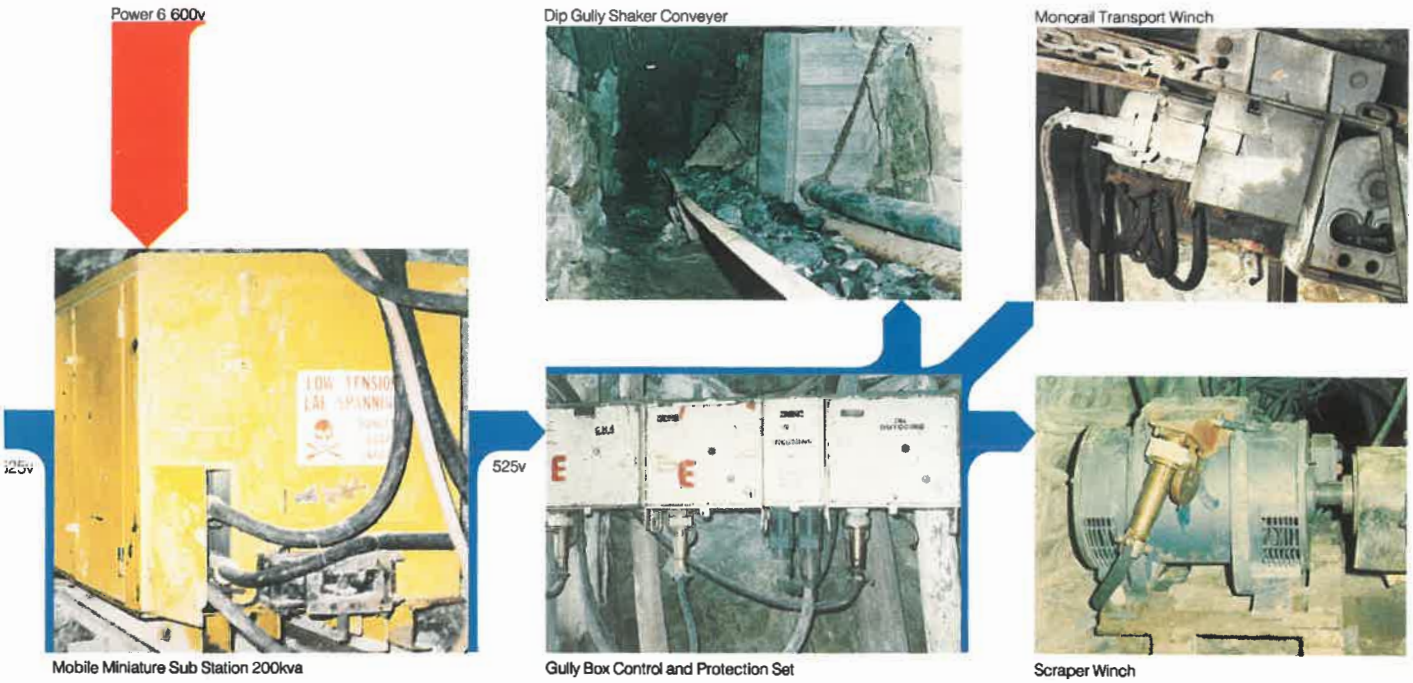
*These are available normally only to members of the Chamber of Mines.

Publications

Morphological and anatomical observations on some Precambrian plants from the Witwatersrand, South Africa. D. K. Hallbauer, H. M. Jahns and H. A, Beltmann. *Geologische Rundschau,* vol. 66 (2) (1977), p. 477-491.

Some safety aspects of electrical reticulation in gold mining stopes, with regard to the fire hazards. D. H. P. Jackson. Association of Mine Managers of South Africa. *Mine Fires Symposium,* April 21 (1977), Stilfontein, Transvaal.

The plug-in facility exists throughout the entire low-tension network.



The mechanism of fracture of hard rock using drag bits assisted by water jets. M. Hood. *Symposium: Erosion: prevention and useful applications,* October 24-26, 1977. American Society for Testing and Materials, at the Colorado School of Mines, Golden, Colorado.

An appraisal of impact ripping as a means for advancing the face in a gold mine stope. G. T. Buckler. *Chamber of Mines Research Review 1976/77.*

Dilute oil-in-water emulsion as a hydraulic fluid for gold mine stoping machinery. D. G. Wymer. *Chamber of Mines Research Review 1976/77.*

Seismic activity around the rockcutter face at Doornfontein gold mine. R. J. van Proctor. *Chamber of Mines Research Review 1976/77.*

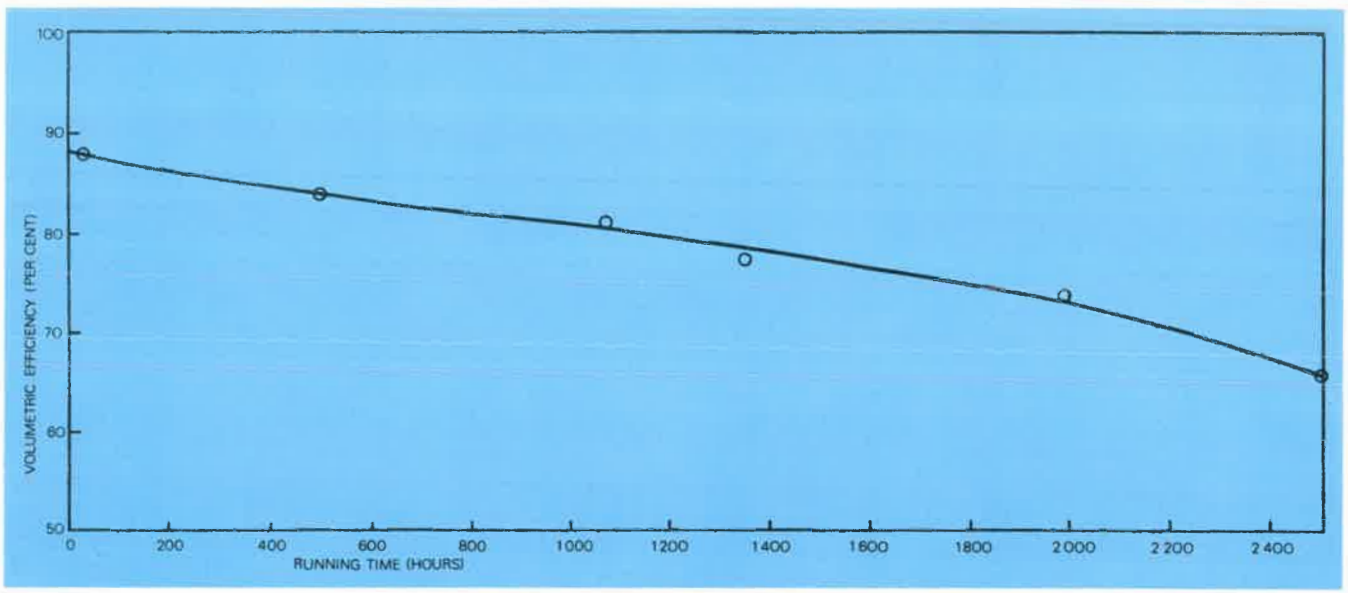
Morphology and microtexture of minerals from fossil gold and uranium placers. D. K. Hallbauer. *Chamber of Mines Research Review 1976/77.*

Progress in the development of mechanized stoping methods. N. C. Joughin. South African Institute for Mining and Metallurgy, *O.F.S. Colloquium: Mechanical Equipment for Underground Use.* Nov. 16-17, 1977, Welkom, O.F.S.

Geochemical and morphological characteristics of gold particles from recent river deposits and the fossil placers of the Witwatersrand. D. K. Hallbauer and T. Utter. *Mineralium Deposita,* vol. 12 (3) (1977), p. 293-306.

A new port-plate (right) for a hydraulic axial piston pump; after running for 2 500 h on dilute oil and water emulsion it was found to have deteriorated because of cavitation erosion (left).

The graph shows the resulting change in performance. The deterioration can be minimized by choice of the most appropriate emulsifiable oil.



Electronic and Mechanical Engineering

Towards the end of 1976 the Electronics and the Mechanical Engineering Divisions and the Instrument Workshop were amalgamated to form Electronic and Mechanical Engineering (EME). The staff complement numbers 88 including 15 professional posts and 47 technical posts. The Rock Properties Testing Division was transferred to the Mining Operations Laboratory.

Most of the work of EME is concerned with assisting the five Laboratories by providing an advisory service and by designing, constructing and modifying equipment.

Mechanical engineering and instrument workshop

During the first half of 1977 the new 1,8 MN servo-controlled prop-testing machine was completed. The final design and manufacture of the loading frame and the installation of the machine were done by the Mechanical Engineering Workshop. This powerful and versatile machine will be used for routine testing of rapid-yielding mine props and for experimental and development work on other support devices which are necessary for safe mining at greater depths.

Also completed early in the year was the construction of the 30 kW centrifugal mill which has been installed on surface on a mine and which is providing the Metallurgy Laboratory with data which will be important in the design of a proposed 1 000 kW milling machine.

The new 1,8 MN servo-controlled prop-testing machine.

Roller cutters, if they are to be used to mine ore in gold mine stopes, will have to operate far more economically than they do at present. A machine has therefore been designed for investigating the mechanism of rockbreaking by rolling cutters at forces and speeds which occur during operations such as raise- and tunnel-boring. It is expected that construction of this equipment will be completed during the first quarter of 1978. It is hoped that this testing machine will provide the data necessary for the development of economical cutters and hybrid cutting systems.

Impact rippers, or hammers, are thought to have considerable potential for breaking gold-bearing rock. Because of the severe limitations to space in stopes and the hardness of the rock, impact hammers of suitably small size capable of delivering blows of power sufficient to break the rock need to be selected or developed. A device to determine quantitatively the rock-breaking capacity of a hammer in relation to the blow energy, type of impulse and frequency has been constructed. This test rig also records the "signature" or nature of the impulse delivered by the hammer. The nature of this impulse is influenced by numerous factors such as the geometries and relative velocities of the hammer and tool components.

A falling-mass test rig, the impact energy of which is known accurately, has been constructed; by means of this equipment the relationship between blow energy and breaking ability of impact hammers can be determined. The hammers tested to date have shown a marked lack of mechanical reliability and it has been necessary to build a further hammer test rig in which a machine can be run for a sufficiently long period of time to test the life of hammer components under simulated service conditions.

A considerable amount of assistance is being given to the Mining Technology Laboratory in the construction of a new stand-off ripper which is an alternative to the conventional impact ripper, and assembly of the machine is proceeding.

The Chamber of Mines is the only supplier of the konimeter which is the accepted standard means for sampling air-borne respirable dust in mines. Meeting the demand for these instruments imposes a heavy load on the Chamber's instrument-manufacturing facility. The design of the konimeter has recently been improved to simplify the manufacture and maintenance of the instrument without affecting it as a dust-sampling device. The new konimeter has not yet been fully tested but it is expected that a considerable improvement in reliability will be achieved.

A stope simulator has been constructed for the Human Resources Laboratory for studying the perception and reaction of a man to hazardous situations arising in a stope due to the presence of loose rock in the hangingwall and face.

ELECTRONICS DIVISION

Communication

The design, testing and documentation of a general-purpose mine radio transceiver was completed and a large batch of the instruments is being manufactured. Numerous demonstrations and tests which were made during the year

showed that this equipment will be very useful in providing communication between men in a number of mining situations. Besides use of the radio by rescue and fire-fighting teams, it can be used in raise boring and other mechanized mining tasks, for shaft inspection and for communication between men in stopes and travelling ways and on surface as has been shown by a small network tested in two coal mines. Because of the poor radio propagation characteristics of rock, existing metallic conductors such as power cables are used to help propagate radio signals underground. It is necessary, therefore, for personnel who use the radio equipment to be given training so that they understand the practical difficulties involved in making full use of conductors.

Telemetering

The stress on a raise borer cutter has been measured, transmitted by radio and successfully recorded. The information showed that large transient forces with high-frequency components are exerted on a cutter.

This was done by means of strain gauges attached to a prepared and calibrated cutter and connected to the multi-channel radio telemetering equipment which is mounted beneath the raise-borer reamer. The telemetering equipment is battery-operated and is designed to withstand the severe vibration of the reamer and the spray of water. Further field trials will provide valuable information about the magnitude and the direction of components of the forces exerted on cutters, this information will be used in improving the design of cutters and methods of reaming.

Two types of multi-channel radio telemetering equipment have been made. One is used for transmitting fast dynamic information and the other is used for transmitting information which has a long response time.

The effectiveness and reliability of a fire detector network which was installed in a mine was examined. The detectors responded to a fire which started during a blasting period and indicated clearly their value in detecting a fire. Difficulties were caused by the high humidity of the mine environment and, therefore, improvements to the equipment to overcome corrosion were proposed to the suppliers.

Remote radio control

Remote radio control equipment was constructed for the control of a dip gulley conveyor, two mono-rail conveyors and a few rockcutter power packs in an experimental mechanized stope. Radio as a means for control is being compared with other electrical controllers which require long trailing cables. The equipment has been shown to be very reliable and has the advantage that in the event of failure it can be replaced immediately with a spare unit whereas a cable fault takes a considerable time to repair.

A simultaneous 12-channel remote radio controller has been made for controlling a new impact ripper. The hand-held controller is small and will enable the operator to move freely about the machine without being hampered by an electrical trailing cable or by numerous hydraulic hoses.

Automatic control

Various methods of controlling the temperatures of cold service water in a mine were examined by simulation with a digital computer. It has been shown that a number of variables are involved in the problem and that a very simple type of controller is not suitable if the mine does not have adequate storage capacity for water. Because of the random nature of the temperature and the flow rate of the available water supply and of the demand for cold water a predictive and adaptive control is necessary. The most suitable control strategy for a particular application is being examined and the basic elements of a simulation model will be designed so that various types of installations can be tested.

Seismology

Improvements were made to a seismic network which operated continuously throughout the year and provided a great deal of information about seismic activity in a mechanized stope. Instruments placed at this stope face recorded interesting micro-seismic events and have stimulated further investigations. On account of all the seismic and other data which has to be processed a minicomputer which has a graphic display has been installed and will be used for selecting and locating all the seismic events.

The mine radio transceiver which may be used for communication during fire-fighting or rescue operations or for many other mining operations.

Metallurgy Laboratory

A robust 20-channel tape recorder suitable for continuous seismic recording was designed and made and has proved to be very reliable. Further machines are being made for other seismic networks.

*Research reports

The installation and operating procedure for radio equipment used underground. B. A. Austin. *Research Report No. 22/77.*

The Doornfontein seismic network. B. T. A. Hetherington. *Research Report No. 20/77.*

An interim report on the radio communication system installed underground at Greenside Colliery, Apex Mines Ltd. B. A. Austin and G. P. Lambert. *Research Report No. 39/77.*

A review of the regulation concerning the control of acoustic noise in industry and the possible effect of the regulation on the use of percussive drills in mining. A. R. Atkins, H. V. Robson and Z. J. Walczak. *Research Report No. 33/77.*

Publications

The transmission of radio signals in deep-level gold mines indirectly via power cables. B. A. Austin and I. Keldic. *Electronics Letters.* Vol. 13 (16) (1977), p. 462-463.

The use of an integrated circuit generator in low-pass filters for telemetry applications. B. Bowles. *Electronics Engineering.* Vol. 49 (597) (1977).

*These are available normally only to members of the Chamber of Mines.

Previously there were three major areas of activity within the Laboratory. Of these the work concerned with new uses for gold was transferred to Intergold during the year, and that on the development of portable assay instruments moved towards a satisfactory conclusion. Accordingly greater attention could be directed to procedures for the concentrating of gold-bearing ores underground. The staff was reduced to 41 of which 18 were professional posts and 14 were technical.

Concentration of gold-bearing ore underground

Work has continued on the development of a compact process for the recovery of gold and other metal values underground, so that the waste generated can be used as backfill. The approach being taken is to model the metallurgical circuit on the computer, and to identify areas where assumptions must be made regarding the performance of equipment. Such assumptions mean either that further studies must be made of the performance of available equipment, or that novel equipment must be developed to satisfy the demands of the circuit. In addition, the model can also be used to identify parameters in the circuit which affect the overall performance of the circuit significantly, so that particular attention can then be paid to the accurate determination of those parameters. Finally, the model can be used for dynamic studies to ensure that the circuit is stable, and to identify possible control strategies.

It is hoped in this way to evolve as efficient a circuit as possible, to delay the construction of a complete pilot plant for as long as possible, and in the meantime to construct plants to resolve the specific difficulties identified in the model. With this approach, the eventual pilot plant will be then close to full-scale so that it can be developed rapidly to the demonstration stage with significant savings in the total cost.

The accompanying flow diagram of the circuit is modelled with information presently available. Some significant findings which have been incorporated in the model are noted below.

The gold in the reefs is significantly coarser than has previously been believed, as is shown in an accompanying figure which indicates mesh sizes for undisturbed gold particles recovered from a variety of reefs. The mesh sizes shown are approximate in some instances, and in those cases are based upon an estimated shape of a gold particle equivalent to a parallelopiped of dimensions 1 : 0,4 : 0,4.

This relatively large size of the gold particles implies that the gold is released from the ore more readily than is generally assumed.

Gold has been found to be one of the most floatable constituents of the ore. This is indicated in the adjoining figure in which the amounts of gold and gangue minerals floated are compared as a function of particle size. Over the size range of 50 to 500 μm, the proportion of the gold floated is at least twice that of the gangue minerals floated.

In a "rougher" flotation step, a significant quantity of fines is floated, so that flotation is partly a classification process. The excellent degree of flotation of all fines in the −50 μm range

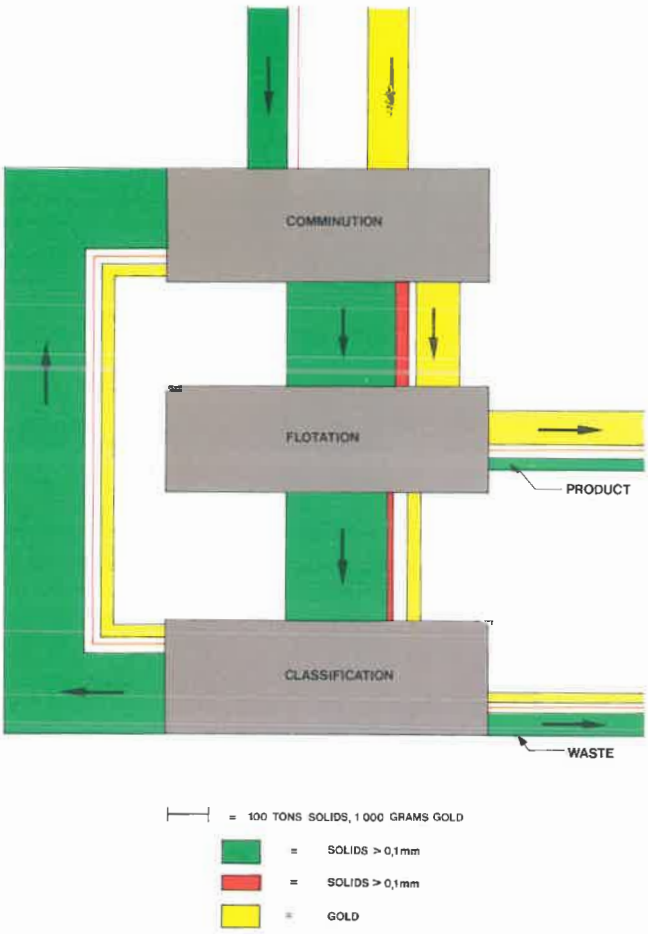
and the effect on the overall circuit is clear from the accompanying figures. The mass of −0,1 mm solids in the flotation product is shown to be more than double that of −0,1 mm solids in the classifier overflow, the "waste" stream. The classifier is thus relieved of a significant burden of fine slimes.

The classifier has been found to be an efficient scavenger of gold, and to recycle 93 per cent of the gold fed to it back to the mill. This occurs because the density of the gold-silver alloy, which is the usual form of gold in the reef, is so much higher than that of the gangue minerals. Consequently hydraulic classifiers such as hydrocyclones concentrate the gold in the underflow.

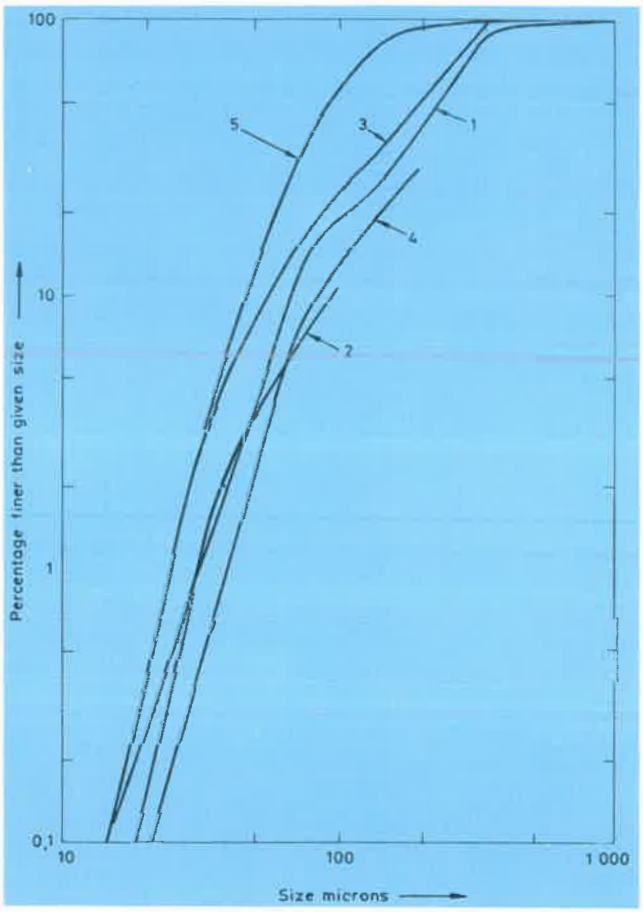
With regard to the unit processes used, a number of problems identified in the modelling studies have either been solved, or engineering studies initiated. For instance, computer models of the action inside centrifugal mills indicated that the power drawn by a mill of a configuration such that the ratio between the mill diameter and the diameter of the centrifuge was greater than 1, would be greater than that predicted from tests on mills for which the ratio was less than 1, and this was found experimentally to be the case. Similarly studies were conducted on the flow of material through centrifugal mills. Tests at Durban Roodepoort Deep gold mine have led to the development of satisfactory designs for feeders and discharge mechanisms. A possible site for testing the 1 MW machine has been found, and a contract for the erection of the machine on this site is being negotiated.

Two potential problem areas were identified in the study of the flotation process, namely, the prevention of sanding during flotation from coarse (—3 mm) material, and the large volume of the equipment required to float gold from a total feed of the order of 300 tons per hour. Studies on sanding in flotation cells have led to a novel design of cell which gives improved agitation. A comparison of the kinetics of flotation of gold as a function of the design of the flotation machine showed that a significant improvement in the speed of flotation could be achieved by the use of a cell of novel

Schematic of the flow of coarse and fine solids and gold in the suggested underground concentration circuit.



Mass-mesh size distributions of undisturbed gold particles from various reefs.
1. Ventersdorp contact. 2. Main. 3. Kimberley. 4. Carbon leader. 5. Basal.



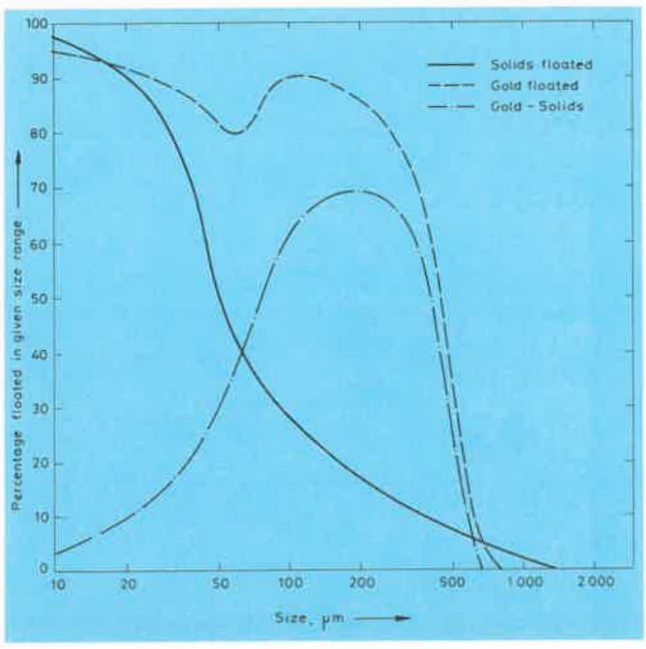
design. This increase in kinetics results potentially in a lower volume being required for a given duty, and preparations are being made for tests on larger-scale equipment.

In studies on classification, existing models of the performance of hydrocyclones were extrapolated into the region of coarse cut-point and high-density particles required by the proposed circuit. The limited data available indicated that the extrapolation was valid, but because the model had shown a high sensitivity to the effect of classification on overall recovery, it was decided to construct a pilot plant to test the ability of a 750 mm-diameter cyclone to make a coarse cut and to scavenge gold. Construction of this plant was started at West Driefontein gold mine towards the end of the year.

Work on the control of a conventional circuit at Blyvooruitzicht gold mine continued to provide valuable understanding of the dynamics of mill circuits which could be incorporated into the model of the novel circuit. During the year recommended modifications were made to the Blyvooruitzicht circuit and these appeared to have the desired beneficial effect.

An investigation into the desired properties of backfill was brought to a satisfactory conclusion. It was found that −1 mm "grits" having a bi-modal size distribution could be placed hydraulically with less than 35 per cent voids. This fill material was free-draining and somewhat stiffer than cement-stabilized slimes. This is indicated in the figure in which a comparison is made between the uniaxial stress-strain curves for various materials at a constant height-to-diameter ratio. Studies on the placement of fill were initiated in co-operation with Stilfontein G.M. Co. Ltd., where cement-stabilized slime was placed around a shaft during pillar extraction. Instruments were placed in the fill to determine the behaviour of the fill as it came under load, and to test the instrumentation. It is hoped during 1978 to place grits over a large area in a demonstration of both emplacement techniques and of the benefits of backfill.

Variation of flotation recovery with size for gold and gangue minerals.



Portable assay instruments

During the year work on the first prototype of the portable gold assay instrument was completed. The results of experiments at Marievale and Blyvooruitzicht showed that despite a minor electronic fault in the instrument, which reduced the performance slightly, the major source of "inaccuracy" in the measurement arose from counting statistics. With scanning measurements, therefore, a good estimate could be made of the gold content of the face provided sufficient length of face was scanned. When the reef was narrow the instrument appeared to be able to indicate whether the face was pay or non-pay in a scanning distance of less than 5 m.

A minor source of "error" was found to result from instrument and operator variations. Drifts in performance were present in the first prototype, but these could be allowed for by regular calibration.

Unfortunately, the actual values measured in the experimental stope at Marievale gold mine were so low that little could be interpreted on the actual distribution of gold. At Blyvooruitzicht gold mine, on the other hand, the variation in gold content of contiguous samples was so high that it was necessary to scan a significant distance of the face to obtain an accurate estimate of the average gold content. Nevertheless the correlation between scan measurements and the gold content of 0,5 m blast samples was about 80 per cent for scan distances of 4 m.

The second prototype instrument that was delivered in April 1977 was in most respects a significant improvement on the first, although the mass of the probe was above specification. It was used underground from May until early November and performed satisfactorily. At the end of the year results of these experiments were being assessed. The preliminary findings were that, in comparison with those for the first prototype, instrument and operator variations were far lower. In a careful test between two operators no significant difference could be detected.

Personnel from the geological and valuation departments of one of the mining houses underwent a training course on the second prototype, and reported favourably on their findings except for the lack of a simultaneous uranium assay facility. Accordingly it is intended to add a channel for uranium assay during 1978.

There was a four-month delay in the delivery of the third prototype which was originally scheduled to arrive in September 1977. This delay permitted the specification of the third prototype to be refined and the problem of the supply of sources to be resolved. At the end of the year it appeared that difficulties experienced by local manufacturers of sources had been resolved.

Miscellaneous

Work continued on the use of fire-fighting foams when difficulties were identified in the use of both two-component foam compound mixtures and available foam generators.

Work leading to the specification of a filtration system for making moderate quantities of drinking water from service water in stopes was completed and it is hoped to test prototype filters during 1978.

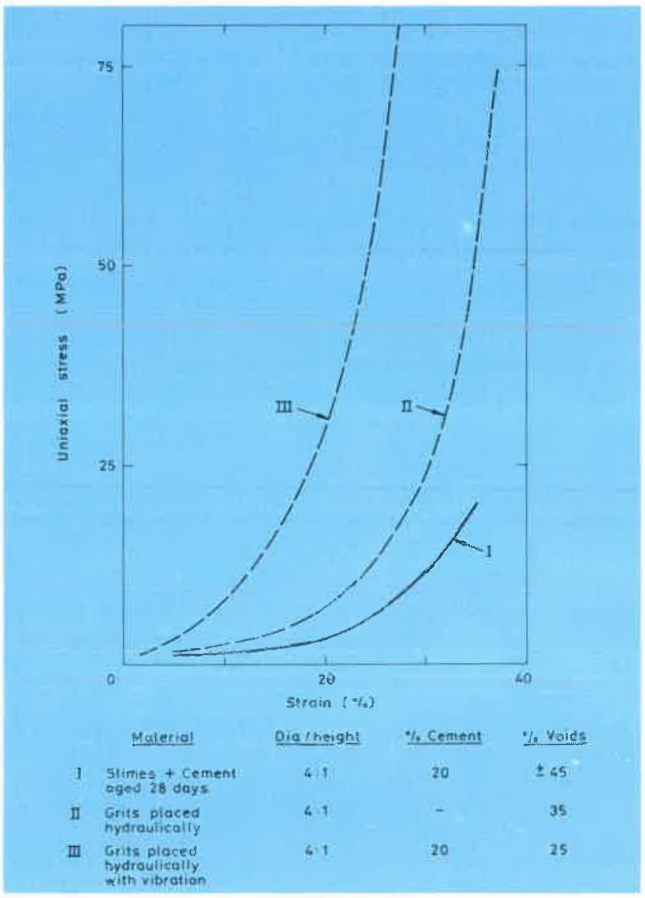
*Research reports

The testing to specification of the first and second prototypes of the portable gold analyser, and the specification for the third prototype. P. J. D. Lloyd and R. Rolle. *Research Report No. 45/77.*

Supplies of cold potable water in stopes — a feasibility study. J. D. Greig, F. A. Hawkins, P. D. J. Lloyd and R. W. Quail. *Research Report No. 29/77.*

Composition of commercially available gold jewellery alloys. T. Groenewald, A. W. Quail and Elise Krugel. *Research Report No. 3/77.*

Comparison of stress-strain behaviour of cemented slimes and uncemented grits.



	Material	Dia / height	% Cement	% Voids
I	Slimes + Cement aged 28 days	4:1	20	± 45
II	Grits placed hydraulically	4:1	-	35
III	Grits placed hydraulically with vibration	4:1	20	25

Radioactivity in sulphuric acid plants: third annual check on safety procedures. P. J. D. Lloyd, J. D. Greig, D. J. van Niekerk and M. J. Quinn. *Research Report 64/77.*

Publications

Minimal variance control strategies for wet milling circuits. American Institute for Mining Engineers. A. L. Hinde and R. P. King. *A.I.M.E. Spring Meeting,* Atlanta, Georgia, March 1977.

Control of milling circuits using simple feedback loops. A. L. Hinde. South African Institute for Mining and Metallurgy. *Winter School on Grinding,* August 1977.

A portable gold analyser for *in situ* ore analysis. D. A. Gedcke, R. Rolle and P. J. D. Lloyd. Institute for Engineers and Electrical Engineers. *Annual Conference on Applications of X-ray Analysis,* Denver, Colorado, August 1977.

Recent developments and improvements in foams used for fire-fighting. P. J. D. Lloyd, R. W. Quail and J. D. Greig. *Association of Mine Managers' Circular No. 3/77 Part II,* April 1977.

Centrifugal milling. P. J. D. Lloyd. South African Institute of Mining and Metallurgy. *Winter School on Grinding,* August 1977.

Mining and development in Africa. P. J. D. Lloyd. *International Association for the Exchange of Students in Technology and Engineering Symposium.* From Africa to Africa, Johannesburg, August 1977.

Difficulties in the use of plastics in mining. P. J. D. Lloyd. *Plastics Institute of South Africa Symposium,* Johannesburg, August 1977.

Potential applications of thiourea in the processing of gold. T. Groenewald. *Journal for the South African Institute of Mining and Metallurgy,* vol. 77, (1977) p. 271-223.

The influence of particle sizes and shapes on the performance of backfill grits. A. L. Guise-Brown and A. L. Hinde. *Chamber of Mines of South Africa Research Review 1976/77.*

A fresh look at noxious atmospheric contaminants on gold mines and collieries. J. D. Greig. *Journal of the Mine Ventilation Society of South Africa.* November 1977. Vol. 30, p. 213.

*These are available normally only to members of the Chamber of Mines.

Mining Operations Laboratory

The activities of this Laboratory are concerned with strata control in coal and gold mines, blasting in gold mines and the development of planning tools for gold mines. In addition, the Laboratory provides a number of services to members of the industry and other organisations. The staff numbers 37, of which 24 posts are professional.

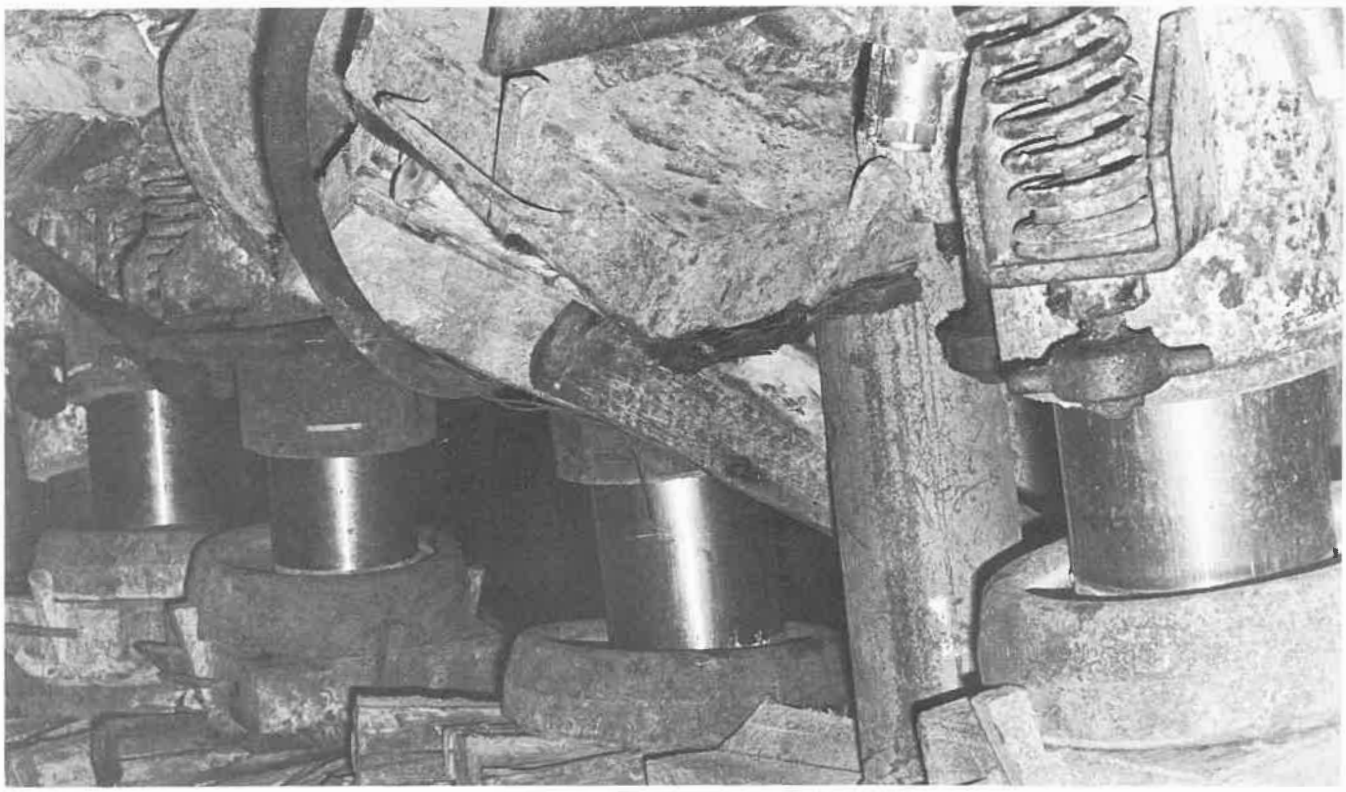
Strata control

Rockbursts continue to be the major hazard in deep-level gold mining. Considerable research has, therefore, been directed to this important area. During 1977 three seismic research networks were in operation and good progress was made in two fields of investigation. At Western Deep Levels gold mine, where the Anglo American Corporation and the Chamber of Mines co-operate on a joint rockburst research project, good progress was made in quantifying the relationship between mining-related parameters such as face geometry and to a lesser degree face advance and seismicity in terms of the spatial rate of energy release. The presence of faults and dykes has been shown to result in an increased level of seismic activity comparable to an increase in the effective spatial rate of energy release of about 30 MJ/m^2. This information has already proved to be of considerable importance from a long-term planning point of view.

The regional seismic network in the Klerksdorp district which covers an area of 250 km^2 has been up-graded to accommodate up to 20 geophones which will result not only in improved network reliability but also more accurate location of rockbursts. The pattern of seismicity in this district differs greatly from that in the deeper mines of the Central and East Rand and of the Far West Rand. Seismic events in the gold mines of the Klerksdorp area tend to be associated with major geological disturbances and structural zones. For example, nearly 90 per cent of all seismic events on one of the mines occur at the base of a very competent layer of glassy quartzite which is situated in a graben structure. Many of the other events in this district, and in particular most of the large events, are associated with fault zones. Apart from its importance in the study of fundamental aspects of seismic events the information collected to date has been shown to be of considerable value in the formulation of long-term mining plans.

During 1977 the instrumentation was completed of an experimental hangingwall cross-cut situated some 80 m above the plane of the reef and slightly ahead of an advancing longwall face in the lower Hercules section of E.R.P.M. The instrumentation comprises several tilt- and strainmeters installed by the Bernard Price Institute for Geophysical Research to study strain changes in the source area of seismic

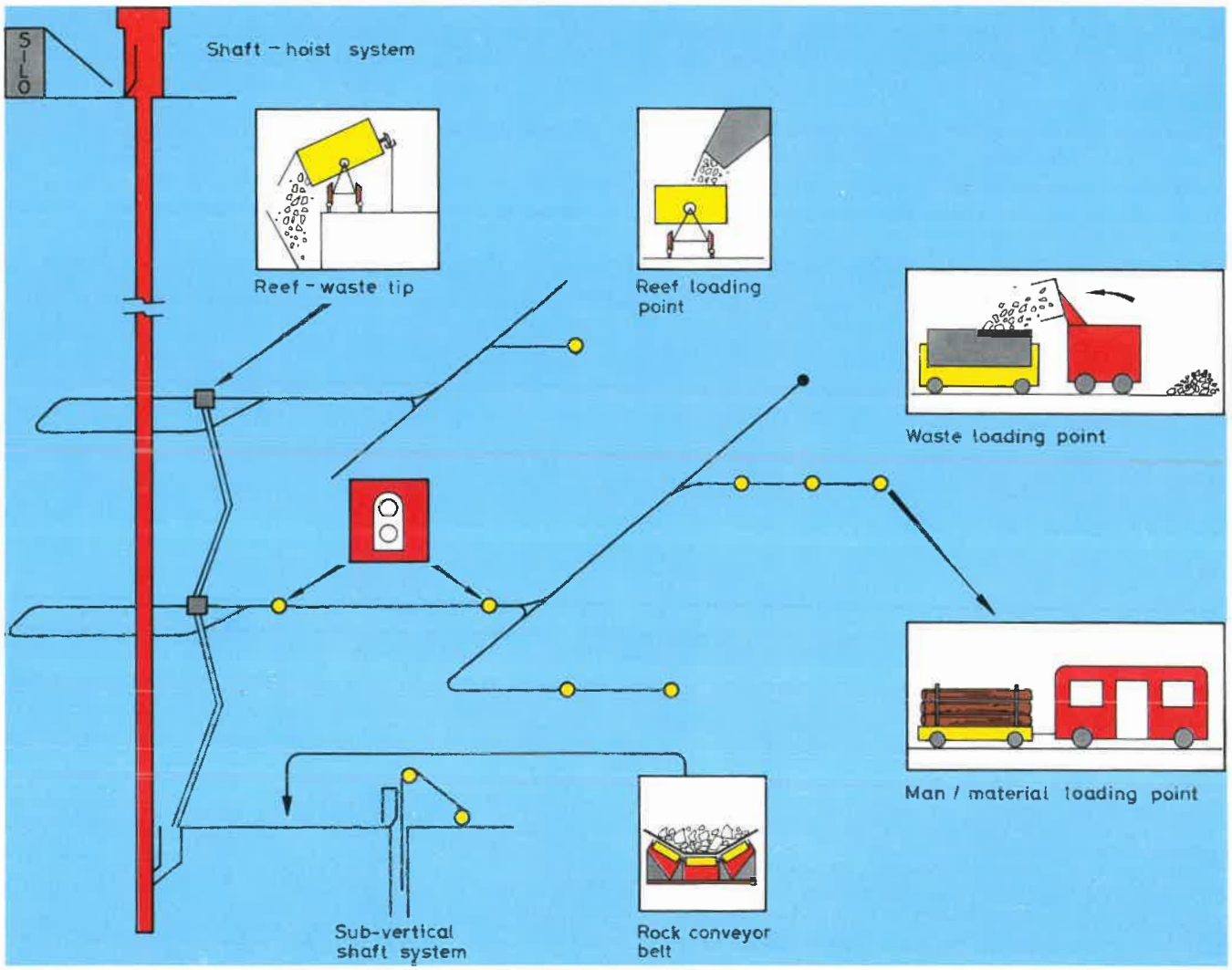
Considerable savings in permanent support and improved conditions in the working area close to the stope face have been attained by the development of massive 1,5 MN barrier chocks. These supports are installed within a distance of four to six metres from the stope face and advance with the face.



events. In addition, several extensometers up to 100 m long were installed in a vertical downhole to monitor strata behaviour at different elevations above the reef horizon before, during and after undermining the cross-cut. In addition this cross-cut is also being used to evaluate the performance of six different types of tunnel support systems and to investigate extreme stress conditions.

Earlier research has shown that active rapid-bearing support installed close to the stope face is of utmost importance for good strata control. This was highlighted again by the underground trial of forty 1,5 MN barrier chocks in a remnant stope at Blyvooruitzicht gold mine. The experience gained with barrier chocks at this mine suggested also that the density of permanent support in the mined-out area can be reduced significantly if there is good face support. To evaluate the technological and economic aspects of a mining system in which permanent support is used only alongside the stope gullies, a further field trial of barrier chocks was started at Western Deep Levels gold mine during the latter half of 1977. Although the test is still in its early stages the results obtained to date are very promising. Work on conventional support systems for gold mine stopes continued but the emphasis changed from the use of pack support to stick and pipe-stick support. A new 1,8 MN servo-controlled testing machine with an exceptionally wide dynamic displacement ranging from a few millimetres per hour to two metres per second has made it possible to evaluate support characteristics under different loading conditions.

The simulation program TRANSIM II can aid in the design of improved underground transport systems. Design variables that can be modelled include tip and boxhole characteristics, bunker sizes, train routing and traffic control policies, and shaft rock-pulling schedules in a multi-level environment.



Mine planning

The complex nature of many gold mining operations suggests that good use can be made of computer-based planning tools. Over the years several computer models have been developed to assist mine managements in the solution of complex planning problems. The most widely used programs are in the field of strata control and ventilation. During 1977 a general multi-level transport simulator, "TRANSIM", was completed and tested extensively and applied successfully on four mines. Work on a new compressed-air network simulator, "COMPAIR", has been completed; this simulator is particularly well suited to model complex compressed-air problems involving one or several loops in the network.

The large-scale application of a short-term production planning system, "SPPROSIM", on one of the mines has failed partly because of difficulties in gathering the required information and partly because of a lack of direct involvement of the production personnel concerned. Since the success of many of the computerized planning tools depends on the availability in suitable form of large volumes of data, further attention will have to be given to this question.

During 1977 work commenced on the development of functional gold mine models to evaluate the technical, organizational and economic impacts of changes to existing mining systems. Because of the complex interactions and the difficulties experienced in obtaining some of the basic information required for the economic evaluation of new developments it is expected that initially progress will be slow.

Blasting

Blasting is still the single most important method of rock breaking in the gold mining industry. This is illustrated by the fact that every day some 600 000 shotholes are fired to develop shafts, tunnels, orepasses and other service excavations and to extract the gold-bearing reefs. Detailed studies on a number of mines have shown that stope blasting is an operation in which there is considerable room for improvement. One of the main problems which arises in practice is the firing in sequence of up to 150 shotholes. In order to study this aspect fully a blasting gallery was established in a return airway at Stilfontein gold mine. It is possible, with the aid of this gallery, to simulate stope blasts under working conditions. All relevant data such as the sequence of and the time interval between, individual shots, the variations in burning rates of the igniter cord and the safety fuse and the failure of any of the components of the system are recorded electronically. In this way it is possible not only to evaluate different sequential firing systems but also to control the quality of blasting accessories.

Regular meetings with representatives of AECI ensure that close contact is maintained between the supplier and the users of explosives and blasting accessories. Many useful developments such as, for example, the introduction of a new generation of igniter cords, "STOPECORD 9" and "STOPECORD 12", have resulted from this collaboration.

Rock properties testing

A large number of uniaxial, triaxial and indentation tests were performed with the stiff testing machine. The main purpose of these tests was to provide basic information on the mechanical and physical properties of various rocks. As in the past a considerable amount of testing machine time was devoted to experiments by the Metallurgy Laboratory on aggregates for mine backfill.

Services

One of the main functions of the Laboratory is to assist the industry with the introduction of new concepts and techniques in the field of strata control, blasting and mine planning and to assist in the solution of specific problems in these areas at the request of the industry.

During 1977 the number of requests by members of the industry and other organizations for assistance increased considerably. Most noticeable were the requests in connection with the introduction of longwall mining in coal mines and enquiries regarding blasting in gold mine stopes. As in the past the Laboratory continued to assist suppliers of hydraulic stope support with the testing and the development of their products. The testing of rock specimens at the request of mines and suppliers of equipment continued to be an active area and almost one half of all tests conducted during 1977 fell in this category.

*Research reports

An evaluation of factors affecting mine tunnels. N. Wiseman. *Research Report No. 50/77.*

TRANSIM II — Mine transport simulator — users' manual. *Research Report No. 51/77.*

COMPAIR — Compressed air network simulator — users' manual (revised). D. J. T. van Niekerk. *Research Report No. 102/76.*

Publications

Register of computer programs in use in the South African mining industry — Issue II. *Chamber of Mines Research Organization, Feb. 1977.*

A computer program for the simulation of compressed air systems. D. J. T. van Niekerk. *Chamber of Mines Research Review, 1976/77.*

The implementation of dynamic programming for the solution of variational problems. J. A. L. Napier. *Proceedings of the 1977 Conference of the Operations Research Society of South Africa.* Port Elizabeth, October, 1977, p. 126-136.

*These are available normally only to members of the Chamber of Mines.

Research Services

Research Services consists of the Dust and Industrial Hygiene Divisions. There are 56 posts of which 22 are professional.

The Dust Division provides a wide variety of services to the mining industry on all aspects of dust problems affecting the industry.

The Industrial Hygiene Division concerns itself with aspects of heat physiology, acclimatization, applied physiology and ergonomics. It includes a Biochemical Section which is concerned with the analysis of blood, urine and air.

Dust

In addition to the many services provided to all mines the main activity of the Dust Division is the regular independent monitoring of dust conditions in controlled gold mines to assist in dust control and to determine the allocation of differential monetary levies. Any operations which produce high concentrations of dust are investigated with the object of reducing or controlling these dust levels. The dust conditions on surface plants of uranium-producing gold mines are also determined and a watch is kept on dust levels at the Rand Refinery and at NUFCOR.

Work is being directed towards developing a dust-sampling strategy involving the use of personal gravimetric samplers which will enable sampling to be done on a continuous basis. It is hoped that this will permit more meaningful and representative assessments to be made than was possible previously. The method, apart from giving more meaningful results, will be more economical than the method currently in use.

Heat acclimatization

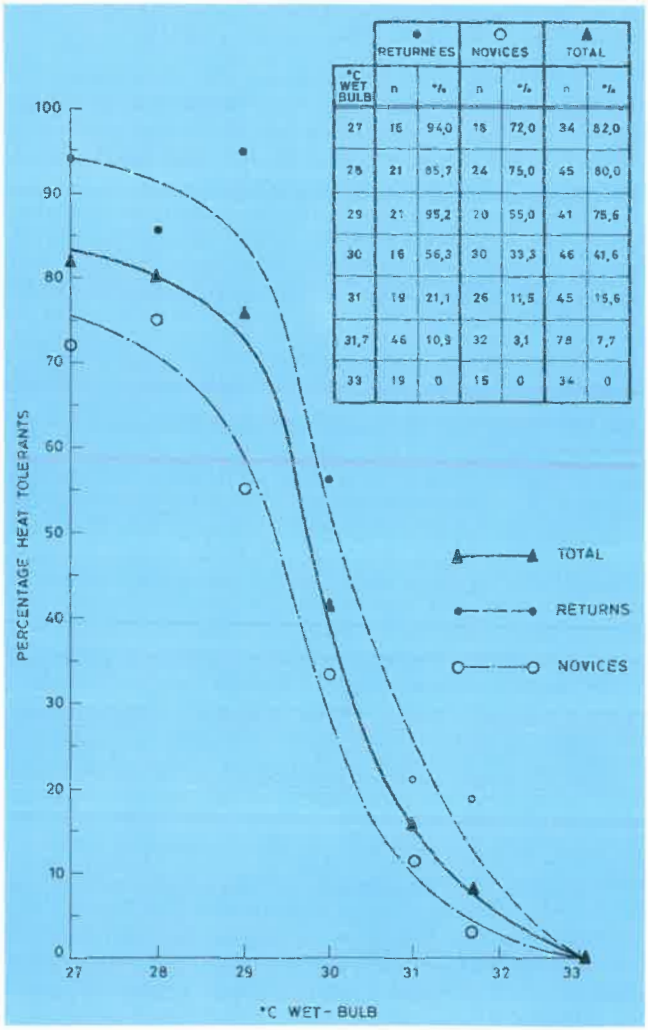
Advances continue to be made in the improvement and application of heat acclimatization procedures employed by the mining industry. Attention has been focused mainly on the reduction of the number of unproductive shifts while still maintaining a high standard of safety to the individual.

It has long been known that the degree to which individuals are tolerant to heat varies widely. While factors which contribute to heat intolerance, such as old age, low body mass or surface area, and low physical working capacity have been determined, all efforts to devise a reliable test of heat tolerance have been unsuccessful, mainly because the physiological responses of selected groups of men to successive heat exposures were very inconsistent. The introduction of ascorbic acid (vitamin C) supplementation has changed previous concepts and has opened up new avenues of investigation. Consequently, a series of heat-tolerance tests has been developed for various underground environments and, as can be seen from the accompanying figure, this approach holds great promise for decreasing the number of acclimatization shifts. Evidence has also been obtained to support the view that hyper-heat-tolerant men (T_O 37,5°C* or less during the heat tolerance test) can be posted directly underground without there being any need to acclimatize them further.

Mines in which underground wet-bulb temperatures do not exceed that for a specific heat-tolerance test can now apply this test and thereby eliminate the need for further acclimatization of a specific percentage of the labour force. The percentage of heat-tolerant men will, of course, increase with decrease in the underground wet-bulb temperature. Alternatively, a hot mine in which there is a section where the temperature does not exceed, say, 29°C WB, could apply the 29°C heat-tolerance test and so decrease the acclimatization load by 76 per cent.

The feasibility of acclimatizing by another procedure those returnees with intermediate levels of heat tolerance ($T_r \leq 39{,}5$°C or T_O 37,6 to 38,5°C during the heat tolerance test) has also been investigated. It was shown that these men

Percentage heat-tolerant individuals following performance of the heat tolerance test at various wet-bulb temperatures. Any individual with $T_r \geq 38{,}5$°C during the heat tolerance test is classified as heat tolerant. Dry-bulb, wet-bulb temperature difference maintained at 1,6°C.



*T_r = Rectal temperature T_O = Oral temperature

can be acclimatized safely and effectively during the performance of productive work in an underground environment of 31,5°C to 32,5°C wet-bulb provided that for 5 to 8 days they wear special microclimate suits which prevent their body temperatures from rising to excessively high levels. All the novices who fail the heat-tolerance test and those returnees who are shown to be unduly heat-intolerant will have to undergo the normal acclimatization procedures.

Ascorbic acid supplementation remains an essential part of all the above procedures. Unfortunately, it has been shown that the rate of loss of heat acclimatization during periods when men are not exposed to heat is not affected by vitamin C supplementation.

Codes of practice for the introduction of these procedures are in preparation.

Human heat stress

In human heat stress research the emphasis has tended to move away from the derivation of heat-transfer equations to the practical application of existing information and the accumulating data. Attention has therefore been focused more on physiological studies, and during the year work was begun on the application of the equations to the study of heat transfer phenomena in man whose skin is not fully wetted with sweat, even though sweat drips from his body. This is expected to be an important factor in the determination of heat stress limits, or of a cooling-power concept for unacclimatized men.

Attention has been directed also at the problem of variations in the physiological responses of individuals to heat, and pertinent data from experiments on large groups of unacclimatized men are being collected. These data will establish a basis for applying the heat-transfer equations to the solution of the problem of defining upper environmental temperature limits for unacclimatized men. Research in this direction would be of particular relevance in the assessment of goals for the present programme of mine cooling. Preliminary work on heat tolerance limits which has been initiated indicates large gaps in our understanding of the nature of the heat stress experienced by unacclimatized men.

Protective clothing

Gloves with a nylon base and PVC palm are now commercially available in two sizes. These gloves were designed anthropometrically and fit the hands of either Black or White workers.

Arm and elbow guards manufactured from a nylon material have been tested on various mines and found to be effective and to be well accepted by the workers.

A contract has been negotiated for the manufacture of a universal-fit nose/mouth mask to replace the nose clip/mouthpiece of the Proto Mark IV closed-circuit apparatus. This will ensure greater safety of brigadesmen and facilitate voice communication by radio.

Noise and illumination

A study is being conducted of noise levels in the gold mining industry. Measurements made with dosimeters were found to correlate well with values obtained with sound-level meters in a previous study.

An evaluation was made, at the request of the Prevention of Accidents Committee, of the visual perceptibility of four colours, namely, verdigris green, signal red, golden yellow and strong blue, when they are used on signs and signals underground. When symbols in these colours on white and grey backgrounds were observed at levels of illumination ranging from 10 lux to daylight under simulated underground conditions, it was found that a level of illumination greater than 100 lux was required to ensure good perception of all the colours. At levels of illumination below 60 lux perception of yellow and red on a grey background was better than that of green and blue. Use of any of the colours underground will require supplementary lighting to ensure good perception.

Microclimate suit showing insertion of block of dry ice.

Services

Routine visits were made during each quarter to 29 acclimatization centres to advise and assist in their operation and to examine and certify supervisors. Two training and two refresher courses were arranged for Black and White acclimatization supervisors, respectively. The circumstances of seven heat stroke accidents were investigated.

The analysis of urine, blood and air samples for uranium and lead content was transferred from the Metallurgy Laboratory to the Industrial Hygiene Division during 1977. These samples are obtained from personnel at uranium plants, on the mines, at NUFCOR, and at the Rand Refinery.

Persons referred by the Social Services Department were tested for heat and exercise tolerance in order to establish a physiological basis for their inability to work in underground areas.

*Research reports

The practical measurement of heat stress in the gold mining industry. J. M. Stewart and A. Whillier. *Research Report No. 6/77.*

Loss of acclimatization to heat during periods of no heat exposure. G. G. Rogers and P. C. Schutte. *Research Report No. 7/77.*

Experimental investigation of convective heat transfer from nude man. J. M. Stewart, A. J. van Rensburg and W. W. Voss. *Research Report No. 14/77.*

Annual ventilation report for the period October 1975 to September 1976. A. Yaxoglou. *Research Report No. 15/77.*

The dust retention efficiencies of a variety of commercially available respirators. J. H. Quilliam and J. A. L. Krüss. *Research Report No. 17/77.*

Heat acclimatization by a method using microclimate cooling. P. C. Schutte, G. G. Rogers, C. H. van Graan and N. B. Strydom. *Research Report No. 24/77.*

A survey of dust conditions in controlled gold mines during the period February 1976 to August 1977. A. Yaxoglou. *Research Report No. 44/77.*

A theoretical analysis of the skin wettedness factor for acclimatized men in typical underground environments. U. C. Galimidi, A. J. van Rensburg and J. M. Stewart. *Research Report No. 48/77.*

The elimination of heat acclimatization in selected heat-tolerant individuals. P. C. Schutte, G. G. Rogers and N. B. Strydom. *Research Report No. 49/77.*

A code of practice for heat tolerance testing and microclimate acclimatization. G. G. Rogers, P. C. Schutte, C. H. van Graan and N. B. Strydom. *Research Report No. 61/77.*

Underground illumination and the selection of heavy vehicle drivers: De Beers Consolidated Mines. C. H. van Graan and P. C. Schutte. *Research Report No. 63/77.*

Publications

Endurance training for rugby players. P. L. Jooste. *International Medical Symposium on rugby football injuries.* Johannesburg. March 1976.

Weight training-value and contra-indications. P. L. Jooste. *International Medical Symposium on rugby football injuries.* Johannesburg. March 1976.

Warming-up and cooling-down exercises. G. G. Rogers. *International Medical Symposium on rugby football injuries.* Johannesburg. March 1976.

Carbohydrate, fat and protein requirements for rugby players. P. L. Jooste. *International Medical Symposium on rugby football injuries.* Johannesburg. March 1976.

Influence of tobacco, alcohol and sex on the rugby player. N. B. Strydom. *International Medical Symposium on rugby football injuries.* Johannesburg. March 1976.

Influence of water and electricity balance on sport achievement capability. C. H. van Graan. *International Medical Symposium on rugby football injuries.* Johannesburg. March 1976.

The detection and treatment of weak joints and muscles. N. B. Strydom. *International Symposium on rugby football injuries.* Johannesburg. March 1976.

Some aspects on the visual acuity, colour deficiencies and dark adaptation of Black mine workers. C. H. van Graan. *The Electrical Engineer.* October 1976, p. 11-17.

Microclimate protection as a method of heat acclimatization. C. H. van Graan and P. C. Schutte. South African Pharmacological Society and Physiological Society of Southern Africa. *Congress,* Durban. October 1976.

Selection of a method to measure mean skin temperature. A. J. van Rensburg and J. M. Stewart. South African Pharmacological Society and Physiological Society of Southern Africa. *Congress,* Durban. October 1976.

Loss of acclimatization to heat in man during periods of no heat exposure. G. G. Rogers. South African Pharmacological Society and Physiological Society of Southern Africa. *Congress,* Durban. October 1976.

Some physiological aspects of comrades marathon running. P. L. Jooste. South African Pharmacological Society and Physiological Society of Southern Africa. *Congress,* Durban. October 1976.

Sleep patterns after exercise and thermal stress. R. Bortz, R. Clark, P. L. Jooste, D. Mitchell and C. M. Shapiro. South African Pharmacological Society and Physiological Society of Southern Africa. *Congress,* Durban. October 1976.

Development and evaluation of heat transfer equations for a model of clothed man. J. M. Stewart and R. F. Goldman. *International Conference on Bio-Engineering.* Cape Town. April 1977.

Vitamin C conquers heat stress in mines. N. B. Strydom. *Scientific Progress.* Vol. 10 (1), 1977, p. 2-3.

*These are availabie normally only to members of the Chamber of Mines.

Changes in the level of serum vitamin C in mineworkers. N. B. Strydom, G. G. Rogers, W. H. van der Walt and A. van der Linde. *Journal of the South African Institute for Mining and Metallurgy,* vol. 77 (10), 1977, p. 214-217.

Prescribing thermal stress limits. J. M. Stewart. South African Association of Physicists in Medicine and Biology. *Annual Congress, 1976.*

Exercise and stress. P. L. Jooste. Physiological and Pharmacological Society of Southern Africa. *Congress,* Johannesburg. March 1977.

Heat stress limits for men working in the gold mining industry. J. M. Stewart and A. J. van Rensburg. *Journal of the Mine Ventilation Society of South Africa,* vol. 30 (4), 1977, p. 85-98.

A physiological approach to physical fitness. N. B. Strydom. Medical Association Congress. April 1977. Bloemfontein. *South African Medical Journal,* vol. 51, 1977, p. 642.

Physical requirements for rescue breathing sets. N. B. Strydom. *Mine Fires Symposium.* Stilfontein. April 1977.

A theoretical consideration of heat transfer from nude man. J. M. Stewart and A. J. van Rensburg. *Chamber of Mines Research Review.* 1976/77, p. 58-72.

Fitness and sports injuries. N. B. Strydom. *Symposium on Injuries in Sport.* Johannesburg. July 1977, p. 18-20.

Mountaineering as exercise. N. B. Strydom. Johannesburg Council for Adult Education. 9 July 1977.

Some physiological aspects of squash rackets. *Congress: Research in sport, physical education and recreation.* P. L. Jooste and J. M. Stewart. Stellenbosch. August 1977.

Ergonomics — a vital science. Work Study Association of Kimberley. C. H. van Graan. August 1977.

Hittetoleransie toets vir die seleksie van Swart mynwerkers. P. C. Schutte. Physiological and Pharmacological Society of Southern Africa. *Annual Congress,* Potchefstroom. October 1977.

Die katabolisme van spesifieke nieveresterde vryvetsure gedurende arbeidstoestande. A. van der Linde and P. L. Jooste. Physiological and Pharmacological Society of Southern Africa. *Annual Congress.* Potchefstroom. October 1977.

Saturation levels of physiological conductance. A. J. van Rensburg and J. M. Stewart. Physiological and Pharmacological Society of Southern Africa. *Annual Congress.* Potchefstroom. October 1977.

An investigation into the causes of dust production at main tips and the effect on dust concentrations when doors are installed. J. H. Quilliam and A. Yaxoglou. *Journal of the Mine Ventilation Society of South Africa,* vol. 30 (3), 1977, p. 53-62.

The consolidation of footwall dust in underground intake haulages and travelling ways in gold mines. J. H. Quilliam and A. J. P. van Wyk. *Journal of the Mine Ventilation Society of South Africa,* vol. 30 (12), 1977, p. 245-247.

Environmental variables affecting fitness testing. N. B. Strydom. *International Committee on Physical Fitness Research Symposium.* Trois-Rivieres, Canada. July 1976.

The influence of endurance training on rowing performance. P. L. Jooste, D. B. Read and N. B. Strydom. *International Committee on Physical Fitness Research Symposium.* Trois-Rivieres, Canada. July 1976.

Effects of plasma ascorbic acid levels on heat acclimatization in man. H. F. Kotze, W. H. van der Walt, G. G. Rogers and N. B. Strydom. *Journal of Applied Physiology.* Vol. 42 (5), 1977, p. 711-716.

Maximum heat stress limits based on heat transfer equations and the rectal temperature response of nude acclimatized men. J. M. Stewart and A. H. van Rensburg. *Proceedings International Symposium on Temperature Regulation.* International Union of Physiological Sciences. Lille. 1977.

Ascorbic acid and heat acclimatization. N. B. Strydom, G. G. Rogers and P. L. Jooste. *Proceedings International Symposium on Temperature Regulation.* International Union of Physiological Sciences. Lille. 1977.

Surface areas for calculating heat transfer from nude and clothed men. C. L. Vaughan, J. M. Stewart and A. J. van Rensburg. 27th International Union of Physiological Sciences. Paris. 1977. *Proceedings.* vol. 13, p. 2326.

Physiological conductance responses during acclimatization to a hot dry and a hot wet environment. G. G. Rogers, L. C. Senay, D. Mitchell and N. B. Strydom. 27th International Union of Physiological Sciences. Paris. 1977. *Proceedings,* vol. 13, p. 634.

Coal Mining Laboratory

The Coal Mining Laboratory was established on 1 January 1977 to carry out research and development on behalf of coal producers; this work was previously conducted by the Mining Operations Laboratory. The Laboratory operates within the Research Organization under the Collieries Research Advisory Committee.

Staff

During its first year of operation 18 posts were assigned to the Coal Mining Laboratory, 16 of which were professional. A good nucleus of staff had been established by the year-end and the major portion of the programme was under way.

Research programme

During the year significant research and development has been done to give a firm foundation upon which to base the work of the Laboratory for the coming year. Following consideration of the forseeable needs of the coal mining industry, the available resources of the Laboratory, and effectiveness of a research contribution, the three principal areas of investigation defined at the outset have been confirmed and enlarged. These comprise computer applications in the field of organization and management, coal cuttability in relation to the operation of continuous miners and shearers, and the use of fly ash to improve extraction from underground workings. A number of subsidiary specialist investigations were conducted, most of them in collaboration with other laboratories within the Research Organization.

Computer applications

Investigations have been mainly in the areas of coal reserves prediction, mine planning techniques and mine management information systems. Considerable demand and opportunity exist particularly in the last two areas for development work at collieries.

Geostatistical techniques have been embodied in a computer program designed to produce daily, weekly or monthly yield and quality forecasts for mines producing low-ash export coal from the Witbank No. 2 seam.

The program which is of modular construction, is suitable for use on minicomputers or terminals.

A new computer suite to simulate production in bord and pillar sections has been brought to the prototype stage. Considerable work remains to be done to produce a practical tool, and a review of objectives has been initiated to determine the best way of continuing this project consistent with available manpower.

An earlier investigation into the utilization of underground production machinery recommended the establishment of mine-based information and control systems. System analysis has been carried out at a large mechanized colliery and a detailed specification has been produced for such a system calling for the establishment at the mine of a control and communications centre containing a small minicomputer.

After a lull of some years there is new interest in computer aids to planning underground coal mines. A colliery is collaborating with the laboratory to establish procedures whereby the production simulator "PROSIM" will be used as a regular planning tool for mine design and budgeting purposes.

Coal-getting without explosives

Four principal areas of investigation emerged as being of particular importance, namely: the monitoring of continuous miners' logistics and production performance, on-site testing of coal characteristics, laboratory testing of coal cuttability and, finally, continuous miner field trials.

A routine system has been established for gathering performance and breakdown information from the increasing number of continuous miners in production. The analysis and reporting of results have been computerized.

On-site testing of coal characteristics has involved mainly field trials with a prototype penetrometer to determine indentation and ploughability of different coal seams. Work has been concentrated on the development of suitable core drilling techniques, modifications to the hydraulic circuits of the prototype penetrometer, and the establishment of the required force range and sensitivity and other design criteria for a regular penetrometer instrument. Some success has been achieved in devising a test technique appropriate to South African coals and in determining the design requirements of a suitable instrument with which to undertake the routine cataloguing of coal seams.

Laboratory tests using an instrumented drag pick to determine the mechanical characteristics of cutting into coal blocks are considered to be an essential part of fundamental investigation into the basics of non-explosive coal-getting. To this end a metal planing machine suitable for conversion into a coal cutting test rig has been acquired and is being installed at the Carlow Road Laboratory. This will allow investigations to be made into cutting forces, the effects of pick geometry, depth of penetration, cutting patterns and so on.

Field trials with a Lee Norse continuous miner aimed at confirming the theoretical results derived from these laboratory tests will be conducted also to determine the total effects of certain design criteria such as drum speed, pick spacing, sumping and shearing forces, and cutting forces on the efficiency of the machine, the production of dust and the size of coal product for point attack and chisel picks in a variety of coal seams.

Trials at APC Kriel Division with the Lee Norse experimental continuous miner early in the year indicated the need for a comprehensive refit of the transmission and drum assembly of the machine to adapt it to the tougher cutting conditions in South African coal, and the need for a complete redesign and re-manufacture of the special sumping thrust-assistor unit. A major refit and refabrication of the machine was therefore undertaken by the suppliers; this occupied most of the year. The opportunity was taken to make a number of modifications to the machine, notably in safety and overload

protection, the fitting of accessories to facilitate test procedures, and a comprehensive instrumentation to enable aspects of mechanical, electrical and hydraulic performance to be continuously monitored and recorded. A data reduction and analysis system was also designed. This preparatory work is now virtually complete and field trials will commence early in 1978.

Emphasis is being placed on the need to co-ordinate the results obtained from the on-site penetrometer tests, the laboratory cutting trials and the full-scale continuous miner trials.

Mining methods

Studies on items of underground equipment and the application of computer programs to problems of mine design, belt layouts and performance standards, which in the past have formed a substantial part of the coal research and development activity, were this year curtailed severely owing to the staff shortage. The small number of investigations undertaken were concerned with continuous miner operation, stone dusting mechanization and underground communication. Preliminary surveys of literature and available techniques have been made in preparation for underground trials of the stowing of power station fly ash to improve the stability and extraction from workings.

*Research reports

Geostatistical Investigation of the No. 2 Seam in the Witbank Area — reports Nos. 2, 3, 4 and 5. I. D. Wood. *Research Report Nos. 99/76, 100/76, 5/77 and 21/77, respectively.*

An approach to determine the optimum economic level of maintenance and stand-by in a group of mechanized coal mines. M. P. Roberts. *Research Report No. 107/76.*

SIMSECT: A set of programs for detailed simulation of face operations in coal mines. Design concepts and prototype version. M. P. Roberts and N. N. A. Gerakis. *Research Report No. 23/77.*

A study in variogram estimation in the No. 2 seam at Delmas Colliery. M. I. Watson. *Research Report No. 55/77.*

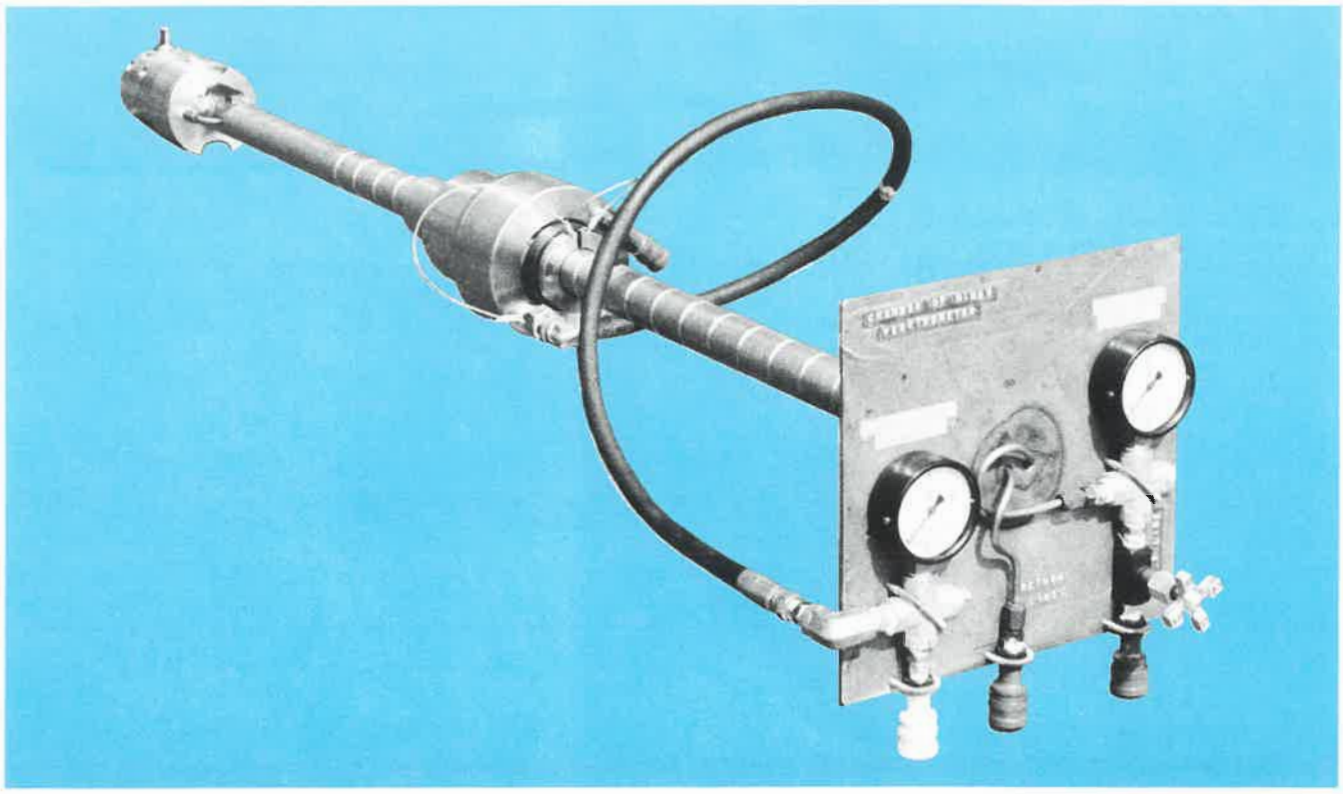
Effectiveness, operation and costs of mechanized stone dusting equipment. E. W. A. Noyons. *Research Report No. 2/77.*

Publications

The use of laser beam deflectors for the alignment of multiple entries in bord and pillar workings. P. King. *Information Circular.* August, 1977.

A geostatistical guide to the choice of drill pattern and block size in reserve estimation and mine planning. I. D. Wood. *Chamber of Mines Research Review 1976/77,* p. 101-108.

Prototype coal penetrometer used for on-site indentation and ploughability tests.



*These are available normally only to members of the Chamber of Mines.

Mining Operations Laboratory

The strata control research work in collieries was strongly influenced by the general trend towards a better utilization of the country's coal reserves. The introduction of mechanized longwall mining systems as a means for improving percentage extraction necessitated detailed studies of the strata behaviour in the vicinity of longwall faces and the performance of support systems under local conditions. Investigations were carried out on the longwall faces at Sigma and Coalbrook Collieries. Apart from observations of the development of the goaf and the behaviour of the massive dolerite sill load and convergence, measurements were made on the hydraulic supports. Criteria for the selection of longwall support systems were derived from these observations. Present work is being concentrated on a quantitative description of the behaviour of the dolerite sill which can impose severe restriction on the application of longwall mining systems. The use of flyash to improve percentage extraction in bord and pillar mining is presently being studied at Springfield Colliery. A full-scale experiment has been designed in which the bords have been filled with ash close to the roof of the workings. The function of the ash is to provide a working platform for the top coaling operation and confinement to the coal pillar. Most of the work done to date has been concentrated on the determination of the properties of the ash.

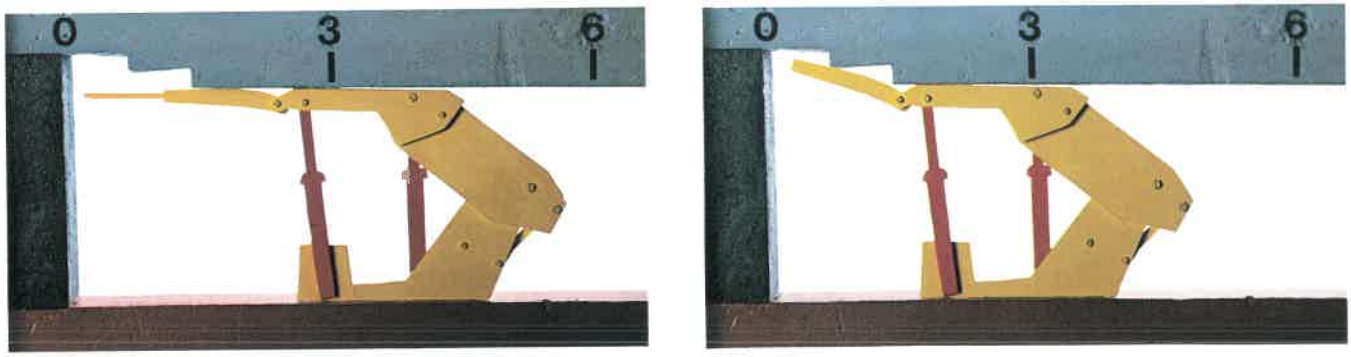
*Research reports

Some considerations concerning the selection of longwall support systems for use under typical South African coal mining conditions. H. Wagner, J. J. Steijn and J. M. Galvin. *Research Report No. 26/77.*

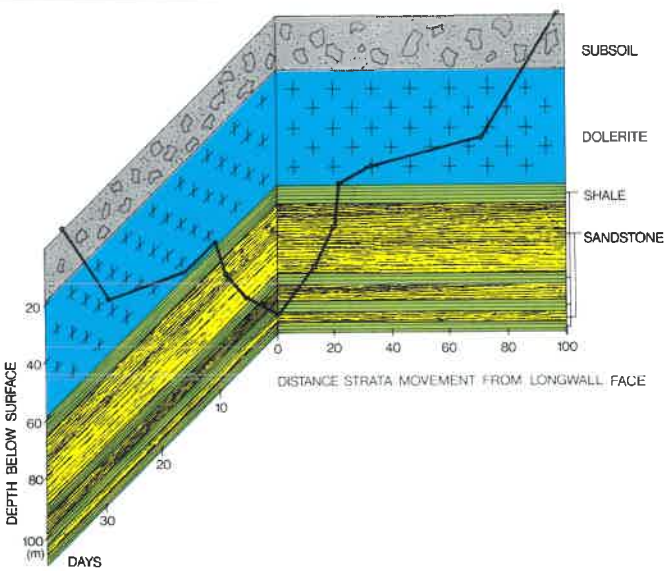
Publication

Longwall support requirements in the light of local strata conditions. H. Wagner. *Anglo American Corporation Longwall Symposium,* Nov. 1977.

Model studies of and underground measurements on mechanized longwall supports have resulted in a better understanding of basic support requirements on longwall faces. Geometric parameters such as length of cantilever and position of hingepoint have an important influence on achieving the support objective.



The strata behaviour in the vicinity of many South African longwall faces is strongly influenced by the presence of a competent dolerite sill which tends to overhang thereby causing severe stress problems at the coal face. The dolerite sill plays an important role in the design and support of longwall faces.



*These are available normally only to members of the Chamber of Mines.

Advisory Committees

Research Advisory Committee

M. D. G. Salamon
Research Adviser, Chamber of Mines of South Africa (Chairman).

A. C. Lawrence and N. C. Joughin
Assistant Research Advisers, Chamber of Mines of South Africa.

E. Schmid
Anglo American Corporation of South Africa, Limited.

W. T. Ruhmer
Anglo American Corporation of South Africa, Limited, representing Sub-Committee of Consulting Metallurgists.

D. A. Immelman
Anglo-Transvaal Consolidated Investment Company, Limited.

J. C. J. van Rensburg
General Mining and Finance Corporation, Limited.

S. Craib
General Mining and Finance Corporation, Limited, representing Sub-Committee of Consulting Mechanical and Electrical Engineers.

A. N. Brown
Gold Fields of South Africa, Limited.

K. Reim
Johannesburg Consolidated Investment Company, Limited.

D. D. Waterman
Rand Mines, Limited.

J. D. McNamara
Union Corporation, Limited.

G. H. Grange
Technical Adviser, Chamber of Mines of South Africa.

Collieries Research Advisory Committee

M. D. G. Salamon
Research Adviser, Chamber of Mines of South Africa (Chairman).

A. C. Lawrence
Assistant Research Adviser, Chamber of Mines of South Africa.

F. Chilton
Anglo American Corporation of South Africa, Limited.

D. F. H. Grave
Anglo American Corporation of South Africa, Limited, representing Sub-Committee of Group Ventilation Engineers.

J. L. P. Mackenzie
Anglo American Corporation of South Africa, Limited, representing Sub-Committee of Consulting Mechanical and Electrical Engineers.

L. F. Duvel
General Mining and Finance Corporation, Limited.

E. L. Atkinson
Gold Fields of South Africa, Limited, and Chairman of the Strata Control Advisory Committee of the Coal Mining Research Controlling Council.

M. J. Deats
S.A. Iron and Steel Industrial Corporation, Limited.

R. Smith
Johannesburg Consolidated Investment Company, Limited.

M. J. Pryde
Kangra Holdings (Pty) Limited.

B. J. Love
Lonrho South Africa, Limited.

N. Zolezzi
Rand Mines, Limited.

G. H. Grange
Technical Adviser, Chamber of Mines of South Africa.

Officials

M. D. G. Salamon
Research Adviser

A. C. Lawrence, N. C. Joughin
Assistant Research Advisers

Human Resources Laboratory
N. L. Robertson, *Director*

Environmental Engineering Laboratory
A. Whillier, *Director*

Mining Technology Laboratory
N. C. Joughin, *Acting Director*

Electronics and Mechanical Engineering
J. P. M. Hojem, *Chief Engineer*

Metallurgy Laboratory
P. J. D. Lloyd, *Director*

Mining Operations Laboratory
H. Wagner, *Director*

Coal Mining Laboratory
P. King, *Director*

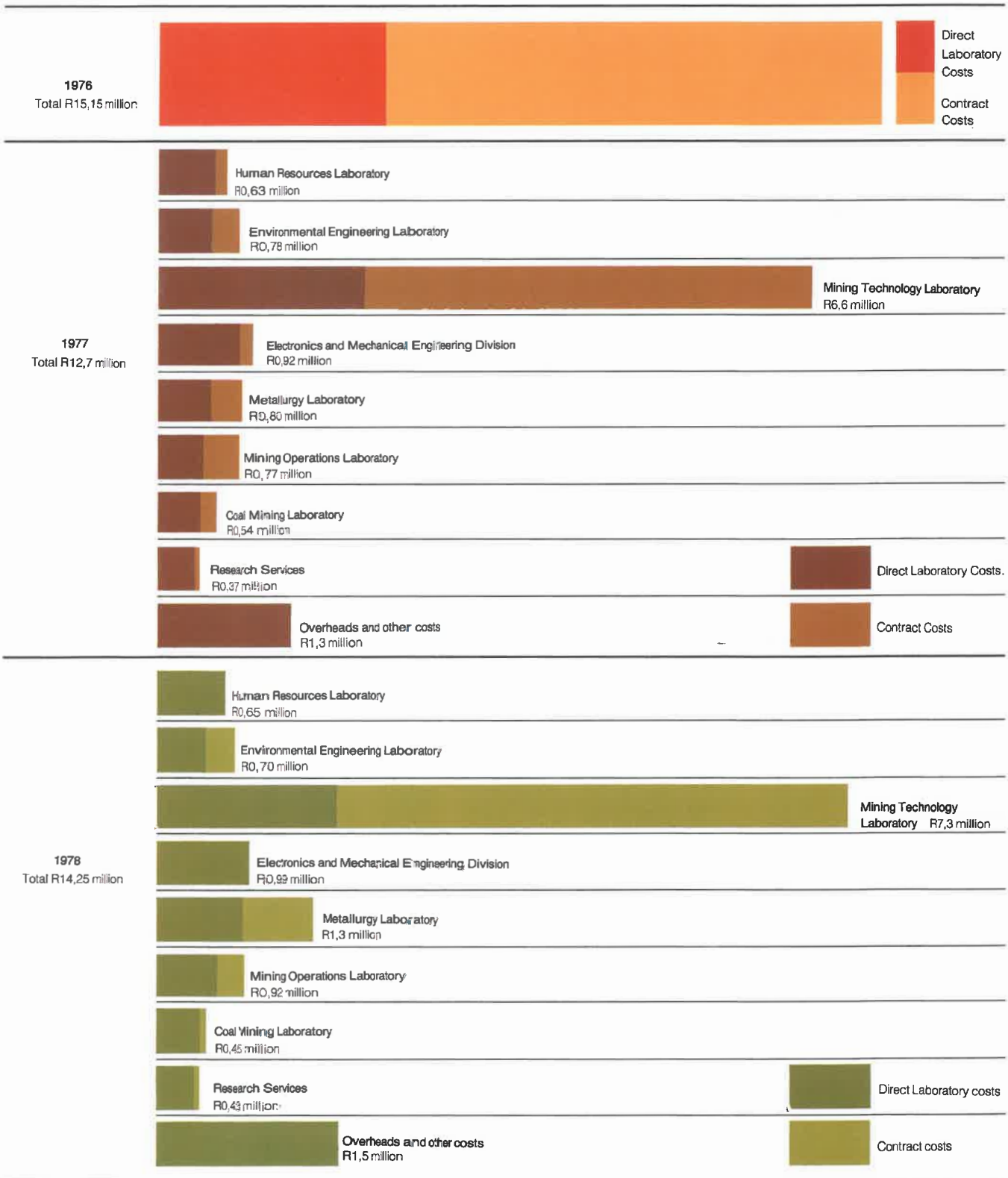
Research Services
N. B. Strydom, *Manager*

Information
F. H. Lancaster, *Chief Information Officer*

Library
Miss J. L. Dunstan, *Librarian*

Printed by J. G. Ince & Son (Pty.) Ltd., Johannesburg

Budget


1976
Total R15,15 million
Direct Laboratory Costs
Contract Costs
1977
Total R12,7 million
Human Resources Laboratory
R0,63 million
Environmental Engineering Laboratory
R0,78 million
Mining Technology Laboratory
R6,6 million
Electronics and Mechanical Engineering Division
R0,92 million
Metallurgy Laboratory
R0,80 million
Mining Operations Laboratory
R0,77 million
Coal Mining Laboratory
R0,54 million
Research Services
R0,37 million
Overheads and other costs
R1,3 million
Direct Laboratory Costs.
Contract Costs
1978
Total R14,25 million
Human Resources Laboratory
R0,65 million
Environmental Engineering Laboratory
R0,70 million
Mining Technology Laboratory R7,3 million
Electronics and Mechanical Engineering Division
R0,99 million
Metallurgy Laboratory
R1,3 million
Mining Operations Laboratory
R0,92 million
Coal Mining Laboratory
R0,45 million
Research Services
R0,43 million
Overheads and other costs
R1,5 million
Direct Laboratory costs
Contract costs