DISCUSSION

The use and conservation of coal in South Africa

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INTRODUCTION

It is a pleasure to have read Mr Schuman's wide ranging and highly informative paper and also to congratulate him.

Before proceeding to give views on the use and preservation of coal in South Africa, it is perhaps apposite to look at the South African scene on the world canvas. Mr Schuman's figures in his Table I are highly revealing. The Table shows expected consumption, export and import demand in the year 1980 by the continents of the world. The Republic of South Africa is shown as one of only four exporting countries at that date, although in the interim, Australia has become an exporter and will continue to grow as an exporter of coal. Huge fields have been proved in recent years.

There is reason to think that for some years, coal and its economical uses have been under-estimated. The importation of oil carries a constant question mark and the exciting possibilities expressed in the uses of Uranium a decade ago for power generation, appear to have met with some setback. Present indications are that breeder-reactors will be delayed until about 1990. The capital cost of such reactors, too, is enormous. By 1980 it has been estimated that 20 per cent of the energy required by the leading ten nations of the world will come from nuclear power, but 80 per cent would then remain for fossil fuels and hydro generation.

COAL DEMAND AND USAGE

It is of interest to record that coal production in all the countries of Europe has declined markedly in the last 25 years. This is due to competition from oil, gas and nuclear power and also for sociological reasons; but there are signs that efforts will be made to resuscitate, at least in some measure, the mining of coking coals for which there is a strong and growing demand. Possibly all hard coal now mined in Germany has coking properties and that country is self-sufficient in this commodity. Germany might perhaps consider selling coking coal to her neighbours and importing additional coal for power-raising purposes.

It has been frequently stated in American publications that the coal reserves of the U.S.A. are sufficient for 1 000 years. What that means, I do not know, but it is at least an indication that America has huge reserves of coal. Domestic and export demand in the U.S.A. in 1968 exceeded production for the first time. In 1969, the United States' output amounted to some 556 million tons, an increase of less than 2 per cent on the previous year. The output achieved fell short of demand, domestic and export, by more than 7 000 000 tons. This has caused and is continuing to cause anxiety in the U.S.A.

In many countries young men for a number of reasons, largely environmental and social, are not coming forward in sufficient numbers for mining requirements and the same pattern has revealed itself in the Republic. This is, indeed, alarming because mining men in large numbers will be required to meet the estimated tonnage requirements set out in the following Table:

TABLE I

ESTIMATED REPUBLICAN DEMAND AND USAGE FOR COAL IN MILLIONS OF TONS

Market	Approx. present demand 1970	Predicted demand 1975	1980	1985	1990
Power stations	28,0	40,0	53,0	72,0	96,0
Carbonization	7,0	10,5	15,0	23,0	23,0
Oil from coal	4,0	6,2	10,0	14,7	21,5
Industry	6,7	7,5	8,0	10,0	11,5
Railways	6,5	6,3	6,2	6,1	6,0
Merchants	3,3	3,7	4,0	4,1	4,2
Mines	1,2	1,1	1,0	0,9	0,8
	56,7	75,3	97,2	130,8	166,0

Export demand is not included.

It is difficult to visualise the replacement of these coal requirements either by oil or by nuclear fuels. The coal must be mined and men are required for the purpose. Unless a greater section of the population is allowed to participate in the more responsible aspects of mining, there is a serious likelihood that demand will not be matched by output.

In addition to local demand, a lively export trade is possible. Exports are dependent on the future capacity of the South African Railways and Harbours and on Government policy. An export figure of 10 000 000 tons per year during the decade can be visualised and this figure would raise total estimated sales production to a figure of over 100 000 000 tons in 1980.

At this point, it is necessary to examine the desirability or otherwise of exporting coal. How much coal can the country afford to export? Perhaps this question is best related to the Republic's coal reserve. Supposing a total figure of 250 million tons is to be exported during this century, this would represent only about 1 per cent of the country's extractable reserves as published in the Coal Advisory Board's report. This percentage is quite insignificant and it is to be remembered that no geologist or engineer would claim accuracy of this order in any calculation of the country's coal resources. An export of 10 000 000 tons of coal per year would earn the Republic not less than R60 000 000 a year in foreign exchange or a massive total of R1 500 000 000 by the turn of the century. If related to a depletion date based on the 4 per cent growth rate published in the Coal Advisory Board's report, the total export tonnage envisaged would shorten the life of our reserves by less than six months, more than 60 years from now. This fact ignores the greater percentage extraction which would be made possible by higher revenue to which reference is made later.

At the interest rates which now appear to be part of our way of life, the present value of one rand sixty years hence is about half a cent. It is submitted that the value of the country's infra-structure that can and would be created through this export trade far surpasses the value which can be attached to an equivalent tonnage underground in sixty years time. In fact, posterity would have grounds to criticise us only if we do not avail ourselves of the opportunity to capitalise.

It is of interest to observe that most external buyers of coal are interested in coking coal and low ash coal. Export permits are required for the export of coal from South Africa, whilst legislation expressly forbids the export of natural metallurgical coal, although permits have, on occasion, been granted for the export of such coal. In the event, this poses the question — from whence will coking coal and low ash coal come? Metallurgical and/or low ash coal can, in fact, be beneficiated from some of the No. 2 seam bituminous coalfields. This fact supplies owners of those fields where the No. 2 seam is present, the opportunity of making the optimum use of this type of coal; since much of the No. 2 seam contains a low ash coking or blend coking fraction of coal. In such fields it is possible to supply two products, viz: the coking or blend coking fraction referred to and a middling product. This middling product would, on occasions report as a reasonably high grade steam raising coal or alternatively, an excellent power station coal. Since much of the No. 2 seam has this dual characteristic it would be verging on folly to burn the metallurgical fraction in any type of steam raising plant.

As already indicated, not all the No. 2 seam coal contains a coking or blend coking fraction; but the possibilities of using non-coking low ash coal as a stock feed for form-coke making are clearly indicated and a commercial plant is presently being considered for this purpose in the Republic. In addition, such coal might well find an export market for either form coke making or power generation.

CONSERVATION

A great many people have talked at length on the advisability of conserving raw coal resources by making better use of these resources. This is clearly highly commendable but the salient facts as they stand at present are in contradiction to this self-evident policy.

The facts as they are from a technical point of view can be stated:

1. In the Transvaal geological sequence of coal measures starting from the bottom, there sometimes exist five seams and sometimes less. Where all seams exist, four of them (excepting the No. 3 seam) are often exploitable.
2. The steam coal users are accustomed to a high grade quality steam coal at a low price. By far the greatest reserve of such coal in the great Transvaal coalfields, exists in the No. 2 seam.
3. The No. 4 seam, being of a lower grade, is generally exploited for power station purposes but the No. 2 seam when values have not been high, has also been used for this purpose.
4. The No. 5 seam is usually a good blend coking coal and is used by steel makers.

Coal at the cheapest possible price for all consumers has led to certain seams in the various coalfields being exploited to the detriment of others. It is repeated that most steam raising coal comes and has come in the past from the No. 2 seam. Thus, where a field contains several seams and sometimes as many as five seams, the mining engineer is left with an almost insuperable problem. If the demand is, say, for the No. 2 and 5 seams a mining geometry is devised whereby as much of the No. 5 seam as possible is removed, commensurate with safety, at the lowest possible cost. Sufficient coal must be left in situ to protect the surface from subsidence, since the surface is generally not owned by the colliery companies. The No. 2 seam must also be removed in such a manner that not only the surface is taken into consideration but the Nos. 5 and 4 seams as well. Hence, a very substantial array of pillars must be left in the No. 2 seam to support coal, intact, lying above it. Such a pillar layout can be designed for a safe mining geometry over the next few successive years, or otherwise for a period of many years ahead in the expectation that the No. 4 seam will one day be mined. In the former case where the safety factor is not high, the weathering and spalling of coal pillars will, over the years, render the mining of No. 4 seam unsafe.

Cheap mining is achieved but at the expense of the nation's coal reserve; but the cheaper mining in the two cases mentioned above will be attained in the first instance because tramming distances and other factors will be more favourable. Thus, huge tonnages of coal may well be permanently sterilised. The cheapest form of mining yet devised in South African coal fields, is the bord and pillar mining method and the reason for the cheapness is that the roof, in general, is so strong that little timber or other local support is required. Coal is left in situ to take care of regional support problems, not the least of which is the necessity of preserving the surface if surface rights are not held by the colliery company.

Measures to make the best use of our coal resources suggest themselves:

1. Colliery owners should, where possible, purchase freehold title. Economic factors militate against this.
2. Mining first the seam lying closest to the surface and sequentially downwards is highly desirable. Mining of all seams concurrently could in fact be practised, provided markets can be obtained for the respective products.
3. Strip mining of coal lying reasonably close to surface is desirable for high percentage extraction, but it is doubtful that much coal exists for applications of this technique.
4. Other methods of high extraction rates are practical, such as primary development followed by stooping. This is now being done mechanically and with success on a number of mines in the Republic. Obviously the surface will subside and a critical aspect would arise if the coal seam is close to the surface; wide cracks would open up to surface and the mine could be flooded in a severe storm.
5. Longwall mining too has its application in this country but, in general, only where seams are too narrow for stooping. Costs are high in longwall mining, often due to the hard nature of our coals for shearing purposes and to the very expensive equipment. However, at depth, bord and pillar mining followed by stooping will become expensive and in the decades ahead longwall mining will almost certainly achieve popularity.
6. Full use of the potential of existing colliery companies should be used. The potential often comprises the ability to mine other seams concurrently with the seam being mined in terms of current demand. The Witbank complex of coalfields is ideally suited for this purpose and great quantities of No. 4 and low grade No. 2 seam suitable for power-raising purposes could be supplied by existing colliery companies. So long as this possibility is neglected, the danger of certain seams being left unmined forever exists because it is to be remembered that mining geometries cannot supply both the answers to the present and to the future. A safe mining geometry of today will be very different in ten to twenty years time when weathering and spalling have had effect. Therefore, a coal seam in the upper strata of a seam that has been mined below, is in danger of permanent sterilization. Many millions of tons are involved.

Against the background set out above, it is possible to look forward with confidence to a bright future for coal in South Africa. Internal demand will grow and the opportunity for export is manifest. A coal age for the Republic is in the offing and export possibilities give the mining industry an opportunity of preparing coal to its best technical advantage and selling it at a reasonable profit.

F. W. STUTTERHEIM

'n Belangrike eienskap van die steenkoolmark in Suid-Afrika, wat miskien nie genoeg deur Mnr Schumann beklemtoon word nie, is dat so 'n groot deel van die totale afset aan een enkele klant gelewer word. Van die 55.1 miljoen ton steenkool wat in 1969 in Suid-Afrika en Suidwes-Afrika verbruik is, is 22 miljoen ton aan Evkom gelewer. Evkom se steenkoolbehoefte verteenwoordig ook 'n steeds toenemende deel van hierdie jaarlikse totaalverbruik. In 1949 was dit slegs 26 persent van die totale steenkoolverbruik in die Republiek en Suidwes-Afrika maar hierdie persentasie het teen 1969 aangegroei tot 40 persent.

Tabel I toon hierdie toename van Evkom se aandeel in die land se totale steenkoolmark.

TABEL I

STEENKOOLVERBRUIK VIR DIE ONTWIKKELING VAN ELEKTRISITEIT AS 'N PERSENTASIE VAN DIE TOTALE STEENKOOLVERBRUIK IN SUID-AFRIKA EN SUIDWES-AFRIKA

Jaar	Persent van totaal verbruik	
	Evkom	Totaal vir Elektrisiteitsontwikkeling
1949	25,7	36,4
1950	27,3	39,3
1951	27,6	39,4
1952	27,0	38,5
1953	27,9	40,6
1954	30,0	42 7
1955	30,6	43,0
1956	30,6	41,8
1957	30,5	41,6
1958	30,3	39,1
1959	32,9	41,1
1960	33 7	41,0
1961	33,4	41,9
1962	35,4	44,4
1963	36,3	45,3
1964	36,6	45,7
1965	36,2	44,9
1966	37,1	47,1
1967	38,8	48,4
1968	38,8	48,1
1969	40,0	49,2

Soos Tabel I aantoon, is die steenkoolbehoefte van Evkom tesame met ander ondernemings wat elektrisiteit ontwikkel tans nagenoeg die helfte van die totale jaarlikse steenkoolverbruik, en neem hierdie breukdeel nog steeds toe.

Net soos die ontwikkeling van elektrisiteit 'n vername faktor in die vraag na steenkool is, is die koste van steenkool ook 'n belangrike faktor in die kostestruktuur van die elektrisiteitsbedryf. Hierdie feit word in Tabel II geïllustreer:

Tabel II toon aan dat die skaghoofkoste van steenkool tans bykans 55 persent van Evkom se totale kragstasiebedryfskoste uitmaak. Dit is ook duidelik dat hierdie belangrike koste-element teen 'n vinniger tempo as die ander bedryfskostes toeneem en dus 'n groeiende deel van die totaal verteenwoordig. Ten spyte van 'n progressiewe

TABEL II

STEENKOOLSKAGHOOFKOSTE EN STEENKOOLVERVOERKOSTE AS PERSENTASIES VAN EVKOM SE KRAGSTASIEBEDRYFSKOSTE

Jaar	Steenkool-skaghoofkoste	Steenkool-spoorvragkoste
1949	41,6	18,5
1950	41,1	20,1
1951	42,1	21,9
1952	43,6	22,2
1953	43,4	22,7
1954	42,8	24,9
1955	45,3	24,8
1956	47,9	23,1
1957	47,8	23,6
1958	48,1	24,0
1959	49,6	23,3
1960	48,6	26,3
1961	51,8	24,1
1962	53,5	22,4
1963	54,5	20,2
1964	54,2	26,2
1965	54,3	26,9
1966	54,0	18,2
1967	54,6	18,0
1968	54,8	17,0
1969	54,8	15,9

verbetering in die kragstasierendement en 'n gevolglike afname in die steenkoolverbruik per eenheid ontwikkel, is daar nogtans 'n styging in die steenkoolkoste per eenheid ontwikkel.

Steenkoolspoorvragkoste verteenwoordig 'n dalende persentasie van Evkom se kragstasiebedryfskoste omdat nuwe steenkoolkragstasies by steenkoolmynskaghoofde geplaas word en spoorvrag dus as 'n koste-element uitgeskakel word.

Soos van Tabel III afgelei kan word, was die gemiddelde skaghoofkoste per ton steenkool aan Evkom gelewer in 1969 sowat 3.4 maal so hoog as die ooreenstemmende koste 20 jaar vroeër. Weens verbetering in die rendement van die kragontwikkelingsproses is die verhoging in die steenkoolkoste per eenheid elektrisiteit ontwikkel oor dieselfde periode van 20 jaar egter beperk tot 'n faktor van sowat 2.4. Hierdie laer faktor verteenwoordig egter ook nog 'n ongewenste inflasiekoers, wat soos in die verlede deur beide die steenkoolmynbedryf en die elektrisiteitsbedryf bekamp sal moet word.

TABEL III

EVKOM

Jaar	Gemiddelde skaghoofkoste van steenkool rand/ton	Gemiddelde steenkoolverbruik lb. per eenheid ontwikkel	Gemiddelde skaghoofkoste van steenkool sent per eenheid ontwikkel
1949	0,482	1,799	0,0433
1950	0,512	1,793	0,0459
1951	0,587	1,764	0,0518
1952	0,720	1,787	0,0643
1953	0,749	1,726	0,0685
1954	0,809	1,661	0,0672
1955	0,893	1,624	0,0726
1956	0,990	1,573	0,0779
1957	1,028	1,566	0,0805
1958	1,066	1,526	0,0813
1959	1,121	1,504	0,0843
1960	1,193	1,488	0,0888
1961	1,297	1,486	0,0964
1962	1,339	1,479	0,0990
1963	1,392	1,455	0,1012
1964	1,383	1,417	0,0978
1965	1,417	1,395	0,0988
1966	1,516	1,367	0,1036
1967	1,565	1,327	0,1038
1968	1,614	1,276	0,1029
1969	1,671	1,225	0,1023

Die gegewens in die drie tabelle was bedoel om te benadruk dat daar 'n groot wedersydse afhanklikheid bestaan tussen die steenkoolbedryf en die elektrisiteitsbedryf. Die ekonomiese welvaart van elkeen word direk deur die ekonomiese gesondheid van die ander beïnvloed. Ten spyte van die toekomsmoontlikhede van kernkrag en ander energiebronne sal hierdie onderlinge afhanklikheid in die toekoms voortduur. Dit is dus vanselfsprekend dat die elektrisiteitsbedryf en die steenkoolbedryf ten volle met mekaar sal saamwerk. Albei bedrywe kan alleen voordeel uit sodanige samewerking put, en dit geskied sonder dat eie belange daarvoor ingeboet hoef te word.

Mnr Schumann wys daarop dat die bereiking van verhoogde herwinning van steenkool sal verg dat „omstandighede geskep moet word waarin 'n hoër afboudoeltreffendheid ekonomies gemaak kan word", en huldig die opinie dat die Staat 'n groot rol sal moet speel in die skepping van hierdie gunstige ekonomiese klimaat vir die steenkoolbedryf.

Die vervoerkoste van steenkool is een van die struikelblokke wat groter afboudoeltreffendheid in die steenkoolmynbedryf ekonomies ontmoedig. Veral as ons aan 'n moontlike uitvoerhandel dink is dit duidelik dat slegs steenkool van hoër gehalte die spoorvrag- en skeepvragkoste kan regverdig en hier ontstaan 'n gevaar van roofbou tensy 'n ekonomiese mark ook gevind kan word vir die laegraadse steenkool wat andersinds 'n afvalproduk of 'n onontginde restant sou wees.

Dit is 'n eienskap van die tegniek van elektrisiteitsontwikkeling in termiese kragstasies dat bykans enige brandstof doeltreffend benut kan word mits die kragontwikkelingsinstallasie daarvoor ontwerp is, en die prys van die brandstof laag genoeg is om te vergoed vir die hoër kapitaalkoste en hoër bedryfskoste met inbegrip van instandhoudingskoste, wat met laegraadse brandstof gepaard gaan.

Die rendement van die verbrandingsproses in 'n groot moderne stoomketel is besonder hoog; sowat 90 persent van die hitte-inhout van die brandstof word aan die stoom oorgedra, en hierdie hoë rendemente kan ook in ketels van spesiale ontwerp met steenkool van relatief swak gehalte bereik word. Op die oog af blyk dit dus dat daar groot moontlikhede kan bestaan vir die verhoging van afboudoeltreffendheid en die voorkoming van roofbou in die steenkoolbedryf deur wedersydse samewerking tussen die steenkoolbedryf en die elektrisiteitsbedryf. Hierdie moontlikhede kan egter net verwesenlik word as hulle gepaard gaan met tasbare ekonomiese voordeel vir altwee die betrokke bedrywe.

Die wetenskap het op die gebied van die transmissie van elektriese krag sodanig gevorder dat die langafstandvervoer van steenkool vir gebruik in groot kragstasies teen realistiese of selfs gunstige spoortariewe moeilik geregverdig kan word, en onderworpe aan die beskikbaarheid van verkoelingswater moet 'n nuwe groot steenkoolkragstasie noodwendig by die skaghoof van 'n groot steenkoolmyn geplaas word. Dit bring mee dat die betrokke kragstasie en die betrokke myn ekonomies baie heg aan mekaar verbind word. 'n Vermindering in die steenkoolaanvraag van die kragstasie bring nie 'n proporsionele vermindering in die totale bedryfskoste en ander koste van die steenkoolmyn mee nie omdat sekere sogenaamde „vaste kostes" tussen wye grense nie op 'n verandering in die produksie van die steenkoolmyn reageer nie. Om te konkureer sou steenkool van 'n ander bron dus aangebied moet word teen 'n gelewerde koste wat nie alleen laer is as die gemiddelde produksiekoste van die myn by die betrokke kragstasie nie, maar teen 'n prys wat goed vergelyk met die inkrementele produksiekoste van hierdie myn. Die „ander bron" sou dus nie alleen baie naby die betrokke kragstasie geleë moet wees nie, maar 'n vermindering van die huidige koste vir die grootmaatvervoer van steenkool oor kort afstande sou waarskynlik ook nodig wees.

Afgesien van terloopse verwysing na kaloriewaarde is daar in die referaat geen bespreking van die kwaliteitsgradering van steenkool nie, en dit is ook 'n eienskap van die Suid-Afrikaanse mark dat daar min prysdifferensiasie ten opsigte van steenkoolkwaliteit toegepas word. By die plasing van 'n nuwe steenkoolkragstasie is die keuse van die betrokke steenkoolaanbod vir Evkom van deurslaggewende belang, en in hierdie keuse word 'n groot aantal faktore in oorweging geneem waarvan die verwagte gemiddelde steenkoolkoste per ton, en die verwagte gemiddelde kaloriewaarde slegs twee is. Die kapitaalkoste van die voorgenome kragstasie, sy instandhoudingskoste en bedryfskoste sowel as sy verwagte betroubaarheid (gemeet aan die afsluittempo of „outage rate") is almal faktore wat beinvloed word deur verskillende aspekte van die kwaliteit van die aangebode steenkool. Voor die finale ontwerp van die kragstasie kan steenkool van verskillende kwaliteite oorweeg word, maar in 'n bestaande kragstasie wat ontwerp en ingestel is vir steenkool van 'n gegewe vlugtige gasinhoud, vergruisbaarheid, asinhoud, skuurgehalte en ander eienskappe kan 'n verandering in die steenkoolkwaliteit groot probleme meebring. Dit mag interessant wees om kortliks die invloed van een van hierdie kwaliteitsnorme te noem, naamlik die skuurgehalte („abrasiveness") van die aangebode steenkool.

Steenkool van hoë skuurwerking bring groter slytasie in die steenkoolmeule, toevoerpype en branders mee en gaan gepaard met hoër instandhoudingskoste. In die ketel self is daar erosieskade wat verminder kan word deur spesiale ontwerp van die ketel om die snelheid van die gasse laer te hou. Dit verg egter 'n groter ketel met hoër kapitaalkoste. Die hantering van die groter asinhoud bring ook verhoogde bedryfskoste mee. Onder sekere omstandighede mag dit ekonomies voordelig wees om die kwaliteit van die steenkool vooraf met 'n wasproses te verbeter deur die verwydering van sommige van die sakdelike bestandele. Al hierdie kostes moet teen die alternatief van steenkool van beter kwaliteit opgeweeg word. As daar min of geen prysdifferensiasie tussen die verskillende kwaliteite gestaan sal hoëgraadse steenkool voorkeur geniet. Beter prysdifferensiasie impliseer dat steenkool van besondere gehalte duurder mag word, maar laegraadse steenkool goedkoper. So 'n verandering in die prysstruktuur mag meehelp om enige skadelike vermorsing van laegraadse steenkool te verminder omdat daar teen die laer prys 'n beter mark vir sulke steenkool gevind mag word. Hierdie is miskien een manier waardeur die steenkoolbedryf sonder aktiewe inmenging van die Staat die gewensde ekonomiese klimaat kan help skep om groter afboudoeltreffendheid te bevorder.

Die landswye verbinding van Evkom se kragstasies bring mee dat die vraag na steenkool in enige besondere geografiese gebied prysgevoeliger word as wat voorheen die geval was. Binne sekere perke kan die lasfaktor by kragstasies met 'n lae steenkoolprys per gelewerde eenheid verhoog word, en die lewering van kragstasies waar steenkool duurder is buite spitsure beperk word. In sy strewe om elektrisiteit teen die laags moontlike koste te lewer, is dit Evkom se eerste plig om voortdurend die ekonomiese aspekte van verskillende alternatiewe energiebronne teen mekaar op te weeg. Hierdie sluit nie alleen steenkool van verskillende kwaliteite in nie, maar ook waterkrag, kernkrag, olie of, moontlik in die toekoms, gas. In die referaat word tereg daarop gewys dat daar tans nog 'n mate van onsekerheid bestaan oor die ekonomiese voordele van kernkragstasies teenoor steenkoolkragstasies. In Suid-Afrika speel geografiese faktore egter 'n belangrike rol. Vir die lewering van elektrisiteit aan die kusgebiede bied kernkragstasies of oliekragstasies by die kus 'n besparing ten opsigte van transmissiekoste en ook 'n besparing van die skaars waterbronne in die binneland.

Dit is vanselfsprekend dat Evkom en die steenkoolbedryf saam die risiko's en laste van hierdie onsekerhede van die toekoms dra. Die belange van die twee bedrywe is heg saamgesnoer en elk is vir die ander onontbeerlik. Noue samewerking tussen die twee bedrywe is 'n eerste vereiste vir gesonde elektrisiteitsverskaffing sowel as vir 'n gesonde steenkoolbedryf in Suid-Afrika. Mnr Schumann se referaat is 'n waardevolle bydrae in die strewe na hierdie doelstellings en is gelewer op 'n tydstip wanneer die probleme daaraan verbonde dringende aandag verg.

E. J. MAUNDERS

In its studies to determine the probable future role of nuclear power in South Africa the Atomic Energy Board naturally gets an insight into the future use of coal for the purposes of electricity production. In cooperation with ESCOM a study is being conducted to try and determine which combination of hydro power, fossil fired plants and nuclear power stations will give South Africa her electricity supply at the lowest cost, and from this study we shall eventually have a better idea as to what the country's needs are in terms of coal and uranium.

The question of coal reserves has already been dealt with, but that of uranium reserves is both interesting and relevant. Table 1 carries the world uranium reserves as compiled in April 1970[1]. Despite some recent dramatic finds in Australia, South Africa, with 200 000 short tons of U_3O_8, still has the third largest reserves of low-cost uranium in the world. Depending on the type of reactor in which this is used, this is roughly equivalent to between 10^9 and 10^{11} short tons of coal, or in other words probably of the same order of magnitude as the currently quoted proven coal reserves. In such a situation as this, some form of long term economic study is clearly desirable in order to ensure that the best use is made of these energy reserves. In the following paragraphs I will attempt to describe our method of approaching this problem in as simple a manner as possible, and afterwards give some preliminary results obtained with illustrative rather than our most accurate data.

This problem has been tackled before in many other countries, but all known previous studies[2] have used what is called a "point model", which neglects the geographical location of power plants and load centres. For our system, with its five widely scattered load centres, the point model representation is inadequate, so we have had to develop a technique to analyse the electricity system in two dimensions, taking full account of the 400 Kv transmission line system with which Escom is linking these load centres.

In the illustrative calculations presented later we have chosen to study the 25 year period from 1978 to 2003. 1978 is the date when Escom plan to have their first nuclear power station fully operational, and is therefore an obvious choice of starting date. Before the computer can be applied to the task of simulating the system we first have to specify the location of the load centres, their magnitude, and their demand growth rates. As an illustration we shall assume a 7.9 per cent national average growth rate distributed amongst the load centres as follows:— the Johannesburg-Pretoria area 7.3 per cent (below the national average); the Durban area 9.9 per cent; the Port Elizabeth-East London region 8.9 per cent; Cape Town 7.8 per cent; and the Bloemfontein-Kimberley area 7.9 per cent. These load growth rates lead to a total installed capacity of about 80 000 Mw by the year 2000, which is significantly higher than that predicted by Dr Straszacker[3]. However, these figures are considered good enough for illustrative purposes. We also have to specify the size and location of existing fossil-fired power plants, hydro-electric schemes, and transmission lines, as well as the electricity system load-duration curve, fuel and plant costs and other economic parameters. The model is capable of handling resource constraints on, for example,

TABLE 1

WORLD URANIUM PRODUCTION AND RESERVES
(Below $ 10 per lb. U_3O_8)

Country	Reserves: as at April 1970		Reserves: Net changes since 1969 report[f]	Actual production 1969		Production capacity planned for 1973		Production capability attainable by 1975	
	Short tons U_3O_8	Metric tons U	Short tons U_3O_8	Short tons U_3O_8	Metric tons U	Short tons U_3O_8	Metric tons U	Short tons U_3O_8	Metric tons U
France	45 000	35 000	0	1 600	1 250	2 300[a]	1 800	2 300	1 800
Italy	1 500	1 200	+ 1 500			120	92	120	92
Portugal	9 600	7 400	+ 100	103	94	300	230	300	230
Spain	11 000	8 500	0	72	55	550	425	550	425
Turkey	2 300	1 800							
Yugoslavia	1 300	1 000	— 2 900						
SUB-TOTAL EUROPE	70 700	54 900	— 1 300	1 775	1 399	3 270	2 547	3 270	2 547
Argentina	10 000	7 700	+ 1 000	55	42	88	68	88	68
Australia	21 700	16 700	+ 11 000	330	254	1 500	1 150	1 500	1 150
Brazil	1 000	800	+ 1 000						
Canada	232 000	178 000	+ 32 000	4 500	3 460	5 500[a]	4 230	13 000[b]	10 000
Central African Republic	10 400	8 000	+ 10 400			780	600	780	600
Gabon	13 500	10 400	+ 9 500	650	500	780	600	780	600
Japan	2 700	2 100	+ 2 700			40[c]	30	40	30
Mexico	1 300	1 000	+ 1 300	40	30	200	155	200	155
Niger	26 000	20 000	+ 14 000			970[c]	750	1 940[d]	1 500
South Africa	200 000	154 000	+ 5 000	4 000	3 080	6 000	4 600	6 000	4 620
U.S.A.	250 000[e]	192 000	+ 70 000	11 600	8 900	19 000	14 600	23 000	17 700
TOTAL	839 300	645 600	+146 600	22 950	17 665	38 138	29 430	50 598	38 970
Round figures (10^3 tons)	840	645	+ 147	23	18	38	29	51	39

(a) Capacity now available.
(b) Attainable by 1975, markets permitting.
(c) Available by 1971.
(d) Available by 1974.
(e) Does not include 90 000 short tons U_3O_8 by-product.
(f) Same geographical basis except that present compilation omits Congo (Kinshasa) and Germany.

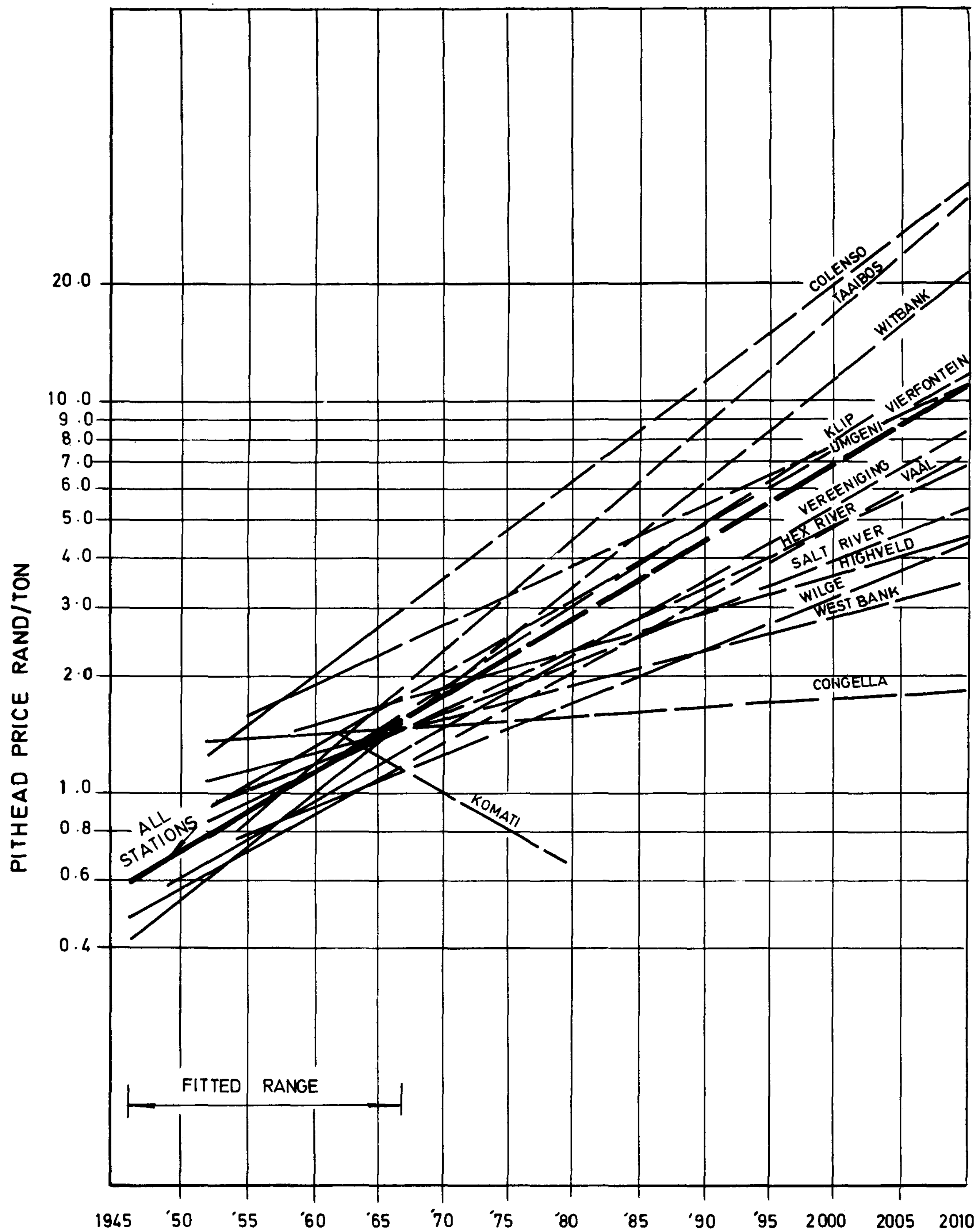
PITHEAD PRICE RAND/TON
20.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.4
1945
'50
'55
'60
'65
'70
'75
'80
'85
'90
'95
2000
2005
2010
COLENSO
TAAIBOS
WITBANK
VIERFONTEIN
KLIP
UMGENI
VEREENIGING
VAAL
HEX RIVER
SALT RIVER
HIGHVELD
WILGE
WEST BANK
CONGELLA
KOMATI
ALL STATIONS
FITTED RANGE

Fig. 1

fuel or cooling water. For the purposes of this exercise we shall specify that after 1980 both nuclear and coal-fired generating plants will have to employ dry cooling installations when erected inland to cool the turbine condenser cooling water.

With this information specified the computer can be set to work. The study period is examined at three monthly intervals until a power requirement is identified for a particular area. When this happens all possible ways of supplying this power must be examined. In this illustrative example we will consider either a fossil-fired plant constructed at the load centre requiring the power, or a pit-head station together with any transmission line that may be required, or one of the following three types of nuclear reactor, sited at the load centre: a LWR or an SGHWR both of which use enriched uranium fuel, or a CANDU which runs on natural uranium. More details may be gained about these reactor types by consulting reference[4].

The next step is to determine the present-worthed cost of operating the entire system over a period of 15 to 20 years with each of these alternatives operating against what is, initially, a guessed pattern of future installations. The choice which leads to lowest overall system costs is selected, and this whole procedure repeated again and again until the study period has been covered. We then start again, going back to the beginning of the study period and repeating the exercise, only this time running costs are evaluated against the installations chosen during the first iteration. At the end of this and any subsequent iterations the plant installations made on the current and the previous pass are compared, and the study is terminated if these two lists agree. This is then the pattern of installation which leads to minimum overall system costs.

The costing exercise is quite complex as there are many factors to consider, some even being a function of the geographical location of the proposed installation. For example, the cost of coal after it has been transported, or the cost of electricity after transmission from a pit-head power station. We also have to consider the difference in generating cost structure for the various types of installation, that is both the ratio and absolute values of capital and running costs, because this determines the order in which the systems are used to match the ever varying system load. Another complication is the relative difference in capital costs between fossil and nuclear stations, which diminish as station size changes. Further, we have such problems as costing the complicated nuclear fuel cycle and determining the present and future cost of coal, see Fig. 1[5], for example. For the purposes of this contribution we have assumed a pit-head coal price of R1.25 per short ton in 1969 and allowed this to escalate in price at various rates. The nuclear fuel cycle already contains an overall escalation factor of about 3 per cent per annum, but this is not spread uniformly over the period of study.

That, roughly, is the structure of the problem — what of the results? It must be emphasised again that the figures I shall quote are only produced in order to give an indication of what sort of competition may exist

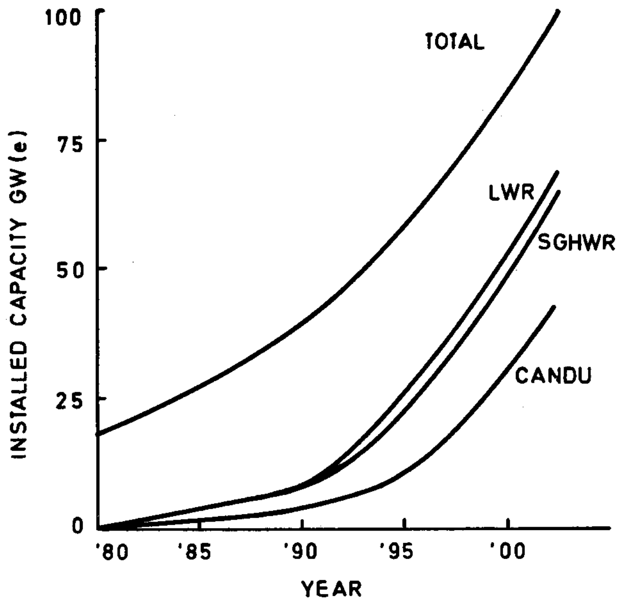

Fig. 2

between coal fired and nuclear stations. More accurate forecasts may be published next year[7].

Fig. 2 carries the results of an optimisation along the lines sketched above. The line marked "total" is, of course, the predicted installed capacity of coal-fired units if the nuclear alternative is not considered. The coal price escalation rate, which is $2\frac{1}{2}$ per cent per annum in this case, becomes relevant when the reactors are allowed to figure in the calculation. The calculated installed capacity of each reactor type is represented by a separate line on Fig. 2. They find themselves installed in differing numbers because each has its unique set of power costs. Since the installations are determined within the calculation on purely economic grounds it is hardly surprising to find that the earliest stations are found in the regions of high cost coal — the coastal regions. The build-up of nuclear capacity is slow until 1990 when, due to an increase in unit size, inland installations suddenly look attractive. They then begin

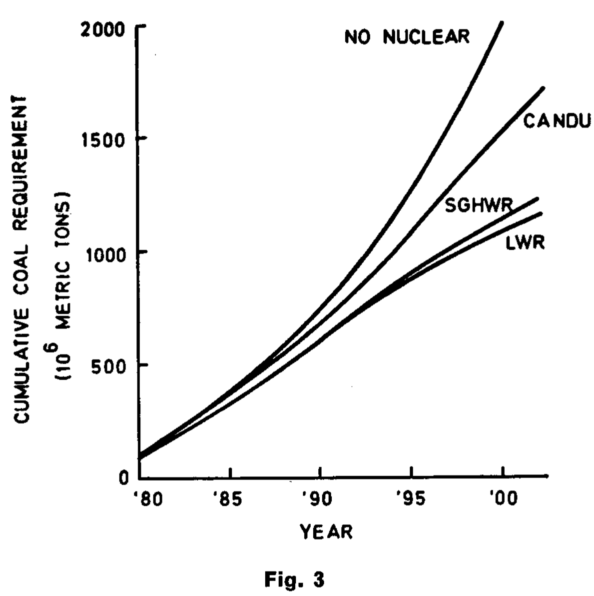

Fig. 3

to be installed at the biggest load centre, and consequently the rate increases. The figure further shows that by the year 2000 something like half the country's installed capacity should be nuclear.

This situation would reflect on coal requirements for electricity production as illustrated in Fig. 3. This indicates that, if nuclear plants were excluded from the calculation, then by the year 2000 we might have used 2000 million metric tons for this purpose alone. This is roughly in line with figures quoted in a recent publication by the Coal Advisory Board[9]. The more expensive reactor of the three, the CANDU, is installed less widely than the other two simply because of its cost, but it nevertheless manages to reduce the coal consumption by 25 per cent to 1 500 million metric tons. The most widely installed, cheapest, reactor of the three almost halves the coal consumption, bringing it down to 1 100 million metric tons or about 10 per cent of the currently quoted saleable reserves in the present mining areas: that is not allowing any credit for our potential reserves. Note that these numbers derive from the situation most favourable to the coal-fired plant, the 2½ per cent fuel cost escalation rate.

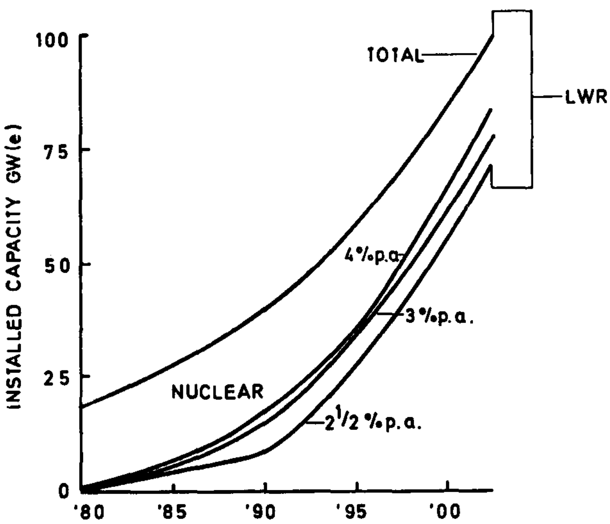

Fig. 4

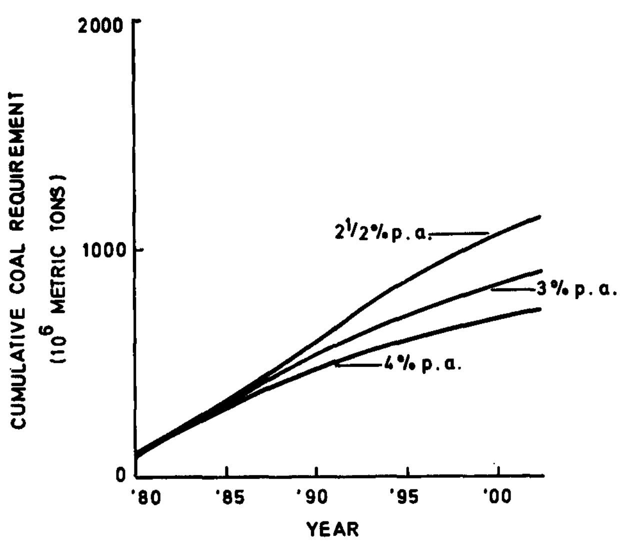

Fig. 5

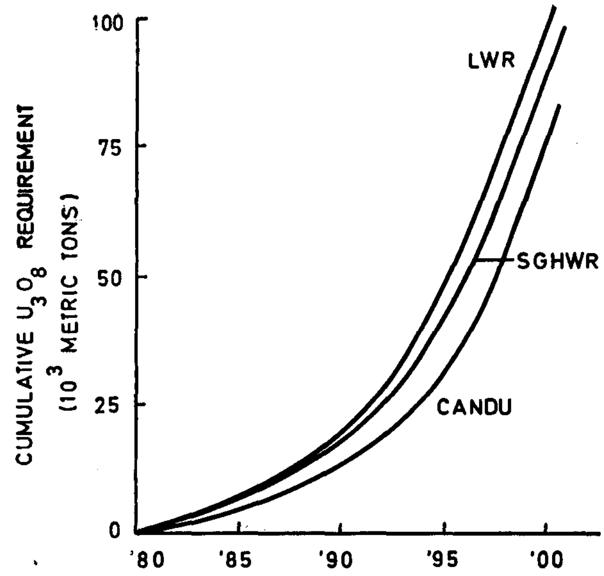

Fig. 6

Fig. 4 shows what happens if we consider higher escalation rates. Values of 3 per cent and 4 per cent have been chosen to compete against an LWR, and these slowly price the coal-fired units out of the power generating market. In the case most favourable to nuclear, and with a 4 per cent coal-price escalation rate, lowest system costs are achieved when the nuclear component accounts for 80 per cent of the total installed capacity by the year 2000. In this case, as Fig. 5 shows, cumulative coal requirements for power generation up to the year 2000 would only be 700 million metric tons.

So far we have only considered unfavourable price changes for fossil-fired plant. With regard to capital costs, experience overseas[8] seems to indicate that both fossil-fired and nuclear plant costs seem to escalate at a common rate. However, any increase in the cost of the nuclear fuel cycle would tend to rob the nuclear alternative of some of its share of the market in the cases outlined above, but these increases would have to be relatively greater than for fossil fuel because in the case of the coastal installations, at least, fuel costs for the nuclear plant are a much smaller fraction of the total unit generating cost than is the case for a comparable fossil-fired unit.

Although these figures are only of a preliminary nature they do seem to indicate that the continued exporting of coal, at the rates mentioned in Mr Schumann's paper, should cause no energy deficiency on the home market. Indeed, if our preliminary figures turn out to be accurate it would seem that unless the pithead price of coal can be kept low, then there is likely to be a considerable amount available for this and other purposes, especially when one considers the efforts being made overseas, to develop alternative ways of power generation.

Whilst there would appear to be an adequate supply of coal to tide us over the next 30-40 years, by which time other sources of power may be available to us, there would appear to be a case for a closer examination of our low-cost uranium reserves. Referring to Fig. 6, and taking the case least favourable to the nuclear alternative, it appears possible that by the year 2000 we may need almost half our currently quoted low cost reserves for our own use. We have not, of course, allowed one of the more advanced types of reactor to be introduced into this illustrative example. Reactor types are being developed which will lead to very large reductions in the rate of usage of uranium ore, but factors which could control the date of introduction of these into the South African electricity system indicate that they may not appear until after 1990. By this time over half our currently quoted low cost uranium reserves will probably be committed for use, if not actually used.

Admittedly, these forecasts may be based on an optimistic growth rate, but nevertheless there is a smaller margin between our known reserves and our likely requirements for the next 30 years in the case of uranium, than for coal. This, to me, indicates an urgent need to make a careful study of our uranium resources and such studies are already being undertaken at the Atomic Energy Board.

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AUTHOR'S REPLY TO DISCUSSION

I shall reply very briefly if I may. I want to thank Mr Henderson for his contribution. It is the product of considerable study and will in turn be studied with great interest. Mr Henderson sets out the facts connected with the conservation of coal and he has given us a valuable balanced appraisal.

Mnr F. W. Stutterheim se bydrae is ook vir ons van groot waarde en sal verder in diepte bestudeer word. Ons staan natuurlik hier voor die probleem dat mnr Stutterheim Evkom verteenwoordig — die mense wat meeste van ons steenkool koop en "the customer is always right". Mnr Stutterheim het daarop gewys dat die skaghoofkoste per ton steenkool aan Evkom gelewer in 1969 sowat 3.4 maal so hoog was as die ooreenstemmende koste 20 jaar vroeër, en nou te staan kom op sowat R1.68 per ton. Net om die sakie in perspektief te kry, kan 'n mens noem dat die koste van Amerikaanse steenkool gelewer aan kragstasies gedurende die afgelope jaar met meer as hierdie bedrag gestyg het. Afgesien van 'n paar Amerikaanse oopgroewe, produseer ons nog steeds die goedkoopste steenkool ter wêreld. Of dit op langeduur in landsbelang sal wees, is 'n ander vraag.

Mnr Stutterheim het verwys na kwaliteitsgradering en veral skuurgehalte van steenkool, as dinge waaraan die bedryf nie genoeg aandag gee nie. Ek stem met hom saam en ek wil graag daarop wys dat as daar 'n nasionale standaard vir definisie van steenkoolreserwes is, en veral as dit ingestel is om deur 'n komper gevoer te word, dan sou dit baie makliker wees om aan hierdie vereistes te voldoen. Sekere maatskappye weet al uit bitter ondervinding hoe belangrik hierdie eienskappe is, maar dit sal nie in die algemeen erken word tensy ons nasionale standaarde stel nie.

Mr E. J. Maunders gave us a fascinating glimpse into the problems which we have been studying, but seen from the other side of the fence. He has certainly enriched our appreciation of the complexities of power problems. One is a little surprised when he speaks of the low thermal efficiency of a conventional power station. We look forward to the day when the same efficiency can be attained by nuclear stations, this presumably will be possible with breeder reactors around the year 2000. He also pulled our legs by showing a slide of a conventional thermal station and said that this represented the opposition. I believe that long before the end of this century, there will be no opposition at all and it will be a case of adversity making strange bedfellows.

In conclusion, I would again like to thank the contributors for a most interesting discussion.

B. D. MAREE — S.A. AKADEMIE

Ek wil graag namens die Akademie die Instituut bedank vir die geleentheid om hier saam te vergader. Daar was 'n soortgelyke geleentheid in 1966 toe professor Straszacker van die Akademie ook 'n gesamentlike vergadering gehad het met die Instituut. Baie dankie mnr die President vir die samewerking.