Minerals and Manpower

PRESIDENTIAL ADDRESS

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INTRODUCTION

What I want to discuss is the future pattern of manpower in the mining industry, and I should like to begin by examining some relevant statistics.

There are four areas that must be examined. Firstly, the future rate of production of different minerals must be estimated. Secondly, an assessment must be made of the balance of different mining technologies likely to be used for each mineral. Thirdly, the manpower requirements for each technology must be determined. And, fourthly, the future manpower resources of the country must be explored.

FUTURE RATE OF PRODUCTION

As far as the future rate of production is concerned, I have chosen as a starting point the report of the Commission of Enquiry into the Export Industry — the so-called Reynders Report. In this report, which was tabled in 1972, the Commissioners have included an estimate in money terms of the future rate of exports of minerals that is required if the Republic is to reach its targets for foreign exchange earnings. Projections were made for the years 1980 and 2000. I have converted these to physical units at 1970 prices.

To these estimates I have added the domestic requirements, based on two sets of figures. In the first projection, the annual rate of growth of demand in the domestic sector has been taken as 3 per cent for base metals and non-metals other than carbon, and 5 per cent for coal; in the second projection, the growth rates are estimated at 5 and 8 per cent respectively. The result is two projections of the future production rate of the mineral industry, excluding gold, platinum, and diamonds (Table I). As my derivations are reasonably in accord with the estimates produced by the National Institute for Metallurgy† and the prognosis of the Economic Development Programme for 1972 to 1977, I feel some confidence in accepting them.

MINING TECHNOLOGIES

The second area, the estimate of different mining technologies, is even more speculative than the first. Mining engineers should always design the exploitation method for a given deposit so as to achieve the highest return on capital invested, i.e., they should use the operation of lowest total cost inside the spectrum of known and appropriate technologies. I think that our engineers, and possibly our entrepreneurs, have been a little slow in taking advantage of some of the technologies that have been developed in other countries, particularly in the area of surface and trackless mining. To some extent this may have been due to the myth that we shall always have an abundant supply of cheap labour and to some extent due to market limitations; but it must also in some instances have been due to professional conservatism. By this I imply an over-commitment to the traditional methods with which the senior mining engineers were well acquainted, and a reluctance to recommend the adoption of appropriate capital-intensive methods of which they had no personal experience.

This situation is fast changing. I am informed that more than a dozen large draglines are on order for South African mines. Draglines are essential items of equipment for strip mining in its most efficient form — and strip mining is the most productive mining method known, when productivity is measured, as it will be throughout this address, by tonnes of ore produced per employee over a given period of time.

Open-pit operation — again a technology with high productivity — is also increasing; and the capacity of the equipment used is rising, 12 and 15-yard shovels becoming commonplace.

Trackless equipment is the standard on at least two underground mines in the Republic and has been experimented with in other mines, including a gold mine.

There is a new spirit abroad, and, suitably nurtured, this must lead to technological advance and increased productivity. The recent announcement by the Chamber of Mines of South Africa of a plan to spend a hundred and fifty million rands in a crash programme to find ways of converting narrow-seam hard-rock mining to a capital-intensive, as opposed to a labour-intensive, operation is a further pointer to this new approach. Traditionalists will, as a matter of course, oppose these trends. It is far easier to continue on well-established lines than to try new methods. But whether this is in the shareholders' and in the country's best interest is another matter. The state and the industry have a common interest in raising productivity by advancing technology.

For the analysis given in Tables II and III, I have assumed that all increases in the production of minerals will be at productivity rates at least equal to those of the most efficient present producers in each given area. Further, I have assumed that 50 per cent of the increase in coal production will come from strip-mining operations, and that all increase in iron production will come from open-pit operations. Copper, lead, and zinc are assumed to continue at the current proportion of 55 per cent from open-pit operations, and the remainder of the increase in production is taken at productivity rates for trackless mining.

For diamond mining, I have assumed an increase in open-pit ton-

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†Estimate produced for the Economic Advisor to the Prime Minister.

TABLE I

GROWTH OF THE MINERALS INDUSTRY

(production in sales units—1000's—base minerals)

Mineral	1970			1980					2000				
	Export	Domestic	Total	Exp.	Dom_1	Dom_2	Tot_1	Tot_2	Exp.	Dom_1	Dom_2	Tot_1	Tot_2
Copper	90	31,3	121,7	400	42	51	442	451	1 212	76	135	1 288	1 347
Iron	2 100	5 810	7 910	10 000	7 800	9 500	17 800	19 500	30 300	14 200	25 100	44 500	55 400
Chromium	954	290	1 244	2 060	390	473	2 390	2 472	6 060	706	1 250	6 766	7 310
Manganese	2 000	760	2 760	5 200	1 020	1 240	6 220	6 440	15 750	1 850	3 280	17 600	19 030
Coal	1 100	50 350	51 450	14 000	82 070	108 760	96 070	122 760	42 420	217 510	506 800	259 930	549 220
Asbestos	241	27	268	500	36	44	536	544	1 500	65	117	1 565	1 617

The listed base minerals accounted for 85 per cent of labour in base minerals in 1970. All other base minerals will be assumed to grow at the average rate of all minerals including gold, platinum, and diamonds.

TABLE II
LABOUR REQUIREMENTS OF THE MINERALS INDUSTRY
ASSUMING NO CHANGE IN TECHNOLOGY OR AVERAGE GRADE

Mineral	1970	1980		2000	
		Tot_1	Tot_2	Tot_1	Tot_2
Copper	11 541	41 900	42 800	122 100	128 000
Iron	6 002	13 500	14 800	33 800	42 000
Chromium	4 895	9 400	9 700	26 600	28 800
Manganese	8 045	18 100	18 800	51 300	55 500
Coal	72 555	135 500	173 100	366 600	774 500
Asbestos	19 817	39 600	40 200	115 700	119 600
Sub-total	122 855	258 000	299 400	716 000	1 148 000
Others	22 534	29 200	30 700	40 500	41 800
Gold	413 272	413 000	413 000	100 000	100 000
Diamonds	21 005	30 500	30 500	31 000	31 000
Platinum	61 167	99 700	99 700	264 000	264 000
Total	640 833	830 400	873 300	1 151 500	1 584 800
Growth rate		2,6%	3,1%	1,9%	1,9%

TABLE III
LABOUR REQUIREMENTS OF THE MINERALS INDUSTRY
ADJUSTED TO TAKE ACCOUNT OF CHANGES IN TECHNOLOGY

Mineral	1970	1980		2000	
		Tot_1	Tot_2	Tot_1	Tot_2
Copper	11 541	41 900	42 800	122 000	128 000
Iron	6 002	10 400	11 200	20 000	27 000
Chromium	4 895	6 200	6 400	11 500	12 000
Manganese	8 045	9 200	9 300	13 000	13 500
Coal	72 555	84 000	95 500	156 000	271 500
Asbestos	19 817	39 600	40 200	115 700	119 600
		191 300	205 400	438 200	571 600
Others	22 534	26 500	27 300	30 500	33 000
Gold	413 272		413 000		100 000
Diamonds	21 005		30 500		31 000
Platinum	61 167		99 700		264 000
Total	640 833	761 000	775 900	863 800	999 600
Growth rate		1,73%	1,93%	0,89%	1,49%

NOTES:
Copper No change is expected as the bulk of copper already comes from open-cast mines.
Iron It is assumed that all increases will be at current rates of open-cast operations, i.e. 2250 tonnes/employee/year.
Chromium All increases will be at the rate currently achieved by the most productive operations, i.e. 850 units/employee/year, instead of the current average of 400 units/employee/year.
Manganese All increases are assumed at maximum present efficiency of 3000 units/employee/year instead of the average of 560.
Coal 50% of the increase at 1500 tonnes/employee/year, 50% at 7500 tonnes/year instead of the average of 700 tonnes/employee.
Asbestos No change is anticipated.

nages up to 1980, and thereafter a reversion to block-caving methods until the end of the century. I have assumed that no material change in the productivity of deep-level narrow-tabular mining will occur, so that gold and platinum mining are assumed to have constant productivity over the next two-and-a-half decades. In effect, here, I am offsetting the steady general improvement in productivity in the industry against the decline in grade of deposit exploited.

MANPOWER PATTERN

I turn now to the third area to be explored — that of the manpower pattern inside each technology, and here I must enter a caveat. In the time available, and with the facilities available, I have been able to investigate no more than a sample of the mining operations in this country. Nevertheless, I have covered a broad spectrum of technologies. I should like to acknowledge, now, my indebtedness to the Chamber of Mines of South Africa, to De Beers, Iscor, Anglo Vaal, General Mining, and the GME's office for their cooperation and kindness in making available statistical material for this analysis. I have no doubt that, had time permitted an extended survey, I should have had an equally courteous response from all the other organizations in the mining industry.

In analysing the manpower pattern, I have divided the employees into five categories:

1. Managerial/Professional
2. Supervisory
3. Skilled Workers
4. Semi-skilled Workers
5. Unskilled Workers or Labourers.

I define an unskilled worker on a mine as a person who has received less than three months of specific training; a semi-skilled worker as a person who has received between three months and three years of specific training; a skilled worker as a person who has received more than three years of either specific or general training; a supervisor as a person who has been promoted from the skilled ranks; the managerial/professional category embraces persons promoted from the supervisory

TABLE IV

DISTRIBUTION OF LABOUR FOR VARIOUS MINING TECHNOLOGIES IN MANPOWER CATEGORIES — PERCENTAGES OF TOTAL EMPLOYEES

Type	Management/ professional	Supervisory	Skilled	Semi-skilled	Unskilled	Semi- and unskilled	Tonnes of ore/ employee/year
Narrow Tabular underground							
Hard rock, deep-level	0,23	1,61	17,6	47	34	81	220
Coal (partly mechanized)	0,22	1,24	10,85	38,1	49,6	88	950
Coal (fully mechanized)	0,50	1,54	11,23	33	53	86	1 400
Massive underground							
Hard rock	0,6	2,4	5,9	30,9	60,2	91	800
Others	1,64	2,7	15,2	7	73	80	1 230
Trackless	1,04	2,81	16,8	21	58	79	1 700
Surface							
Open-pit, hard rock	1,58	5,6	22,4	24	46,0	70	2 250
Open-pit, others	1,66	3,9	13,5	15,6	65,3	81	5 200
Strip mining	1,25	4,0	20,5	38	36	74	10 000

TABLE V

PRODUCTION (MINING) LABOUR FOR VARIOUS TECHNOLOGIES IN MANPOWER CATEGORIES — PERCENTAGES OF TOTAL EMPLOYEES

Type	Management/ professional	Supervisory	Skilled	Semi-skilled	Unskilled	Semi- and unskilled	Total	Tonnes of ore/ employee/year
Narrow tabular underground								
Hard rock, deep level	0,08	1,11	11,0	44,5	24,5	69	81	220
Coal (partly mechanized)	0,09	0,54	6,3	36,6	36,1	73	80	950
Coal (fully mechanized)	0,19	0,14	6,3	29,5	35,9	65	73	1 400
Massive underground								
Hard rock	0,20	1,50	3,1	13,8	48,3	62	67	800
Others	0,36	0,93	5,3	0,4	47,6	48	55	1 230
Trackless	0,31	2,20	2,8	7,9	20,7	29	34	1 700
Surface								
Open-pit, hard rock	0,45	1,04	1,19	6,1	6,2	12	15	2 250
Open-pit, others	—	1,05	1,43	10,24	16,6	26	29	5 200
Strip mining	0,75	1,00	3,75	12,75	8,75	21,5	27	10 000

ranks and graduates in appropriate fields.

These categories could be subject to the criticism that there is a lack of definition of the general educational background to which they are referred. Nevertheless, if one examines the personnel in the mining industry in terms of these definitions, it immediately becomes clear that unskilled and semi-skilled workers have a low level of general training (or education), that the supervisory and managerial/professional categories have a relatively high level of general education, and that skilled workers have a mixture of both — specific training in this category is a substitute for general training within fairly wide limits—but, where specific training is a major component in raising a person to a skilled position, he will remain non-transferable in that category to any other area of the economy and, probably, to any other technologically different area of the mining

TABLE VI

TOTAL LABOUR REQUIRED — ALLOCATED TO MINING TECHNOLOGIES

	Technology	1970*	1980		2000	
A	Narrow tabular, hard rock, deep level	474 439	512 700	512 700	364 000	364 000
B	Narrow tabular, soft rock, near surface	4 895	6 200	6 400	11 500	12 000
C	Massive, hard rock, deep level	8 618	31 300	32 000	91 000	96 000
D	Massive, hard rock, near surface	31 768	52 700	53 400	133 000	137 000
E	Massive, soft rock, deep level	14 005	16 500	16 500	24 000	24 000
F	Surface, hard rock	2 096	6 500	7 300	16 000	23 000
G	Surface, others	9 924	24 600	24 800	38 000	39 000
H	Coal, underground	72 555	81 000	90 700	142 000	238 500
I	Coal, surface	—	3 000	4 800	14 000	33 000
J	Unclassified	22 533	26 500	27 300	30 500	33 000
	Totals	640 833	761 000	775 900	864 000	999 500

* Actual

industry. A similar difficulty exists where supervisors and managers who have risen from the ranks have been exposed principally to specific training in stylized operating procedures.

Perhaps I should explain that, when I refer to specific and general training, I use these terms in the sense of G. S. Becker*. Becker has defined specific training as 'training that has no effect on the productivity of trainees that would be usable in firms other than the one which provides such training', and general training as 'that which increases the productivity of trainees even if they should subsequently go to work in other firms'.

The breakdown of labour into categories was undertaken by the mines so that the interpretation of the definitions is not necessarily consistent, and some anomalies can be expected. However, if we refer to Tables IV and V, it will become apparent that a rough pattern emerges. The capital-intensive methods, generally speaking, have a greater proportion of labour in the management and supervisory categories, and a low proportion in the semiskilled and

*Quoted by Francis Wilson in *Labour in the South African Gold Mines 1911-1969*, Cambridge University Press.

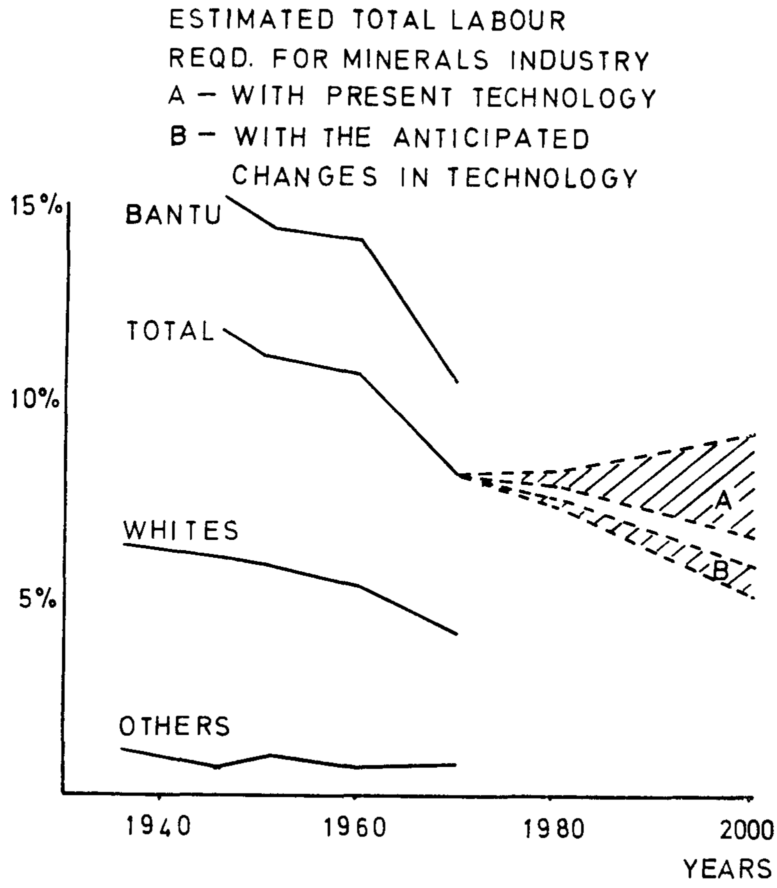

Fig. I—Percentage of economically active population in the mining industry

TABLE VII

TOTAL LABOUR REQUIREMENTS, 1970 — ALLOCATED TO CATEGORIES

Technology (as in Table VI)	Management/ professional	Supervisory	Skilled	Semi-skilled	Unskilled	Total
A	1 091	7 638	83 501	220 898	161 309	474 439
B	11	117	531	1 835	2 401	4 895
C	52	207	508	2 663	5 188	8 618
D	330	893	5 337	6 782	18 425	31 768
E	230	378	2 129	980	10 288	14 005
F	33	117	469	503	994	2 096
G	165	387	1 340	1 548	6 484	9 924
H	363	1 117	8 148	23 943	38 984	72 555
I	—					
Sub-totals	2 275	10 854	101 963	259 152	244 073	618 317
J	83	397	3 716	9 444	8 894	22 533
Total	2 358	11 251	105 679	268 596	252 967	640 851
%	0,37	1,76	16,49	41,91	39,47	100,00

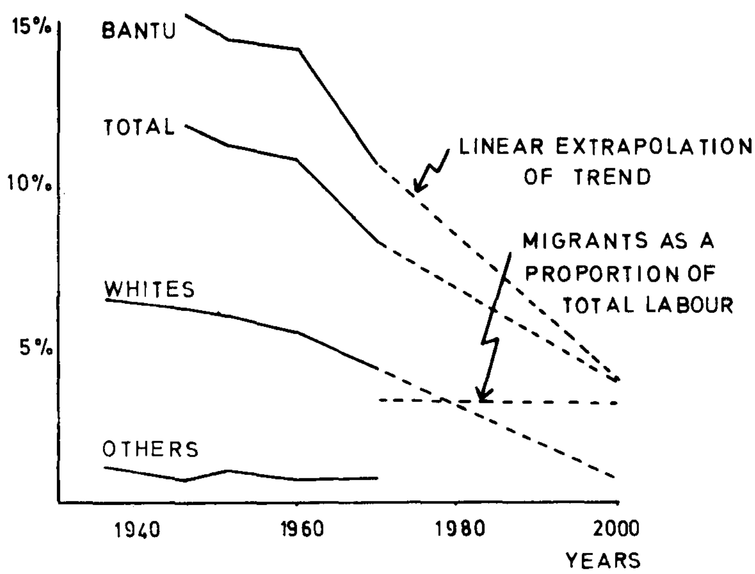

Fig. 2—Percentage of economically active population in the mining industry

unskilled categories. The skilled category seems to remain at materially the same proportion for the various underground methods, but to increase for surface mining.

In the case of the mining operation itself, the proportion of professional labour increases sharply with increased productivity, while the proportion of skilled labour falls.

While acknowledging the inconsistencies in the tabulations, I nevertheless believe that these figures when applied to the total technological changes envisaged for the industry will produce a sufficiently close approximation to the future pattern of manpower for planning purposes, and I propose to proceed on that assumption.

FUTURE LABOUR SUPPLY

Turning now to the fourth area — the likely future supply of labour — we must first consult the demographers to find the likely growth rate of the economically active population. Then, we must determine the percentage of that population which is likely to offer for mining in the future.

I have accepted the growth rate of the economically active population postulated by Professor Sadie of Stellenbosch (Table XII), and draw attention to his prognostication that the Black population will grow at twice the rate at which the White population will grow.

Secondly, I have plotted the percentage of economically active population engaged in mining for each of the available census years (Table XIII).

Referring therefore to Figure 1, it will be seen that in the last 2½ decades this has fallen from 11,75 to 8,1 per cent of the total population, from 15 to 10,5 per cent of the Black population, and from 6,5 to 4,2 per cent of the White population.

This is not unusual or unexpected. Economists have found that, with growth and increased sophistication of an economy, the percentage of the population engaged in the primary sector falls. For this there are two main reasons. Firstly, an increasing proportion of labour finds employment in the secondary and tertiary sectors. Secondly, subsistence-level farming is gradually replaced by more capital-intensive and more productive methods, so that not only the percentage engaged in farming but even the absolute numbers engaged in that sector of the economy will fall. The trend line is presumably asymptotic to some base level at which just sufficient labour is available to exploit the farm lands at near optimum productivity.

A similar pattern is likely to apply to the mining sector, so that, with increased mechanization, with the shift to capital-intensive methods, not only will the percentage of the population employed in mining fall, but we may even have a reduction in absolute numbers — not related to the exhaustion of available deposits. However, here too there must be an asymptote related to exploitation of the necessary number of deposits by the most productive method appropriate to each.

Because of the asymptote, meaningful extrapolation of trend lines becomes even more difficult than usual. If we extrapolate the curves linearly to 2000 (Figure 2), we would conclude that very few Whites would be left in mining, and that the number of Blacks would very nearly coincide with the anticipated number of migrants from outside our borders, i.e., very few South Africans will be engaged in mining in South Africa. It therefore seems preferable to estimate the numbers of people required, to plot these against population projections, and then to examine the likelihood of the required trends being realized.

EXAMINATION OF STATISTICS

Let us now turn to the results of the statistical investigation. In this address I do not propose to deal with the steps in estimating; I propose rather to go direct to the final figures.

In Table III it will be seen that the projected total labour requirement for the mineral industry in 1980 is estimated to be between 735 000 and 749 000, and in 2000 A.D. between 864 000 and 1 000 000. Using Sadie's projection, I have converted these to percentages of the economically active population and have plotted them on Figure 1 as a dotted extension of the total labour graph. By themselves, these curves do not appear unreasonably disturbing. Only some slight flattening of trend would be called for, and the impression gained is that it should be within the compass of the industry to attract the required number of people.

Unfortunately, this impression is not correct. Two vital factors are hidden in the broadness of the general statistic. The first of these is that, of the persons employed in

TABLE VIII

TOTAL LABOUR REQUIREMENTS IN CATEGORIES, 1980

Technology (as in Table VI)	Management/ professional		Supervisory		Skilled		Semi-skilled		Unskilled		Totals	
A	1 179	1 179	8 254	8 254	90 235	90 235	238 713	238 713	174 318	174 318	612 700	512 700
B	14	14	77	79	673	694	2 362	2 438	3 075	3 174	6 200	6 400
C	188	192	751	768	1 847	1 888	9 672	9 888	18 843	19 264	31 300	32 000
D	548	555	1 481	1 501	8 854	8 971	11 251	11 401	30 566	30 972	52 700	53 400
E	271	271	445	445	2 508	2 508	1 155	1 155	12 121	12 121	16 500	16 500
F	103	115	364	409	1 456	1 635	1 560	1 752	3 017	3 389	6 500	7 300
G	408	412	959	967	3 321	3 348	3 838	3 869	16 014	16 204	24 600	24 800
H	405	454	1 247	1 397	9 096	10 186	26 730	29 931	43 521	48 733	81 000	90 700
I	38	60	120	192	615	984	1 140	1 828	1 088	1 740	3 000	4 800
Sub-totals	3 154	3 252	13 698	14 012	118 605	120 449	296 421	300 975	302 519	309 915	734 397	748 603
J	113	117	496	511	4 280	4 393	10 695	10 977	10 915	11 302	26 500	27 300
Total	3 267	3 369	14 194	14 523	122 885	124 642	307 116	311 952	313 434	321 217	760 897	775 903
%	0,43	0,43	1,87	1,87	16,15	16,09	40,36	40,21	41,19	41,40	100,00	100,00
Required growth rate, %/annum	3,31	3,63	2,35	2,59	1,50	1,66	1,35	1,51	2,17	2,42	1,73	1,93

TABLE IX

TOTAL LABOUR REQUIREMENTS IN CATEGORIES, 2000 A.D.

Technology (as in Table VI)	Management/ professional		Supervisory		Skilled		Semi-skilled		Unskilled		Totals	
A	837	837	5 860	5 860	64 064	64 064	169 478	169 478	123 760	123 760	364 000	364 000
B	25	26	143	149	1 248	1 302	4 382	4 572	5 703	5 951	11 500	12 000
C	546	576	2 184	2 304	5 369	5 664	28 119	29 664	54 782	57 792	91 000	96 000
D	1 383	1 425	3 737	3 850	22 344	23 016	28 396	29 250	77 140	79 460	133 000	137 000
E	394	394	648	648	3 648	3 648	1 680	1 680	17 630	17 630	24 000	24 000
F	253	363	896	1 288	3 584	5 152	3 840	5 520	7 427	10 677	16 000	23 000
G	631	647	1 482	1 521	5 130	5 265	5 928	6 084	24 829	25 483	38 000	39 000
H	710	1 192	2 187	3 673	15 947	26 784	46 860	78 705	76 297	128 146	142 000	238 500
I	175	413	560	1 320	2 870	6 765	5 320	12 540	5 075	11 963	14 000	33 000
Sub-totals	4 954	5 873	17 697	20 613	124 204	141 660	294 003	337 493	392 643	460 862	833 501	966 501
J	180	201	647	703	4 548	4 851	10 757	11 524	14 369	15 721	30 500	33 000
Total	5 034	6 074	18 344	21 316	128 152	146 511	304 160	349 017	407 012	476 583	864 001	999 501
%	0,59	0,61	2,12	2,13	14,91	14,7	35,27	34,92	47,11	47,64	100,00	100,00
Required growth rate, %/annum	2,56	3,20	1,64	2,15	0,6	1,1	0,4	0,9	1,6	2,1	1,00	1,5

the mining industry in 1970/73, 40 per cent were migrants from outside our borders. The growth-rate equation when applied to economically active population therefore calls for a growth in the number of migrants in the same proportion as the increase of the indigenous economically active population. On the assumption that migrants will be recruited only for mining, this implies that, of the labour force in 2000, over half a million will be migrants from outside our borders, and they will account for 50 to 60 per cent of the projected total labour force in mining. In gold mining, specifically, I note that migrants now account for 75 per cent of the total labour.

The second factor is that, as we move to more productive technologies, the pattern of employment changes. The proportion of workers in each category does not remain the same, so that the required growth rate of each category is not the same as the average growth rate of persons employed in mining.

With regard to the first factor, four questions arise. One, will our neighbouring countries agree to this number of their citizens being employed on our mines? Indications are that they may not. Two, will mining enterprises other than gold, platinum, and coal be allowed to accept recruits from other countries? Three, is it wise for our government to allow so large a number of foreign eggs in its economic basket? Four, will migrant peasant labour be suited to the tasks?

This last question takes us to the second factor — that of the changes in the employment pattern. From Table IV it can be seen that, in the more productive gold mines, only 0,23 per cent of employees are in the professional/managerial category, 1,6 per cent in supervisory occupations, and 17 per cent in skilled occupations.

By comparison, in surface mining we find 1,5 per cent in the professional/managerial category, 4,5 per cent in supervisory occupations, and 19 per cent in skilled occupations.

More significant in its implication is the fact that unskilled and semiskilled production labour, tradition-

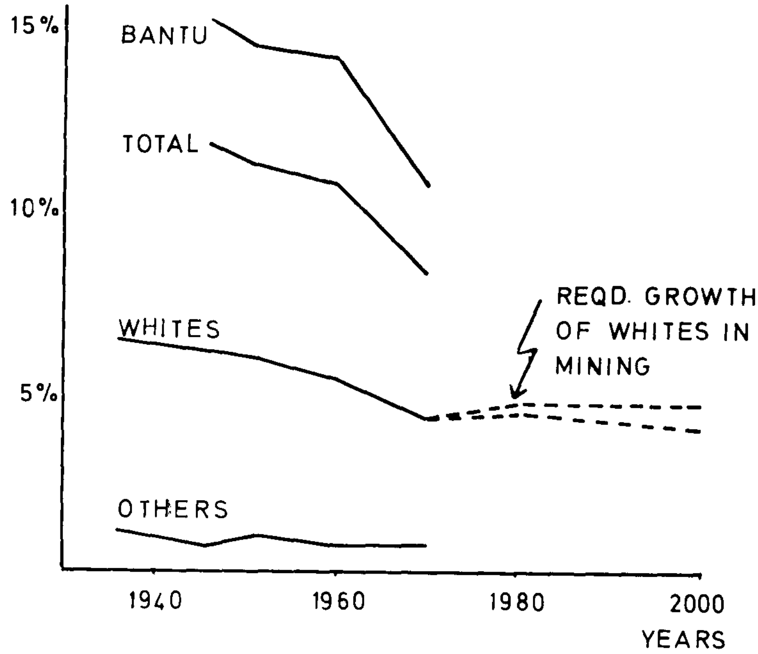

Fig. 3—Percentage of economically active population in the mining industry

TABLE X

MANAGEMENT/PROFESSIONAL CATEGORY IN PRODUCTION (MINING) (NUMBER OF PERSONS)

Technology (as in Table VI)	1980		2000	
A	410	410	291	291
B	6	6	10	10
C	63	64	182	192
D	163	166	412	425
E	59	59	86	86
F	29	33	72	104
G	111	112	171	176
H	154	172	270	453
I	23	36	105	248
Sub-total	1 018	1 058	1 599	1 985
J	37	38	58	68
Total	1 055	1 096	1 657	2 053
%	0,14	0,14	0,19	0,21
Total management	3 267	3 369	5 034	6 074
% Mining	32%	33%	33%	34%
% Narrow tabular	38,86	37,41	17,56	14,17
% Surface mining	15,45	16,51	21,00	25,72

ally the main occupation of migrants, accounts for 70 per cent of all employees in gold mines, but less than 20 per cent of all employees in surface mines.

In passing, it should be noted that even the most productive operations in our country do not compare with the best productivities in overseas countries in equivalent technologies. Exactly why this should be so might make an interesting study, which is not my purpose now, but it seems clear that the socio-political mores of South Africa, some of which are enshrined in the law, are a causative influence.

However, let us first examine the proposition that the current ratio of Blacks to Whites in the mineral industry must be perpetuated. In 1970, this ratio was materially 10:1, which would imply that between 83 000 and 100 000 Whites would be required in mining by the year 2000. In 1970, one-fifth of the economically active population was White. By 2000 this is expected to have fallen to one-eighth.

As can be seen in Figure 3, a reversal of trend would be required to bring about a 10:1 ratio. A larger percentage of the economically active Whites would have to enter the mining industry than is the case at present. Although this is not impossible, it would imply that the ratio of Blacks to Whites in other sectors of the economy would be increasing at more than their proportionate rate or, in other words, that White job opportunities in the other sectors of the economy will decline relative to the overall growth of job opportunities. It is not apparent that the mining industry can rely on such an event. In fact, a linear extrapolation of the trend line would prognosticate fewer than 20 000 Whites in mining by the year 2000, or one-quarter of those required if the 10:1 ratio is to be maintained. It is unlikely that either the mining industry or the State could face such a severe reduction in White labour on the mines so soon, so let us examine the implications for the industry if, say, the ratio moves to 20:1, i.e., if 40 000 Whites offer for mining.

Let us assume that the top jobs in mining are substantially undertaken by Whites. The managerial/professional category is estimated to require 5000 to 6000, and supervision 18 000 to 21 000, so that only 13 000 to 17 000 of the 40 000 White persons will be left to fill the traditional skilled and semi-skilled occupations. This will leave 50 000 to 60 000 posts in the traditional White occupations unfilled when the available Whites have been absorbed. There are only three ways in which this situation can be met:

firstly, by drawing skills from other sectors of the economy — this seems an unlikely solution as it implies that the other sectors of the economy will have a reduced demand for White skilled workers;

secondly, by increased immigration of skilled Whites — but the limited success in this direction in the past does not give much reason to believe that the required skilled immigrants will become available;

thirdly, by tapping the resources of the Black population, which seems the only practicable way in which to solve the problem, but it implies increased flexibility of the colour bar and increased training of Blacks.

TABLE XI

PERCENTAGE OF LABOUR IN EACH TECHNOLOGICAL BRANCH

Technology (as in Table VI)	1970	1980		2000	
A	74,03	67,37	66,08	42,13	36,42
B	0,76	0,81	0,82	1,33	1,20
C	1,34	4,11	4,12	10,53	9,60
D	4,96	6,93	6,88	15,39	13,71
E	2,19	2,17	2,13	2,78	2,40
F	0,33	0,85	0,94	1,85	2,30
G	1,55	3,23	3,20	4,40	3,90
H	11,32	10,64	11,69	16,44	23,86
I	—	0,39	0,62	1,62	3,30
J	3,52	3,48	3,52	3,53	3,30
	100,00	100,00	100,00	100,00	100,00
Total surface	1,88	4,47	4,76	7,87	9,50

TRAINING

If my figures are correct, we shall need to train an average of at least 2000 Blacks per year from 1970 to the end of the century if the minerals industry is to meet the production targets set for it. This quite literally means training Black fitters and turners, electricians and miners, surveyors and samplers. We are already 8000 behind. The problem is an industry problem. The solution will have to be found in the political arena.

Even if legal and socio-political bars are modified, such a training programme cannot be mounted unless sufficient recruits with the necessary minimum standard of general education — Std VI for miners, Std VII for artisans, and Std X for junior officials — are available. It is the prerogative of the State to provide this general education.

The median age of Black workers in the mining industry now is 28. If the age distribution holds for the year 2000, then more than half the labour force of Blacks has already been born. We do not have any leeway at all in establishing programmes and facilities for the general education of the future work force — in fact, we have no leeway even in establishing programmes and facilities for training in skills — we might even need a crash programme of adult education at basic levels.

Should such a general education programme prove impossible or unpractical of implementation so soon, I can think of one other way to meet the industry's need for skills, and that is to fragment the skilled tasks and in this way to spread the industry's restricted number of skilled workers in supervisory capacities over large numbers of 'limited skill' workers, each of whom has been trained to carry out a prescribed piece of the skill span normally associated with that trade.

Admittedly, this may increase to some extent the numbers in the 'skilled' and 'limited skill' occupations, but it will make it possible to accept, as trainees, recruits with a standard of general education lower than that now demanded for full-skill training.

There is a further important implication. The time spent in training, even to the 'limited skill' level, will be measured in months or years rather than in weeks, and much of this will be general training as opposed to specific training. No firm or industry could embark on such a programme unless it were going to benefit from it by continuing to employ at least a major proportion of the trainees. Similarly, the trainees would be unlikely to undertake the training programme unless there were some sort of career opportunity held out at the end. The migratory system does not seem to fit either of these requirements.

Urban Blacks are more likely to have reached the general education levels necessary for this type of training than are those from rural or subsistence-farming backgrounds, so that career opportunities will have to be created to attract urban, educated Black people into the skilled-worker level of the mining industry, and a further class of non-migratory mine worker will have to emerge. This matter is further complicated by the attitude, common to Blacks and Whites, that white-collar jobs are to be preferred to blue-collar jobs, so that some means will have to be found to change attitudes, and, without the creation of career opportunities, this attempt is unlikely to succeed.

We are faced with a very considerable problem in the socio-political field. It is not purely an industry problem. It seems to me to be a national problem and to deserve attention, and urgent attention, from the appropriate departments of the State. I notice that Dr Diederichs, this afternoon, has taken steps to encourage the training of Blacks. Perhaps other departments will now do likewise.

MANAGERIAL/ PROFESSIONAL CATEGORY

I should now like to turn my mind to another aspect of the manpower equation. As technology moves from labour-intensive to capital-intensive, there is a decrease in labour requirements in all categories for a given volume of physical production, but there is a very marked increase in the proportion that falls into the managerial/professional category in particular.

In narrow-tabular mining, the proportion in this category can be as low as 0,15 per cent, whereas in surface mining it could be as high as 1,66 per cent — an increase of more than ten times (Table IV).

I have therefore estimated the requirements in each of the periods under scrutiny for total managerial/professional personnel, and particularly for production personnel in this category (Tables X and XI).

What emerges is that the required growth rate of the managerial/professional category is considerably in excess of that expected of the economically active White population.

Here, the possible solutions are more limited. The median age of Whites in mining is 36 years, and obviously the median age of management will be higher (Table XIV). Certainly, if the past is any guide, the men who will be responsible for the top technical control of the industry in the year 2000 left the universities ten years ago, and the men who will hold the top technical posts on the mines are at university now. Unless we are going to have a surprisingly young group of mining engineers and managers in charge of

TABLE XII

ECONOMICALLY ACTIVE POPULATION OF REPUBLIC OF SOUTH AFRICA

	1970	1980		2000		Growth rate* per annum
White	1 497 460	1 706 000		2 213 000		1,31 %
Coloured	703 620	965 000		1 815 500		3,21 %
Asian	180 000	234 000		397 000		2,67 %
Bantu	5 605 140	7 295 000		12 356 000		2,67 %
Total	7 986 220	10 200 000		16 782 000		
Mining	640 833†	761 000	776 000	864 000	1 000 000	
% of total	8,02	7,46	7,61	5,15	5,96	
Mining with unchanged technology	640 833	801 200	842 600	1 111 000	1 543 000	
% of total	8,02	7,85	8,26	6,64	9,22	

**Population Explosion in Southern Africa*, by Dr Nic J. van Rensburg, p. 79.
†Department of Mines, *Mining Statistics*, Government Printer, 1970.

the industry, we shall have to re-cruit experienced people from outside our borders or re-train selected supervisors. Neither of these is likely to be easy.

For the general category of managerial/professional (i.e. mechanical and electrical engineers, mine secretaries, medical doctors and so on), the industry can hope to attract suitably qualified people from other sectors of the economy. In the fields of mining engineering and mine management, extractive metallurgy, mining geology, and exploration geophysics, no such source is possible.

As it has not been possible for me to discover how many mining engineers/managers there are in the industry, I must proceed by deduction. If the proportion in the whole industry is similar to that of the gold mines, then it is possible to calculate that some 920 manager/engineers are active on the mines in South Africa. To this must be added the engineers in the head offices of mining finance houses and other controlling companies, those in the service of the State and the teaching and research institutes, those in the manufacturing industry supplying the mining industry, and those in private consulting practices. These can very conservatively be estimated at 200. So we conclude that some 1100 mining engineers are currently employed in this country.

This statistic includes all persons employed as underground managers or above. Goode has claimed that many of these people are technician engineers or technicians, and broadly I tend to agree with him. However, we are looking to the future, and here there must be a change. Firstly, technicians may well be able to accept responsibility for engineering control on mines where the operations are largely routine — where the consistency of the orebody is such that methods change extremely slowly and where experience is a sufficient guide to necessary action; when the accent is on the application of tried and trusted procedures in the most efficient way, and not on the development of procedures to meet rapidly changing conditions. The decision-making process and the background skills required for engineering control of working faces advancing at 15 feet per month, producing say 40 tonnes per day on average, and those required to control an operation where your major excavating unit is clearing 70 tonnes per minute 24 hours per day, are obviously very different.

Secondly, I believe that our mining industry does not know how expensive it has been not to have specialist mining engineers on their large mines. The concept of the engineer-manager seems to me to have been overtaken by circumstance and by time.

Thirdly, with the passing of the Professional Engineers' Registration Act, there must be a subtle pressure towards requiring that senior technical posts be filled by people who meet the educational and training requirements for registration as professional engineers. In passing, it is worth noting that the government of New South Wales has recently enacted that only holders of university degrees in Mining Engineering can be accepted as candidates for their equivalent of our Mine Managers Certificate — and that this was in response to pressure from the export sector of their mining and minerals industry.

Fourthly, when the regulations under the registration act are promulgated, there will be areas of the work currently performed by mine managers that will be classified as restricted to professional engineers; i.e., technicians and technician engineers will no longer be able to take responsibility for these areas.

Fifthly, the demands on engineers are going to change. In 1970, 50 per cent were in narrow-seam hard-rock mining, and 7 per cent in surface mining. By the end of the century, there could be as few as 14 per cent in narrow-seam mining, and as many as 27 per cent in surface mining.

If these points are borne in mind, it seems to me that a greater proportion of mining engineers will have to be graduates.

NEED FOR GRADUATES

Of the 1100 mining engineers now active in the Republic of South Africa, about 25 per cent are estimated to be graduates, which accords with the fact that there are 269* registered professional engineers in the mining-engineering category.

Now let us assume that the demand for mining engineers who have an academic background is going to increase, so that, by the year 2000, 75 per cent of mining engineers will be graduates. Let us further assume that wastage, i.e. loss to the mining industry, will be 15 per cent. This implies that 1800 graduate mining engineers will have to enter the industry in the period 1970 to 2000, i.e., 60 per year. This — 60 per year — is hardly a large number to expect from a country whose economy has largely been built on mining, and whose minerals industry is required to grow at above average rates if the targets for the economy are to be achieved.

If a period of five years of postgraduate experience is necessary before a graduate can undertake professional responsibilities, the problem of supply becomes more acute. At the prognosticated rate, there should already be nearly 300 graduates in industry at the postgraduate-training level. There are in fact only some 200 graduates in the mines at all levels, so that the training level

*As in June 1974.

TABLE XIII

PERCENTAGE OF ECONOMICALLY ACTIVE POPULATION IN MINING*

	1936	1946	1951	1960	1970
White	6,33	6,02	5,80	5,36	4,19
Coloured and Asiatic	1,22	0,78	1,02	0,74	0,78
Bantu	n.a.	15,20	14,43	14,10	10,50
Total		11,81	11,11	10,75	8,22

*South African Statistics, 1972, Government Printer.

TABLE XIV
AGE DISTRIBUTION OF LABOUR IN GOLD MINES
(AGE IN YEARS)

	Blacks	Whites
First quantile	22,6	26,6 — 25% below this age
Median	28,4	36,0 — 50% below this age
Second quantile	35,7	47,2 — 75% below this age
Mean	30,4	37,5

is unlikely to have more than 50 graduates at maximum. Since the most junior of the 2000 A.D. mining engineers will have graduated by 1995, this means that, in twenty-one years, we shall require 1750 graduates in mining engineering — 80 per year.

The lamentable state of affairs is that our universities are producing only about 10 to 12 mining graduates per year — not even enough to replace those who retire on superannuation. In other words, if we are to rely on our own resources, then at present rates there will be fewer graduate mining engineers in the industry by the year 2000 than there are now.

If we turn to another field in which academic training is importnt — that of extractive metallurgy — we find a very similar picture. The NIM Minerals Manpower Committee reported in October 1972 that, if we depended on our own resources, there would be a deficit of 28 extractive metallurgists every year. This is likely to be an understatement because all graduating metallurgists (18 per year) were assumed to have taken up careers in extractive metallurgy, whereas in fact many of them are physical metallurgists. Nevertheless, the annual requirement of graduates is spelt out as 46 for the five years to 1977 and can be expected to accelerate thereafter.

If we are to extract our minerals at the projected rate, attention must be focused on two further areas — exploration geology and applied geophysics.

There is no official course for applied geophysics at any university in the Republic. With regard to geology, one of our universities offers a degree course in Mining Geology, which is producing some two or three graduates a year Science graduates in geology can and do, enter the exploration geology field, so that it becomes very difficult to estimate either supply or demand. But we can note that about 20 per cent of the professional posts in the Government Geological Survey are vacant, which indicates an undersupply in both areas.

To sum up, it is then quite clear that the minerals industry will have no difficulty in absorbing 80 mining engineering graduates, 50 extractive metallurgists, and say 20 to 30 mining geologists and geophysicists per year — a total of 150 graduates in the minerals-engineering field.

RECRUITING

The infrastructure at the universities would not require any major modification to enable them to deal with such a number of students, and the courses on offer are of a standard that can bear comparison with the best in the Western World. Yet current output is less than 30 graduates per year, despite extensive campaigning by the mining industry, a generous allocation of bursaries, and adequate starting salaries and fringe benefits.

It is difficult to see how more can be done in what could be defined as the direct recruiting drive.

In many other parts of the Western World, notably Britain and Australia, the mining schools are filling up, and this appears to be the result, in part at least, of what could be termed indirect recruiting: the interest engendered in schoolboys by the excitement of new discoveries, the publicity given to the vital importance of minerals and mineral exploitation, the challenge of overcoming increasingly complex technical difficulties, the certainty that the minerals industry will not only survive but will grow, and grow rapidly, so that this is the time to get in on the ground floor.

I suspect that the small but marked increase in the number of first-year students in the minerals area at our universities this year is more the result of the dramatic increase in the gold price, and the consequent attention to gold mining in the press and on the radio, than it is to any direct recruiting effort.

Similarly, the publicity given to the Saldanha Bay scheme and the Richards Bay development could be increasing the awareness in schoolboys of the minerals industry and its challenge. Possibly, time and effort directed towards expounding the excitement, importance, challenge, and size of the minerals industry would awaken interest in the schoolboys of this country so that they have this information in their spectrum of awareness when it comes to choosing a career.

PRODUCTION TARGETS

To return to the main theme. If we cannot meet the manpower requirements in the professional sphere, then what, if anything, will the industry be able to do to meet the production targets set for it?

In most of the base-metal areas, we shall produce, even by 2000 A.D., only a small proportion of the world's supply. Our prices will have to be competitive if we are to retain and expand our export markets, and this will remain true if we beneficiate the ores, and sell metals or metal products as we ought. This will inevitably call for high-efficiency, low-cost operations, which in turn demand superior engineering design — more precise valuations, optimum equipment selection and design, optimum layout and control, and optimum processing; in short, superior engineering and management in all phases of each project, from initial planning to control of the front-line operations. This will not be simple without an adequate supply of fully trained engineers, but, if they cannot be supplied in adequate numbers, it is possible that a process of fragmentation, similar to that which I discussed as appropriate for the area of the skilled worker, could be applied. An almost automatic consequence would be the separation of the mining and metallurgical engineering functions from the management function. This in turn means that mining and metallurgical engineering, in their own right, must become careers at least as rewarding in terms of status and remuneration as that which mine management is today. It also means that technical responsibility will have to be separated from management responsibility.

In this way, we may be able to spread our slender resources of engineering skills more thinly, and by appropriate legislative and policy change allow engineers to accept responsibility for specifying technical standards without having to accept responsibility for operator performance.

Allow me to underline that such a change will not reduce the need for top-level manpower in the mining industry. It would only be a device to reduce the demand for academically trained engineers, which will inevitably be forced upon us if the numbers offering for professional training do not increase dramatically in the next few years. The preferred solution, and the one that is least demanding in terms of total manpower, is to recruit and train the total requirement of engineers now. The alternative is to increase the number of mining technicians and technician engineers — which might prove marginally less difficult.

This also is as much a national problem as an industry problem, and it will not be solved if one partner stands aloof.

CONCLUSION

The mining industry has a significant role and possibly a vital role in sustaining the growth of our economy, certainly to the end of the century, and possibly far beyond. Unless suitable steps are taken now to modify the attitudes of South African workers, Black and White, to work in the mines, to adjust the socio-political mores that govern our labour policies and manpower structure, to change the legal and traditional framework inside which we build the organization of mining enterprise, and to recruit and train new categories of mine workers — unless these steps are taken, I cannot see how enough South African manpower, White or Black, will offer for mining, nor can I see that those offering will be of sufficient calibre to staff the industry.

The increase in the price of gold has given us some respite — the evil day has been moved a little further into the future. We are nevertheless in grave danger of too little and too late and, the more we mechanize and intensify the capital factor, the more urgent will become the demands for engineers and the demands for skilled workers. The State and the industry have little time in which to face up to the problems, but a solution must be found, and found soon.

Time is not on our side.

NIM report

The following report is available free of charge from the National Institute for Metallurgy, Private Bag 7, Auckland Park, 2006.

Report No. 1646

Examination of the methods of analysis for calcium fluoride in fluorspar.

A comparative study was made of the precision, accuracy, and speed of five methods for the determination of calcium fluoride in fluorspar. The five methods investigated were pyrohydrolysis with three methods of measurement, measurement with an ion-sensitive electrode, determination of total calcium by the use of two different final procedures, X-ray fluorescence, and neutron activation. In the assessment of the pyrohydrolytic procedure, account was taken of residual fluoride retained in the flux, the efficiency of the collecting medium, and the effect of traces of flux, which may be carried over during distillation, on the determination of fluoride. The method was considered to lack reproducibility because of very variable amounts of residual fluoride. Of the two procedures for the determination of total calcium, that based on a permanganate titration of the precipitated oxalate was found to be superior to the direct titration with EDTA. Rare earths were found to interfere in the oxalate-precipitation method, and their prior removal was found to be necessary. The reproducibility of the oxalate—permanganate method for low-grade samples (CaF_2 less than 30 per cent) is poor.

The most reproducible method was found to be that using an ion-sensitive electrode for the determination of fluoride ions. Interference from a range of elements was negligible for acid-grade material and should not exceed 0,60 per cent relative for samples of 1 to 10 per cent CaF_2. A coefficient of variation of 0,12 per cent for acid-grade samples was obtained in this method, as against 0,2 to 0,4 per cent in the other methods, including X-ray fluorescence, where total calcium was determined and the calcium that is soluble in acetic acid was deducted. A coefficient of variation of 0,8 per cent was the best that could be obtained by a fast-neutron technique involving the $^{19}F(n,2n),\rightarrow{}^{18}F$ reaction.

The reproducibility and accuracy of the various methods investigated are good when compared with those of the results from a number of international laboratories, which illustrate the range of variations obtained by several analysts using different methods, and suggest that the placing of a specification limit of 0,1 per cent absolute on acid-grade fluorspar is unrealistic.

A recommended laboratory procedure for the determination of fluoride in fluorspar (by the use of an ion-sensitive electrode) is detailed in an appendix.