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Some productivity perspectives for the South African mining industry

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SYNOPSIS

The rate of productivity improvement in South Africa will have to be accelerated, together with an increase in the total production of goods and services, if the improved living standards pursued by all population groups are to be achieved. During a recent visit overseas, the author was made aware of various perspectives, which are discussed in this paper in the light of the following factors: strategic planning, mining technology, and management style.

SAMEVATTING

Die tempo waarteen produktiwiteit in Suid-Afrika verbeter, sal versnel moet word tesame met 'n toename in die vlak van produksie van goedere en dienste om die verbeterde lewensstandaard, wat deur alle bevolkingsgroepe nagestreef word, moontlik te maak. Heelwat nuwe indrukke is tydens 'n onlangse oorsese besoek verkry. Die doel met hierdie aanbieding is om die indrukke te bespreek aan die hand van die volgende faktore: strategiese beplanning, mynboutegnologie en bestuurstyl.

INTRODUCTION

In the seventies, the emphasis in the South African economy was on growth in the output of goods and services. This meant that the benefits of large-scale enterprises could be realized because of a lower unit cost. To many, a feeling of efficiency gained ground since the lowering of the unit cost was accompanied by a rise in unit profit. The motto 'bigger and better' was briefly used to refer to this approach.

As was confirmed during the early eighties, this approach had many disadvantages. The following are probably the most important of these.

- The extent to which the market could absorb the total output of the increased number of larger producers was not adequately taken into account, perhaps because it was not possible to forecast it more accurately.
- The enterprises became larger but not necessarily better in the sense of adequacy, effectiveness, and efficiency, and therefore not necessarily more productive. At the stage when the market necessitated a cutback in activities, the unit costs of certain enterprises increased to such an extent that many of them were ruined.
- It was only after the 'bigger and better' approach had partly failed that due cognizance was taken of the reasons for this failure. The most important reason was probably that, in practice, the approach became 'bigger and therefore better' to many, instead of 'bigger *and* better' as it was originally intended to be.

Today the emphasis is shifting from 'bigger and better' to 'bigger *or* smaller but definitely smarter'. This motto aims at greater flexibility, so that there can be a quicker reaction to changes in the market, whether qualitatively or quantitatively. For this to take place, productivity has to be measured and evaluated continuously, and concerted efforts have to be made to increase the productivity whether the market improves or becomes weaker. When the market does become weaker, it is sometimes necessary, after detailed strategic planning and consideration of the potential benefits of other avenues, to change to other methods or products.

The following should be added to a well-known author's advice of 'Do not attempt to apply a solution until you have accurately defined the problem': 'Don't try to improve productivity until you have accurately defined and analysed the inputs and outputs of the system'.

It is especially in connection with the latter approach that some enterprises overseas create a very favourable impression. This is because they understand the art of starting with a strategic plan and continuing with the exercise until the inputs and outputs of their enterprises have been manipulated in such a way that their productivity increases and their financial results comply with their long-term objectives.

When many new impressions are gained in a short time, as happened during my overseas visit to Britain, Belgium, Germany, and Sweden, one is immediately inclined to link it with one's own work situation and to look for examples by which the productivity of one's own enterprise can be improved. An attempt is made here to discuss the principles of productivity improvement, and to illustrate their application by reference to aspects discussed or observed during the visit. The full tour schedule is shown in Table I.

It is hoped that this paper will stimulate thought on approaches to productivity improvement; it does not suggest that every approach, product, or idea mentioned here is necessarily the best.

PRODUCTIVITY IN PERSPECTIVE

The key to productivity improvement in any system lies

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TABLE I
ITINERARY OF THE TOUR

Country	*Day*	*Place*
England	1	Cambridge University
	2	Cambridge University
	3	Cambridge University
	4	Atlas Copco (GB) Ltd
	5	Royal School of Mines
	8	Wheal Jane Mine
	8	Camborne School of Mines
	9	South Crofty Mine
	9	Camborne School of Mines
Belgium	10	Atlas Copco Airpower
	11	Atlas Copco Airpower
	12	Zolder Mine
Germany	15	Rheinische Braunkohlewerke
	16	Ore Mine Barbara
	16	Atlas Copco-Eickhoff
	17	Bergbau Westerholt
	18	Railway Tunnels
	19	Railway Tunnels
Sweden	22	Atlas Copco (MCT) Stockholm
	23	Research Mine, Kiruna
	23	LKAB/Kiruna
	24	LKAB/Malmberget
	25	Aitik Mine
	26	University of Lulea
	29	Nitro Nobel, Gyttorp
	30	Nitro Nobel, Gyttorp

in the optimal combination of the input factors (or resources) to produce the output factors (or goods and services). The optimal combination of resources implies that only unavoidable costs are incurred due to the maximum *utilization* and more *efficient* use of resources to produce the goods or services. The creation of more *effective* goods and services, namely goods and services that better satisfy the needs of the markets, results in larger shares of the markets, with accompanying lower units costs—and hence larger profits—all other considerations being equal.

The maximum *utilization* of resources really implies that the resources are fully utilized for the purpose for which they are meant to be used. In the case of labour, the people employed for each specific task should utilize the full length of their working time. Similarly, the material should be fully used for production and not wasted as a result of incorrect production methods, low levels of skill or motivation, or poorly maintained machinery. In the case of capital, the items should be fully utilized for the total period planned and for the purpose for which they were obtained.

The *efficiency* of resources refers to the manner in which the resources are used to create outputs of goods and services. In the case of labour, increased efficiency implies that better methods are used by skilled and motivated workers. Likewise, more efficient material suggests that the cost of performing the necessary function at the required standard will be lower as a result of the better materials used. The factor of efficiency in the case of capital items such as machinery is applicable in the same way as that for labour. Orbach[2] describes it as follows:

> The reasons why machines can be utilized faster or slower has to do with the skill-level of their operators and also with the design and quality of the materials being processed by them. Old machinery usually employs old technology and is usually less efficient than new machinery. This is why the acquisition of new machinery is often an important avenue for increased productivity.
>
> . . . but it is also possible to increase productivity by optimizing the combined contribution of the factors rather than by maximizing the contribution of each one separately. While the factors of *utilization* and *efficiency* relate to the process of conversion, which takes place in the production system, *effectiveness* relates to the outcome of the process.

However, it is important to know, not only how to improve productivity, but also how to measure it to determine whether the accompanying advantages can be expected. Productivity is measured from the ratio of output (i.e. goods and services) to input (i.e. resources used in the system considered) in units or prices quoted at the same price level. Productivity improvement is obtained when more goods and/or services are produced with the same or fewer resources, and is indicated by a higher ratio of output to input. The ratio can be compared with a specific standard or with similar ratios in other enterprises to serve as a yardstick for success.

The major advantages of increased productivity are increased profits, economic growth, more job opportunities, and improved standards of living for all population groups. When fewer resources are needed to supply a certain market segment with goods and/or services, costs are lower and profits higher. When the resources in a country are limited, more outputs can be generated in the total economy of the country, and, because more resources are available for the production of more goods and services, the profits can be re-invested to increase the productive capacity of the economy. The latter is the essence of economic growth and provides more job opportunities and improved standards of living.

FACTORS INFLUENCING PRODUCTIVITY

Productivity in the mining industry is affected by many factors, among them planning, technology, and management style.

Strategic Planning

The purpose of strategic planning is to predetermine the direction in which future action should develop. It is therefore not an exact determination of future action, which is called medium- or long-term planning over a specific period.

Drucker[1] recently wrote that management

> will require that the entire business be seen, understood and managed as an integrated process . . . . This process requires a maximum of stability and of ability to anticipate future events . . . . Hence managers on all levels must be able to make decisions which adapt the whole process to new circumstances, changes in the environment and disturbances, and yet maintain it as a going process . . . . The new technology will make new demands for innovation. Not only must the chemist, designer or engineer work closely with production and marketing men but there will have to be the kind of systematic approach to innovation . . . . It will also have to attempt much more systematically to foresee the inherent possibilities of technological and scientific development and to shape manufacturing and marketing policies accordingly . . . . The new technology will result in greater competition. True, it will broaden the market and raise the level of production and consumption, but these new opportunities will also demand consistent efforts to do better on the part of the enterprise and its managers.

This is what is meant by strategic planning. It refers not only to the technological level in an enterprise, but also to the ability of management to combine resources in a manner that gives the best results. It is therefore closely linked to productivity and productivity improvement.

If a company does not stick to its primary objective, it may tend to lose course within the strategic-planning approach. A well-known company, for example, regarded it of cardinal importance to know their primary objective and to define it precisely. After they had defined it as 'supplying serviceable and economic pneumatic systems', they successfully developed several new activities, including the following:

- weaving with compressed air
- producing oil-free compressed air
- becoming involved in North Sea drilling
- compressing various gases
- supplying compressed air in a wide range of pressures and air-flow rates.

If efficient strategic planning is to receive the necessary backing, the following prerequisites are important.

- When having to sell new equipment like compressors, some people feel that technical factors are the only really important considerations. They tend therefore to forget the minor but extremely important considerations like the shape of the compressors, their aesthetic appearance, the time limits for the supply of equipment and services backed-up in the form of planned and routine maintenance services, etc. For these reasons, a well-known company is equipped with well-trained artisans, technicians, and other back-up personnel; well-developed computer-supported systems; research and development divisions with the necessary skilled personnel; well-motivated and enthusiastic personnel; and facilities for the continuous training of their own and customers' personnel. When there is no real difference in technical performance between companies, these can become the deciding factors in profitability because of the bigger market shares they create.
- Sound and constructive cooperation between all parties concerned is essential. This is particularly true of the enterprises in Sweden. The State defines objectives for developmental work and provides funds for this purpose. The universities carry out extensive research in the fields of engineering geology, rock mechanics and stability, and mining methods and equipment, for the development of more productive mining methods. The suppliers of equipment and other commodities provide prototypes and funds for the testing and further development of these items. The final users continually test new methods and technologies, and give the necessary feedback on whether or not improvements have been achieved.

These two prerequisites are the combined factors needed to increase productivity by means of more efficient methods and more effective products. Because of the demands of our times—the technology explosion and the rapid changes it necessitates—it has become imperative that the best brainpower should become involved in the strategic-planning process. In this regard, the Swedish style serves as an example to the rest of the world.

Mining Technology

Mining technology is improving constantly, and slowly but surely the emphasis is shifting, from the optimum utilization of new techniques, to the optimum development of efficient and effective technologies so that the first utilization of such technologies can result in the first benefits derived from them. It is on such benefits that the economic results of the enterprise or country can be based.

This approach demands insight and daring on the part of the management corps in order to ensure that funds are not spent on less important developments. The total expenditure should not exceed the financial benefits that may be derived from the subsequent use of such developments as compared with existing technologies that are being utilized optimally.

Process Development

The iron ore mines in Sweden had to develop new approaches to reach the above-mentioned objectives. The Luossavaara–Kirunavaara Aktiebolag (LKAB) are a case in point. The greatest product-quality problem they faced was the high relative phosphorus content of the iron ore in their Kiruna Mine. New processes for the removal of the phosphorus from the ore had to be development immediately, and today the ore is finely ground, beneficiated, and pelletized. The present target is a phosphorus content of less than 0,02 per cent; in 1970 it had been more than 1 per cent for approximately 60 per cent of the total product.

Similar developments to reduce the K_2O content of the ore and to enable the mine to make directly reduced pellets with unique properties for the technological and economic benefits of its clients places LKAB in the forefront with regard to the development of new beneficiation processes. Their official policy in this connection is best summarized in the words of their Vice-President entrusted with Research and Process Development, Mr Nils Sandberg[3]:

> LKAB is no longer a mining company delivering the raw materials with which nature has happened to provide us. Mining is now followed by an increasingly sophisticated downstream production apparatus which converts the raw material to semi-manufactured products tailor-made to suit the customers requirements and changes in the market.
>
> This change has always been a vital necessity for LKAB. So LKAB must safeguard its competitiveness, through the development of both production methods and products that will give us and the steelworks the best possible overall economic outturn.

Thus, this company has succeeded in altering its product line to become more effective in the market place. It is currently engaged in the development of techniques that utilize new advanced mining equipment, and that will probably help them to develop more productive and more cost-effective mining methods. They have even gone as far as establishing a research mine near Kiruna with the aid and support of the State and the private sector.

New Stoping Techniques

In the LKAB research mine, where sublevel stoping is mainly carried out, various projects are currently in progress with a view to the development of more productive methods. The following serve as examples.

- Cable support techniques are being developed for the underground mines with a view to less ore dilution in the hangingwall areas where waste and ore mixing take place. Much attention is being paid to the method of support, as well as to the design of the cable, in order to create effective support and increase the product output of a given production system.
- A new type of computer-supported feedback system for rock-mechanics measurements and data collection is being installed. Different methods of monitoring are used to obtain data on rock deformations, rock temperatures, rock vibrations, etc. The monitors are placed at predetermined points, and are linked directly to the computer for further analysis.
- A drilling machine for longer holes (in excess of 50 m) with larger diameters is being developed with a view to minimizing deviations from the planned hole directions. The objective is to obtain a deviation of less than 1 per cent to ensure the fragmentation best suited to the transportation methods used in the mine. Much success has already been attained in the achievement of more-effective drilling and blasting results with fewer resources.

Computer-supported Control System

The underground Westerholt coal mine in West Germany uses a very sophisticated computer-supported control system (Fig. 1). The equipment is installed on the surface, and is connected to the underground workings. The system was developed in cooperation with Siemens to automatically monitor the following data:

- gas concentrations at specific underground points
- status of the production equipment
- ventilation flow
- levels in the coal bunkers
- positions of the locomotives
- status of the water pumps
- water levels in the dams.

The efforts at Westerholt are aimed at the better control and utilization of resources and at more-efficient production methods to increase the output with a given combination of resources.

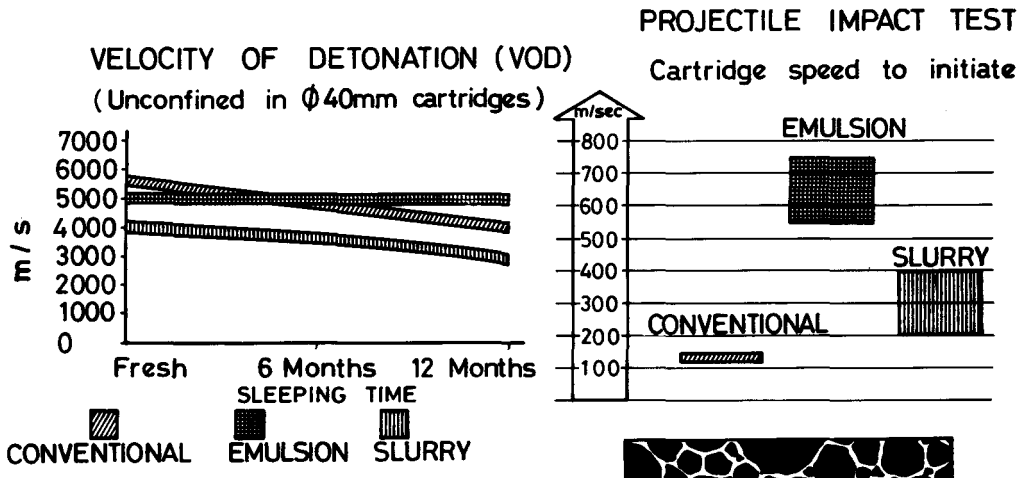
Explosives Technology

Since more suppliers of explosives have appeared on the South African scene, many interesting new products have appeared on the market. At present, there is a gradual shift from slurry explosives and nitroglycerine-based explosives to emulsion explosives, especially in some opencast mines. The last-mentioned explosives show great promise with regard to inherent energy utilization and explosive properties that are better adapted to the demands of the rock that has to be broken. In addition, the keener competition has resulted in more realistic prices, and a greater sense of urgency with regard to developmental work has been instilled in potential suppliers.

During discussions at Nitro Nobel at Gyttorp in Sweden, some very interesting facts emerged about the new generation of explosives (Fig. 2). The following summarizes some of these.

- Bulk emulsions are not cap-sensitive, which ensures safe handling. The projectile impact test, which determines the speed at which a reaction will start in an explosive, indicates that a water gel requires 200 to 400 m/s, while an emulsion requires 550 to 750 m/s.
- Emulsions can be pumped into holes containing water. Even some heavy Anfo containing up to 30 per cent Anfo can be pumped instead of augered.
- Emulsions can be left 'sleeping' in holes for very long periods without adverse effects. An interesting feature is the fact that the velocity of detonation is not influenced by the period in the holes, which indicates that the quality probably remains unaffected.
- Detonation velocities of more than about 4000 m/s can be achieved. The magnitude of the detonation

Fig. 1—The control room at Bergwerk Westerholt in West Germany (Photo: Bergwerk Westerholt)



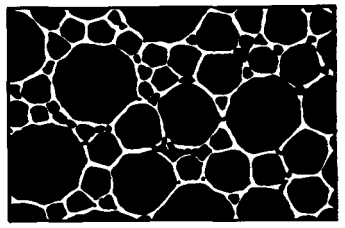
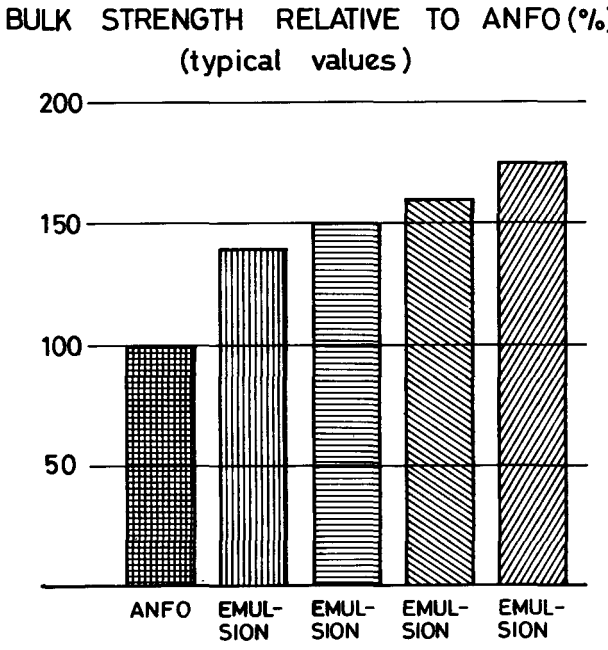
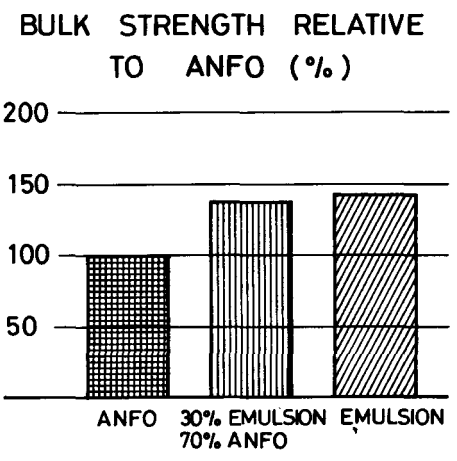


Fig. 2—A comparison of conventional, slurry, and emulsion explosives (Reference: Nitro Nobel)



STRUCTURE OF AN EMULSION UNDER A MICROSCOPE



velocity can be regarded as directly proportional to the quality of the explosive; that is, the higher the velocity, the more successful the thermodynamic reaction in the explosives.

- A useful method of on-site quality control involves determination of the capacitance of the explosives. The lower it is, the better the quality. An on-site index can be developed, and special equipment for the tests is available commercially.

Likewise, interesting developments have appeared in the area of explosive accessories. One of the most interesting is certainly the Nonel initiating system (Fig. 3), which has the following advantages:

- initiating at the bottom of blast-holes is guaranteed,
- delay in the blast-hole results in greater flexibility of delay intervals and blasting-block design
- lateral initiating with the accompanying disadvantages is totally eliminated
- dead packing around an exploding Cordtex line down the hole is eliminated
- energy utilization of the explosive is much more effective
- less fly rock occurs, with accompanying safety advantages
- blasting noise is greatly reduced.

This system still has many disadvantages, but its inherent advantages show so much promise of productivity improvement that the suppliers must be encouraged and supported to make it a reliable system.

One of the greatest challenges of the future is the adaptation of explosives and explosive accessories to the rock

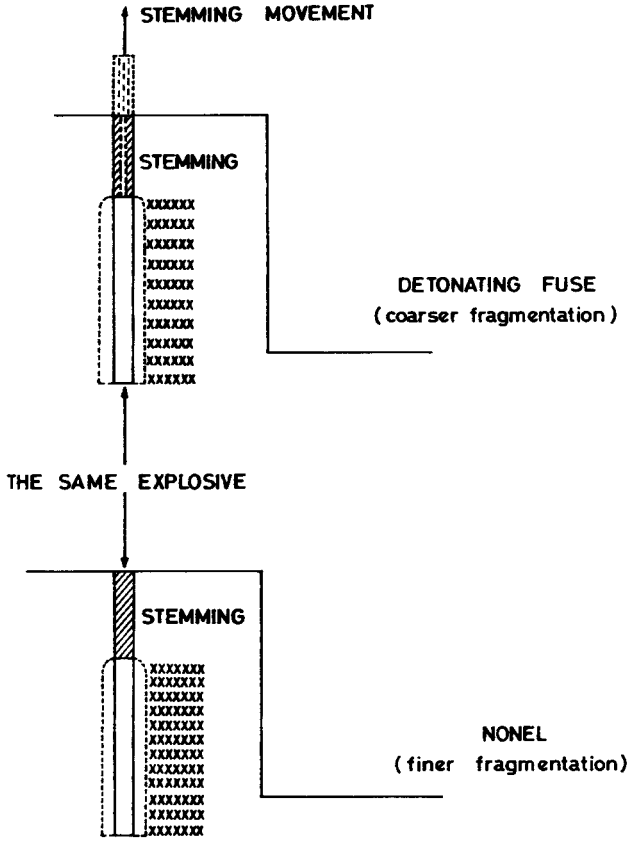


Fig. 3—Schematic representation of an explosion a moment after initiation with a detonating fuse and with Nonel

to be broken in such a way that optimum blasting is achieved. This objective is the subject of many laboratory and other tests currently being conducted in the world. In addition, computer-aided simulation programs are being developed to deal with blasting design on a scientific basis, as well as to develop new explosives and so ensure better and more efficient energy utilization for the breaking of specific rock types. Many of the expected better results achieved with more-efficient blasting agents and methods could be confirmed by means of practical tests here in South Africa.

When more-efficient explosives are used, fewer explosives and even less production-hole drilling are needed for a specific production level. In a hard-rock mine like Sishen Iron Ore Mine, it implies that much fewer resources would be required in certain areas, with the accompanying advantages.

Management Style

A balance must be struck between idealism and realism from the strategic-planning process right up to the actual activities in the mine. New technologies must be weighed against established technologies to ensure that their implementation is feasible and economically viable. This calls for an effective management style to ensure that the objective of the enterprise is achieved.

A management-by-objectives system should be used to assist every manager, in cooperation with his superior, to formulate objectives for himself and for his management unit. His performance should be measured in terms of his ability to achieve the set objectives. The constant aim should therefore be to integrate the objectives of managers in such a way that the Managing Director achieves the main objective of the enterprise.

One objective for each manager is continuous systematic improvement of the productivity of all the production factors. The best way to improve productivity is to create a framework within which all employees can seek and enthusiastically cultivate improvement in the factors that determine productivity.

Within such a system, LKAB/Malmberget in Sweden have a very interesting approach towards productivity improvement. For them, two of the most critical performance areas are the quality of planning, and accurate and productive mining methods.

The first objective, which forms the basis of the second objective, involves the best brainpower and experience in the enterprise. To achieve the second objective, the factors that have the greatest impact on productivity are identified and continuously improved. Typical factors are the following:

- scale of mining activities
- organization and motivation of employees
- technical factors, including loading and transportation, blasting systems, production drilling, etc.
- information systems
- utilization of computers
- utilization of energy
- technical development
- stoping methods.

A very interesting aspect of the LKAB/Malmberget approach is the utilization of Production Groups. These Groups, which are composed of representatives of management, service sections, and production sections, concentrate on the improvement of the factors that influence productivity. The greatest advantages of this approach are that, on the one hand, the management and service sections take thorough cognizance of the practical implications of their planning and decisions; and, on the other hand, that the production sections take thorough cognizance of the potential advantages of improved methods and techniques, and that they carry out these methods to the best of their ability in order to realize the maximum advantages.

Closely linked to this concept of Production Groups is the concept of Quality Circles, which was developed in Japan and is already being utilized worldwide. Both use the motto 'Motivation by involvement' and, if one considers the under-utilization and low efficiency of labour in South Africa, this is perhaps the best battle-cry to motivate the people who know the prevailing conditions in a specific work situation best, not only to solve the problems together, but also to assist one another in optimizing the combined contribution of the production factors.

CONCLUSIONS

The improvement of productivity by means of technological development is an essential part of professional and scientific management. Like a golden thread, it runs through the whole process from the strategic-planning stage to the practical execution of the short-term mine

plans.

The high level of technical skill required for the utilization of existing and new technologies in such a way as to maximize productivity calls for good training, teamwork, and a sense of goal orientation.

Good training includes formal and in-job training, while all parties concerned, both inside and outside the enterprise, should be involved in teamwork towards more-efficient and more-effective mining enterprises. Objectives must be defined and pursued within a well-formulated and accepted management system.

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In situ recovery of minerals

Engineering Foundation is sponsoring a conference on the 'In Situ Recovery of Minerals' in Santa Barbara, California, from 25th to 30th October, 1987. The Conference Chairmen are Kenneth R. Coyne, Bechtel, Inc., and J. Brent Hiskey, University of Arizona. The subject matter of the Conference will focus on the present status of mineral-production methods that utilize non-conventional mining techniques such as *in situ* leaching, borehole mining, leaching after rubblization, and solution mining.

Sessions will be held on the geotechnical, hydrological, processing, engineering design, and economic aspects of these technologies, and will include case histories and current and future developments in research. The programme will include the presentation of papers, workshops, a plenary lecture, and a poster session. The Conference will focus on these emerging technologies with respect to their current development status and future trends and objectives.

Engineering Foundation Conferences were established in 1962 to provide an opportunity for the exploration of problems and issues of concern to engineers from many disciplines. The format of the Conference is designed to encourage discussions of recent developments and to provoke suggestions concerning profitable methods of approach to achieving progress. It is intended that all attendees will participate actively in the discussions. Attendance at Engineering Foundation Conferences is by invitation or application. Those wishing to attend should contact the Engineering Foundation for registration information.

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