Presidential address: The future supply of engineers for the mining industry

by A. N. BROWN*

SYNOPSIS

The importance of the minerals industry in the economy of the country is discussed, and the tremendous changes that have taken place over the past two decades, including the widespread application of computers and the use of mechanization, are outlined.

A discussion of the future of the minerals industry points out that, with the rise in the price of gold, the life of the gold-mining industry can be expected to extend beyond that previously predicted, and that the demand for uranium, which has been depressed, is uncertain. As a result of the oil crisis, the demand for coal has increased and large expansion programmes are planned. These involve coal exports and the use of coal for the generation of electric power, for the production of liquid fuels, and for the smelting of metals. Technical challenges face engineers in every avenue of the minerals industry: in deep gold mines, underground coal mines, strip coal mines, and open-pit mines.

Studies indicate that only one-third of the demand for trained mining and metallurgical engineers is being met and that the position is worsening. However, there are indications that the industry is succeeding in attracting more engineering students, and the supply is expected to improve. These efforts should be co-ordinated, expanded, and intensified.

There is a need to ensure that sufficient teaching staff of the right calibre and experience are attracted to universities and technikons. The first degree course is comprehensive and basic, and specialization through post-graduate study should be encouraged. The influence of national service on the education and training of engineers is discussed.

SAMEVATTING

Die belangrikheid van die mineralebedryf in die landsekonomie word bespreek, en die omvattende veranderinge wat oor die afgelope twintig jaar plaasgevind het, insluitende die wye toepassing van rekenaars en die gebruik van meganisasie, word omskryf. Voornemende uitbreiding van die mineralebedryf weens die verwagte geleidelike styging in die goudprys dui daarop dat die leeftyd van die goudmynbedryf verleng sal word en vroeëre voorspellings sal oorskry. Vraag na uraan het afgeneem en dit is onseker wanneer dit sal herstel.

As gevolg van die oliekrisis het die vraag na steenkool aansienlik toegeneem en groot uitbreidingsprogramme word beplan. Hierdie sluit in steenkooluitvoere en die gebruik van steenkool vir kragopwekkingdoeleindes, vir die produksie van vloeibare brandstowwe, en vir die smelting van verskeie metale. Tegniese uitdagings staar ingenieurs in die gesig in alle vertakkinge van die mineralebedryf: in diep goudmyne, ondergrondse steenkoolmyne, stroopsteenkoolmyne en oop groewe.

Opnames dui daarop dat een derde van die vraag na opgeleide mynbou- en metallurgiese-ingenieurs in die algemeen bevredig word en dat die situasie nog steeds versleg. Daar bestaan bemoedigende aanduidings dat die bedryf in sy pogings slaag om meer ingenieurstudente te lok en daar word verwag dat die situasie sal verbeter. Dié pogings moet gekoördineer, uitgebrei en versterk word.

Akademiese opleiding van ingenieurs word omskryf. Daar bestaan 'n behoefte om 'n voldoende getal opvoedkundige personeel van die regte gehalte en ondervinding aan universiteite en technikons te verseker. Die eerstegraadkursus is omvattend en basies, en spesialisering op na-graadse vlak behoort aangemoedig te word. Die invloed van diensplig op die opvoeding en opleiding van ingenieurs word bespreek.

Introduction

My address deals both with the supply of engineers for the mining industry and with the future of the industry. As a mining engineer, I apologize for placing emphasis on that discipline.

The expansion of the minerals industry as predicted means that there will be a considerable need for trained engineers. In the present climate of world economic recession, which has resulted in a fall-off in the demand for minerals and a consequent drop in metal prices, it is difficult to be enthusiastic or optimistic about the future of the minerals industry. However, we have no option but to be optimistic: this country finds itself today where the minerals industry brought it, and tomorrow the country will be where the minerals industry has taken it. The fundamental challenge is to continue to develop the country for the benefit of all its peoples and to improve the overall quality of life.

The vexing question is whether we shall have adequate manpower and, in particular, engineers to meet the challenge. It is difficult to draw meaningful comparisons between numbers without adjusting them. Such comparisons are complicated further by the inflationary spiral that has persisted unabated for the past decade, the cost changes that have taken place as a result, the high interest rates that have prevailed, and the fluctuating currency exchange rates. For example, although South African gold production has remained fairly constant at around 700 tons per annum, the earnings from gold sales have oscillated with the fluctuating gold price. World events unrelated to the normal market forces of supply and demand seem to have had an overbearing influence on the price.

Comprehensive coverage was given to almost every significant aspect of the minerals industry at the Twelfth Congress of the Council of Mining and Metallurgical Institutions, which was the highlight of the Institute's activities over the past year, and indeed over the past few years. All the important problems were clearly enunciated, and possible future developments were discussed, particularly in a series of excellent plenary papers. Without repeating the statistics, I shall refer to many of the problems and developments that were mentioned at the Congress.

Development of the Mineral Industry

It is perhaps superfluous to underline the importance of the minerals industry to the economy of the country. However, the shortage of engineers may be due in some measure to a lack of appreciation of the facts.

* Department of Mining, University of Pretoria, Hillcrest, Pretoria 0002.

The exploitation of diamonds, followed by that of gold, led to the establishment of a strong mining industry in the land. The country prospered as mining enterprises supplied the capital to finance industrial expansion and earned foreign exchange for the purchase of the imported commodities required for industrial development. Such development is vital since other industries must, in time, take over the role now played by the gold-mining industry. The exploitation of other mineral resources has led to South Africa's becoming one of the world's primary producers of minerals. The industry, as a major employer of manpower, has produced foreign earnings for the neighbouring territories that have supplied labour, and so has contributed to the stability of Southern Africa.

The benefit derived from mineral production cannot be measured in terms of the sales value alone. As pointed out by Nisbet[1], there is a multiplier effect that extends the benefits of the intrinsic value of minerals to a far larger circle. The State, through taxes and lease payments, is a direct beneficiary, and any expansion in the industry is likely to create new jobs, which is an aspect vital to any developing country.

The opportunity given to South African mining engineers to address problems on the frontiers of technology has gained them a high reputation and worldwide respect for their prowess. This is evidenced by the interest and participation of the many foreign visitors who attended the Twelfth Congress of the Council of Mining and Metallurgical Institutions, which was held in Johannesburg in May of this year.

The Republic of South Africa, for a variety of reasons, has for many years had to survive in a hostile political climate in the outside world. It is unlikely that these attitudes will change much in the course of the next two decades, and there will always be those who advocate trade sanctions and boycotts. The country's ability to alleviate the effect of such pressures is evidenced by the oil-from-coal project, which will serve to make the Republic less vulnerable under the threat of oil embargoes.

The country is indeed fortunate that it possesses major reserves of strategic minerals much needed by the free world. It is a matter of great concern to the free world that South Africa and the Soviet Union have more than 50 per cent of six key mineral commodities[2], namely, platinum-group metals, vanadium, manganese, chromium, gold, and fluorspar, as shown in Fig. 1. Of these commodities gold has been the backbone of the country's economy for almost a century. Although a decline in production is predicted, there are many who feel that its influence will persist for many years to come.

Tremendous developments have taken place in the minerals industry over the past two decades. The electronic age has been accompanied by a widescale application of computers in many forms, to the benefit of the industry. Mechanization in all spheres of mining activity has displaced manual tasks, normally executed by Blacks, thereby enriching the quality of jobs. As Blacks continue to advance, they show a growing reluctance to be employed on jobs demanding heavy manual effort under unfavourable environmental conditions. This attitude began to manifest itself at the time that a shortage of

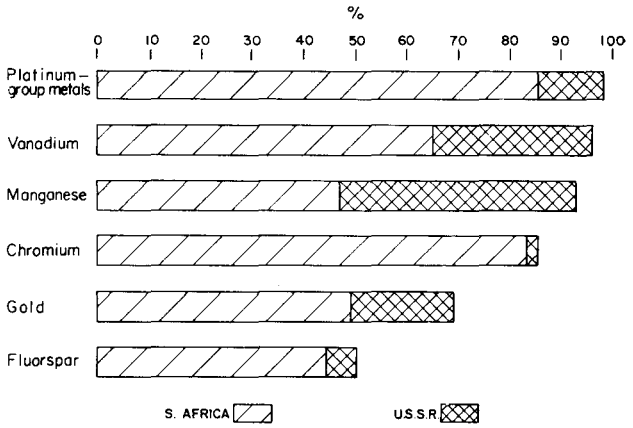

Fig. 1—South Africa's and the U.S.S.R.'s shares of the world reserves of selected mineral commodities

Black labour was experienced during 1975, and accelerated mechanization programmes. The industry has been making determined efforts to close the wage gap, and Black wages have increased substantially; as the cost of labour rises, it becomes uneconomic to limit a worker's output to his manual efforts.

Mechanized mining programmes have brought about positive increases in productivity. Nowhere is this better illustrated than in underground coal mining; the tonnage duty in hand-got collieries compared with that in mechanized collieries is quite remarkable.

The introduction of huge sophisticated machines, particularly for earthmoving, such as draglines, shovels, and trucks, has led to an expansion of open-pit mines and the establishment of a number of strip coal mines. This has resulted in the effective exploitation of multi-seam shallow coal deposits that were previously difficult to mine by underground methods. Extraction rates as high as 90 per cent are being achieved, compared with rates as low as 20 per cent for underground methods.

A complicating factor that has been introduced over the past ten years has been the high rate of inflation, which is generally accompanied by high rates of interest. The planning and establishment of new mines usually represent a long-term undertaking that could extend over ten to twelve years. It may currently cost between R200 million and R600 million to complete a project. When the project is financed with loan capital, the consequences of interest rates that vary between 14 and 20 per cent per annum are frightening. The fluctuations in metal prices add further complications. It requires a thorough application of risk analysis, exemplary forward planning, and strict project control to ensure that there is no overrun on the construction time or project cost.

Although the strength of the mining industry has been its practice of financing new projects largely from internal resources, projects have on occasion been financed with loan capital, with all its attendant risks. The State has always followed liberal mining policies in which the benefits derived from the free enterprise system are recognized. However, when from time to time relief has been required in times of hardship, the State has given assistance to marginal gold mines to enable them to weather the storm. There are other sections of the

minerals industry that could benefit from relief. For example, stockpiles of strategic minerals could be held by the State, as is done in the United States. It is interesting to note that forward buying of gold by the Reserve Bank has been suggested as a means of smoothing out fluctuations in the gold price and bringing a measure of relief to marginal mines.

A huge step forward in the minerals industry has been the reduction in the exportation of metal ores and an increase in that of processed and semi-processed minerals such as ferrochromium and ferromanganese. The sterling efforts by metallurgists in developing economic methods of beneficiation have greatly increased the value of the products exported.

Another important development of the minerals industry has been the establishment of mines in remote rural areas and the creation of the right infrastructure, which leads to the development of a region and, in time, brings prosperity to all who live there. Good examples of such development are offered by Phalaborwa, Black Mountain (near Aggeneys), and the Grootegeluk coal mine (in the strategic Ellisras area near the Botswana border).

Expansion of the Industry

Gold

It has been predicted that gold production in South Africa will decline steadily over the next two decades as the present reserves are depleted. However, some of these predictions date back to the time before the upward trend in the gold price. As the commodity becomes scarcer, the price can be expected to rise in real terms. Fig. 2 shows the gold price, and Table I gives the supply and demand for gold bullion.

This rise would encourage the extraction of ore that is considered at present to be sub-grade, of which there are considerable reserves in wide, low-grade reefs. The concept of the super mine such as the Harmony, Vaal Reefs, Driefontein and Welkom complexes could ensure the mining of large tonnages of low-grade ore at relatively low cost. Low-grade reefs with patchy values are known to exist in working and abandoned mines at relatively shallow depth. An interesting example of what may lie ahead was evidenced by the huge expansion programmes and new projects aimed at the mining of low-grade reserves, stimulated by the extraordinarily high gold price that prevailed during 1980 and 1981. The great depth, with its attendant high stresses, could be a factor limiting the extraction of wide reefs and mining in ground that has been fractured and disturbed by previous mining operations.

The scarcity of gold can be expected to increase as the demand for gold for industrial use exceeds the rate of production of newly mined gold. It is therefore expected that the production of gold in South Africa will persist for many years at levels above the decline predicted in the past.

Uranium

Up to the present time, uranium has generally been produced as a byproduct of the gold-mining industry, although some producers, Beisa Mines in particular, are primary producers of uranium. There are considerable low-grade reserves tied up in surface tailing dams and dumps ready for easy extraction, the process presenting a problem essentially to metallurgical engineers. The uranium market has been depressed over the past five years with world production curtailed in consequence. The demand is influenced by pressure groups, with fears of nuclear conflict or pollution, which have hampered the expansion of nuclear-power projects. There is no doubt

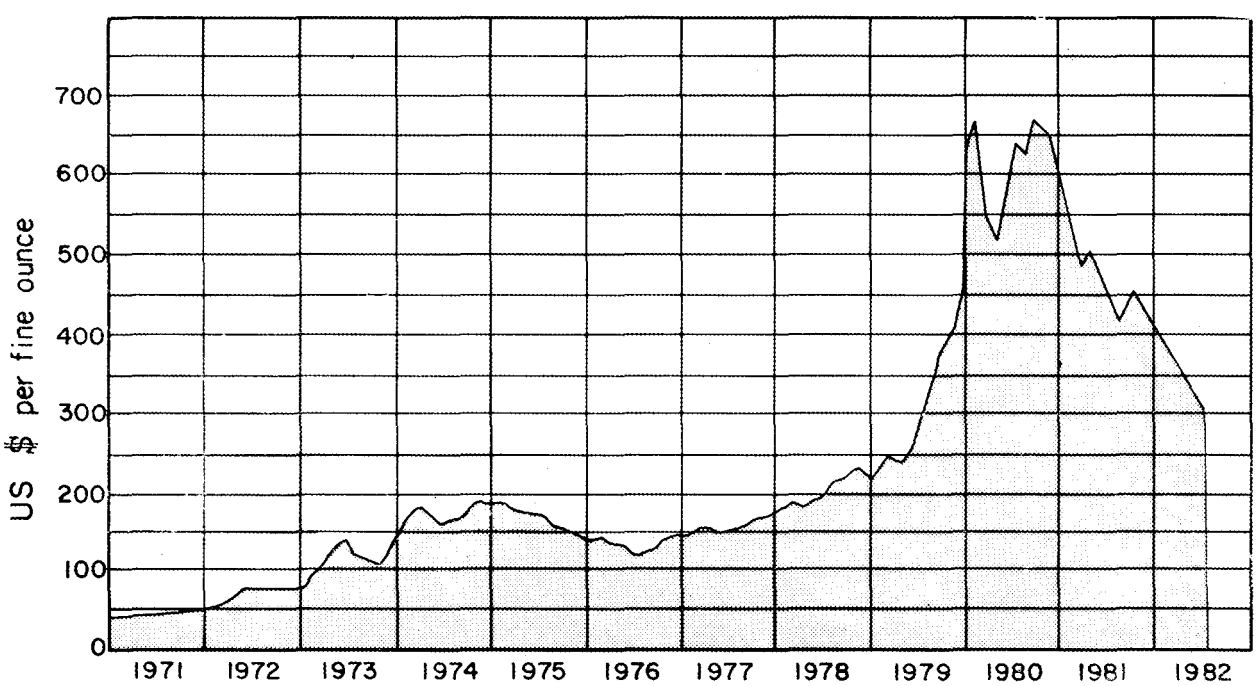

Fig. 2—The average price of gold per fine ounce on the London Gold Market (Source: Chamber of Mines, Annual Report 1981)

TABLE I

SUPPLY AND DEMAND FOR GOLD BULLION AND SOUTH AFRICAN PRODUCTION

Year	South African production t	Total* supplies t	Official† purchases or sales t	Net private purchases t	Demand for gold fabrication and investment t
1960	665	1 226	262	964	—
1961	713	1 346	538	808	—
1962	792	1 333	329	1 004	—
1963	863	1 693	729	964	—
1964	905	1 649	631	1 018	—
1965	950	1 635	196	1 439	—
1966	960	1 218	−40	1 258	—
1967	950	1 245	−1 404	2 649	—
1968	967	1 216	−620	1 836	—
1969	973	1 237	90	1 147	—
1970	1 000	1 270	236	1 034	—
1971	976	1 290	−96	1 386	1 389
1972	910	1 395	151	1 244	1 344
1973	855	1 392	−6	1 398	859
1974	759	1 226	−20	1 246	735
1975	713	1 103	−9	1 112	983
1976	713	1 382	−58	1 440	1 383
1977	700	1 373	−269	1 642	1 419
1978	704	1 389	−362	1 751	1 596
1979	703	1 160	−544	1 704	1 315
1980	673	1 033	230	803	521

Source: Chamber of Mines of South Africa: Annual Report 1980
*Includes net trade with Communist Bloc
†Since 1974 includes activities of State-controlled investment agencies, central bank operations, and IMF sales

that the generation of electrical power from nuclear stations is cleaner and more effective than that by any other means known. Only time will tell when the demand will pick up. Apart from huge resources of uranium in the Witwatersrand Basin, there are extensive reserves in the Karoo, which offer tough challenges to both mining and metallurgical engineers.

The production of uranium has shown a steady growth over the past thirty years, as shown in Fig. 3.

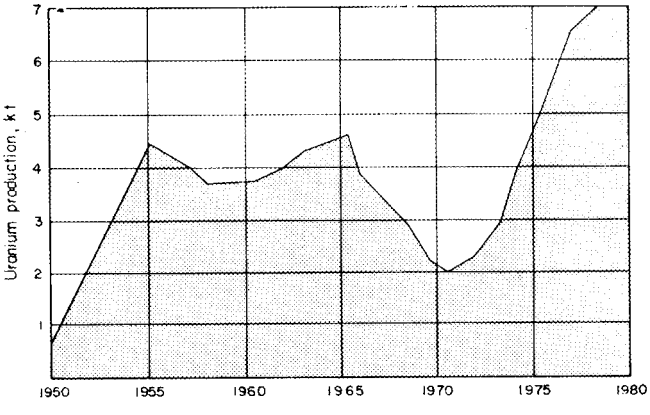

Fig. 3—South African production of uranium

Coal

The coal-mining industry has been transformed from the Cinderella of the minerals industry to its most exciting future prospect. As an export earner, it is destined to become the most important mineral commodity. The change was precipitated by the oil crisis in 1973, causing a marked swing away from the use of oil as a source of power in many countries throughout the world.

The Republic of South Africa has considerable coal reserves – estimated at 82 000 Mt – although they represent only 6 per cent of world reserves. A positive advantage is the low cost of production and the development of coal-washing plants that effectively beneficiate and grade coal products. Table II shows the expected future production of coal.

Great expansion is envisaged in the course of the next three decades to an energy-hungry world. As shown in Table II, coal exports, which were at the level of 1,2 Mt in 1972, have increased to 23 Mt. A further increase to 44 Mt by 1985 and 80 Mt by 1990 presents exciting prospects.

Coal exports have brought a new complexion to the industry in that the higher prices applicable to export products give this sector of the industry attractive profit-earning potential. This contrasts with the relatively low-profit operations associated with the collieries tied to thermal-power stations, where the profits are curtailed by formula in an effort to keep down the cost of electrical power to the consumer. It is perhaps ironic to note that, owing to increases in transportation costs, the rail and seafreight charges now raise the delivered price of coal to many times its production cost.

Conflicting views are held concerning the coal export programme.

One view is held by the sages who feel that high-grade coal is a scarce commodity that could best be used locally for various purposes, including power generation and industrial development to accelerate the growth and creation of job opportunities. They claim that metallur-

TABLE II

SOUTH AFRICAN COAL PRODUCTION AND SALES

Year	Production Mt	Local sales Mt	Exports Mt	Total sales Mt
1970	55,6	51,6	1,5	53,1
1971	57,0	55,5	1,4	57,0
1972	58,4	55,9	1,2	57,2
1973	62,4	59,6	1,9	61,5
1974	66,1	62,4	2,3	64,6
1975	69,4	66,4	2,7	69,1
1976	76,5	69,8	6,0	75,7
1977	85,4	72,3	12,7	85,0
1978	90,4	70,3	15,4	83,4
1979	103,8	74,9	23,3	98,2
1985	—	110	44	154 *
1990	—	—	80	— *
2000	—	250	80	330 *

*Outdated estimate. The estimates are being updated by the Minerals Bureau.

gical-grade coal can best be used for the processing of ferro-alloys and other metals, thereby enhancing their value as export commodities far beyond the intrinsic value of the ore and coal. However, Jochens[3] has underlined the fact that the reserves of metallurgical coal are sufficient to process only a proportion of the country's mineral resources.

The opposing view is that export earnings at the present time are a vital factor in financing industrial and other developments in the country, and that the greatest overall immediate benefit should be obtained. In addition to creating jobs, the provision of the necessary infrastructure (such as the Richards Bay and Sishen–Saldanha rail links) promotes other growth and overall prosperity.

It is clear that a compromise solution, one advocating controlled export, is correct. Overseas trade links and connections are vital to the country at this stage and will continue to be so in the future, and the ability to produce high-grade coal at relatively low cost places the South African coal-mining industry in a very favourable position. If high-grade coal is exported, a challenge is set to use the low-grade fractions locally. The success with which low-grade coal fractions are being used in new thermal-power stations and the efficiency of the generating systems, as pointed out by Smith[4], are tributes to the research effort of local engineers. Exciting developments are reported in which extremely low-grade coals of high ash content, which were previously regarded as waste products, can be used to produce liquid fuels.

Power Generation

The level of industrial development and the prosperity of a nation can be measured directly in terms of power consumption. As in any other country, accelerated industrial development is vital to the Republic in order to broaden the base of its international trade and to create job opportunities for its labour force. The requirements with regard to the creation of jobs have been clearly defined by Hersov[5]. Planned expansion in the sector of power generation is quite formidable. It amounts to an increase in the present consumption of coal for that purpose from the present 60 Mt/a to 160 Mt by the year 2000. This would be equivalent to the building of a new 3600 MW power station every year for the next twenty years. Although the first nuclear station, at Koeberg, is nearing completion, coal is expected to be the base for a very large proportion of the expansion, according to Smith[4].

Since the oil crisis in 1973, there has been a very marked swing away from the use of liquid fuels. The mining industry, which at present consumes approximately 30 per cent of all the electrical power generated, is a good example. Electrical power now amounts to more than 90 per cent of its power consumption. Areas still exist that have a direct bearing on progressive reduction in the consumption of liquid fuels. Among these are trolley-assist systems for open-pit hauling, the installation of in-pit crushers coupled with conveyor belts, the swing to battery or overhead trolley locos, the introduction of electric load–haul–dump units for the transportation of rock, and the use of electric-powered rotary drills in open pits and of giant draglines for the removal of overburden.

Another important facet of the demand for electric power is the growing sophistication of the Black population and its importance as a consumer. As the earning power of Blacks increases with commensurately higher living standards, they will consume increasing amounts of power, and the electrification project in Soweto is evidence of this pattern.

Synthetic Fuels

The oil crisis of 1973 highlighted South Africa's dependence on the importation of oil products and its vulnerability in this regard. The need to gain a measure of independence led directly to massive expansion of the oil-from-coal projects so successfully pioneered by Sasol. The necessity to produce fuel products from local resources was also prompted by a steep rise in the price of crude oil, which produced an unacceptable drain on the foreign exchange that was so sorely needed for other purposes. It also gave impetus to research into the production of methanol and ethanol, which will undoubtedly become important in the years that lie ahead.

Sasol 1, 2, and 3 will thus become major consumers of

coal, with an immediate planned consumption of about 30 Mt/a. As industrial development takes place, the demand for fuel will rise, and the impending success of the giant Sasol 2 and 3 plants will undoubtedly lead to other similar developments. The increased demand is indicated by the high level of new-vehicle sales that has been recorded, even in these recessionary times. In addition, fuel requirements in general industry as well as for aviation purposes can be expected to grow. A pleasing feature of the oil-from-coal process is the development of the secondary industry that has followed in its wake. At Sasol 1, as many as 90 byproducts, ranging from fertilizers to plastics, have created many job opportunities and resulted in considerable industrial development.

Smelting

Expansion in the steel industry at Newcastle, as well as in the ferro-alloy industry at Witbank, Vereeniging, and Steelport, has resulted in a significant increase in the demand for coking coal, form-coking coal, and metallurgical-grade coal for smelting purposes. The focus on the shortage of high-quality coking coal has given impetus to the exploration for new reserves and has necessitated research into ways by which the present coal resources can best be used for metallurgical purposes. Many recent developments have taken place in the establishment of metallurgical processing plants concerned with aluminium at Richards Bay, platinum at Springs, tin at Rooiberg, zinc at Springs, manganese at Krugersdorp, copper at Phalaborwa, and silicon at Pietersburg, all of which do great credit to South African metallurgical engineers. In addition, the production of cement has also shown substantial growth. Such developments have all increased the demand for coal or, in the case of electric furnaces, for electric power. Substantial growth in these industries must occur in the course of the next two decades.

Other Minerals

The recent establishment of a major lead–zinc mine has served to underwrite the independence of the Republic in respect of these minerals and to provide alternative supplies to those from Zambia and South West Africa/Namibia, from which large quantities were imported in the past. The demand for platinum has softened in sympathy with the world recession, but, as the free world's major source of the metal, South Africa's platinum industry must improve as the world economy recovers. Expansion in the production of a host of other minerals, which include chromium, manganese, tin, asbestos, vanadium, and molybdenum, are uncertain.

Technical Challenges

Engineers in the minerals industry face technical challenges in every avenue, and there must be a sufficient supply of engineers if the expansions as outlined are to be successfully achieved in an orderly manner. Featuring among the more important challenges in deep gold mines are the following.

The provision of acceptable environmental conditions is of paramount importance. Uncomfortably hot conditions in working places serve to make gold mining unpopular, which leads to difficulties in drawing and keeping the right kind of labour. But, more important, it severely limits productivity, and this becomes increasingly untenable as wages increase because of the adverse effect on working costs. As mining progresses to greater depth, virgin-rock temperatures of 60°C could be encountered, which present a formidable challenge. Great strides have been made in the field of mine cooling through the use of chilled service water, but much remains to be done. The high cost of electrical power demands that effective and efficient use be made of mine cooling if positive advantage in the reduction of working costs is to be gained through improved productivity. Higher production rates and a reduction in the number of working places are called for. Very interesting experiments are being conducted in the use of ice conveyed in pipes, as opposed to the use of chilled water. The volumes of coolant can be considerably reduced if the latent heat of ice is brought into play, which would lead to 'spin-offs' in equipment and power costs. Another major factor in the consideration of environmental conditions is the effective use of ventilating air, especially in view of the high costs of power. The provision of air at the working faces and the prevention of air leakage have always been thorny problems, which have now assumed even greater importance. It is indeed sad to record that there are so few mining engineers who have specialized in environmental control and who can address these formidable problems.

The gold-mining industry is a major consumer of power, and Jochens[3] has shown that 20 MW·h are used for every kilogram of gold produced. Compressed air, primarily for rock drilling, accounts for a significant proportion of the power consumed, and there is clearly a need to improve the use of compressed air, which is inherently a low-efficiency system. Although much research is being conducted into hydraulic drilling systems with either oil or water as the hydraulic fluid, much work still remains to be done, and the practical application of the systems to production drilling still lies in the future. Another area in which the utilization of energy needs improvement is in scraping and rock haulage. It is pleasing to record that mechanization has resulted in the elimination of many manual tasks, for example in the area of materials handling through the aid of mono-winches, and in sweeping through the use of high-pressure water jets. Efforts to further improve the effectiveness of mechanized systems cannot be relaxed.

Since the first introduction of rock-boring machines in the industry in 1967, there has been considerable expansion to the point where very few long, steeply inclined excavations are constructed by conventional means. However, the operating costs are still considered to be too high, and there is a need to improve the operating efficiency, reduce the costs, and extend the operational scope of the boring units.

Successful mining at great depth would never have been possible without the progress that has been made in the field of rock mechanics. The industry can be proud of the contribution it has made to the science. However, much research work remains to be done in the field of

stress analysis, the control of energy release rates and rock bursts, and the study of seismic events.

The application of electronic fire-detection systems, fire-retarding treatment of mine timber, elimination or reduction of combustible materials, and risk analysis have made a remarkable impact on reducing the incidence of mine fires, and thereby reducing a disruptive and expensive influence on production.

The production processes of rock breaking offer fertile areas for improvement, especially with the introduction of new types of explosives. The lack of a reliable sequential firing system for explosive charges in stoping, estimated to cost the industry as much as R250 million per annum in lost production, still remains an unsolved problem. In general, the fields of rock hoisting and water pumping operate at high efficiency, and the automatic hoisting of rock is commonplace.

Similarly, metallurgical engineers are confronted with many challenges. Perhaps the most exciting development concerns the carbon-in-pulp process, which promises to have wide application in the future. In the field of milling, considerable progress has been made in the use of autogenous mills. Interesting work is being done on flotation, and increased recovery remains a primary objective. With the fluctuating price of gold and the relentless increase in working costs in an inflationary climate, the need for effective cost control is even more of a top priority than it was before.

Progress in underground coal mining has been intimately connected with the introduction of mechanized systems. The application of continuous miners is steadily increasing especially as they are modified and developed to suit local conditions, which involve coal that is generally harder and more abrasive than in other parts of the world. Stooping, on a controlled basis, with a view to increased percentage extraction, is being applied more and more. Work done by rock mechanics specialists on pillar design has ensured safer working conditions and improved extraction. Bold experiments with coal-shearing machines and the development of longwall mining systems, especially at Sasol, are starting to pay dividends, and extension of the systems seems inevitable. Higher extraction rates have brought with them the problems associated with the subsidence of the superincumbent strata. This is of particular significance owing to the presence of the very competent dolerite sills that are found in many coal-mining areas. The mechanized mining of narrow, high-grade coal seams is another aspect that poses interesting problems and that calls for much work to be done.

Metallurgical engineers have made a valuable contribution to the coal industry in developing coal-washing plants and, through heavy-medium separation, producing different grades of coal suitable for various applications, leading to greater overall revenue.

The past decade has seen the establishment of a number of strip coal mines. The application of large, expensive equipment in such operations, such as a giant dragline capable of moving 2 Mt of overburden per month, is an area where much work remains to be done by the mining engineer. The selection of suitable equipment, the effective maintenance of equipment, and the planning of operations are necessary to ensure efficient use of the large high-cost equipment. Rehabilitation of the surface disturbed by mining, which costs up to R11 000 per hectare, and restoration of the ecology have become important issues.

Over the past three decades many impressive open-pit mines have come into being such as the Phalaborwa copper mine, Sishen and Thabazimbi iron-ore mines, Finsch and Koffiefontein diamond mines, Grootegeluk coal mine, and many others concerned with manganese, vermiculite, limestone, and building stone. The economy of scale is generally significant, leading to the use of large drills and earth-moving equipment. The planning of operations, the selection and maintenance of equipment, and computer control are all areas that require the attention of engineers. The use of in-pit crushers in conjunction with conveyors to improve productivity, eliminate liquid fuel, and lower working costs is destined to find wider application.

The Chamber of Mines of South Africa is actively engaged in research over a broad front through its Research Organization, and is working on many of the problems mentioned above. The budget for 1982 is R27 million and is indicative of the size of the research effort and, by implication, the staff required to undertake the work.

Engineers — Supply and Demand

Specific attention has been paid during the past three years to the demand for professional engineers. Studies have been conducted by the Department of Manpower Utilisation and by the Federation of Societies of Professional Engineers. As the information collected by the Department of Manpower in 1979 concerning metallurgical and mining engineers was incorrect, it was not presented in the FSPE manpower report[6] of 1980. Fresh inquiries produced information on the demand for engineers that is considered to be reliable and is contained in the FSPE manpower report[7] of 1982. Table III, which shows the supply and demand situation for the country as a whole over the period 1973 to 1985, depicts a serious situation. The demand is increasing at the rate of 5,2 per cent per annum compound, and the supply is worsening progressively, filling approximately half of the demand at the beginning of the period and falling to one-third of the demand in 1985. Engineers play the key role in industrial development, and it is difficult to imagine how the predicted growth targets will be achieved without enough engineers.

The minerals industry has been consistently short of engineers for a long time, particularly in the disciplines of mining and metallurgy, and was probably the main cause of the spurious estimates mentioned earlier. The seriousness of the situation is clear from Table III, which shows that less than one-third of the required mining and metallurgical engineers have been available in the past. Although a better position is predicted for the immediate future, improving the deficit to 50 per cent, it is not clear how this is to be achieved. The picture of persistent shortages of supply implies, firstly, that there is a very real danger that the expansion programmes envisaged, particularly in the coal-mining

TABLE III

SUPPLY AND DEMAND FOR ENGINEERS

Year	1973	1975	1977	1979	1981	1983	1985
Professional Engineers							
Graduates	641	664	671	828	763	952	987
Immigrants	215	276	351	85	126	136	158
SACPE PT III ..	—					21	25
Supply	856	940	1 112	913	906	1 109	1 170
Vacancies	1 041	974	837	1 455	1 935	1 832	2 087
Demand	1 897	1 914	1 949	2 368	2 841	2 941	3 257
Metallurgical Engineers							
Graduates	14	9	12	24	20	42*	36*
Immigrants	12	10	19	6	8	10*	12*
SACPE PT III ..	—	—	—	—	1	1*	2*
Supply	26	19	31	30	29	53*	50*
Vacancies	56	63	52	57	55	31*	35*
Demand	82	82	83	87	84	84*	85*
Mining Engineers							
Graduates	16	17	8	14	26	32*	36*
Immigrants	12	12	19	6	10	14*	18*
SACPE PT III ..	—	—	—	—	1	1*	2*
Supply	28	29	27	20	37	47*	56*
Vacancies	63	63	64	50	67	60*	55*
Demand	91	92	97	100	104	107*	111*

*Estimates
Source: The supply of, and demand for engineers, FSPE Report, 1982.

sector, will be very difficult to achieve within the limits of time and cost; secondly, that mining ventures cannot be adequately designed when most of the trained engineers in the mining industry are filling managerial posts and, according to some opinion, the industry already suffers from being over-managed and under-engineered. Research effort and technical innovation, which are prerequisites for progress and improved productivity, are starved because engineers fill the production management posts, which are traditionally made more attractive and tend to be filled first. Merely taking cognizance of the shortfall in numbers does not tell the whole story. Supply shortages result in rapid promotions, frequently before persons are ready and therefore not yet competent for the posts, as well as in the use of persons who are not suited to particular positions. If it were possible to fill all the vacancies tomorrow, there would still be a very serious lack of the experience that is a vital element in the make-up of any engineer or manager. These qualities are sorely needed in an industry that is becoming more complex and sophisticated, that requires sound design, and that is exploiting lower-grade ores.

Fundamentally, it seems to be neither right nor wise that the country's premier industry, the minerals industry, which recently produced 70 per cent of its foreign earnings, should be inadequately supplied with engineers. During one of the technical sessions at the 12th CMMI Congress, strong opinions were expressed that the industry needs technical managers and that academic training should be designed to fulfil this need. However, academic institutions aim to educate engineers, and a large proportion of trained engineers eventually progress into management positions. That this should be so is not strange: by virtue of their training, engineers make good managers. However, most engineers spend only a small proportion of their careers practising the profession for which they were trained.

Role of the Mining Engineer

What is the role of a mining engineer? In broad terms, it involves project assessment, project design, construction, operations planning, development of control systems, and research. Outside the areas of mine design, construction, and operation, there are other sectors that take up part of the supply of mining engineers. The more important include

- environmental control, rock mechanics, geostatistics, and evaluation;
- inspection in State departments and the Minerals Bureau, since it is vital to have adequately trained engineers in these areas if a progressive attitude is to prevail (it is sad to record that no new mining graduate has entered this inspectorate during the past eight years);
- research and development;
- teaching in universities and technikons (the importance of a sufficient number of suitable persons to fill posts in educational institutions need not be stressed);
- service industries concerning the supply of explosives, and mining equipment and plant;
- computing concerned essentially with the mining industry.

Reasons for Shortage

The reason for the shortage of metallurgical and mining engineers has been the subject of considerable debate. The promotional prospects are extremely good, and mining engineers in particular are better remunerated on the average than engineers in other disciplines[8]. Careers in the minerals industry are both challenging and fulfilling. As far as students are concerned, the position has been made extremely attractive in that generous bursaries are freely available. There is, for example, scarcely a mining engineer at university who is not a bursar. The practice of selecting promising candidates from among mature staff and sending them to university on full salary is indicative of the industry's desperation to fill its ranks. In recent years, graduates commencing their military training immediately after graduation are retained on full pay.

A significant contribution to the supply of mining engineers has been made through the introduction of the course culminating in the Diploma in Mining that was introduced at the University of Pretoria in 1966. The one-year scheme is aimed at engineering graduates in other disciplines with suitable exposure to the industry. So far, twenty diplomas have been awarded, and the candidates have done extremely well in industry.

Another very important contribution to the supply of engineers, as seen in Table III, is made by immigrants. The supply from this source varies considerably, being influenced by political uncertainty and adverse publicity abroad. However, experience in the mining industry has shown that the retention rate after five years is small in relation to enrolments. It hardly seems right that so important an industry should have to rely so heavily on immigration to supply its needs.

What is the reason for the overall shortage of engineers? The problem was dealt with by Black[9] in 1961, who described recruitment to the industry as 'trying to fill a quart bottle with a pint of cream'. Recent research at the Universities of the Orange Free State and Stellenbosch show that, while the number of Black school-leavers will increase dramatically towards the end of the century, the number of White school-leavers will stagnate or even diminish. The implications seem clear: the only way to satisfy future demand will be to draw on the resources of other race groups, especially Blacks. Concerted efforts are already being made towards the training of Black engineers, especially in civil engineering. The difficulties associated with Black university students, who are disadvantaged because of their background and the quality of their school education, cannot be under-estimated. Interesting experiments with cadet schemes and bridging courses are being pursued at the University of the Witwatersrand. The establishment of engineering faculties on a limited scale at two Black universities has been launched, although with misgivings among the engineering fraternity. The crucial issue of how the Black engineer will be absorbed into industry lies in the future.

The introduction of Black engineers and technicians into mining will be more difficult than in other engineering disciplines owing to the present labour structure. The mining industry, traditionally, has been the employer of large numbers of uneducated and unskilled Black workers drawn from rural, undeveloped areas, these men being employed as labourers on manual tasks. The pattern has changed very considerably with the introduction of mechanization so that most machinery, even the most sophisticated, is in the hands of Black operators. Concerted efforts have been made by the industry to close the wage gap, and Blacks at the top of the wage scale are earning good money. The process of natural evolution has been far too slow, and Black advancement has been retarded by trade unions who have vigorously resisted such moves. The logical area in which to absorb Black engineers initially is in the neighbouring Black States; then, trained White engineers from the Republic, who fill those posts at present, would not be drained off. The second possibility is to employ Black engineers initially in specialist service divisions such as ventilation and rock mechanics. An interesting recent development is the dispensation to allow the use of Blacks as samplers, surveyors, ventilation observers, and work-study observers. At the beginning, the numbers will understandably be small and their education should logically be provided at White universities.

Another source of labour that has remained untapped is the female population. The law makes it difficult, if not impossible, for women to be employed in the technical areas of mining. In overseas countries, it is commonplace for women to be employed on a wide spectrum of jobs on a mine, even to the driving of large trucks and heavy earth-moving equipment. With our abundant labour resources, it seems unnecessary to employ women in these areas, but the employment of trained female engineers in specialist and service areas, more especially in research, metallurgy, and open-pit mining, could make a welcome contribution to the supply of skilled personnel. In other engineering directions, which, admittedly, are less demanding, women are showing greater interest and enrolments are growing.

Remedial Action

It is fair at this point to ask what the mining industry is doing to get its fair share of the available manpower resources. FSPE, through its publicity and education committees, endeavours to attract young people into careers in the engineering profession. SAFUES (South African Federation of University Engineering Students), with brochures and a winter school programme, has the same goal. Frequent advertisements and articles dealing with careers in the minerals industry are placed in a number of special magazines that are aimed at young people such as *Archimedes*. The Phoenix Programme, which is promoted by the Chamber of Mines and the Institute, has been in operation for almost a decade. It offers an intensive one-week programme for groups of mathematics and science teachers drawn from high schools throughout the land. Accent is placed on mining and metallurgy, and the aim is to expose teachers to these disciplines so that they will influence scholars in choosing careers in that direction. Through the Training, Career Guidance and Education Committee, the Institute does useful work in the field of career guidance.

In general, there is a need not only to attract more people into careers as trained engineers in the minerals industry, but also to draw people from the top end of the availability spectrum. Because of the shortage of engineers, and for other reasons that are not clear, too many students have been drawn from the bottom end of the availability spectrum, which has undoubtedly had an adverse effect on overall success rates.

There are encouraging indications that the efforts being made to attract students into the minerals industry are bearing fruit. It seems that the approach is correct and that the right things are being done (Table IV). However, to be more successful, these efforts must be co-ordinated, intensified, and expanded. The first priority should be to create an attractive image of the industry in the population at large. It is disturbing to note that many people, including school teachers, have no knowledge of what the industry is all about. Television is a powerful medium, but an expensive one, which has not been used to full potential. It would be interesting to know just how much influence 'The Villagers' programme, which was woven round life in a mining community, had on the image of the industry.

Visits to mines arranged by career-guidance teachers for senior school children at a time when they are thinking about choosing a career have always been considered important. It is highly likely that such efforts will be more successful when aimed at school children from traditional mining communities. A pilot scheme is at present in operation in which the management of particular mines invites the senior pupils from nearby schools to visit their mines. There also seems to be room for improvement in the follow-up of school pupils who show an interest in careers in the minerals industry. There is great merit in an arrangement practised by the Institute of Civil Engineers. School pupils who express an interest in the profession are put in touch with a member of that institute in a nearby residential area. The engineer then invites the scholar to spend a day with him in order to show him, through the course of the day, what the work of a civil engineer entails. A similar practice could be adopted with advantage by the members of this Institute.

Since the advent of the Professional Engineers' Act, much attention has been directed towards training programmes for engineers-in-training after graduation. The mining industry has always had good training programmes, and monitoring the progress of trainees has served to ensure that young engineers are employed on work for which they have been academically trained and that steady progress is maintained. It is hoped that disenchantment with the industry as a result of uninteresting and seemingly irrelevant work during training will be eliminated.

The demand for engineers in the minerals industry has been positively influenced by the technikons' National Diploma for Technicians. Since the inception of the course in 1968, 446 diplomates who qualified in mining have flowed to the industry in a steady stream. Since 1976, 157 diplomas have been awarded in extractive metallurgy. From 1967, a total of 173 diplomas in metallurgy have been awarded by three technikons, the course being directed towards physical metallurgy (Table V). The courses are practically orientated, with alternating periods of full-time study and practical work. It is understandable that a four-year sandwich course is not as comprehensive, nor is the study material covered to the same depth, as a four-year degree course. However, the diplomate is well equipped to play an important role in the practical environment of a mine, especially as a technical manager, and this is a role complementing that of the trained engineer.

Academic Training

The introduction of two years of compulsory military training has had a marked influence on the type of student studying mining or metallurgy at university. The majority are matriculants straight from school who have had little or no exposure to the industry. Previously, the large majority of students were drawn from the ranks of learner officials after the first year of training, and bursars were selected on their performance during practical training and at technical college. One full year's industrial training formed an invaluable foundation on which to teach metallurgical and mining subjects, since a minimum of time needed to be spent on the rudiments and fundamentals and the students had a better comprehension of the principles. There was also a far higher degree of certainty that the persons were suited to a career in the mining industry. A lack of such certainty is felt to be a major factor bearing on the present loss of young engineers from the industry.

TABLE IV

GRADUATES IN MINING AND METALLURGICAL ENGINEERING

Year	1960	61	62	63	64	65	66	67	68	69	1970	71	72	73	74	75	76	77	78	79	1980	81	82
Mining																							
Witwatersrand ..	15	10	11	10	10	16	7	15	11	5	7	12	15	8	11	11	5	12	7	12	11	22	—
Pretoria ..	—	—	—	—	—	1	2	6	3	8	10	7	7	4	2	5	2	3	4	7	5	11	—
Diploma	—	—	—	—	—	—	3	—	1	1	—	—	1	—	—	—	2	—	2	2	7	1	—
	15	10	11	10	10	17	12	21	15	14	17	19	23	12	13	16	9	15	13	21	23	34	—
Metallurgy																							
Witwatersrand	6	9	4	12	4	5	10	9	5	7	8	8	11	7	3	7	7	4	10	12	13	8	8
Pretoria	—	—	3	3	4	6	12	4	7	6	5	4	8	7	7	2	5	19	15	17	18	24	—
	6	9	7	15	8	11	22	13	12	13	13	12	19	14	10	9	12	23	25	29	31	32	—

TABLE V

DIPLOMAS AWARDED BY TECHNIKONS
MINING DIPLOMAS (WITWATERSRAND)

	Year			1968	69	1970	71	72	73	74	75	76	77	78	79	1980	81	82	Total
MDT* Metall.	.. ..	..	..	3	9	14	20	26	25	15	25	14	24	32	16	30	31	34	320
NDT* Coal	.. ..	..	..	—	—	2	10	12	3	9	10	13	14	8	4	11	14	16	126
Total ..	.. ..	..	..	3	9	16	30	38	28	24	35	27	38	40	20	41	45	50	446
						METALLURGICAL DIPLOMAS NDT* METALLURGY													
	Year		1967	68	69	1970	71	72	73	74	75	76	77	78	79	1980	81	82	Total
Wits ..	.. ..	..	1	1	1	2	4	2	3	8	3	2	4	7	13	6	3	—	60
Vaal ..	.. ..	..	—	—	—	—	—	—	—	—	—	—	3	6	3	5	16	—	33
Pretoria ..	.. ..	..	1	—	2	—	1	4	3	2	—	2	1	9	7	5	9	—	80
Total ..	.. ..	..	2	1	3	2	5	6	6	10	3	4	8	22	23	16	25	—	173
						NDT* EXTRACTIVE METALLURGY													
	Year		1967	68	69	1970	71	72	73	74	75	76	77	78	79	1980	81	82	Total
Wits ..	.. ..	..	—	—	—	—	—	—	—	—	—	7	11	13	22	37	23	41	157

*Four-year course leading to the National Diploma for Technicians

With the advance of technology, courses have become more complex and sophisticated, and the undergraduate engineering curricula are generally overcrowded. There is a tendency for educational establishments to expand courses without eliminating anything from them. The first degree must be regarded as a basic degree in which the coverage of the subject matter is comprehensive but to a limited depth. Academic training in mining and metallurgical spheres has often been criticized because it omits management training. The basic aim is to educate engineers, during which the principles of management are covered. At that particular stage of development before they have had any meaningful industrial exposure, students are not able to benefit from management training. The responsibility for certain aspects of an engineer's training, including management and industrial relations, lies with industry.

Because the first degree is designed to cover subject matter to a limited depth, specialization must follow through post-graduate study. Through the Graduate Diploma in Engineering and honours degree courses, which now cover a wide spectrum, it is possible for a student to specialize in a host of directions. Attendance at such courses must be limited by staff shortages, but the minerals industry should show a more active interest in post-graduate study, especially at the M.Sc. level. There is a disturbing lack of academically qualified people in the fields of environmental control and rock mechanics.

Management training, at an appropriate time in an engineer's development, is best obtained through an MBA or MBL course. Traditionally, the industry has sent its senior management staff to attend short management courses at particular business schools abroad. Management development courses, for example at the University of the Witwatersrand, present an avenue for the training of junior management or technical staff.

Again, because of the limited supply of manpower, difficulties have been experienced in attracting sufficient persons of the right calibre and experience to staff the university and technikon departments. Salary scales, which are not competitive with those of the industry, have led to subvention of posts by the industry to improve the position. Because the academic staff are generally overloaded, attention to research work and consulting assignments suffers, and such efforts are vital in developing staff, forming contacts with industry, and training students. However, the capacity at the present academic institutions for mining and metallurgy is such that the student numbers could be trebled without causing undue strain. Because of the present difficulties of staffing existing departments, it would be extremely unwise to establish new departments of mining or metallurgy until the present facilities are used to full potential.

National Service

Few people would dispute the need for our young people to undertake national service. However, the introduction of two-year compulsory military training has radically influenced higher education and the training of young people, and has brought many problems in its wake. The thorny question arises as to whether military training should precede or succeed academic training. It seems worth while to examine the two alternatives.

The merit of going to university first means that the student, fresh from school and accustomed to study, extends his education without interruption. Later, during his military training, it may be possible for him to be employed on such work as to gain credit towards his engineer-in-training period. The net result is his attainment of the status of a registered professional engineer at an early stage.

Highly motivated graduates have been known to further their studies at universities through extramural part-time courses. However, in the disciplines of mining

and metallurgy, few opportunities and no suitable employment exists to further the engineer-in-training, and the period of military training is a two-year dead gap. Military authorities are reported to be making genuine efforts to solve the problem by employing graduates where possible on work for which they have been trained. It may be possible to extend an existing scheme in which military trainees are stationed at camps near certain institutions (such as the CSIR and Armscor) and spend a proportion of their military training period on suitable work. By this means, some credit is obtained towards engineer-in-training. Something similar may be possible for mining and metallurgy graduates by posting them to Middelburg or Potchefstroom and allowing them to be used on nearby mines for part of their service period. Graduates who are bursars from a mining house now generally have their military pay supplemented, which makes it attractive to graduate before military training.

A negative factor concerning the undertaking of degree studies before military training is that school leavers have had very limited exposure to the industry and do not know if they are suited to careers in mining, which can result in wastage. Also, there is little or no base on which to build the teaching of mining and metallurgical subjects.

There are not many merits associated with military training before university. It is true that such students tend to be more mature, better disciplined, more dedicated, and may be more sure of the direction of their careers. However, on the negative side, such young men have broken the study habit and have lost touch with mathematics and science. Also, there seems to be an urgency to earn money and to fulfil romantic attachments. Taken together, these are potent factors militating against serious study.

The previous pattern of proceeding to university after one year's training as a learner official in which the study habit is preserved has many merits and could possibly be incorporated in the present structure. The difficulty is that, once a school-leaver elects to work rather than to study at a university, he is obliged to proceed immediately on his military training.

It may, for example, be possible to make bursary awards for mining and metallurgy subject to due performance on a one-year type of learner-official course. The bursary holder, having immediately applied for registration at a university, could be accepted provisionally and, on those grounds, be exempted from starting military training for one year. Credit for a portion of the pre-university training, if properly structured, could be recognized by SACPE towards the engineer-in-training period.

Conclusion

The minerals industry is extremely important to the economy of the country, providing capital and foreign exchange for industrial development. A continued rise in the price of gold is likely to extend the life of the industry beyond that previously predicted. In addition, an expansion of the coal-mining industry to provide coal for export, power-generation, liquid-fuel, and smelting purposes will ensure a growing demand for engineers in the minerals industry.

The supply of mining and metallurgical engineers is at present only one-third of the demand, but there are encouraging signs of an improvement in the supply. The efforts being made to attract students into careers in mining and metallurgy appear to be succeeding, but they need to be co-ordinated, expanded, and intensified, especially in projecting the image of the industry. It is inevitable that the future demand for engineers in general can be satisfied only by drawing increasingly on the resources of other race groups, especially Blacks, but the absorption of Blacks into the mining industry will be more difficult than in other industries.

A means must be found to attract sufficient persons of the right calibre and experience to staff the universities and technikons. The industry should encourage post-graduate study to a greater extent, especially in the directions of environmental control and rock mechanics, to meet the challenges that lie ahead. Capacity exists in the present mining and metallurgy departments for substantial increases in student numbers without undue strain and, because of staffing difficulties, it would be unwise to establish new departments.

Efforts aimed at employing graduates, while on military training, on work for which they are qualified should continue. One year's training on a learner-official type of course before attendance at university could reduce the wastage of graduate engineers.

References

1. NISBET, G. Y. Presidential address: The role of mining in South Africa. *J. S. Afr. Inst. Min. Metall.*, vol. 81, no. 9. Sep. 1981.
2. VAN DEN BOSCH, L. W. P. Mining in the world market place. *Mining Survey*, no. 87, no. 4 of 1977.
3. JOCHENS, P. R. Presidential address: The energy requirements of the mining and metallurgical industry in South Africa. *J. S. Afr. Inst. Min. Metall.*, vol. 80, no. 9. Sep. 1980.
4. SMITH, J. H. Plenary address: Escom from the present into the twenty-first century. Twelfth Congress of the Council of Mining and Metallurgical Institutions, Johannesburg, May 1982.
5. HERSOV, B. Plenary address: The South African labour scene twenty-one years on - quo vadis? Twelfth Congress of the Council of Mining and Metallurgical Institutions, Johannesburg, May 1982.
6. LLOYD, P. J. D. The supply of and demand for engineers. The Federation of Societies of Professional Engineers, 1980.
7. LLOYD, P. J. D., and PLEWMAN, R. P. The supply of and demand for engineers. The Federation of Societies of Professional Engineers, 1982.
8. LUKER, I. The graduate gap. *Engineers Employment News*, no. 82. May 1982.
9. BLACK, R. A. L. A review of education and training facilities for the mining industry in South Africa. Trans. Seventh Commonwealth Mining and Metallurgical Congress, Johannesburg, 1961. vol. 1.