J.S. Afr. Inst. Min. Metall., vol. 91, no. 7. Jul. 1991. pp. 249-254.

The rationalization of mine and preparation-plant output to enhance the exploitation of coal reserves in South Africa*

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SYNOPSIS

This paper describes some of the markets for South African coal and their particular coal requirements. It describes how reserves are being used and suggests new strategies to make possible a synergistic approach that would benefit coal producers and end-users.

SAMEVATTING

Die referaat beskryf sommige van die markte vir Suid-Afrikaanse steenkool en hul besondere vereistes wat steenkool betref. Dit beskryf hoe die reserwes op die oomblik gebruik word en dit doen nuwe strategieë aan die hand wat 'n sinergistiese benadering moontlik sal maak wat tot voordeel van alle steenkoolprodusente en eindgebruikers sal strek.

Introduction

The South African coal industry has grown remarkably over the past thirteen years, producing coal for both internal use and for export as metallurgical and steam coal (Figs. 1 and 2). Domestically, there has been a major increase in the use of coal for the manufacture of synthetic fuels by Sasol. Electricity consumption has also increased with the growing economy, and therefore there has been an increase in the coal used by Eskom. (This growth has slackened during the past three years.) Exports have increased dramatically since the signing of South Africa's contract to provide low-ash coal to Japan and the establishment of Richards Bay coal terminal (RBCT).

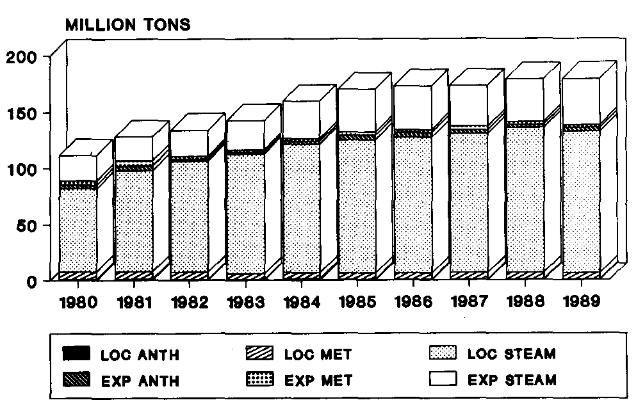

Fig. 1—South African coal sales—local and export (in megatonnes)

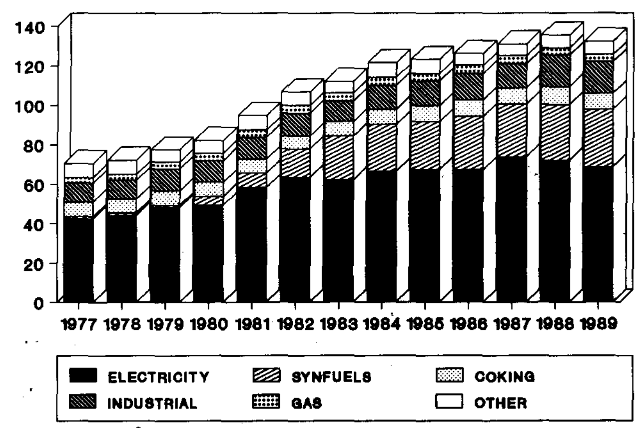

Fig. 2—Coal consumption in South Africa (in megatonnes)

However, except for a few cases (e.g. Grootegeluk and Optimum), mines have been developed in isolation to provide for their own particular type of markets, e.g. washed coal (metallurgical or steam), sized and/or raw products.

The operations at coal mines can be broadly classified into the following types:

- the production of washed products for inland and/or export markets, material that does not satisfy the strict quality specifications required by the markets being discarded
- the supply of the total mine production to an Eskom power station
- the production of Synfuel, for which the feed is sized so that the coarse coal is gasified using established technology and the fine coal is used as power-station feed
- the washing of coal for use as a fuel and/or reductant in iron-and-steel making
- the production of anthracite for both inland and export markets.

* Paper presented at the School on the Total Utilization of Coal Reserves, which was held at Witbank by the South African Institute of Mining and Metallurgy in October/November 1989.

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 Paper received 30th Oct., 1989; modified paper received 25th Feb., 1991.

The purpose of this paper is to suggest some strategies by which both coal producers and users could exploit South Africa's coal reserves to mutual benefit. This synergistic approach could result in other considerable cost saving to both groups. The use of the correct coal for a particular purpose could also result in other global benefits such as environmental protection.

Export Markets

As previously stated, the growth in the South African coal industry began as a result of the contract to supply low-ash coal to Japan, which began in 1972. The contracted sales tons were for 37,5 Mt of coal at an ash content of 7 per cent from 1972 to 1986, and were to be made only from the Witbank No. 2 seam. This contract made possible the development of Richards Bay Coal Terminal (RBCT) and the Blackhill to Richards Bay rail link at an initial capacity of 12 Mt per annum.

A portion of the excess of capacity over 3,5 Mt per annum was used for steam coal, which was produced as a middling product of low-ash coal production. The remaining capacity on the rail link and at Richards Bay was available for other coals produced by the shareholders of RBCT (Transvaal Coal Owners' Association, Natal Associated Collieries, and Anthracite Producers' Association) according to their allocations.

The sale of steam coal produced as low-ash middlings is a good example of production requiring another market, and involving two or more products from one reserve. By the selling of more products from a mine, a sufficient return on investment in colliery and export infrastructure can be achieved.

The emphasis in South African exports has undergone a major change from metallurgical coal, anthracite, and naturally-arising steam coal through RBCT to predominantly steam coal. The quality produced for export is essentially determined by the world coal market; producers cannot change those requirements and still compete. Although the heat value of the coal produced is vital, other qualities particularly the ash, volatile-matter, and sulphur contents must meet each customer's requirements. These requirements can vary widely between global areas, but pressure on all coal users will increase as environmental concern grows, and this will be translated into stricter quality requirements.

Inland Markets

Much of that stated in the previous section also holds true for domestic markets. Transport costs within South Africa are often far more significant than the actual price of coal. It is not desirable to pay for the transportation of large quantities of ash material, even if the downstream processes would allow it.

Sasol

Sasol, being the largest domestic user of coal (apart from Eskom), has already provided an example of the use of coal reserves to suit the available technology. The Sasol complex at Secunda uses only coarse coal in its synfuel process. This is because the gasification of coarse coal is technologically well understood, whereas the gasification of fine coal is still under investigation.

The coal that is fed from Sasol's four mines at Secunda to its two plants is split according to size. The plus 6 mm coal is used for gasification, and the minus 6 mm coal goes to power stations that were built on site specifically to use the fine coal. In a sense, the Sasol process is very undemanding of coal quality: it requires coal with a fixed carbon content of more than 50 per cent for the process to work efficiently. If total coal use had not been possible, increased costs would have been incurred.

Eskom

Eskom is the largest consumer of South African coal and, where possible, uses only those coal reserves which are not considered suitable for other uses. Some of Eskom's power is still provided by small, old collieries supplying small power stations. However, in the past 15 years, only large collieries have been developed to serve power stations of 3600 to 4200 MW.

Usually, coal is received from tied collieries which has been crushed to approximately minus 25 mm. Coal of a reasonably consistent quality is required if a power station is to run in a consistent manner. This can be achieved in a number of ways by the use of coal from multiple sources to even out the quality of the feed, or by the stockpiling of coal from a number of different sources ahead of the power station.

Coal after delivery to a station is milled to 75 μm to produce standard pulverized fuel for the boilers. Increasingly poorer-quality reserves are being used by Eskom. Lethabo power station near Vereeniging, which is fed by New Vaal Colliery, has been designed to burn coal with an average calorific value of 16 MJ/kg. This includes a portion of the plus 25 mm coal, which is washed at high density in a washing plant. (This operation is effectively destoning to remove contamination that arises from the opencast strip mining of old pillars.) This approach provides a consistent feed to the power station, and reduces risks such as a rapid reduction of volatile matter and the extinguishing of the flame.

Power stations are designed to suit the coal that has been tendered for their use. Some of the coal properties that dictate design are calorific value, volatile content, ash content, abrasive index, ash fusion temperature, and hardgrove index. Of these, calorific value is the most important quality since it determines output; volatile content is a major determinant of flame stability, and factors such as ash content and abrasive index affect the operational costs and efficiency.

High ash content and/or low hardgrove index coals have a direct effect on plant capacity, and therefore on the quantity of useful fuel fed to the burners. Ash moves through the process unproductively, and a low hardgrove index results in reduced mill capacity. A high abrasive index results in accelerated wear on power-station components, which gives rise to longer downtimes and higher overhaul costs. However, it is generally accepted that, over a period of time, Eskom will have to use coal of decreasing quality (Fig. 3).

The Future of Coal Reserves

Coal mined in future can be expected to decrease in quality for some of the following reasons:

- the preferential mining of higher-quality coal seams
- the use of mining equipment which, because of its

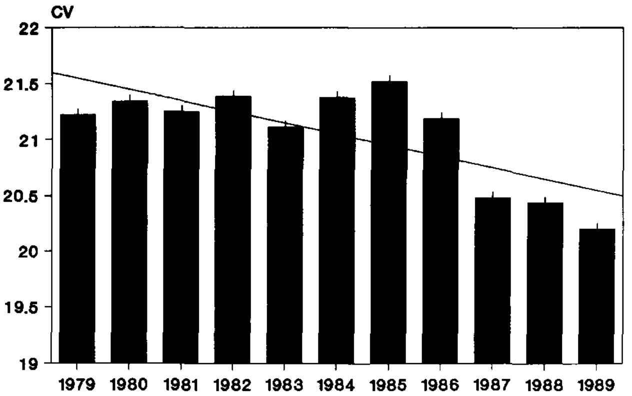

Fig. 3—Calorific value of the coal received by Eskom (in megajoules per kilogram)

scale of operation, is cost-efficient but not coal-selective.

There are several implications in the use of lower-quality coal.

- An increased washing requirement to produce coal of the desired quality at a lower yield.
- Poorer raw coal used will require more downstream treatment to reduce any adverse effects on the environment.
- Liberation by crushing may be needed to obtain adequate yields of clean coal, but the washing of fine coal is more costly and produces coal with a higher moisture content.
- The use of lower-quality feed coal reduces yield, which increases production costs per sales ton.
- The use of reserves with wide-ranging qualities necessitates good blending before use, whether as feed to a coal-preparation plant or in its raw state.

Sources of Coal

In South Africa, coal has been used on a geographical basis. Thus, coal that is considered predominantly suitable for a power station has been used only by a power station that was constructed close to the mine. The reserves used for export or domestic washed coal have mine, plant, and rail networks built in close proximity.

In a number of instances, power-station collieries are located very close to export collieries. However, coal areas within reserves may be better suited for the application on an adjacent property. For example, coal that could be used for export is sent to a power station and *vice versa*. Often, low- and high-quality feeds are blended in order to attain a reasonable wash-plant feed, but this may lower the overall yield. To make the best use of South Africa's coal reserves, a new approach may be required in the rationalization of those reserves.

A power station is built based on a known quantity of heat that it must receive each year throughout its life. However, the selective mining of higher-quality coal for making export products must reduce the overall heat value of those reserves. It is therefore important that Eskom's heat reserve should be restored or even improved by its use of coal that is suited for use as power-station feedstock but is being washed for export. In addition, washed middlings may be used to increase the quality of reserves, even at the same heat value.

The utilization of resources must provide mutual benefits: Eskom, which has specific coal needs, must not become a dumping ground for poor coal. The benefits of such use of reserves must produce electricity at a lower cost per unit, and lower costs for the other parties involved.

Multi-seam Sources

In general, one or more seams are mined in a particular area. In the Witbank area, No. 5 seam is the closest seam to the surface and generally contains potential low-ash coal suitable for metallurgical use. The No. 4, 2, and 1 seams are progressively deeper and vary widely in quality, and have consequently been used in all applications. No. 3 seam is generally too thin to be mined. It would be preferable if the coal from each seam were used in the application for which it is best suited.

Underground Mining

In an underground mine, one specific seam is usually mined, often selectively, so that other, poorer seams in the same geographical area are left behind. A number of sections are needed if high tonnages are to be achieved, and this can have the advantage of producing a more consistent output in terms of tonnage and quality.

The benefits of rationalization are evident if more seams are extracted using the same mine infrastructure. The coal from the extra seams mined can be used as gasifier or Eskom feed in the raw state, or can be fed to a preparation plant either to supplement export production or to upgrade Eskom feed.

If underground multi-seam mining is attempted, the mining of the upper seams may reduce the requirement for the superposition of pillars (to keep the upper seams intact). This can dramatically increase the extraction rates in the lower seams (Fig. 4).

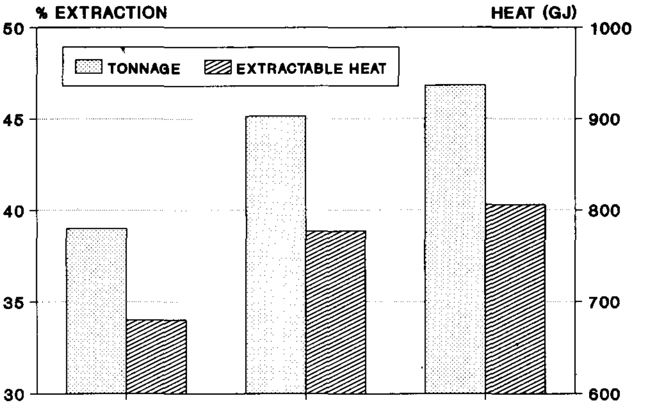

Fig. 4—Effect of the superposition of pillars

Opencast Mining

In an opencast mine, all the ground above the required seam or seams is overburden, even if it contains coal. For example, No. 4 seam may be of poor quality but may cover good-quality seams that are too deep to be mined on their own. The use of the coal from No. 4 seam as power-station or gasifier feedstock effectively lowers the overburden ratio, thereby enabling the deeper seams to be mined more economically.

It is usual that not all the seams in an area would be applicable for one type of use, and that even blending might be difficult. The higher seams would, then, have to be taken out before the lower seams, so that blending according to seam and area would need to take place.

Rationalization Benefits

Effect of Washing Coal for Power-station Feed

Damage to power stations amounting to millions of rands each year is attributed to the presence of abrasive mineral matter in the feed coal. The mechanism and constituents that give rise to a high abrasive index are not well known, but they are known to occur in naturally-arising mined coal in the high-gravity and large-particle-size fractions. Some work has been carried out on the effect of screening and washing on abrasive index and calorific value.

It is known that the YGP test for abrasive index is unreliable due to its nature, particularly when values obtained by different laboratories are compared. Mathematical cumulation is also unreliable. Here, use is made of the results obtained by one laboratory, which were used in calculations to give an indication of the effect of washing and/or screening.

The distribution in the raw coal of mass, abrasive index, and heat are shown in Table I, and the effect of screening at various sizes is shown in Fig. 5. If all the plus 25 mm coal had been discarded, the total loss in mass would have been 40,6 per cent, the heat loss would have been 38,2 per cent, and the YGP reduction would have been 54,2 per cent.

TABLE I
DISTRIBUTION IN RAW POWER-STATION FEED

Particle-size fraction	Distribution, %		
	r.d. 1,8	r.d. 1,8–2,1	r.d. 2,1
Mass			
+80	2,1	0,4	1,1
−80+60	4,7	1,0	1,0
−60+50	5,3	0,7	1,0
−50+25	18,9	2,0	2,4
−25	51,2	3,9	4,4
Heat			
+80	2,2	0,3	0,3
−80+60	5,2	0,5	0,3
−60+50	5,9	0,4	0,4
−50+25	20,9	1,0	0,8
−25	58,3	2,0	1,5
Abrasive index			
+80	1,4	2,2	5,6
−80+60	2,5	4,8	4,7
−60+50	2,5	2,6	4,6
−50+25	7,8	4,9	10,6
−25	18,1	8,7	19,0

The percentage reductions in mass, abrasive index, and heat loss obtained by the washing of the oversize at relative densities of 1,8 and 2,0 are shown in Figs. 6 and 7. If all the plus 25 mm coal had been washed at a cutpoint of 1,8 and the floats added back to the raw minus 25 mm coal, the total loss in mass would have been 9,6 per cent, the heat loss 4,9 per cent, and the loss in YGP 40,1 per cent.

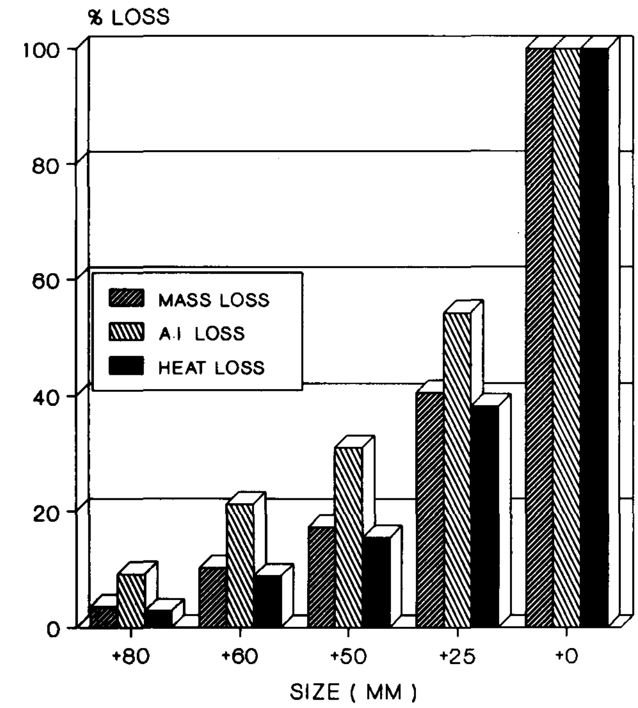

Fig. 5—Effect of screening on raw power-station feed

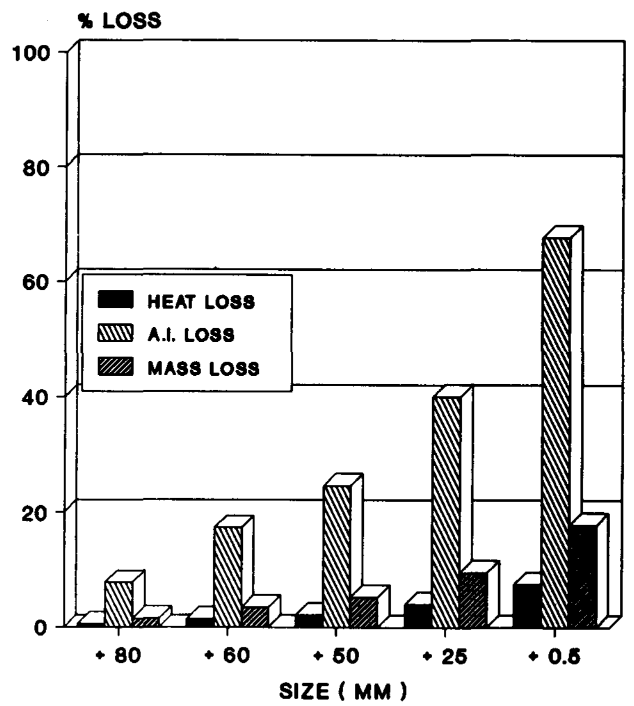

Fig. 6—Effect of washing on power-station feed at a cutpoint of 1,8

There are economic trade-offs between a reduction in the quantity of abrasive material supplied to a power station on the one hand, and a reduction in the available heat per ton, as well as extra capital and plant operating costs on the other. The determination of a monetary

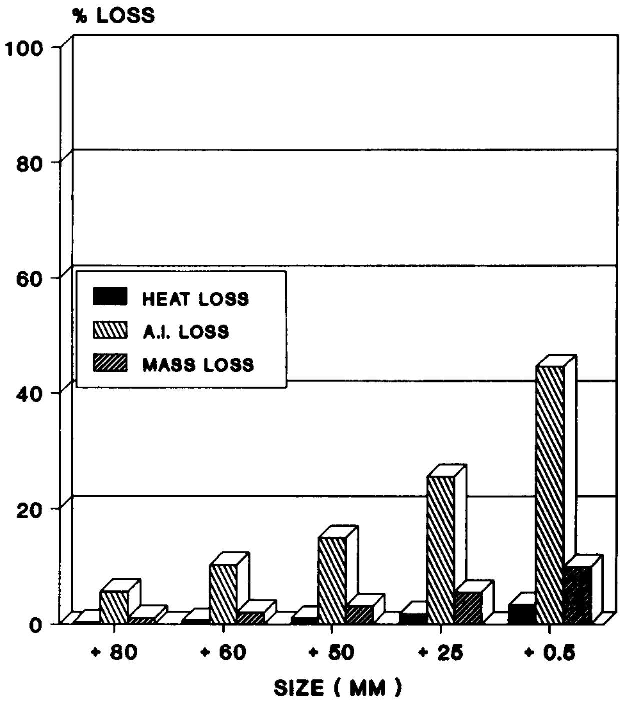

Fig. 7—Effect of washing on power-station feed at a cutpoint of 2,1

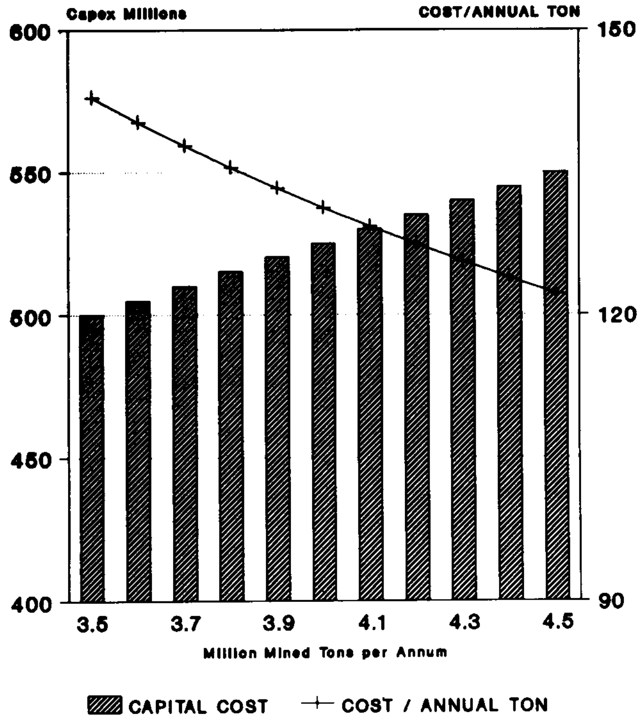

Fig. 8—Capital cost versus mine capacity

figure for damage that can be attributed to coal abrasiveness is extremely difficult, but it must be done to enable a financial justification to be made for a washing plant based solely on reduction in abrasive index.

However, if the reduction of abrasive index is one consequence of efficient resource utilization, then Eskom could save significantly through reductions in downtime and overhaul costs as the result of a policy that could reduce the cost of coal delivered.

Financial Benefits

A mine capable of producing 10 Mt of coal per annum could today cost more than 500 million rands. To increase the mine's output by a further 10 per cent would cost an additional amount of less than 10 per cent. This holds true until further major expenditure, e.g. a dragline, is required (Fig. 8).

In general, most mines are dominated by fixed costs. Rationalization enables mines and plants producing more than one type of coal to have a common infrastructure. As such a mine would already have all the overheads and services, and the only additional working cost required for the additional tonnage would be that of incremental production labour and consumables. This would increase the total costs of run-of-mine coal marginally, up to a maximum capacity that is dictated by the infrastructure.

Fig. 9 shows how the tonnage produced affects the working cost at the same nominal equipment capacity. The only costs to be added are those for coal preparation. As the overall cost is approximately the same, any additional tonnage in the form of middlings is produced at a marginal cost plus only the cost of washing.

For example, a mine employing 2500 people mines 10 sections in double shifts to produce 300 kt of coal per month. The productivity is therefore 120 t per person per

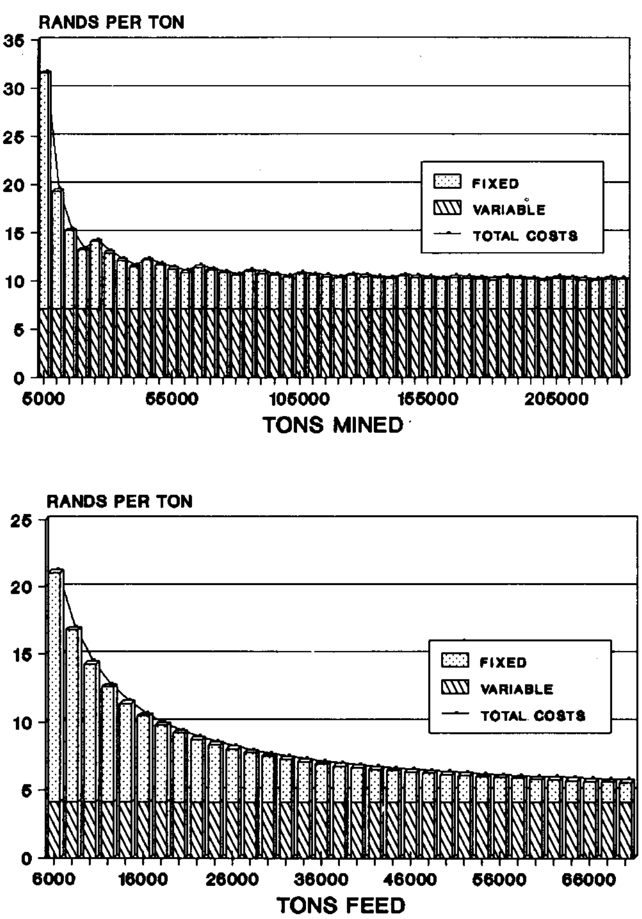

Fig. 9—(a) Mining and (b) coal-preparation costs

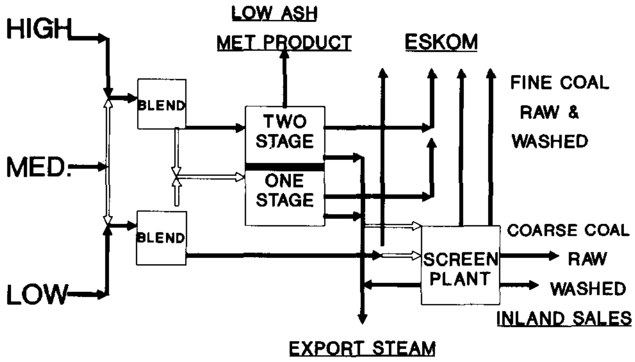

Fig. 10—The supermine operation

month. An extra double section of 60 people would produce an extra 30 kt. The mine would now produce 330 kt per month with 2560 people, a productivity of 129 t per person per month. If the original yield was 60 per cent, the production of clean coal per person per month would have been 72 t. If the overall yield increased to 62 per cent due to rationalization, the production of clean coal per person would become 80 t per person (5,3 t due to the extra mined tons and 2,7 t due to the increased yield).

A major financial benefit results from increasing the total yield from the available reserves. This is achieved by the treatment of better-quality run-of-mine coal in the plant (increasing the high-grade yield) and producing a middling product for the power station by a secondary wash (from coal that would either have been discarded or have produced a lower-yield middling for export), which may be added to the washed portion of the feed. In addition, lower-quality reserves may be used after minimal washing to remove the major contaminants, e.g. a coarse wash only at high densities, which would increase the reserve base. Raising the overall yield decreases the cost per sales ton at the same overall cost.

Other Benefits

The aim in a coal-preparation plant could be either to produce more export tonnage or to place a better-quality export coal on the world market as environmental concerns grow. The dilemma of the South African coal industry is the 'squeeze' occurring because of the lower-quality and/or higher-cost reserves remaining in the ground while the world seeks coal of ever-better quality. With rationalization, the potential exists to supply numerous markets, which also reduces trade risks.

Other benefits would include better utilization of equipment in the areas where rationalization would take place. Mine planning could then utilize a larger pool of equipment, which would ultimately result in more efficient mining.

The 'Supermine'

An ideal or 'supermine' approach could be as follows.

The hypothetical mine has three seams (Nos. 5, 4, and 2), which consist respectively of high-, medium-, and low-quality coal (on the basis of both area and seam). The coal is blended in high- and low-grade stockpiles on the surface, and the preparation plant consists of one- and two-stage circuits, from which a low-ash coal, a high-volatile metallurgical coal, steam coal, and a washed coal of low calorific value are produced.

A screening plant can take coal from either plant, or direct from the stockpiles, the coarse coal produced being used for various markets (e.g. home heating, gasification). The undersize coal and that portion of the coarse coal not required for gasification is sent to Eskom together with washed coal from the plants and raw coal from the blending stockpiles. This scenario is shown in Fig. 10.

The advantages of the supermine would be as follows.

- Three seams can be mined using one mine infrastructure.
- The capital expenditure on the total mine is massively lower than building two or three separate mines.
- The working cost per ton of coal mined is lower since the same fixed-cost component produces a larger tonnage.
- The cost per sales ton is lower owing to an effectively higher overall yield.
- Eskom's cost per unit of electricity generated is lower since a washed product mixed with normal feed contains less contaminants.
- The production is more consistent to wash plants, power station, and gasifiers.
- The production is flexible in that it is suitable for Eskom, for other inland markets, or for export.
- The cash flow is better because some mine development can be phased to occur while revenue is being produced.

The weaknesses of the supermine would be as follows.

- The planning of reserve use is more complicated.
- The degree of blending required is greater than normal.
- The central administration structures are larger and more complicated.

Conclusions

The supermine is an ideal situation in which users and producers can gain maximum mutual benefit. Such a synergistic use of coal reserves is both desirable and possible.

Reserves should be used so that the coal produced from them is employed in the most suitable application. The principal benefit is the overall increase in yield achieved by the combination of what are regarded at present as two or more reserves.

Acknowledgements

The assistance of Mr D. Michael is gratefully acknowledged. The author thanks Rand Mines (Mining & Services) Limited for permission to publish this paper.

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