JOURNAL OF ENERGY IN SOUTHERN AFRICA

Vol.5 No.1 February 1994

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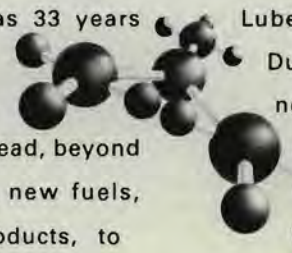

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Profile: Fritz Körte

Managing Director, Atlantis Diesel Engines

From Argentina to South Africa, with a spell in Germany in between. That's the blend that makes up Fritz Körte, enthusiastic and dynamic managing director of Atlantis Diesel Engines (ADE).

He has spearheaded the company's about-turn from one of South Africa's perceived "white elephants" into a market-driven dynamo that is now yielding healthy profits, delivering quality engines, and making its mark on the South African business scene.

Fritz was born to German émigrés in Buenos Aires in 1942, and spent his first six years on farms in remote Patagonia. In 1948 his family moved to Buenos Aires. After matriculating from a private high school in the city in 1960, he entered the University of Buenos Aires, graduating in 1966 with a degree in mechanical engineering.

In 1967 he started working for a company that manufactured copies of starter-motors and alternators under local content rules rather like South Africa's. It was later taken over by Robert Bosch.

Three years later Fritz joined Mercedes-Benz Argentina as an assistant to the plant manager. MB Argentina then employed about 3 000 workers, manufacturing trucks and buses. This is where he received his shop-floor experience, which has served him well with ADE, where he is a familiar figure in the manufacturing areas and at the company's quarterly road-shows, where he and his executive team report on ADE's performance to the work-force.

Fritz is no stranger to political turmoil as Argentina was not an easy place in which to live. In the seventies, frequent terrorist threats were made to the employees of multinational companies but since he was born there, his position was far stronger than that of some of the other foreign employees. In 1975, after two kidnapping threats, his boss left, and Fritz, at the age of 33, became plant manager, probably one of the youngest in MB's history.

For the next eight years he concentrated on manufacturing, then moved to sales, and in 1985 came to ADE.

His reputation at ADE has gone far beyond the borders of the Western Cape. The company, which manufactures diesel engines licensed by Mercedes Benz AG and Perkins Engines of England, has an undeniable reputation for quality. Its engines power some 180 000 trucks, buses, tractors, marine craft, underground mining equipment, and a host of other industrial applications.

Under the leadership of Fritz and four executive directors, ADE has reduced its staff to a tightly-honed, multi-skilled 1 700, increased its exports and parts sales, won an NPI gold award for productivity, received the international ISO 9000 standard which opens up export opportunities such as the multi-million component contract signed with Ssang Yong in South Korea, and has been acknowledged as a top supplier to four of its customers, Delta, Nissan, Samcor and Toyota. ADE was also the recipient of the Road Freight Association award, an acknowledgement that ADE is serving the road freight industry well.

Fritz has also been responsible for a customer-care programme that extends beyond traditional customers into the plant, one that makes communication a corner-stone of the business environment.

ADE has also become very involved in the Atlantis community. As the largest employer in Atlantis, ADE is assisting in the training of the residents and, together with other industrialists, is helping to build up the area.

A lover of classical music, Fritz can often be seen at symphony concerts and the opera, as well as jazz concerts. At weekends, when he is not waterskiing, hiking or cycling with his family, he may enjoy his favourite food – crayfish –, with dry Cape wines.

In 1970 Fritz married Graciela, an Argentinian who has a similar German background. They have three children, Verena, who is a student at the University of Stellenbosch, and Pablo and Martin who have just written matric at the German School in Cape Town.

Upstream petroleum promotion and development: A possible multi-country approach in Africa*

* * M SCHLOSS

Upstream petroleum development hinges on how technical data can be properly gathered, re-interpreted, and, in the end, how resources that are spent on such efforts compare to the risk capital the oil industry is prepared to mobilise in response to such endeavours. Past experience in 21 African countries where petroleum promotion efforts were undertaken resulted in low outcomes of work obligations compared to project costs. Pursuant to the outcome of interviews with the oil industry on the failure of past approaches in Africa, a revamped approach was thoroughly tested in the Red Sea regional basin, which specifically addressed the shortcomings of the country-by-country focus followed in the past. As more parties need to be mobilised in undertaking a petroleum development of a larger magnitude, successful development depends on an understanding of what each stakeholder can contribute to the investment process, and how to organise such contributions to help the reconciliation of the interests and capabilities of all parties concerned. A key element thus involves an approach to such investments which assures the organised participation of key stakeholders across national boundaries and professional expertise. There are not many such projects which have been undertaken elsewhere in the world, since most of the significant petroleum provinces are within the jurisdiction of a single country. The few other experiences where analogous efforts were needed and successfully undertaken, have been the North Sea oilfields and, to a lesser extent, in the provinces between Indonesia and Malaysia. Since most potential African oilfields straddle between countries, the approach used in the Red Sea seems to be the one that offers a greater potential for the continent's upstream petroleum development.

Keywords: upstream petroleum development; Red Sea; Gulf of Aden; Africa; Sub-Saharan Africa

Introduction

One of the intransigent facts of life is that the future always comes sooner or later - and it is always different from the way it has been projected. Even the mightiest of countries and institutions will be in trouble if they do not work towards the unpredictable future. This paper attempts to address the rapid changes that have taken place in the energy field and to examine what could be done in the African context.

The events in the Gulf, in 1990, and their fall-out throughout the world, show how much the supply of petroleum and its products can be radically changed in unforeseen ways. In a way, these events should come as no surprise. In the last two decades there have been sharp changes in the prices of crude oil and petroleum products on which most of the countries throughout the world depend for their supplies. The essentially unstable supply/demand interface has significantly affected oil-producing countries and particularly adversely, the oil-consuming nations, mainly those low-income countries with limited options to adjust to rapidly changing terms of trade.

As long as present production and transportation technologies remain as they are, hydrocarbons trade will continue to be the single most important item in many countries' balance of payments, and in many cases, fiscal revenues - whether they are importers or exporters of petroleum. For this reason, petroleum-importing nations will have to make deliberate attempts to:

- make better use of their existing sources of petroleum and petroleum products, and alternative sources of energy, maximising the efficiency of their utilisation, and husbanding them as the precious resources that they are, through improved policy, regulatory and institutional actions[(1)];
- more efficiently manage the supply and distribution of products through regional co-operation, i.e., bulk buying and stockage on an intra-regional basis to control the costs, and with distribution rationalised across national boundaries through bilateral and multilateral agreements[(2)]; and
- diversify their sources of supply through the development of their own endowment of natural resources to the maximum extent possible.

As the latter is in the final analysis, the more "resilient" and sustainable solution, this article focuses on this option.

The first factor to be borne in mind is that resource development in general, and petroleum resource development in particular, is a highly capital- and technology-intensive activity, requiring capabilities that are not available to many producing and consuming nations. The search for, and development of petroleum resources, in general, requires the assistance of the international petroleum industry. The industry has the capability of effectively assessing the technical risks of exploration in frontier areas, and evaluating the probability of economic success should they elect to undertake exploration in a given area. It is imperative therefore, that the interest of the industry be engaged if these efforts are to be effective. Effectiveness thus requires that the country understands what the petroleum industry requires, and what it has the capability of providing, if the resulting partnership is to be successful.

By the same token, the potential rewards of success need to be mutual. For the company, the rewards revolve around the profitability of the venture and the repatriation of the invested funds and their resulting dividends. For the country, it is the injection of foreign income, the fiscal revenues from the taxes paid by the company on its share, the associated development of infrastructure in the form

* The findings, interpretations, and conclusions expressed in this publication are those of the author and do not necessarily represent the views and policies of the World Bank, or its Board of Executive Directors or the countries they represent.

** Corporate & Budget Planning, Planning and Budgeting Department, World Bank, 1818 H Street, N.W., Washington, D.C. 20433, United States of America.

of roads, pipelines, housing, schools, hospitals, etc., which are often located in remote areas of the country. In addition, there is the creation of jobs on a significant scale, the training and transfer of knowledge to the national technical and non-technical staff, the development of governmental institutions, the strengthening of universities, and the establishment of related research facilities, which in time could spin-off other developments in the country.

Supply/demand relationships: Where does Africa fit?

The issue in the bulk of potential African oilfields is for the countries concerned to be in the position to demonstrate to the oil industry that part of exploration funds should be spent in this area rather than in already well-established areas, such as the North Sea, the Persian Gulf, or the Gulf of Mexico. Without the required diversion of these exploration funds to the "frontier regions" included in the continent, there will be no discoveries and hence, no petroleum development in the bulk of the region.

In this context it is worth taking a look at where the known supplies of oil and gas are in the world today, where the consumers are located, how much oil will be available in terms of remaining years of supply, and lastly, what changes are likely to occur in these relationships in the future.

Figure 1 dramatically shows that fully two-thirds of the world's reserves of petroleum are located in the Middle East, the great bulk of them in fact being contained in the countries around the Persian Gulf.

On the other hand, as can be seen, the consumers are not where the supplies are, but rather, one third of the consumption of the world's petroleum is in the Western Hemisphere, principally North America; and another third is consumed in Europe and the former Soviet Union.

It is clear that Africa and the Asian areas largely fall outside of this global supply/demand relationship, yet the demand for petroleum is very real and much at the forefront of each of the national leader's minds in this rapidly growing and developing area. Before going on to describe what changes are likely to occur in these relationships in the future, it is useful to take a look at how much of a supply of petroleum there is in the world. Figure 3 shows that the known supply of oil and gas in the world today,

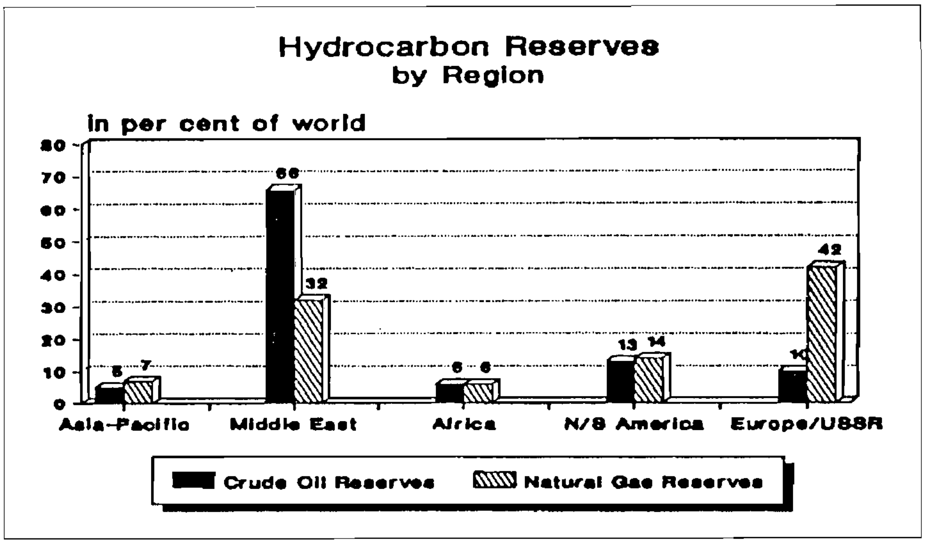

Figure 1: *Hydrocarbon reserves by region*

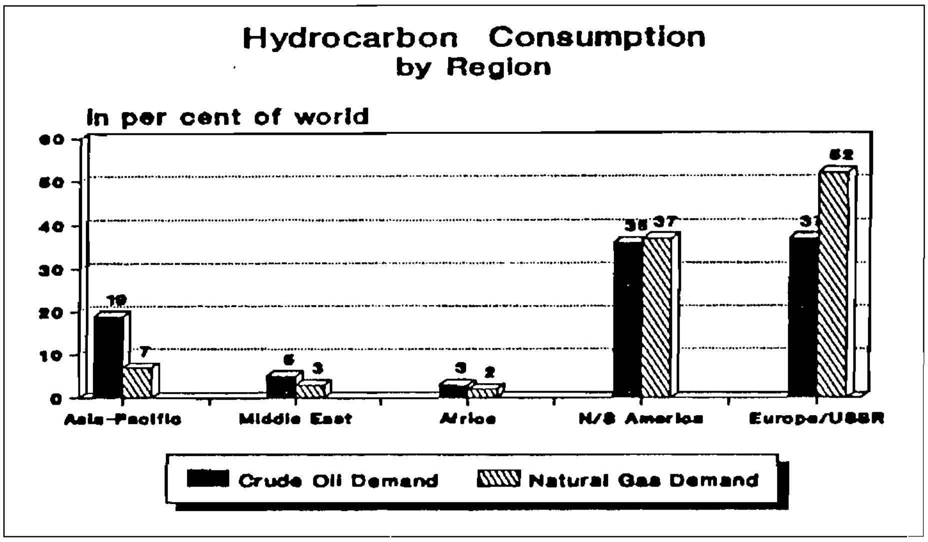

Figure 2: *Hydrocarbon consumption by region*

as expressed in terms of years of consumption, is based on today's rates of usage. Even if no other exploration well is drilled, it is clear that the world is not running out of oil. There are forty years' worth of consumption remaining to be supplied to the users as can be seen in Figure 2.

Inasmuch as the supply side is clearly not in danger of disappearing, it is perhaps more beneficial to look at the demand side. Figure 3 examines the forecast for growth of demand during the period 1989-93. It is readily apparent that the industrialised world's demand for petroleum is growing at the relatively low rate of one to two percent per year, including Japan, at the end of this forecast period. Even with the best of intentions, it is unlikely that these modest growth rates will be reduced appreciably through conservation, more efficient usage of energy, or other means. These nations, in sum, will continue to consume the vast majority of the world's known supplies of oil.

Turning to the developing nations, it is intuitively apparent that no action on their

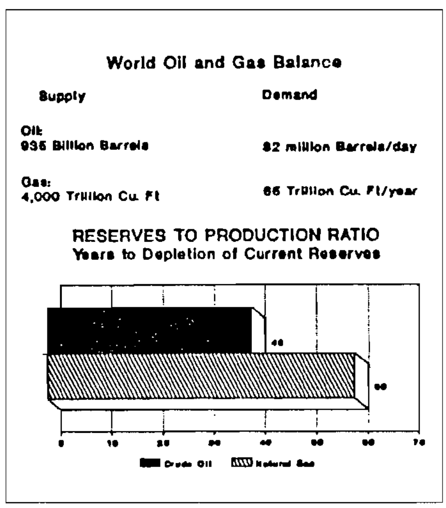

Figure 3: *World oil and gas balance*

part will appreciably affect the consuming habits of their industrialised brethren. It is equally apparent that the developing countries will increase their rate of consumption at rates in excess of four percent per year - a natural outcome of early stages of development normally associated with the urbanisation and industrialisation processes.

The only reasonable conclusion that may be drawn from the foregoing is that the developing countries will have to develop their own source of supply with respect to petroleum, as the entire world is perilously dependent on Persian Gulf oil supplies. To do this requires expertise and a financial capacity which most countries are unable to provide. Other measures must be taken to obtain the services of the international oil industry, which does have these capabilities.

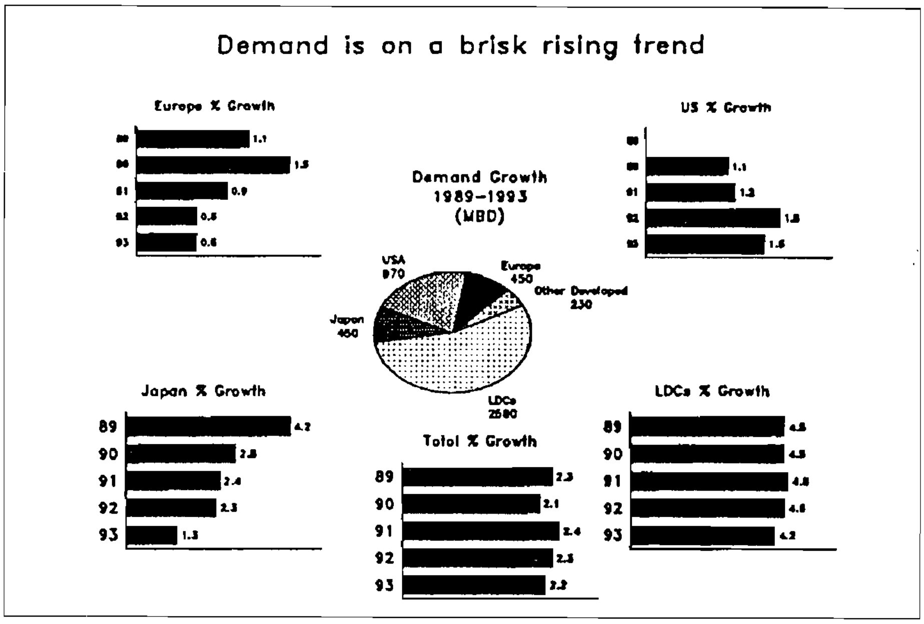

Figure 4: *Demand growth 1989-1993 (million barrels/day)*

Petroleum exploration promotion projects: A review

In response to the energy crisis of the 1980s, the World Bank spearheaded a petroleum development programme aimed at increasing exploration activity over a number of countries - particularly in Africa, which was severely hit by sudden increases in the prices of hydrocarbons.

Petroleum development projects were primarily designed to bring the exploration potential of a country to the attention of the petroleum industry and to encourage active industry involvement in the research required in the exploration programmes in these areas. These projects often also re-examined the petroleum-related contractual terms and economic conditions of the country to ensure that they were competitive with other exploration areas of the world. At times, the projects assisted in the development of governmental institutions which would be competent to deal with the petroleum industry, in order to provide an attractive investment climate for companies. The overall project objective was to induce the petroleum industry to enter into active exploration in these countries. This was accomplished by attempting to reduce the industry's perception of the inherent technical, economic and political risks which were believed to be present in these areas.

Close to forty of these promotional projects have been undertaken, nearly two-thirds of which have been in Africa. The bulk of such activity concentrated on higher-risk, unexplored "frontier" basins, where the petroleum industry was otherwise unlikely to enter into exploration commitments.

A detailed study of the effectiveness of these programmes was undertaken in Sub-Saharan Africa. Although the petroleum sector has benefitted in almost every case through improvements in petroleum legislation, contractual terms and technology transfer in the area of staff training, the results have been mixed when viewed in statistical terms. Contractual work obligations undertaken by companies wishing to explore in these countries as a result of these promotions have ranged from zero to a maximum of US$350 million in the case of Madagascar, and US$100 million in Kenya. As noted in the following graph (Figure 5), average resulting work obligation benefits obtained from these efforts averaged a low 1:3,36 cost-benefit ratio (with some 10 percent achieving high impact and the rest just breaking even).

Survey of the key players

Oil Companies and Consulting Industry: In the light of these results, a market survey of oil companies utilising these petroleum promotional products was undertaken. The most significant result of the survey was the observation that oil companies found that, to be industrially useful, a comprehensive study of an entire

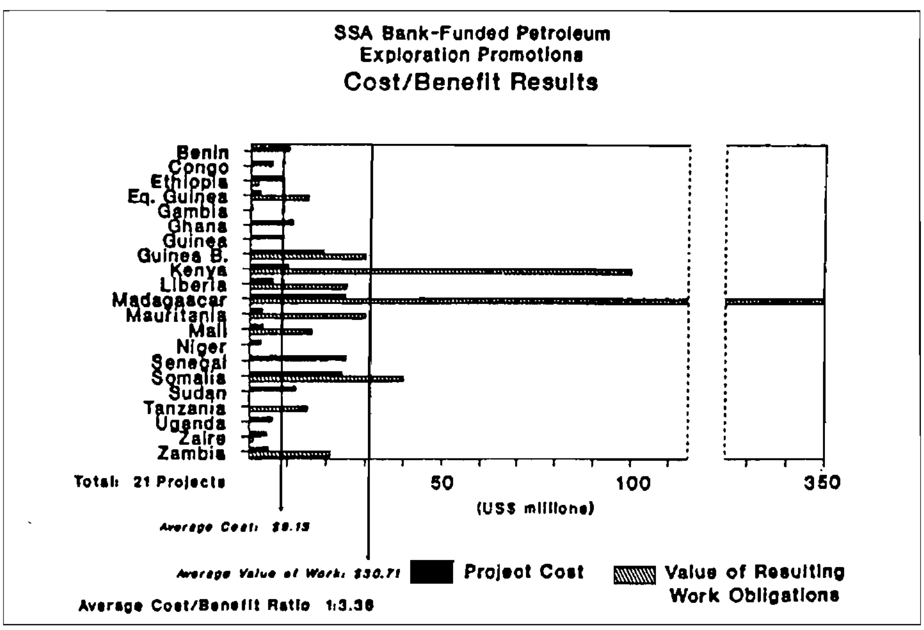

Figure 5: *SSA Bank-funded petroleum exploration promotions: Cost/benefit results.*

basin was required - rather than details in individual countries.

As most African countries contain portions of one or more prospective sedimentary basin, the market survey results strongly suggested that a multi-national basin exploration promotion would be more effective than would a series of country-specific promotions in the same basin. The petroleum technology employed in the study, although not state-of-the-art, would be, nevertheless, that which is conventionally utilised by the oil industry. This inevitably has ramifications for regional co-ordination, governmental involvement not normally present - with consequent dampening of the industry's interest in exploration investments.

In retrospect, it became apparent that, with respect to the individual country-specific exploration promotion projects, the Bank had targeted the wrong consumer. The promotional efforts had been focused on the requirements of the governments to whom the loans were made, rather than those of the petroleum industry, which is the user of the project's outcomes.

Following the selection of the Red Sea as the prototype area for a pilot regional promotion, thirty-four oil companies and consulting institutions were interviewed in depth, to obtain their views on the basin and its exploration potential. Some 88 percent of those interviewed were positively inclined towards multi-entity participation and to World Bank involvement in assisting in such process - even though this implied significant opening of information in the very company-specific and proprietary conceptualisation stage of exploration. Moreover, the highly supportive response was broad-based and equally distributed across all types of companies.

In the case of the Red Sea basin, specific concerns were found to be common to nearly all companies interviewed regarding: (i) *data availability*, particularly where existing analytical results are often outdated because of the rapid evolution of exploration technology, and the information is spread among the countries concerned; (ii) *technical and economic risk assessment,* mainly associated with the prospects of the basin having the type of rock geochemistry that would hold oil-fields that could be of commercial value; (iii) *political risk assessment,* where the governments of the basin have differing reactions to petroleum industry negotiations; and (iv) the loss of *corporate memory*, resulting from broad dismissals (following oil price declines) of their knowledgeable senior technical staff familiar with the region.

Governments: The interviews in seven countries which share the basin were focused on developing an understanding of the relevant agencies' interest in such a project, their views on its usefulness, and their requirements as to their involvement in the project.

Initial governmental reactions to the project proposal were that the databases were viewed as national assets, with considerable monetary value. Arrangements would thus have to be worked out to realise the value of such information in return for the provision of their data to the project. The main concerns were: (i) the *data condition* and the need for assistance in its retrieval and organisation: (ii) *ownership of information* while allowing conclusions derived from the study to be widely disseminated to increase exploration interest; (iii) appropriate *confidentiality arrangements* whereby no company could appear to receive preferential access to the data, nor could data confidentiality be compromised; (iv) *access to the project technology* and its transfer to the governments was insisted on as an integral part of participation; (v) absence of proper and operational *working relations among countries,* a number of which had conflict with one another. In sum, the initiative was viewed by the authorities concerned as a venue where they could meet and informally discuss issues of mutual economic interest, under a proper technical framework.

"As most African countries contain portions of one or more prospective sedimentary basin, the market survey results strongly suggested that a multi-national basin exploration promotion would be more effective than would a series of country-specific promotions in the same basin."

Other Parties: To fund such an experiment, donors had to be sought who could guarantee the neutrality of the work and the mobilisation of the best possible know-how from wherever necessary. This was secured through agreements with the United Nations Development Programme, and bilateral ***donors*** willing to allow the use of resources in this manner. All parties felt it necessary to associate a multilateral organisation with technical, operational and financial credibility to act as executing agency for the project, and to assure the necessary transparency and neutrality. Similarly, both governments and oil companies wanted to assure the scientific integrity and coherence of the project, and to ensure that the most up-to-date and relevant techniques and methodologies were mobilised. This called for an involvement of ***academic institutions*** in selective areas and the appointment of advisors of international stature to ensure quality control of the technical aspects of the initiative.

Reconciling stakeholders' objectives: A new approach

Project Concept: To reconcile the specific industrial and governmental requirements, involving the introduction of new parties to the process, a two-track project development scheme was put in place. This consisted of the establishment of a work station in Cairo, which was manned by consultants and technical experts under whose direction most of the collection, integration and common archiving of basin-wide data sets were undertaken. This work was accomplished largely through trainees supplied by each government.

The second track involved the undertaking of a highly sophisticated analytical study of such data in European consultants' laboratories. Focused technical analyses and evaluations of areas that were specified during the pre-project interviews as being of particular industrial interest were undertaken, utilising the subsurface, well-cuttings data in particular for these studies.

The two sets of work output were integrated at the Cairo work station

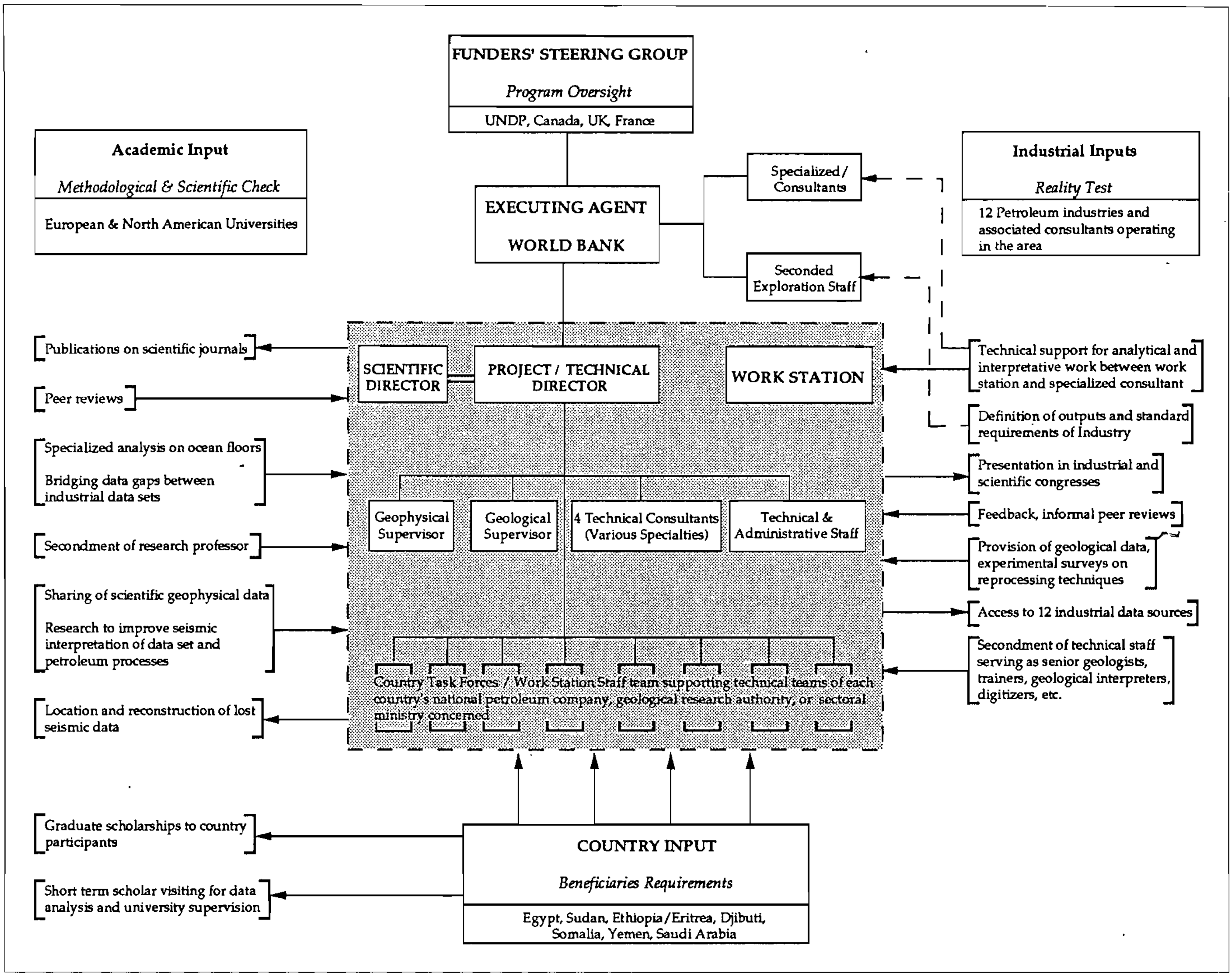

Table 1: Project inputs and the key players involved

throughout the duration of the project, as conclusions became available. The results derived from the overall project work involving both the Cairo and European results have been published in international scientific journals. The two tracks enabled the interventions of the countries' industrial donors and academic inputs to be provided in their areas of competencies, is shown schematically in Table 1.

Work Station and Task Force: Each governmental task force sequentially brought its data set to Cairo to work directly on it. Where data were missing from the governmental files, duplicates were obtained for the project from the companies which originally acquired the data. Literature searches were undertaken for each country and scientific research data incorporated into the study. A total of 107,4 man-months of hands-on training and technology transfer occurred in this fashion over the period.

More importantly, in contrast with traditional assistance approaches to projects, where consultants provide technical support as self-contained products, normally in the form of data processing and analysis, in this case the focus was hands-on training of task force personnel. The supervision work involved individual instruction for each task force member on the techniques of data manipulation, computer storage, integration, interpretation, digitalisation, archiving and report writing. The ensuing task forces' outputs were regionally integrated and forwarded for detailed analyses in European technical laboratories.

Specialised Analytical Studies: The oil companies, on the other hand, were concerned with the analytical evaluations of the basin's capacity to generate oil rather than gas, where this capacity was located within the basin, and how it related to the reservoir rocks in which the newly-generated oil would be entrapped. To address these concerns required the services of highly specialised consulting companies, most of which were established in Europe. As it was impractical to have these laboratories and their personnel moved to Cairo so that the work could be undertaken within the region, these studies were undertaken in Europe, and concentrated on cutting edge technical analyses.

Technical Reviews: Following each task force's stay in Cairo, a two-day project technical meeting was held. These were attended by the task force members, each of the governmental representatives, the project management, staff, consulting experts and donors. The purpose was to review the results, integrate them into the previous work, and discuss the direction of future work. Decisions were all made by consensus. The resulting transparency of process contributed materially to the continued success of the project.

Integration of Project Results: The subdivision of work between Cairo and the European laboratories created two separate outputs. The external shape of the sedimentary envelopes was developed by the Cairo-based task forces utilising the seismic data. The analytical study of the contents of each of these envelopes was undertaken in the European laboratories, utilising the well cuttings and surface outcrop samples.

The integration of these two components was an iterative process, with the results available at the time presented at each of the Cairo project meetings. The analytical results and their interpretations were presented as reports to each of the participating countries, and were updated as new data were obtained. An integrated report of the entire data set was written by the project staff and also submitted to each country. Near the conclusion of the project, a regional chapter was written, describing the general geologic setting of the basin, and this was included in each country report.

Peer-review: Each of the reports supplied to the participating countries was extensively reviewed through a rigorous internal peer-review process. The major findings of the project have been published in peer-reviewed scientific journals to insure scientific accuracy and acceptance by the international petroleum industry. By the same token, abstracts of this work were published in technical journals. These journals are read by the majority of technical and managerial personnel in the oil industry, who were targeted as the principal users of the outputs.

Outcomes of the new approach

The project has been a success, particularly from both the industrial and governmental perspectives. As can be observed in Figure 6, contracts for areas under active exploration started to increase significantly since project execution. The arrangements provided the required transparency of process in the separation of governments and the petroleum industry, yet allowed the two sides to productively interact. This role cannot be effectively replicated by either consultants or representatives of the industry, both of whom have commercial motives underlying their efforts.

Industrial reaction to the project's peer-reviewed results has been uniformly favourable, with expressions of interest as to where this multinational project concept may be applied elsewhere. The outcome of the project was remarkably positive:

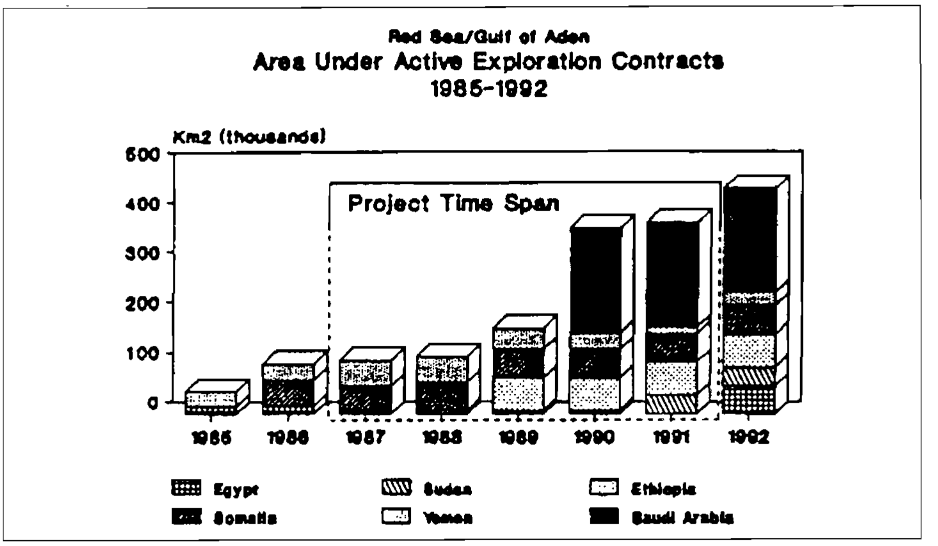

Figure 6 *Red Sea/Gulf of Aden: Areas under active exploration contracts: 1985-1992*

— Industrial activity increased at the rate of 700 times the cost of the initiative - or more than 200 times the same ratio in traditional Bank petroleum development projects, as can be seen in Figure 7.

— The mobilisation of cutting edge scientific and academic knowledge to analyse the conditions of the area led a fundamental reinterpretation of geological potentials in the basin.

— Upgrading technical staff to better equip the concerned countries to deal with the oil industry proposals and their results.

— Regional co-operation between the concerned governments improved, with a strengthening of the agencies involved.

— Technical data, their codification, organisation and accessibility to the industry were enhanced.

— Donor activity has been effectively mobilised and focused on experimentation and development of new approaches.

Other prospective areas in Africa for regional hydrocarbon assessment projects

The results in the Red Sea survey are generating interest to replicate the project in other parts of the world. The criteria for selecting such projects lie in the large-

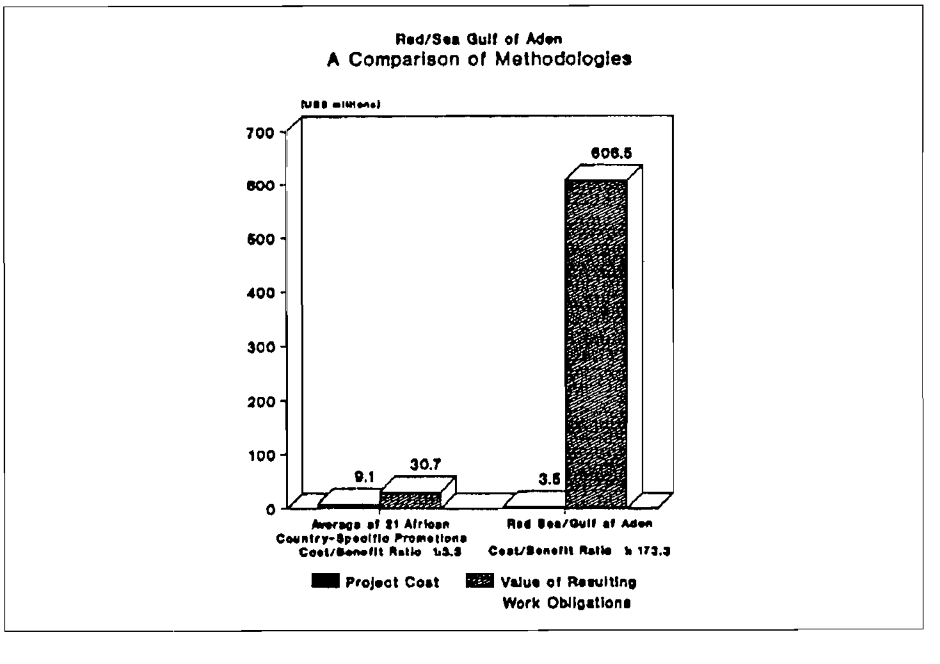

Figure 7: *Red Sea/Gulf of Aden: A comparison of methodologies*

scale geology encompassed in this area, which relates to the very origins of the continent. Areas which appear to be amenable to such a holistic investigative approach in Sub-Saharan Africa are:

— West Africa, from the Niger delta to Senegal, in which Africa appears to have separated from South America. The clues along the continental margin relating to this event are subdivided among ten nations, and thereby lost in the clutter of separate, self-contained data sets;
— The Rift Valley, in which the present continent of Africa appears to be slowly pulling apart, splitting into two separate continents. Abundant data have been acquired from the lakes which are prominent in this feature, but little is known of the interlaken areas. Yet, all evidence points to the requisite source and reservoir rocks for the generation and entrapment of petroleum being present, if only the clues could be assembled in their appropriate order; and
— The East African Passive Margin, from the Horn of Africa in Somalia down to Maputo, where the Indian subcontinent, accompanied by the platelets of Madagascar, the Seychelles and Mauritius separated from the ancestral African continent. As with the Rift Valley, there are abundant clues as to how this continental-scaled feature occurred, and where the appropriate components for petroleum accumulation are to be found, but they must be compiled, examined in their totality and evaluated as a composite body of information, before the clues can be put together into a meaningful set of petroleum exploration plays.

A sense of regional geologic backdrop, against which each country may focus its individual petroleum plays is lacking. Although industrial interest is increasing somewhat, much remains to be done. A great deal of individual country effort has gone into national promotion. Based on the hard evidence resulting from the Red Sea, it would appear that much more can be gained by expanding these existing works into a regional framework.

The benefits of such efforts will go well beyond the technical aspects to include significant technology transfer and technical training using national data to focus on national problems through the medium of on-site international expert supervision of national staff. Regional institutions will be strengthened, for example, local universities and other institutions of higher learning will benefit from the increase in scientific interest in the region, and it is likely that a permanent research station would be established to continue the work following the end of the project.

Concluding reflections

Three areas should not be overlooked in the intricacies of petroleum development. First, much of the economic literature dealing with the subject relates to one issue: the establishment of more investor-friendly enabling environments. By concentrating on policy and regulatory issues that ultimately impinge on the profitability of ventures, the approaches assume *ceteris paribus* - all things being equal. In the process, they ignore complex interactions of investment decisions with technological development, jurisdictional and proprietary issues. Yet these factors have a powerful influence, particularly in the more upstream and research-oriented-type ventures. Looking at the participatory-based approach in the Red Sea, it is hardly an exaggeration to state that organisational arrangements enabled factors of production and institutions to interact amongst themselves, and that they can play as important a role as the policy environment *per se*. It should thus come as no surprise that the impressive results in the Red Sea took place in the face of the lowest level of petroleum prices in a whole decade and considerable political conflicts in the area at the time.

> **"By looking at the data through different eyes, a quantum leap in the understanding of basin development and its role in petroleum generation has been achieved."**

Secondly, one often forgotten concern relates to the mobilisation of state-of-the-art science, which is advancing at a surprising pace, and transfer of know-how. Today, accumulated geological information can be "re-read" and "seen" in an entirely new light - thereby saving considerable resources in new drillings and other major investments. Innovative scientific thinking has been applied to the existing data in ways not previously used in such a comprehensive fashion. Old data have been re-examined in the light of modern thinking; the signal-to-noise ratio has been dramatically improved through improved understanding of the story which the data has to tell. By looking at the data through different eyes, a quantum leap in the understanding of basin development and its role in petroleum generation has been achieved. Its effect has been as dramatic as that of the development of the compact disc over the vinyl phonograph record, or the fax machine over the telex. The depth of comprehension that has resulted from looking at all the data in the same holistic manner has been truly breath-taking from the points of view of both petroleum exploration and scientific endeavour. More broadly, the know-how is increasingly becoming a factor of production, just as capital and labour was a decade ago. For a region so detached from know-how development such as Africa, this poses special problems[3]. Under the circumstances, the organisation of this know-how needs to overcome constraints and safeguard the interests of all parties concerned.

Finally, with the transition of economies to a more global and technologically-driven world where information and innovation are pivotal resources, the development of new approaches to mobilise the necessary know-how become critical. For a long time, traditional approaches were based on hierarchically differentiated inputs based on the simple, essentially repetitive, efforts of each party concerned. Where new approaches need to be established among different parties, holding different elements of a project resolution, and more open, interactive modes of operation are needed. Seen in this light, the survey described in this article, particularly its organisational and quality control features, can be seen as a prototype for transferring know-how in a way that is acceptable to key players in the industry and countries concerned. More importantly, the substantially greater outcomes of the projects over traditional approaches can be attributed to the design and execution features of the initiative, which placed key shareholders in the pilot's seat, so to speak - thereby responding to their specific needs. The resulting approach, a cross-breed between the traditional project and technical assistance, could be the forerunner of the new type of products the Bank could provide to respond to the changing problems developing countries face.

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Thermonuclear fusion: An energy option for the future

*J A M DE VILLIERS

Future energy options are limited due to adverse associated environmental effects as well as finite resource availability associated with most classically established power generating methods. It is essential to look for other options which should have sustainability and more acceptable features. Thermonuclear fusion, for a long time almost an elusive dream, could very well become such a reality in the next century. This paper gives an overview of fusion starting from the basic nuclear reactions and proceeding through to conditions required for energy extraction in a controlled way. The two main approaches, magnetic and inertial confinement, are briefly reviewed with the emphasis being placed on more recent achievements and expectations for longer-term applications.

A contribution to international developments in the field of fusion has been provided by an in-house fusion research programme at Pelindaba. A brief report on the achievements of this programme is given, followed by concluding remarks on a possible future scenario for the Sub-Saharan region.

Keywords: nuclear fusion; Tokoloshe; tokamak devices

Introduction

Energy is the principal driving force of human technological endeavour. It is well known that the limited quantity and distribution of currently available energy sources will adversely influence future development. More seriously, converting basic sources on a large scale to a usable form impacts dramatically on the environment. Problems like global warming, toxic and unmanageable radioactive wastes are real despite advances toward solutions over a wide front. It is not surprising that the public at large is becoming more and more concerned about safety, health hazards and the general quality of life. An alternative, more benign, future energy option is becoming a necessity which cannot be ignored. Energy derived from thermonuclear fusion has many inherently attractive features which may fulfil these needs provided its development can be completed timeously.

The idea that thermonuclear fusion reactions between hydrogen nuclei, or protons, are responsible for the sun's copious energy, dates back to 1929. From then on, mankind envisioned the harnessing of this energy source on Earth. Unfortunately the reaction rate for protons proved to be much too slow for use in any conceivable confinement scheme but the stars. The two other hydrogen isotopes, deuterium (^2H or D) and tritium (^3H or T), are much more attractive candidates, but formidable problems remain. Fusion reactions between these isotopes and some other possibilities are as follows:[1]

$$D + T \rightarrow {}^4He + {}^1n + 17{,}6\ MeV$$

$$D + D \rightarrow {}^3He + {}^1n + 3{,}3\ MeV\ (\sim 50\%)$$

$$D + D \rightarrow T + {}^1H + 4{,}0\ MeV\ (\sim 50\%)$$

$$T + T \rightarrow {}^1n + {}^1n + {}^4He + 11{,}3\ MeV$$

$$D + {}^3He \rightarrow {}^4He + {}^1H + 18{,}3\ MeV$$

$${}^1H + {}^6Li \rightarrow {}^4He + {}^3He + 4{,}0\ MeV$$

With the total mass of the reaction products typically less than that of the reacting nuclei, the difference is released as energy as indicated for each reaction shown above.

Fission of heavy elements is the opposite of fusion, energy also being released in that process involving the splitting of a heavy nucleus into two medium mass fragments. This is because the average mass/nucleon is high for both the light and heavy nuclei with a minimum at a medium atomic mass number around 50. After Fermi's demonstration of controlled fission in December 1942 and the subsequent uncontrolled fission bomb explosions a few years later, it was realised that fission itself could be used for creating the extreme conditions required by fusion. History proved this viewpoint right through the first so-called hydrogen bomb explosions. The very fact that the feasibility of fusion was first demonstrated starting from uncontrolled explosions, rather than the other way around as for fission, underlined the inherently more difficult conditions required for this process.

High temperatures are necessary for thermonuclear fusion reactions to take place. This is required for the positively charged, mutually repelling nuclei to approach each other close enough in collisions to react. In terms of the Maxwellian-averaged cross-sections, the (D,T)-reaction is by far the best one to aim for. At temperatures of 10^8 K (~10 keV), reaction rates would be one to two orders of magnitude higher than for either of the two (D,D) or the (T,T)-reactions, and even more for the other two listed reactions. The (D,T)-reaction has several disadvantages. Firstly, the very high energy neutrons (14,1 MeV) generated, may rapidly damage the first wall of confinement devices if conventional materials are used and they also render surrounding structures radioactive. Secondly, only 20% of the total energy is carried by the α-particle for heat deposition inside the reaction volume to sustain a fusion burn condition. Lastly, the reaction not only needs D, which is abundantly present in nature, but also T, which is extremely rare. It is, however, envisaged that T will be bred quite efficiently through both the $^6Li(n,\alpha)T$ and $^7Li(n,n',\alpha)T$-reactions while at the same time thermalising the neutrons for utilisation of their energy in the form of heat through conventional exchangers. The (D,D)-reactions are obviously important for testing purposes and also considered an attractive future possibility because no T is required and neutron energies are lower. The last two reactions listed also fall into this category since the reaction products consist of only charged particles which may be utilised directly for power production.

At the high temperatures needed for fusion, matter exists in plasma form. Briefly, a plasma is an ensemble of charged particles which is globally neutral. It exhibits the typical characteristics of gases and fluids but is, in addition, also subject to electromagnetic interactions. Plasmas are plagued by a whole host of possible instabilities depending on the prevailing conditions. For example, a current-carrying plasma is

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inherently unstable without an external stabilising magnetic field. Such a field, if strong enough, provides tension to inhibit the deformation of the plasma column through self-pinching, kinking or flute formation (the so-called m=0, 1, 2, 3, ... instabilities). Also, in general, as is found in fluids, a high density plasma cannot be supported by one of a lower density when a force is present in this direction (Rayleigh-Taylor (RT) instability).

Fusion conditions

Following Dolan[2], the average energy density for a thermal fusion plasma can be written as $3n\theta$ where it is assumed that electron and ion densities and temperatures are approximately the same and equal to n and θ respectively, with the latter expressed in joules. It is also assumed that the impurity and the α-particle densities are both much less than the fuel ion densities. At equilibrium condition one finds

$$P_{ext} + P_{\alpha} = 3n\theta/\tau_E + P_{rad} \quad (1)$$

where P_{ext} represents the total external plasma heating power density, P_{α} the contribution to heating by α-particles, τ_E the non-radiative energy confinement time and P_{rad} the radiative power density loss. For steady state conditions the fusion power gain ratio is given by

$$Q = P_f/P_{ext} = P_f/(3n\theta/\tau_E + P_{rad} - P_{\alpha}) \quad (2)$$

where P_f represents the total fusion power density. Solving for $n\tau_E$, one gets

$$n\tau_E = 3n^2\theta/(P_f/Q + P_{\alpha} - P_{rad}) \quad (3)$$

The foregoing shows that, in addition to a high temperature to enable fusion reactions, the plasma density must be sufficiently high and/or the energy confinement time long enough for significant fusion gain. The latter two parameters can be varied independently as long as the product $n\tau_E$, called the Lawson criterion or confinement quality, exceeds a minimum value depending on the reacting nuclei. For the (D,T)-reaction it is required that $n\tau_E \geq 10^{20}$ m^{-3} s at 10 keV, or more stringently in terms of the so-called fusion performance parameter, the triple product $n\tau_E \geq 10^{21}$ m^{-3} s keV. Here it is assumed that the system efficiency is ~30% and that losses occur through electron radiation only, which implies that the effective or average charge of ions in the plasma $Z_{eff} \sim 1$. Equation (3) shows with large P_{rad} the denominator becomes negative, implying that there will be no value of $n\tau_E$, even if $Q \rightarrow \infty$, where the power balance condition could be satisfied. Even small amounts of impurities cause rapid cooling of the plasma through spectral line radiation and also adversely affect both n and τ_E. A few percent in total of the lighter elements can be tolerated but only about 0,01% of heavier elements, like tungsten, could inhibit fusion burn.

An important way to achieve the required conditions for fusion is to keep the hot plasma away from the material walls of a container by using magnetic fields to order the random movement of the charged plasma particles (Figure 1). This approach is called magnetic confinement fusion (MCF). Many magnetic configurations with promising features have been looked at thus far with varying degrees of success. An important milestone for MCF is to achieve a fusion gain Q=1 which is called breakeven. Here plasma densities are typically $n \sim 10^{20}$ m^{-3}, which is a fairly good vacuum compared to air density of approximately 10^{25} molecules m^{-3}. Such a low density implies only a few milligrams of fuel. To achieve the minimum value of $n\tau_E$, energy confinement times should be rather long ($\tau_E \sim 1$ s). A fusion gain Q~30 is envisaged for a typical MCF-reactor under steady burn conditions.

"An alternative, more benign, future energy option is becoming a necessity which cannot be ignored. Energy derived from thermonuclear fusion has many inherently attractive features which may fulfil these needs provided its development can be completed timeously."

A second approach, which differs dramatically from MCF, is inertial confinement fusion (ICF) which goes to the other extreme to achieve good confinement quality. Here, for practical reasons, very high densities and thus very short energy confinement times are needed (typically $n \sim 10^{31}$ m^{-3} and $\tau_E \sim 10^{-10}$ s). The compression of small pellets (mm dimensions or smaller) to densities about 1000x higher than that of solid hydrogen is achieved by means of beam irradiation. These beams cause rapid surface ablation which leads in turn to an inwardly directed inertial force (Figure 2). Here the most important fusion performance parameter is the areal density ρr of the fuel pellet, where ρ and r are the compressed density and radius respectively. It is estimated[3] that $\rho r \sim 0,2$ g cm^{-2} is equivalent to MCF's breakeven $n\tau_E$. However, in practice this is not sufficient, since factors of 10-20 and 3-20 respectively, due to low implosion and driver efficiencies, have to be overcome. These obstacles will largely be compensated for by a high burn efficiency yielding Q>100 through fuel compression to $\rho r \sim 3$ g cm^{-2} prior to ignition. This will limit the required target mass and also bring the

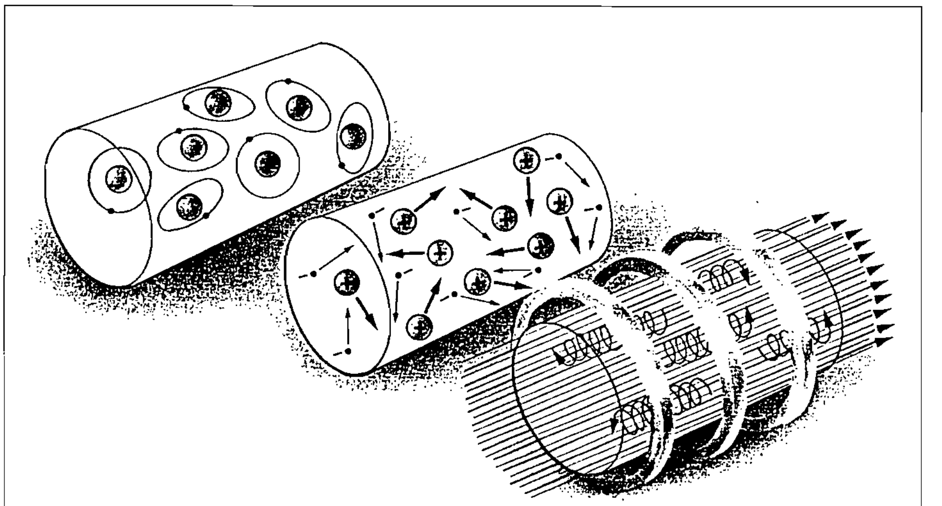

Figure 1: From left to right is shown a neutral gas, an ionised plasma, and the ordering of plasma particles in an axial magnetic field.

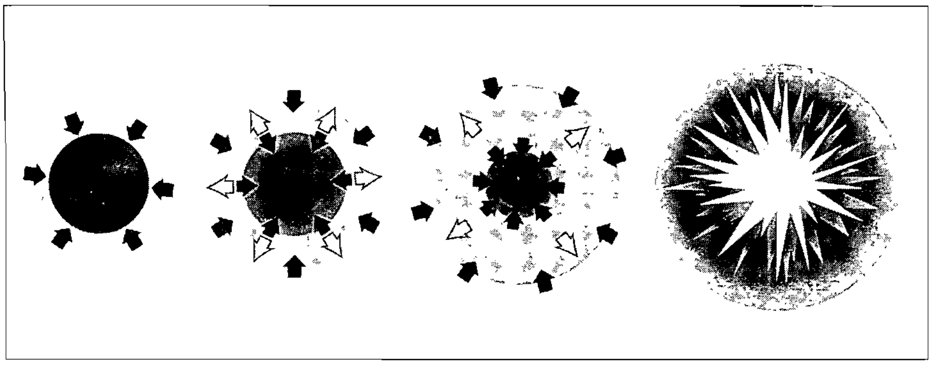

Figure 2: In ICF an initial plasma forms under intense beam irradiation of the pellet which leads to surface ablation (left). The resulting inwardly directed inertial force compresses the fuel to very high densities. Finally, ignition starts from the centre and expands outward.

total driver energy down to acceptable low MJ-levels but requires an absolutely symmetric beam impact pattern in both time and space over the entire implosion phase. It is envisaged that a 5 mg spherical (D,T)-shell will be compressed to typical plasma densities $n \geq 10^{31}$ m^{-3} in about 10^{-8} s after which a central hot spot at $\theta \sim 10$ keV should ignite and be followed by an expanding burn lasting about 10^{-10} s through α-heating of the dense shell. The process has to be repeated at ~5 Hz for a typical 1 GW reactor and with the force per micro explosion equivalent to about 250 kg conventional explosive, special shock absorbing techniques will be required to protect the container walls and energy extraction will be complex.

Progress in magnetic confinement fusion (MCF)

The early fifties were marked by classified MCF research activities with different confinement devices in many countries. The situation changed completely at the Second Atoms for Peace Conference in 1958 where the foundation was laid for international collaboration. Interestingly, in the same year, British scientists dramatically announced the observation of fusion neutrons from (D,D)-reactions in experiments with their toroidal pinch device called ZETA[4]. However, it was realised subsequently that instabilities caused by the self- pinching of a current-carrying plasma column rather than thermal reactions, caused the neutron emission. In the U.S.A. another type of toroidal device called a stellarator, was the favourite. In this device, a set of toroidal magnetic field coils, as well as a set of helical windings, define the confining field. The plasma itself carries no current at all which makes it essentially a DC-device, but it requires external heating systems. In the former U.S.S.R. a completely different approach was taken with yet another type of toroidal device called a tokamak (an acronym which roughly translates to "toroidal magnetic chamber"). In this device, a plasma current pulse is induced through an external primary transformer winding closely coupled to the secondary, which is a barely ionised plasma ring (Figure 3). Rapid ohmic heating takes place to temperatures of about 2 keV depending on the available flux swing. However, at these temperatures plasma resistivity becomes too low for efficient further ohmic heating so that additional external heating systems are also required. An important second function of the current is to establish a poloidal magnetic field which, together with the toroidal field, defines a helical magnetic confinement configuration.

The tokamak concept attracted a lot of attention at the Novosibirsk Conference[5] of the International Atomic Energy Agency (IAEA) in 1968. At that time, as was subsequently confirmed, scientists at the Kurchatov Institute achieved a fusion performance parameter $n\tau\theta \sim 2 \times 10^{17}$ m^{-3} s keV with a tokamak called T-3. This was a very significant improvement over previous results obtained with a variety of other devices. From that time on, with additional incentive provided by the energy crises of the early seventies, tokamaks became very popular worldwide for MCF research. Even at present, tokamaks are still leading contenders with about 80 in use with different features and sizes[6]. Of these, the Joint European Torus (JET), a joint undertaking by the European Union and situated in the U.K., is the largest. It has minor radii of 1,25 m horizontally and 2,10 m vertically and a major radius of 2,96 m. Plasma currents range from 5-7 MA with a total external heating power capability

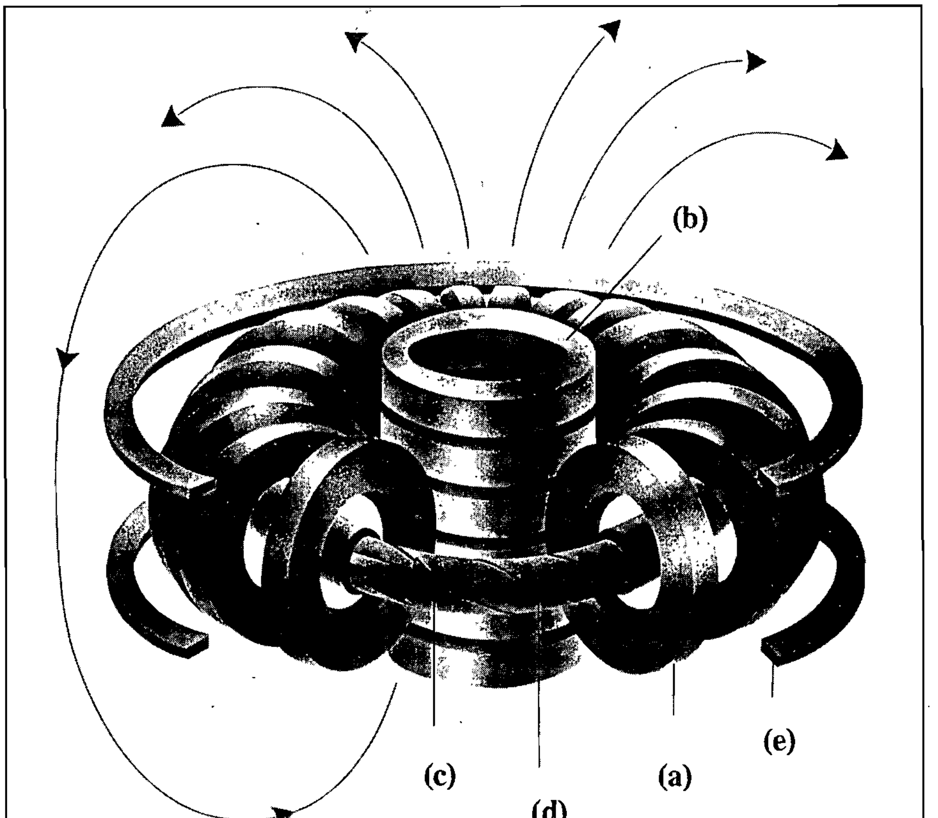

Figure 3: A schematic of a tokamak showing the main components: The toroidal field coils (a), the primary transformer (b) to induce the plasma current (c) resulting in the helical confining field (d). An overall vertical field defined by another set of coils (e) is used for plasma column equilibrium.

of ~50 MW. The popularity of tokamaks does not mean that other approaches to MCF are being neglected. On the contrary, there are about 20 stellarators, 30 magnetic mirror machines, 50 pinches of one kind or another, and even more of a variety of other configurations in current use[6]. Most devices are small in size and dedicated more towards basic research than obtaining good performance parameters. Only a few stellarators (most of which are due to become operational soon) and a significant number of existing tokamaks fall in the latter category.

Tremendous advances have been made over the past 2-3 decades towards a better understanding of the underlying physics around MCF through studies of its theory and experiments with a large variety of devices[7][8]. This is particularly true for tokamaks where an improvement of the performance parameter of about four orders of magnitude has been realised. Briefly, these advances in a number of different areas are summarised as follows:

(i) Confinement

Earlier experimental results showed a degradation of confinement with increasing heating power but a number of newly discovered operating regimes proved to be 2-3 times better. Among these are the so-called H-mode characterised by steep gradients in the edge density and temperature profiles, hot ion mode where ion temperatures exceed that of electrons, and strongly peaked density profile modes achieved through the injection of frozen D-pellets. A record-breaking energy confinement time[9] of 1,4 s has been achieved with JET, but only at very low heating power.

(ii) Plasma purity

Since an influx of impurities deteriorates performance, it was customary to prepare vacuum chamber walls through vigorous discharge cleaning and/or Ti-sublimation prior to regular tokamak discharges. Newer techniques include the protection of the first wall and plasma-facing components with low Z materials, such as, C, B, or even Be. Modern devices are also equipped with so-called magnetic diverters, where the magnetic topology is such that the incoming impurities flow through narrow slits out of the main chamber and are absorbed on special plates. It is envisaged that reactors would need such diverters not only to get rid of impurities but also of accumulated He-ash.

(iii) Operation

The operational regime of tokamak discharges is limited by maximum values of the plasma current, density or pressure. Close to these limits degradation of confinement, fast growth of characteristic instabilities, or minor/major current disruptions may take place. The latter implies a vast energy dump on a short time-scale which may be disastrous in a big machine so that a better understanding of the detailed plasma behaviour is mandatory for safe operations.

(iv) Heating

Plasma heating technology is well advanced so that a number of options, or combinations thereof, can be chosen from. Adiabatic compression of the plasma column on time-scales shorter than the energy confinement time in the direction of either the minor or major radius, or both, is well proven. Neutral beam injection systems with output power up to tens of MW and energies to about 150 keV are commonplace. A record peak ion temperature[10] of about 35 keV has been observed on TFTR in the U.S.A. through the injection of 30 MW neutral beams at 110 keV. Plasma heating by means of electromagnetic waves at a number of characteristic resonant frequencies is also well understood and quite efficient. Frequencies range typically from the low MHz to the ~100 GHz region, and the output power of individual oscillators ranges from ~100 kW to a MW or more, depending on frequency. Certain beneficial synergistic effects have been observed through using two or more heating systems simultaneously.

(v) Current drive

Since tokamaks are inherently pulsed devices, it is important to find other means to maintain a plasma current in view of longer burn times for future reactors. Non-inductive current drive by means of wave heating has been demonstrated convincingly. In particular, a record 70 minutes has been obtained with wave heating at the lower hybrid frequency with a small tokamak called TRIAM-1M[11]. Also, the so-called bootstrap or self-current in tokamaks may be enhanced under certain conditions to provide a substantial 80% of the plasma current.

(vi) (D,T)-plasmas

On 9 November 1991, a dramatic press release from the JET team announced the first achievement of (D,T)-fusion in a magnetic confinement device. They chose a fairly conservative operating regime and studied a few discharges, injecting up to a maximum of 12% T into a pure D-plasma[12]. Through careful observation of relevant parameters including neutron energies and count rates, they concluded that up to 2 MW (D,T)-fusion power has been released in a 2 s pulse with a neutron emission rate of $6x10^{17}$ s^{-1}. Typical performance parameters ranged up to $9x10^{20}$ m^{-3} s keV. For the first time the gain factor has been measured in a (D,T)-plasma as Q_{DT}~0,2. Had the operating conditions and the gas mixture been optimally chosen, projections indicate Q_{DT}~1,1 could have been reached.

(vii) International Thermonuclear Experimental Reactor (ITER)

Since confinement quality scales roughly as volume, it became evident that bigger and better tokamaks are needed for further advances in MCF. This implies that costs are becoming prohibitively high for single countries or even regions so that the U.S.A., the EU, Japan and the former U.S.S.R. agreed to collaborate towards a common goal under the auspices of the IAEA. This saw the formation of a joint venture called the International Thermonuclear Experimental Reactor (ITER) Conceptual Design Activity (CDA) in April 1988. This study was successfully completed[13] by the end of 1990 and showed "the way to the stars"[14] with the overall objective to demonstrate the scientific and technological feasibility of the practical utilisation of fusion power. The main design parameters are summarised in Table 1. The projected construction costs were estimated at the time to be about US$5 billion. By mid-1992 a new protocol was signed by the main partners[15] to signal the start of the Engineering Design Activity (EDA) which, if successful, will take about 6 years to conclude before construction could start.

Plasma major radius R_0 (m)	6,0
Plasma minor radius a (m)	2,15
Elongation	1,98
Toroidal field on axis (T)	4,85
Maximum plasma current (MA)	22,0
Nominal fusion power (GW)	~1
Pulse length (s)	>200
Controlled burn gain Q	>30

Table 1: ITER principal conceptual design parameters

(viii) Reactor concepts

There are still a number of important scientific and technological questions around practical MCF reactors. These include α-heating, T-breeding, erosion and the detailed behaviour of plasma-facing materials under intense heat,

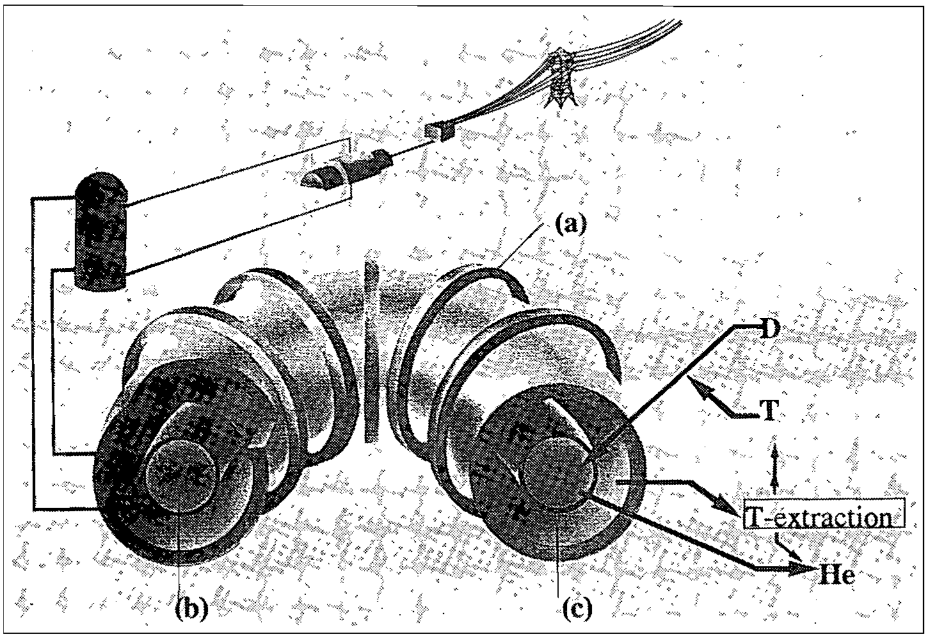

Figure 4: A schematic of a toroidal reactor, showing D and T (from an extraction system) used as fusion fuels with He being the waste product. The superconducting toroidal field coils are shown (a) with the burning plasma in the centre (b). Surrounding the vacuum chamber is the T-breeding and heat exchanging blanket and shield (c).

particle and 14 MeV neutron fluxes, low activation structural materials, remote handling in a rather complex geometrical environment, etc. Despite all these and other unknowns, conceptual fusion reactor designs have existed for quite some time[16][17] (Figure 4). More recent studies show enormous advances over a wide field[9][18][19]. A few examples are the following:

- MCF reactors could be designed with inherent passive safety even under conditions of worst case accidents which is in strong contrast to any fission reactor;
- Usage of SiC-composites for structural materials could make a fusion reactor 10^6 times less radioactive than a fast breeder reactor, after even one day, which would mean an acceptably low environmental impact;
- Through particular optimisation, both the plasma current and external heating systems could be about half as much as those planned for the ITER for a better fusion power yield;
- Wall erosion and power densities can be kept within tolerable levels;
- The projected cost of electricity compares well with that of advanced fission reactors and is about 30% higher than that for conventional coal-fired plants.

A small school of thought in the fusion community favours fusion/fission hybrids[20] as an important and necessary intermediate step towards a pure fusion commercial reactor since it would allow a valuable opportunity for technological optimisation. In a hybrid it is envisaged that fertile materials, like ^{232}Th or ^{238}U, could be used to breed fissile materials, ^{233}U or ^{239}Pu, by transmutation through neutron irradiation in a blanket surrounding the fusion reaction volume. The required gain could be quite low initially (Q~3) so that current MCF technology may almost be sufficient. A hybrid like this would not only be much safer than controversial fission breeders but could provide fuel for as many as 5-10 advanced fission reactors with improved safety features. However, the possible proliferation of nuclear materials with such a scheme is a serious inhibiting factor.

Progress in inertial confinement fusion (ICF)

It is a pity that large parts of ICF programmes have been, and still are, classified because of their close connection to weapons research, especially in the U.S.A. There are signs, however, that views are changing so that ICF's possible energy options for the future may become more evident to the community at large. Despite these hurdles, not enough is known to conclude at this stage that significant progress has been made since the early sixties when some research programmes were started in this field. The exceptional suitability of lasers, even small ones, to achieve a high irradiance for studies of laser/solid interactions enabled meaningful research. At present almost 50 such experiments[6] are being done with different kinds of lasers in an energy range from a few joules to the 120 kJ of the well-known NOVA Nd:glass laser system at the Lawrence Livermore Laboratory[21]. This system with its 10 beams can operate with pulse lengths of between 0,1 and 3 ns and in addition to its basic wavelength of 1,05 μm, operations at 0,53 and 0,35 μm are also possible at reduced energies. A more recent approach is the development of high-powered light ion beam pulsed accelerators as possible ICF drivers and about 40 devices of varying sizes are in use. The most well-known example here is the PBFA II at the Sandia Laboratory[21] with its 36 beams arranged around a target chamber. It is designed to accelerate 15 ns pulses of Li^+–beams to 30 MeV and delivers a total of 2 MJ. Heavy ion beam accelerators are also viewed as viable possibilities but only a few small systems[21] are in their early development stages at present.

The so-called HALITE/CENTURION classified programme[22] conducted in 1988 by the U.S.A. at the Nevada nuclear weapons test site, proved that an inertial fusion capsule can be imploded to give a high fusion gain. This put to rest any fears that it may not be feasible, and laboratory work is continuing with confidence.

Targets

Initially typical targets for ICF research consisted of glass micro balloons filled with solid, liquid or gaseous D. More recently, good results have been reported with thin-walled hollow spheres made of a low Z polymer foam and soaked in liquid D. These high aspect ratio targets[23] allow sufficient time for acceleration of the outer skin towards the central core. Target diameters range up to 1 mm and wall thicknesses are in the region 5-50 μm. It is realised that a high surface finish is required (smoothness ~1μm) to keep the development of the RT-instability within tolerable levels. More complicated targets, typically envisaged for ion beam drivers, consist of multiple layers with a high Z tamper like Pb on the outside to absorb the energy and contain the pressure, followed by a pusher of Al which would also shield the fuel from pre-heating, and then lastly, a thin fuel layer around a central void.

Laser drivers

Nd:glass lasers have dominated the ICF research scene thus far due to their well-advanced state of development, their versatility and the high beam irradiance which can be achieved. However, they are very inefficient, have a low repetition rate and a basic wavelength of 1,05 μm making them unsuitable for reactors. At longer wavelengths, non-thermal electrons are generated which preheat the target core before compression. This is not desirable, so the so-called indirect drive approach is mostly followed[3]. Here the beams are first absorbed in a high Z enclosure or hohlraum, which surrounds the target. The hohlraum emits secondary electrons to drive a hydrodynamically, fairly stable implosion, which is less sensitive to asymmetries and details of the irradiating beams. However, the energy coupling is, in general, less efficient and laser/plasma instabilities develop easily in the surrounding plasma also at the longer wavelengths. Despite such difficulties, the NOVA system in the U.S.A. achieved a fusion gain Q~0,2 with ~10^{13} neutrons per shot. The 10 kJ Gekko XII laser in Japan reached a record compressed density[24] of 600 g cm^{-3} with a fuel doped plastic shell, but the neutron yield was significantly lower than expected.

The KrF laser at a wavelength of 249 nm and broad bandwidth is a much better driver for the direct drive approach. Here more beams are generally required to achieve better implosion symmetry (like the 48 beams of the AURORA system at Los Alamos), as well as beam smoothing techniques to eliminate spatial non-uniformities which form seed spots for the development of the RT-instability[3][25]. Also, to achieve reasonable efficiencies (~8%), long basic pulses have to be extracted from these lasers so that special techniques are necessary to subsequently shorten them considerably (~100x). Although these problems have been solved successfully, the cost is a much more complex optical system which remains very vulnerable to damage by UV light.

Light ion beam drivers

The generation of light ion beams (LIB) as ICF drivers is essentially less complex, more efficient (~20%) and more cost-effective than lasers. The technique requires the application of a high-powered pulse of short duration to a so-called ion diode. Ions are extracted from a porous anode and accelerated in a single step through an annular cathode. The anode/cathode extraction geometry, self and auxiliary magnetic fields determine the basic focusing quality of the beam. Significant progress has been made with several devices, especially with the world's largest ICF driver facility[26], PBFA II, briefly mentioned above. Typical milestones achieved so far include the acceleration of ~2 MA of rather pure Li^+-beams to ~10 MeV. Remaining problems centre around the unacceptably large beam divergences and unknowns regarding beam transport over distances of several metres of plasma channels to the target. Beam intensities are still in the low TW cm^{-2} region whereas the eventual aim is ~100 TW cm^{-2} to achieve high fusion gain with targets of a few millimeters in diameter.

Heavy ion beam drivers

Recent studies have shown that heavy ion accelerators could also be viewed as possible ICF drivers and, although quite large compared to other drivers, may yield power costs at acceptable levels. Accelerator technology is essentially well established, reliable, efficient (~30%, implying lower target gain requirements), and would easily attain the high repetition rates needed. Heavy ion beams of Bi+, Cs+ or Xe+ are viewed as possible candidates due to their useful characteristic stopping ranges for target interactions[25]. They have to be accelerated to energies in the range of 1-10 GeV with a total current of ~50 kA. It is estimated that ~10 main beams, each consisting of multiple beams per accelerating structure, will be needed for the required intensity of >100 TW cm^{-2} on a target of a few mm diameter. Encouraging successes have been obtained so far in small-scale experiments, but much more work is needed.

> "Thermonuclear fusion looks as if it will become a viable energy option sometime in the future, even for the Sub-Saharan Africa region. Admittedly, formidable technological hurdles have yet to be overcome but attractive incentives remain."

Reactor concepts

A number of ICF reactor concepts exist[25] and work is continuing in this field. Primarily, reactors must contain the shock, reaction products and debris of the micro explosions, breed T and capture the thermonuclear energy. The main features of such reactors are rather sturdy containment vessels able to withstand ~400 J, <1 ns pulses at a repetition rate of ~5 Hz with access ports to feed and position targets accurately and allow entry for multiple energetic beams of some sort for irradiation. Innovative shock absorbing techniques are planned such as, a buffer shielding gas, a carbon fabric blanket, a free-falling liquid (LiF/BeF_2) curtain or a flowing bed of Li_2O granules. Possible damage to beam line components along lines of sight poses problems but these are being addressed in various ways.

Expected future developments

Considering the large volume and advanced state of MCF-related research world-wide, it is only reasonable to expect further progress in the understanding of confinement physics, instabilities, disruptions, etc., in the near future. This will undoubtedly feed back to the larger devices to enable better performance parameters. At least two tokamaks, JET and TFTR (in the U.S.A. and also equipped for T-handling), should reach at least breakeven conditions soon. A number of other tokamaks in the U.S.A., Europe, Japan and Russia, and a few large stellarators due to start operations in the near future, can be expected to contribute towards new knowledge. In view of international commitment to the ITER project and general agreement on the scientific feasibility and technological goals, one can expect at least the EDA to continue. It is possible, however, that politics around the machine's siting, allocation of sub-contracts and the availability of funds may cause delays before construction can start.

In ICF it is expected that the NOVA system may once more be upgraded provided the initial development of a 5 kJ single laser beam with new technology is successful[3]. This may lead to the first MJ class laser driver with 200-300 individual beams. Upgrades of KrF lasers can also be expected with the aim to prove their viability as candidate ICF drivers. Near-term objectives for LIB drivers would be an improvement in beam intensity before serious target interactions could be attempted. Heavy ion beam drivers have a long way to go but may have other applications too, such as, fissile fuel breeding through spallation or processing of long half-life radioactive waste through transmutation.

One may even see alternate and, hopefully, less complex approaches coming to the fore. An example here is the application of new high power pulse technology to the well-researched linear Z-pinch[27][28]. Fast-rising current pulse discharges along a frozen fuel fibre appear to stay stable long enough to compress it to very high final plasma densities (~10^{33} m^{-3} estimated to be possible for a 2 MA, 200 ns pulse).

To conclude, it is undoubtedly true that most, if not all, scientific issues have either been solved or else addressed to such an extent that the practical realisation of fusion power seems possible. Technological unknowns in fields such as, ignition, burn, materials, neutronics, reliability and maintainability factors, etc. remain and their practicality will first have to be assessed. At this stage it is difficult to predict how the first experimental fusion reactor will look, let alone when it will go operational to address such issues. It seems likely that an MCF device such as ITER, or an equivalent, will be the leading contender in the near-term. Much depends on the world's socio-political circumstances, economic growth rate and environmental pressures for providing the incentive and funding to go ahead.

Fusion studies in South Africa

During the early seventies the Atomic Energy Board, the predecessor of the current Atomic Energy Corporation of SA Ltd (AEC), decided to launch a fusion research programme. The aims of the programme were to give scientists and engineers the opportunity to contribute to the international knowledge concerning the exploitation of fusion as an energy source, and to acquaint themselves with the related techniques and problems in the field. The programme centred around the most promising experimental magnetic confinement device, namely, a tokamak called Tokoloshe, named after a mischievous spirit in local folklore (Figure 5). Only a few scientists, engineers and technicians were available to design, construct and commission the machine (Table 2) at Pelindaba[29]. All the accompanying sub-systems, like the power supplies (toroidal field: 350 V/30 kA, programmable ohmic heating/equilibrium field: 1 500 V/10 kA) and high-power switchgear, were also designed and built locally.

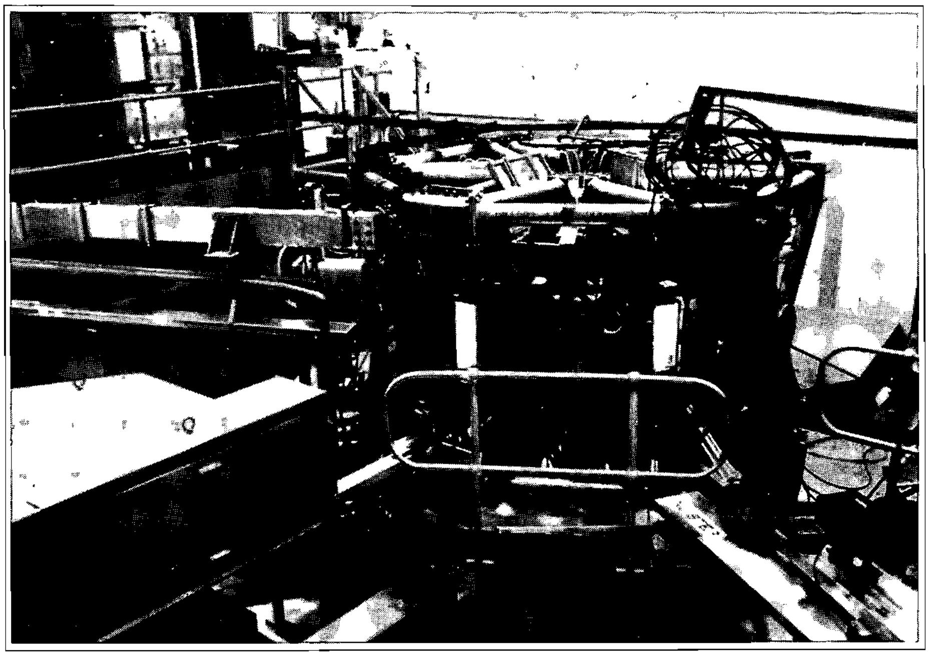

Figure 5: Photograph of the Tokoloshe tokamak. The plasma from a low power discharge is visible through the diagnostic windows

Major radius (m)	0,52
Minor radius (m)	0,28
Plasma cross-section	circular
Plasma current (kA)	≤200
Pulse duration (ms)	≤50
Toroidal field on axis (T)	≤1,2
Ohmic heating flux swing (Vs)	0,45
Electron temperature (eV)	≤450
Ion temperature (eV)	≤330
Line averaged plasma density (m^{-3})	≤6×10^{19}
Energy confinement time (ms)	≤4

Table 2: Machine and plasma parameters of the Tokoloshe tokamak

By the early eighties the major equipment and a number of diagnostic systems were in place and ready for use. The latter included the following:

- A ruby laser Thomson scattering system for electron temperature, density and confinement time measurements;
- A μ-wave interferometer for line averaged plasma density;
- Soft and hard X-ray spectroscopy and flux;
- Visible/VUV/neutral particle spectroscopy and flux;
- A variety of electromagnetic sensors and edge plasma probes;
- A high-speed framing camera.

The machine monitoring, control and data acquisition were handled by a dedicated CAMAC-based computer system able to handle a large amount of data in the short duration of a typical discharge.

Tokoloshe's low aspect ratio (somewhat lower than JET) enabled relatively high plasma currents and consequently, quite useful plasma temperatures (~6×10^6 K), even at low toroidal fields. From the start the programme concentrated on the study of characteristic instabilities which plague all tokamaks and, under certain circumstances, lead to major current disruptions. These could be disastrous in big machines considering the large amount of energy dumped on a very short time-scale. In 1987 an opportunity arose to fit the machine with poloidal windings inside the plasma current limiter and three sets of stellarator-like helical windings with different helicities attached to the outside of the vacuum chamber. Current pulses through these sets of windings enabled the influencing of different helical instabilities (typically m=0, 1, 2, and 3) in a resonant fashion[30]. Valuable insights were gained into the behaviour of these instabilities by varying the amplitude, current direction and timing of pulses relative to the main plasma discharge for every specific set of windings. It was, for instance, possible to create conditions to

- stimulate or subdue growth of particular instabilities;

- stop a characteristic rotation of the plasma column as a whole;
- trigger or delay minor or major disruptions;
- significantly shorten or lengthen the discharge duration.

The rather unique facility was fully utilised to obtain new research results on tokamak plasma behaviour (for example, Figure 6) which were published in fusion research journals[31][32] or presented at international conferences[33]. In recent times the AEC decided to change its mission to concentrate resources on the development and marketing of commercial products. The inevitable implications were that funding became scarce for research with a long time-horizon for practical applications. For this reason, the Fusion Studies Programme was terminated on 30 September 1992 and Tokoloshe, with its proven and only partially exploited research potential, became redundant. However, for those participants, the exciting mischievous spirit stays alive!

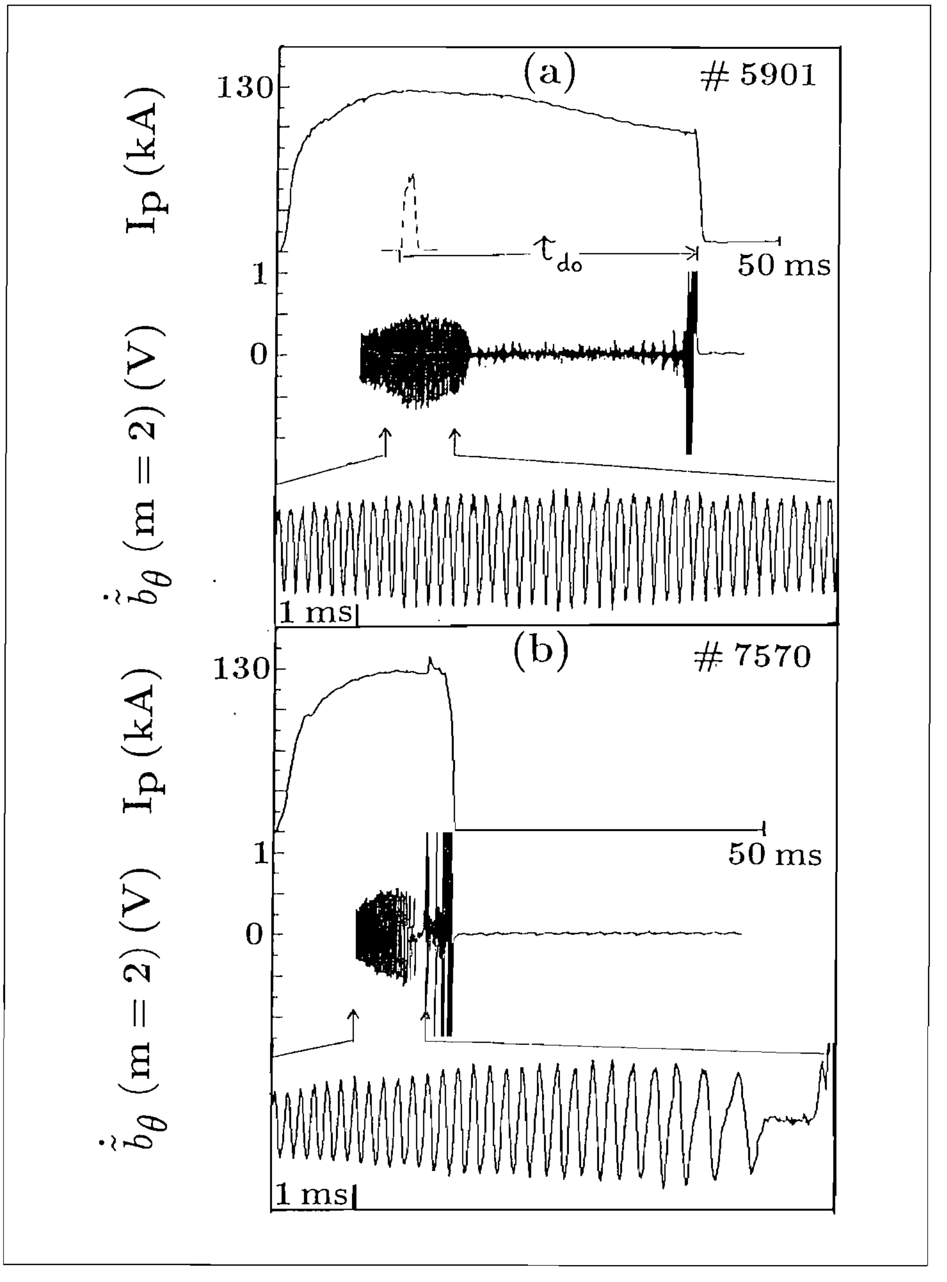

Figure 6: *A sample of typical results obtained with the Tokoloshe tokamak. A reference discharge is shown in (a) with the plasma current, I_p, normally disrupting at about 40 ms. The signal from a rotating m=2 mode is also shown. Mode locking is induced by means of a ~2 kA pulse through the relevant helical coil which leads to an early disruption (b).*

Fusion in the Sub-Saharan Africa region

It is generally accepted that the Sub-Saharan Africa region has ample conventional energy resources, like coal, oil, gas, and a large hydropower potential which will first have to be fully exploited before new options are seriously introduced. With a more long-term view in mind, one may very well ask whether the region should continue to utilise its more classical forms of power generation only, yet still aim for technological growth. A more healthy mix of energy sources is certainly called for. An ample supply of raw materials for power production is not enough - it cannot last forever. Moreover, hazardous emissions from burning hydrocarbons are a real threat. The region, as part of the global village, will not escape possible future prescriptions on how to generate its power. Solar power will certainly have its place and will bring upliftment to remote areas, but cannot supply large-scale industry. Classical Pressurised Water Reactors (PWRs), especially possible smaller and inherently safe versions of these reactors, are definite options, but here too fuel supply is finite and there is a radioactive waste problem which the region as a whole could hopefully address. Fast breeder reactors, once viewed as the final answer to mankind's energy needs since they can, in principle, produce more fuel than they consume, are no longer considered to be attractive mainly for reasons of safety. It appears that the general public's perceptions world-wide are rather negative on all nuclear safety aspects at present. Moreover, there is even a school of thought that the African continent should become a nuclear-free zone, which is worrying.

Thermonuclear fusion looks as if it will become a viable energy option sometime in the future, even for the Sub-Saharan Africa region. Admittedly, formidable technological hurdles have yet to be overcome but attractive incentives remain. Why not aim for environmental friendly and abundant fuel with required needs as much as about seven orders of magnitude less than coal? Clarke[15] predicted that fusion energy could supply ~30% of the world's power needs by the year 2100, with ~24% for the African continent. With this as a possible scenario in mind, it is time for the region to plan for its future energy needs. A good way to start could be to pool resources and start an energy-orientated fusion research programme with strong international links. The alternative is to become totally excluded from exciting new energy technologies.

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The 8th Pacific Rim Coal Conference, Sun City, Bophuthatswana, June 1993

* C J GROBBELAAR

This review of the 8th Pacific Rim Coal Conference gives a broad overview of the main points made, with particular relevance to South Africa.

Keywords: coal; steam coal; coal exports

That the trade pattern in international coal sales is determined by the market and not by the producer, was the clear message brought by the delegates at the conference. This has, in part, given rise to the current low international free-on-board price of $23/ton for steam coal which is, in turn, mainly due to the over-supply of steam coal as well as to the entry of new low-cost producers such as Indonesia, Venezuela and Colombia, to the world market. Although Indonesia and Colombia have had a significant effect on the international steam coal markets, exports from these new coal exporters are, however, limited by a high internal demand for coal due to rapid economic growth and the lack of infrastructure to export the coal.

Importers often make unrealistic forecasts of the future demand for coal. This again leads to an over-supply by producers, which places additional pressure on the coal price to the eventual advantage of the importers. In addition, low international prices for steam coal suppress capital investments in new production capacity. With a maximum extension of existing production capacity, South African coal exporters can achieve a level of 60 million tons per annum (Mt/annum) before new capacity will be needed for the estimated 70 Mt/annum to be exported by the year 2000. The viability of new production capacity is therefore dependent on a significant improvement in world coal prices.

Although South Africa can no longer be regarded as an international supplier of low-priced steam coal, due partly to the abolition of the so-called sanctions discount, this country still has the reputation of being the world's most reliable supplier of consistent quality coal products. Our coal is still in demand world-wide, and has succeeded in maintaining its market share both in Europe and the Far East in spite of the distances involved.

The South African coal industry is under pressure to maintain current production costs or even to reduce them, and to increase productivity in order to remain a competitive supplier. Profit margins are being eroded by inflation, rising running costs mainly due to salary increases and by increases in transport and port costs. The South African coal industry has indeed made significant inroads in the improvement of productivity, but the levels of those in Australia and the U.S.A. can only be matched through improved education and training. Ample proof of the seriousness with which the South African coal industry views this matter if it intends remaining competitive in the world coal market, is that the major mining houses have already instituted programmes to achieve this.

"The South African coal industry is under pressure to maintain current production costs or even to reduce them, and to increase productivity in order to remain a competitive supplier."

Because of the rising demand from the electricity generating industry, the growth outlook for the demand for internationally traded steam coal is very positive. From 195 Mt/annum in 1992, this could approach 340 Mt/annum by the year 2000. It is anticipated that South Africa's share could be 70-75 Mt/annum by then, depending on whether the coal producers can hold their own against the other major producers. Export capacity at the Richards Bay Coal Terminal was recently upgraded from 44 Mt/annum to 54,5 Mt/annum to accommodate an expected growth rate of 2 Mt/annum to an estimated 64 Mt/annum by the year 2000. The ultimate potential export capacity of Richards Bay which has been quoted as 100 Mt/annum is probably too optimistic. At best, given the expected growth in coal exports and assuming that the planned second terminal (known as the South Dunes Coal Terminal or Red Terminal) at Richards Bay materialises, an estimated 76 Mt/annum is likely.

Sasol is currently entering the final stage of determining the feasibility of the controversial South Dunes Coal Terminal (SDCT) after promising results from the pre-feasibility study. Sasol is in partner-

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ship with a number of coal producers (some of which have had no previous access to existing port facilities), forming the Coalex consortium of potential exporters. Although the SDCT will have an initial capacity of 12 Mt/annum, exporters question the viability of this undertaking under the prevailing conditions in the international steam coal trade. Sasol, nonetheless, remains positive of its potential viability and, being a coal user itself, has the advantage of being in a position to advise potential users on the efficient use of its specific type of coal. In addition, Sasol's coal reserve base and capabilities for operating very large collieries place it in a competitive position to be able to also serve the power utility market of the future.

Because coal generally has a negative image world-wide, it is important that producers not only mine and market their products, but that they should also get involved in promoting the clean use of coal. It was also suggested that the coal industry should move away from the promotion of coal through the medium of reporting and advertising and pay more attention to promoting it in terms of its uses and its most important benefit of providing cheap and reliable electricity to people for improved quality of life. If efforts are not made to counter this negative image, international restrictions could be implemented that would be harmful both to international and local coal producers. For example, the implementation of the much-debated carbon/energy tax will compound the pressures on coal producers and users to implement more efficient and clean coal technologies faster. Of crucial importance to the general acceptance of coal as a clean, reliable and affordable energy source is the transfer of clean coal technologies from the developed countries to the developing parts of the world where sustained economic growth is expected to be mainly dependent on coal.

The Domestic Use of Electrical Energy Conference, held at the Cape Technikon on 18-19 October 1993*

** N BEUTE

This review summarises the main points made at the conference with particular relevance to South Africa.

Keywords: energy efficiency; electricity; lighting

The conference was organised by the Cape Technikon in association with the SAIEE, Eskom and the Universities of Cape Town and Stellenbosch. The papers presented gave a well-balanced overview of the issues involved in the field of domestic electrical energy. Various challenges facing the electricity industry were highlighted, the development needed to face these challenges was discussed, and solutions were addressed.

The Keynote Address was given by Mr Ronnie Kingwell, General Manager of the Eskom Distributor in Cape Town. He addressed issues such as, the backlog of households without electricity, subsidised tariffs, equality of supply, sensitivity to customer and community needs, a national domestic tariff, and the challenges facing the Electricity Distribution Industry.

Dr Ernst Uken from the Cape Technikon presented a paper on energy efficiency labelling of domestic appliances, which attracted much interest. The effects of overseas schemes encouraging labels to be attached to new domestic appliances, indicating their energy efficiency and running costs, were described. All available information suggests that energy efficiency labelling of selected appliances should be seriously considered. A star-rating, indicating the kWh per annum under normal use, would be most informative to the prospective buyer. A 5-star energy efficiency grading system for refrigerators, freezers and air-conditioner units was recommended. Steps needed to implement such a scheme for South Africa were proposed.

Mr Robert Henderson from Eskom's Technology Research and Investigations, presented a paper on lighting. Methods of saving electricity through the correct choice of lighting system and the efficient use of lighting were discussed. Estimates of the domestic lighting load are about 60 kWh per home per month. The lights burn for short periods in the mornings and evenings, at or near the national peak load times. About 50 MW electrical energy savings could be achieved through lighting if half of all domestic consumers each lowered their lighting load by 40 watts at peak times. This would be possible if a 9-watt compact fluorescent lamp is used instead of a 60-watt GLS lamp. A lowering in demand by this small amount would result in a national cost saving of about R1,3 million per month at a demand charge of R26 per kVA per month. In Europe and the U.S.A. a number of schemes have been introduced to encourage domestic customers of electrical energy to use energy efficient lamps. It was suggested that similar schemes should be pursued for use in South Africa.

The conference was well supported by the University of Pretoria. Their staff and students presented six very interesting papers. Mr G van Harmelen presented a paper on a physically-based model for water-heater controller design. In this paper, a CLR physical load modelling method was presented for those cases where the flow field in a volume etc. (for a room, oven, geyser) was known. The implementation of the conservation equations in discretised forms to produce tri-diagonal matrices is a straightforward procedure and was solved directly. In cases where the flow field is not known, an iterative expanded procedure has to be followed. With these implementations, most of the thermostatic-type devices found in a home can be physically modelled. In order to illustrate the use of physical models in system simulations, a test result relating the comparison between a conventional thermostat and a price-sensitive, fuzzy logic controller was shown. Future work will entail the solution of the set for unknown flow fields, the expansion of the fuzzy logic controller into the adaptive realm, and comparisons between this type of controller and other types such as neural networks.

The paper entitled, "Implementation of Controlling Hot Water Cylinders" was presented by Mr Ian Patterson from H.B. Malan Inc., and was very well received at the preliminary session. The effect of controlling domestic hot-water cylinders for typical South African consumers was analysed at the national, distributor and consumer level. Very useful and practical guidelines were given for the consumer who wishes to reduce his water-heating costs.

In total, 33 papers were presented at the conference. Some of the papers gave a clear indication of how the future national load will increase because of the additional domestic load which will be the result of the implementation of electrification programmmes and increased appliance ownership.

Several papers dealt with intrusive and non-intrusive load-monitoring equipment, models for domestic loads, the marketing of appliances and electricity to first-time users, energy savings, and other aspects of domestic electrical energy.

On the whole, a positive response was received from the delegates, indicating that there is a need for this type of conference to be held on a regular basis. The next conference is to be held in Cape Town, March 1995.

* Copies of the proceedings and information on future conferences may be obtained from the author.

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COMPARATIVE ENERGY COSTS IN SOUTH AFRICAN CITIES RELATED TO HEATING VALUE

JANUARY 1994											
Energy source	Consumer prices			Cost of energy (c/MJ)			*Relative heating costs			Heating value	
	Coast	Inland	Units	C.T.	Jhb	Dbn	C.T.	Jhb	Dbn		
Coal A (Peas)	241,70	64,90	R/Ton	0,86	0,23	0,55	3,41	1,00	2,37	28,0	MJ/Kg
Elect.	18,50	18,31	c/kWh	5,14	5,09	5,52	22,17	21,94	23,80	3,6	MJ/kWh
Heavy Furnace Oil	47,06	60,26	c/litre	1,15	1,47	1,15	4,95	6,34	4,95	41,0	MJ/1
Illum. Paraffin	85,63	97,53	c/litre	2,31	2,64	2,31	9,98	11,37	9,98	37,0	MJ/1
Petrol (Premium)	167,00	178,00	c/litre	4,81	5,13	4,81	20,76	22,13	20,76	34,7	MJ/1
											MJ/1
Diesel	143,90	154,40	c/litre	4,02	4,28	4,02	17,35	18,46	17,35	38,8	MJ/1
Power Paraffin	90,00	101,90	c/litre	2,40	2,72	2,40	10,35	11,72	10,35	37,5	MJ/1
LPG	95,00	107,30	c/litre	3,47	3,92	3,47	14,97	16,90	14,96	27,4	MJ/1
Gas											
Cape Gas	40,00	–	R/GJ	4,00	–	–	17,26	–	–	–	
Gaskor	–	16,50	R/GJ	–	1,65	–	–	7,12	–	–	

This table shows comparative energy costs (in SA cents/MJ) in selected South African cities (coastal and inland) based on a range of energy sources. The following criteria were taken into consideration in the calculation of the cost of energy:

(1) Transport costs for coal were obtained from Spoornet. Railage of coal was calculated from Saaiwater to Cape Town and from Saaiwater to Durban respectively.

(2) The energy cost has been calculated on the bulk delivered price for consumers, i.e. includes VAT and other charges.

(3) All figures for electricity have been based on energy requirements for large commercial users.

(4) Electricity prices have been based on typical monthly accounts for large users (see Table 5 of the Energy Price List in *Selected Energy Statistics: South Africa).*

(5) A 75% load factor has been used in the calculation of the Gaskor prices.

(6) The relative heating costs are shown in relation to the cheapest energy source, i.e. coal in Johannesburg.

(Source: *Selected Energy Statistics: South Africa*, No. 28, February 1994).

Energy news in Africa

Agroforestry

The Manjokota Community project in Zimbabwe is being undertaken in a rural district which is drought-prone and the centre of a successful agroforestry project. The 91 families in the area have converted one and a half ha. of land into fields of castor beans, sunflowers, and tree species such as acacia albida/karoo (Miunga) and Leucaena leucocephala.

Zimbabwe implemented the initial phase of the Rural Afforestation Programme (RAP) between 1983-1989, and the second phase began in 1990. Under this phase, agroforestry assumed a much higher profile. Under the five-year operational plan of the Forestry Extension Division (FES), the primary goal is to make tree-growing and tree-caring a component of agricultural land management systems in the communal and resettlement areas. Within this framework, emphasis will be on farm production diversification, increasing vegetative cover, soil improvement, and enhancing woody biomass for rural farmer needs. Some of the strategies of the plan include the promotion of new tree planting technologies, tree nursery establishment, strengthening existing practices, training of field officers and establishing local seed centres.

The plan envisages such results as practical agroforestry models for different agro-ecological conditions, an increase in the acceptance of the concept as well as a significant increase in fruit and fodder trees in the eight pilot districts.

Despite its promise, there are a number of formidable obstacles to the widespread adoption of agroforestry, especially in areas where it has not been traditional.

(Source: Development Dialogue, October/November 1993)

Electricity

The Zambia Electricity Supply Corporation (ZESCO) has implemented an increase in tariffs which includes price rises of up to 700%. This has outraged the utility's major customers. Zambia Consolidated Copper Mines, whose account represents around 70% of the ZESCO's revenue, has rejected the increases and refused to honour any bills based on the new price tariffs. ZESCO has a policy of disconnecting defaulters and claims that it can sell all its surplus power to neighbouring countries. More serious over the long term is the predicted destruction of forests around Lusaka and other major towns as a result of the price rises. It is feared that the people will turn to charcoal instead of electricity as an energy source.

(Source: Modern Power Systems, December 1993)

Zimbabwe's power supply system is in trouble. The Zimbabwe Electricity Supply Authority (ZESA), the country's sole electricity distributor admits that the system is inadequate for the country's needs. Obsolete equipment and the unavailability of foreign currency to acquire spare parts has been blamed for the many black-outs experienced.

The Zimbabwe National Chamber of Commerce feels that the country's power supply problems lies in the privatisation of the state-owned power utility.

However, ZESA announced at the end of 1993 that it plans to invest Z$10 billion over the next six years to enhance its production and transmission-distribution capacity. The programme will be financed by Z$6 billion in foreign capital, Z$1,5 billion from domestic borrowing, and Z$2,5 billion from the utility's own funds.

Other projects planned include:

(i) a 500 MW interconnection with South Africa,
(ii) a 500 MW interconnection with the Cahora Bassa dam in Mozambique,
(iii) the rehabilitation of the South Kariba dam (the capacity of which is to be increased from 666 MW to 750 MW),
(iv) the restoration of the Harare and Manyati thermal power stations, and
(v) continued work on Hwange power station.

These investments do not cover the building of a 1 600 MW hydroelectric power station at Batoka Gorge.

(Source: Development Dialogue, October/November 1993
Africa Energy & Mining, 3 November 1993)

Hydro-electricity

A third hydroelectric power and dam across the Zambesi River at Batoka Gorge, is under consideration by Zambia and Zimbabwe. If approved, the $3 billion funding for the project will be provided by the World Bank.

The Batoka Gorge is a narrow gorge 50 km below the Victoria Falls and the plant will have an installed capacity of 1 600 MW. The lake which will form behind the dam would cover an area of 31 km^2, compared to Kariba's 5 500 km^2.

The project has come up against harsh criticism from environmentalists who claim that the Batoka lake would back up water to the existing power station in Livingstone, only 2 km from the Victoria Falls, thus affecting the scenic beauty of the site. It will also flood the ancestral shrines and homes of the local Toka-Leya tribe.

(Source: Modern Power Systems, December 1993
International Water Power & Dam Construction, January 1994)

The members of the Permanent Joint Committee (PJC) on Cahora Bassa have announced that major international agencies have expressed willingness to provide the necessary funding to re-start the project. The PJC consists of members from South Africa, Portugal and Mozambique.

Eskom's Dr Ian McRae, lead the South African delegation. He said that the rehabilitation of the project was being delayed by a shortfall of $40-50 million, caused by the withdrawal of funding promised by the Italian government. However, alternative sources of funding have been found.

Dr McRae is confident that work will soon begin in South Africa on the construction of pylons for the power lines and that field-work will begin after the rainy season, at the end of April. It is expected to take another two to three years before the system is operating at full capacity.

Cahora Bassa is seen to be important to South Africa, Mozambique and Southern Africa as a whole. For South Africa it will provide inexpensive and renewable electricity, important for the rebuilding of the country's economy. The scheme is a key component of the interconnected grid for the region.

For Mozambique and the Southern African region, the project will provide job opportunities and stimulate the economy on local and national levels.

(Source: Eskom News Release, 17/11/93)

A £40 million hydroelectric deal in Lesotho could be in the balance because of a tendering row between the African Development Bank and the Lesotho Highlands Development Authority (LHDA). The dispute arose after the LHDA decided to combine the two civil contracts for the 80 MW Muela hydroelectric scheme. Originally separate bids were invited for the underground powerhouse and the 55 m high, 180 m long Muela dam.

(Source: International Water Power and Dam Construction, November 1993)

The African Development Bank has made a loan of UA62,30 million to finance the construction of the Barbara dam in Tunisia, the total cost of project being UA151,61 million. The project involves the construction of a storage dam with a total capacity of 74 x 106 m^3, a pumping station with a discharge outlet, and a culvert for transferring water to the Medjerda Wadi Basin.

(Source: International Water Power and Dam Construction, November 1993)

Natural gas

The Foxtrot gas and electricity project of the Ivory Coast is to receive funding from various donor agencies. Several engineering companies and a consortium of various organisations are to discuss a feasibility study for developing other gas prospects in the area. The areas for exploration are situated offshore on the eastern edge of the Ivory Coast. The gas fields are all very marginal with reserves in the range of 25-30 billion m^3. Because of the delay in putting together the financial package, it is unlikely that the field will be put into production until early 1996.

The gas is likely to be exported to Ghana to power a 300 MW combustion turbine and a combined cycle power station to be built at Aboadse, near Takoradi. The Ivory Coast gas could eventually be combined with gas to be produced by the Ghana National Petroleum Corp. from the Tano basin. This is seen as an alternative to using Nigerian gas supplied by pipeline that will cross Benin and Togo to Ghana.

The Ivory Coast will only use LPG extracted from the gas, marketed through the Compagnie Ivorienne de Raffinage and Gaz Cote d'Ivoire.

(Source: Africa Energy & Mining, 2 February1994)

Oil

Sasol Oil recently announced that it has concluded a term of arrangement for the supply of 1 Mt of Kuwait crude oil. The announcement follows the commissioning of the upgrading of the Natref refinery during November 1993 at a cost of R390 million. The Natref upgrading will enable the refinery to process relatively heavy crudes with a high sulphur content.

Sasol has already processed a trial shipment of Kuwait crude at Natref, and has successfully upgraded the high-sulphur crude oil to premium quality products.

(Source: Engineering News, 18/2/94)

Solar energy

Solar-powered water pumps have been installed at eight schools in the drought-ridden areas of KwaZulu. It was found that ordinary hand pumps were insufficient for the schools which were situated far from regular electricity supplies. The pumps were equipped with dc/dc convertors which did not need batteries.

(Source: Engineering News, 18/2/94)

Details of authors

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Dr Beute's doctoral thesis focussed on the domestic use of electrical energy. An analysis was made of the present and future use of domestic electrical grid energy in the developed, as well as the developing sectors of the South African community. Special attention was given to the domestic hot-water load. Models were developed to represent the electrical load of the South African domestic sector.

During the last few years Dr Beute has also been involved with the Cape Technikon's Energy Research Unit. Six major research reports on energy conservation and the domestic sector use of energy have been produced.

Dr Beute serves on a few committees of the Engineering Council of South Africa, and he serves on the Framework Committee for Technology. He is also Chairman of the Cape Western Centre.

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Johan de Villiers graduated with a B.Sc. and M.Sc. from Potchefstroom University and then completed a doctorate in 1961 while lecturing part-time at the same university. He joined the Atomic Energy Board, the forerunner of the present AEC, at the end of 1961. Two years were spent as a Post-doctoral Fellow at the Argonne National Laboratory in the U.S.A. specialising in accelerator-based fast neutron physics and nuclear electronics. This work was continued and expanded at Pelindaba from 1964-1974. He then joined the newly-formed Fusion-related Plasma Research Programme in 1974, and spent the following year as a visiting scientist at the Massachusetts Institute of Technology working on the tokomaks, Alcator-C and Macrotor. Since then he has participated in the design, construction, commissioning and subsequent research on the Tokoloshe tokomak at Pelindaba, with a special interest in machine control, data acquisition and diagnostic systems.

Dr de Villiers held the position of Division Head, and was later made Chief Consulting Scientist responsible for the Fusion Studies Research Programme at the AEC.

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Chris Grobbelaar started his career in 1979 as a researcher at the Industrial Hygiene Branch of the Chamber of Mines, during which time he enrolled for further studies in the field of energy at RAU's Institute for Energy Studies.

In 1983 he joined the Energy Planning Division of the Department of Mineral and Energy Affairs (DMEA) where he was responsible for coal and coal-related activities. From 1989 to 1991, he was Programme Co-ordinator for Coal and Energy & the Environment at the former National Energy Council.

In 1992 he was appointed to his present position at the DMEA's Chief Directorate: Energy, where his responsibilities involve activities for the development and formulation of a coal policy with specific emphasis on the efficient and clean beneficiation and use of coal.

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Miguel Schloss joined the World Bank in 1969, and has since held various positions in the Technical Department of the Africa region and in the Country Departments of the Latin American region. He is presently head of the Corporate and Budget Planning Division.

Prior to joining the World Bank, Mr Schloss was the Deputy Manager of Marplan (Interpublic) in Chile, and Credit Manager of Dow Chemical in Mexico.

Forthcoming energy and energy-related conferences:

1994

JUNE 1994

27-30

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Menlo Park 0102,
South Africa
Tel.: (012) 348 5205 (Sonja Weber)
Fax.: (012) 348 5220

13-14

REGIONAL ENERGY FORUM FOR SOUTHERN & EASTERN COUNTRIES Cape Town, South Africa

Theme: Mobilising energy for growth strategies for the Nineties for sustainable development into the 21st century

Enquiries: Mr Ian Israelsohn/
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18-21

2ND SOUTHERN AFRICAN INTERNATIONAL CONFERENCE ON ENVIRONMENTAL MANAGEMENT (SAICEM II)
Victoria Falls, Zimbabwe

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Borrowdale, Harare, Zimbabwe
Tel.: (263) (4) 739 822
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Telex: 22126 ZW

NOVEMBER 1994

24-25

A RESPONSIBLE APPROACH TO CLEAN AIR Cape Town, South Africa

Organiser: National Association for Clean Air (Western Cape Branch)

Enquiries: Hans Linde
Tel.: (021) 400 3080
Fax.: (021) 211 980

Recent energy publications

ALLISON C B and DUTKIEWICZ R K

The efficiency and cost-effectiveness of space heating appliances using traditional and transitional fuels in South Africa. Rev.ed.
Nov-1993. 50p.
Report no. EO9128

The objective of the project was an assessment of the available domestic heating equipment used in the developing sector and an assessment of heating efficiencies. The fuels for space-heating are wood, coal, anthracite, paraffin and gas. A stove test procedure and the necessary apparatus for assessing heater performance were designed. A measurement of heater performance and efficiency, as well as the evaluation of cost-effectiveness was developed. The results of the tests showed that efficiencies vary from 17,1% for brazier to 67,7% for the gas heater. The operating costs of each of the tested devices were calculated, including capital and energy costs.

CHEEK J B S and PRETORIOUS M

Variable-frequency series-resonant (VFSR) cable tester
Jul-1993. 43p.
Report No. EL9107

A previous project (1989/90) involved an investigation into the feasibility of using the variable-frequency, series resonant (VFSR) technique to produce equipment capable of doing on-site AC pressure tests on installed high-voltage cables. The current project was to develop, based on the experience gained with the 70 kVA prototype, a much larger VFSR cable tester capable of testing capacitive loads of up to 3 MVA at voltages between 33 kV-190 kV. In the first phase of the project, the problems with the existing 70 kVA prototype were addressed and additional features added. In Phase 2, a completely new 3 MVA unit, incorporating all these improvements and features, was developed and tested.

HOLM D

The state of knowledge of passive and thermal design of dwellings.
Nov-1993. 26p. + appendices
Report No. EO9307

This project surveys the present state of knowledge of passive thermal design of dwellings in South Africa. The report goes on to describe the problem, the methodology used leading to results and discussion from which conclusions are deducted, and recommendations are made.

JAMES B

Mabibi energy consumption patterns
Nov-1993. 122p.
Report No. EO9001

This is an extension of the Mabibi Wind Energy Demonstration Project, examining energy consumption patterns in this remote rural community and comparing them with results achieved by other researchers for different rural and urban communities. The project also examines the way in which social, institutional and environmental forces determine and inform people's energy consumption behaviour.

MADAMS R

Social forestry for energy in rural areas.
Jan-1994. 111p.
Report No. EO9005

The objectives of the project were: (i) to identify and describe limitations common to tree planting projects and social forestry planning attempts; (ii) to identify issues which need to be investigated in planning a regional programme of tree-growing activities; and (iii) to develop and set up two demonstration pilot social forestry projects. Section 1 of the report is a general introduction to the project. Section 2 discusses the limitations to previous community tree planting projects, and includes a literature review. Section 3 describes the information needed to plan social forestry activity. Section 4 describes the two pilot nursery projects set up in Gazankulu.

MATHEWS E H

A new computer program for the design and management of energy efficient buildings and HVAC systems as well as their control: A total new approach
Oct-1993. 53p.
Reprt No. ED9103

The goal of this project was to develop a new tool, called EASY, for the design and management of energy-efficient buildings and HVAC systems. It presents a concise description of the motivation and philosophy behind the development of this software. The project also illustrates the applicability of the software in practice.

O'LEARY B M and DIAB R D

A technical and financial analysis of renewable energy applications in KwaZulu.
Sep-1993. 78p.
Report No. EO8001

The project aims to examine the comparative abilities of small-scale renewable energy conversion technologies, such as hydro-electricity, pv and wind generators, to supply the energy demands of rural clinics in the Natal-KwaZulu region. Costs are compared in each case, as well as the technical advantages.

PALMER DEVELOPMENT GROUP

Electricity consumption rates in selected South African townships: Phase II.
Feb-1993. 1V.(various pagings)
Report No. EO9122

The purpose of this comparative study of electricity usage in 10 South African townships was to obtain electricity supply and consumption data, to derive current and historical electricity consumption patterns for the townships and to determine the critical factors influencing these consumption patterns. The townships studied were Motherwell, Ibhayi, Galeshewe, Sobantu, Alexandra, Jouberton, Mangaung, Umlazi, Kwaguqa and Kagiso.

All these reports are Final Reports and are the result of research funded by the Chief Directorate: Energy, Department of Mineral and Energy Affairs. The publications can be ordered from: The Librarian, Chief Directorate: Energy, Department of Mineral and Energy Affairs, Private Bag X59, Pretoria 0001, South Africa, unless otherwise indicated. Prices are available on request from the Department of Mineral and Energy Affairs.

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