

# ENERGY WORLD



The magazine of The Institute of Energy

Number 179  
June 1990

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Substitute fuels features  
PLUS pull-out section  
Coal in the 21st  
Century

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**'Research in PowerGen after  
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(Director of Technical and Research Department,  
PowerGen)

on

**Friday, 29 June 1990 at 11.15 am**

at the

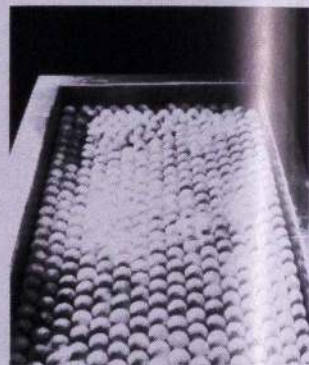
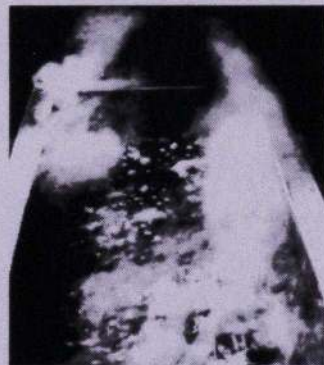
**Coal Research Establishment,  
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**Editorial assistant:** Johanna Fender BA

**Advertisement sales:** David Speculand, Tel. 0235 833815

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## COVER STORY

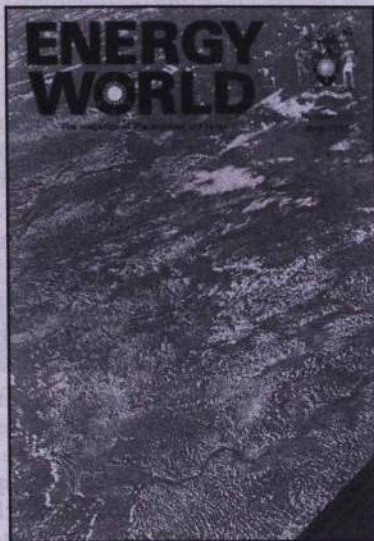
Our cover photograph shows the north coast of South America and Venezuela, taken from a satellite in earth orbit. Venezuela's Orinoco region has huge reserves of bitumen, which forms the basis of Orimulsion, an important new fuel. A bitumen-in-water emulsion, it has all the convenience of a liquid fuel and is claimed to be the first major development since natural gas.

Manufactured using technology developed by British Petroleum and Petroleos de Venezuela, SA, the fuel's handling, combustibility and flue gas properties have been evaluated in laboratories at the Intevep Combustion Research Facility in Venezuela and at BP's Sunbury Research Centre in the UK.

Extensive trials have demonstrated that the fuel has excellent combustibility, relatively low nitrogen oxide emissions and can be handled and stored in a similar manner to heavy fuel oil. Orimulsion can be used, with only minor modifications, in the great majority of oil and coal designed industrial water-tube boiler plants.

Cover photograph by courtesy of NASA/BP Oil UK Limited.

\*For an independent analysis of the properties and prospects for Orimulsion, see our series of feature articles beginning on page 8.



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## TERMS OF CONTROL

Energy World is circulated free of charge to all paid up members of The Institute of Energy. To libraries, organisations and persons not in membership it is available on a single subscription of £70 for 11 issues. Energy World is also available with the Journal of The Institute of Energy (quarterly) at a combined annual subscription of £130.



# Setting a new agenda

UNDER the title: 'To be, or not to be ...' Brian Brinkworth wrote a Viewpoint for the May edition of *Energy World* on some of the options for the future of the Institute. I am not going to cover the same ground, though I will remind readers that Brian did invite comment.

Whatever form The Institute of Energy adopts as being the most appropriate structure for the next decade or more, it is certain that the objectives of the Institute, as set out in our Charter, will continue. The Institute is uniquely placed as was recognised by the Secretary of State for Energy when he spoke recently at our annual luncheon. He said: "In a history lasting over 60 years, The Institute of Energy has become an unrivalled centre of scientific and engineering knowledge on virtually every aspect of energy development. I would like to pay tribute to the invaluable contribution which it has made — and continues to make — to the increased understanding of energy issues in this country."

I felt therefore that it might be useful, at the start of this, the last decade of the 20th century, to try and look forward and see what the opportunities are for the Institute and its members.

Clearly the importance of energy to society will increase. The availability of energy is important to any developed society, particularly an industrial society such as ours. But at the end of a century during which most of the world's available fossil fuel reserves have been consumed, we have to think and plan ahead for the next century.

There is no short term lack of energy, and indeed it might sometimes seem that there is a surfeit of energy. This situation could continue for some years, though there may be some short term problems caused by the lack of investment in new resources when energy prices have been very low. In the long term, however, the pressures of world population growth, the demand for greater industrialisation and comfort standards, must mean that energy costs will rise and there will be overall shortages of fossil fuel to meet the demand unless the developed and the developing world can substantially change their ways.

The Institute published in 1973 a report called *Energy for the Future*. In many ways it was a prophetic document and a review prepared in 1986 concluded that most of the findings were still valid. The Institute believes that it is now time to look again at the situation particularly when in the last few years the position as to availability of energy has been very confused. A working party is being set up and it is hoped that a report will be prepared before the next World Energy Congress in September 1992.

Key to conclusions about the adequacy of energy supplies for the future are of course factors relating to the way in which we use energy. This Institute has always been concerned with energy efficiency even when the public and sometimes it appears, the Government's attitude, to energy efficiency waxes and wanes.

As Walter Patterson commented at a recent Institute conference, energy is valued for the service it provides — comfort, convenience, manufactured goods, and so on. He suggested that the Institute should be renamed 'Energy Services'. This is I think extreme but it does emphasise that the Institute needs to become more active at the user end. Its support of the National Energy Efficiency Association (NEEA) is a step in the right direction but the Institute needs to become much more involved in supporting the Department of Energy in their efficiency programmes.

There are many calls for a national energy policy; I agree with Med Thring that energy strategy is rather a better term. The Institute should, with other bodies such as the NEEA, seek to develop a coherent 'strategy' and advance it to government and to the general public.

A major concern during the '90s will be the environment. It may seem to have been recently discovered by the public, but the Institute mounted a major conference in 1973 called *Fuel and the Environment* for which the Duke of Edinburgh both chaired the organising committee and gave the opening address. The role of the Institute must be to encourage informed debate both by correspondence in our publications, and by organising conferences. Where 'facts' have to be determined the Institute should encourage the necessary research and the Institute should seek to inform both the public and the legislature.

In the post privatisation period the Institute should seek to encourage continued research, development and demonstration in new technologies which might make better use of our available energy sources or improve the environment. There is a grave danger that in an economic milieu dominated by the need to produce short term paybacks that medium and long term development of renewables, 'clean coal' and oil combustion and greater energy efficiency should be the subject of conferences, articles in the *Journal* and *Energy World* and special interest groups should be set up to deal with specifics.

The reconsideration of nuclear power, on the basis of its economics, public acceptability, and the disposal of radioactive waste, will be necessary very soon, and the Institute, together with other bodies, such as the British Nuclear Society, must ensure rational consideration of the factors involved.

The Institute has an important function in education at all levels. Its support of CREATE in primary and secondary education, the development of appropriate tertiary education courses with universities, polytechnics and colleges, and the growing importance of mid career development to ensure that, in a rapidly changing world, people can maintain their professionalism, all mean that this will be a growing responsibility during the next decade.

I also believe that with the growing awareness of the global nature of energy and associated environmental problems and the strengthening links with Europe, both western and eastern, means that The Institute of Energy should be pro-active in seeking associations with similar bodies overseas and encouraging the spread of knowledge in energy matters throughout the developed and the developing world.

Looking forward therefore I see that there is much that the Institute in whatever form it is to be constituted in the future, can and must do in the coming decade. There are great opportunities and great responsibilities for members of the Institute; and there are grades of membership open to all individuals and all organisations involved in every aspect of energy production preparation, distribution and utilisation.

**Doug Willis**  
President (1990-91)



## Bangladesh expands power network in rural areas

FARMERS and small rural industries in Bangladesh will gain access to electricity through a project that will expand the country's network of rural power cooperatives. IDA — the World Bank affiliate that lends on concessional terms to the poorest countries — is supporting the project with a credit of SDR 79.6 million (\$105 million).

The project marks the beginning of the fourth phase of the government's programme to provide electricity to all parts of the country by the year 2005. By the

completion of the current phase in 1993, an estimated 18 million people in rural areas will have gained access to electricity.

The IDA credit will help finance four new power-distribution cooperatives in Comilla, Dinajpur, Manikganj and Cox's Bazar. Each cooperative would serve about 500 villages, each with about 30,000 consumers. The credit will also finance expansion of seven existing networks and the rehabilitation of distribution lines and substations formerly owned and

operated by the Bangladesh Power Development Board.

The project includes technical assistance for Bangladesh's Rural Electrification Board and is expected to stimulate the growth of rural agro-processing industries, will generate jobs and raise the incomes of people living in villages served by the cooperatives.

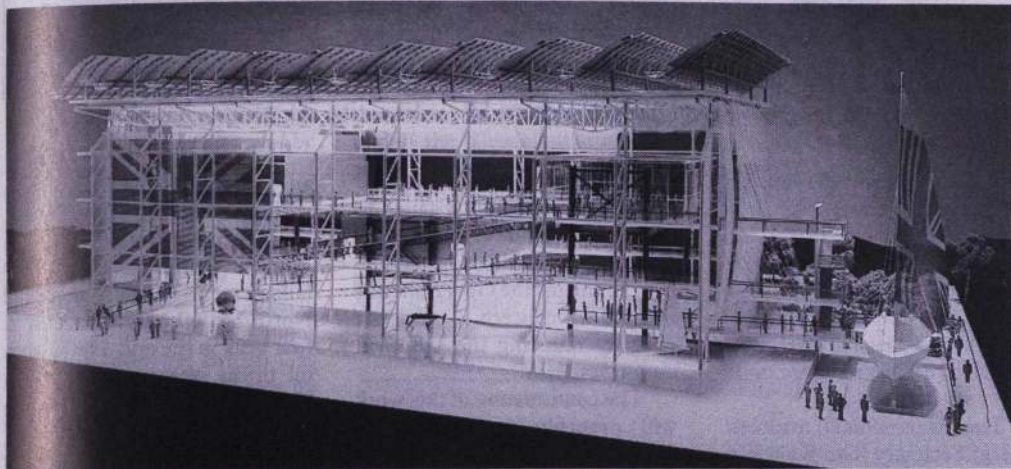
Extending the power supply to rural areas will also enable expansion of irrigation systems, resulting in increased agricultural production.

## 34 nations sign declaration

AT AN international environmental conference held in Bergen, Norway, on 16 May, a reluctant US, Canada and the UK signed a declaration urging aid to developing countries to help reduce chlorofluorocarbons.

All 34 represented nations signed the declaration, which included a controversial 'precautionary principle' stating that action should be taken even before there is scientific proof that industrial emissions are escalating climate change.

## Thorn EMI to provide IBMS for British pavilion at Expo '92



A FULLY integrated building management package is being provided by Thorn EMI for the British pavilion (a model of which is pictured above), at the Expo '92 exhibition in Seville, Spain.

The package will include security, fire protection, lighting and environmental control

systems. Half the cost of the project is being met by Thorn EMI, who have been working closely with the UK Department of Trade and Industry on the project.

Thorn Security pioneered the development of this system (IBMS) to meet the growing market for 'intelligent' buildings.

## Acquisition by CNIM

PREVIOUSLY under private ownership, International Wanson Group, based in Brussels, of which Wanson Co Ltd is the British subsidiary, has been acquired by CNIM (Constructions Industrielles de la Méditerranée) of France and now becomes a partner with the other major CNIM subsidiary Babcock Enterprise of France. Each of these two subsidiaries has a turnover of more than £50 million and together they represent nearly half of the CNIM group turnover.

The name of Babcock has been associated with Wanson for many years, particularly in the UK where only earlier this year the formal links ceased. Babcock Enterprise of France, although sharing the same roots, has no current tie with Babcock in the UK. The new group must now rank as the leading industrial energy equipment manufacturers in Europe.

## BOT agreement

EWBANK Preece, the international engineering consultancy based in Brighton, UK, is providing engineering supervision to Hopewell Holdings of Hong Kong for the dismantling of a 200MW gas turbine power station in the United States and its re-erection in the Republic of the Philippines.

The power station is part of a build, operate and transfer (BOT) agreement between Hopewell Holdings and the National Power Corporation of the Philippines.

## 'Slant' well in Colorado, USA

A US Government-financed contractor has begun drilling an experimental 'slant' well through Colorado sandstone and coal formations in a test that could open up new natural gas supplies in the 1990s.

The three-year, \$4.3 million field project is being funded by the US Department of Energy at a site near Rifle, Colorado. It is intended to determine if drilling 'sideways' could produce commercial quantities of natural gas from the concrete-like 'tight' sandstone formations scattered throughout the western US.

Drilling at an angle exposes more of the gas-bearing sands and coals to the wellbore and can potentially increase production rates and lower costs compared to conventional vertical wells. Nearly all commercial horizontal

drilling today is done for oil. Several experimental, horizontal gas wells have been drilled previously in the eastern shale formations, but never in the tight sand deposits of the West.

In western Colorado alone, an estimated 420 trillion cubic feet of natural gas is thought to exist in a section of a tight sand formation called the Mesaverde Group. As much as two-thirds of this gas lies in lenticular sands, with the rest occurring in blanket formations.

The US Geological Survey has estimated that more than 5,400 trillion cubic feet of gas exist in the two largest tight sand basins in the West — an amount that far exceeds the roughly 200 trillion cubic feet of producible gas known to exist in conventional US reservoirs.

## Plans for gas pipeline in GDR

IN CONNECTION with the construction of the MIDAL natural gas pipeline by Wintershall AG, Kassel, as reported in *Energy World* in No 174, its cooperation partner, the Kombinat Gasanlagen, Mittenwalde/GDR, plans to build a natural gas pipeline extending over some 250 km and involving total capital expenditures of approximately 350 m DM. The Kombinat has filed its project with the respective ministries and agencies in the GDR.

The pipeline is planned to extend from Philippsthal (FRG/GDR border) in Hesse to Sayda (GDR/CSFR border) in Saxony.

The projected pipeline is planned to start operation in 1993.



## Labour attacks return to deficit in fuel trade

THE Labour Party have criticised the return to an overall deficit in Britain's fuel trade and the Government's energy policies which, they claim, has led to the small deficit in 1989 and the continued deficit that the Party says has continued in the first quarter of this year.

Quoting figures obtained from various official sources, Mr Frank Dobson MP, Shadow Energy Secretary, said that in 1989 fuel exports totalled 119 million tonnes coal equivalent (mtce) while fuel imports totalled 125 mtce, leaving a deficit of 6 mtce.

In January to March 1990 the trend was continued with total exports at 33.7 mtce and imports totalling 37 mtce, leaving a deficit of 1.3 mtce.

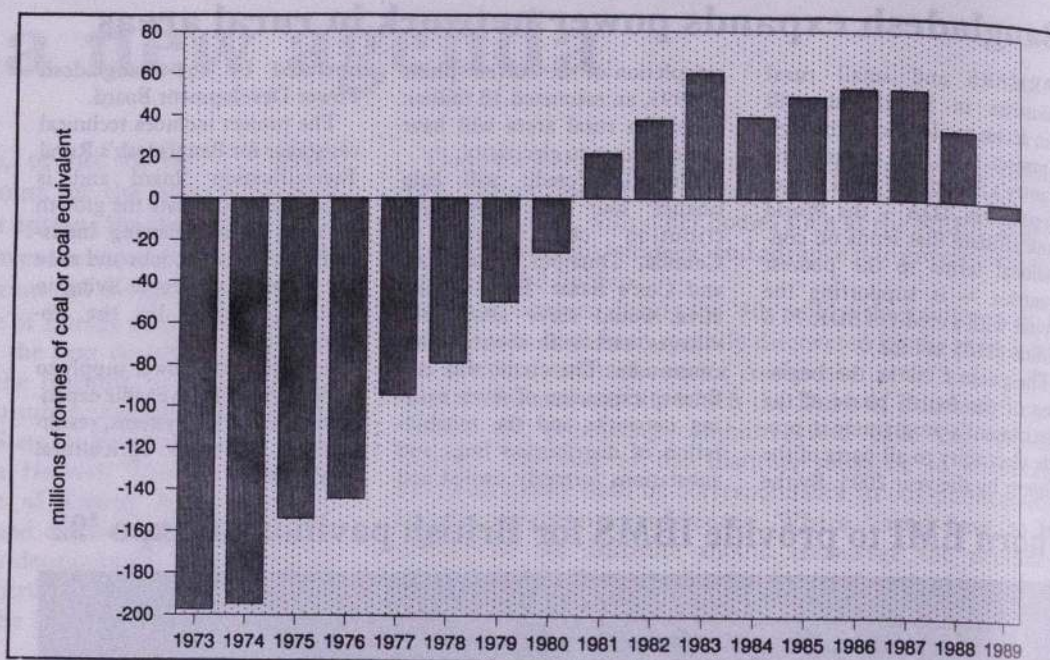
Mr Dobson pointed out at a House of Commons Press conference that this decline in Britain's fuel trade had followed an improvement during the 1970s as North Sea oil came on stream, culminating in a surplus for the first time in 1981. This surplus reached a peak of 60 mtce in 1983, but in 1988 the figure had declined to 33 mtce.

Looking at the figures in cash terms, Mr Dobson said the value of the fuel trade surplus had declined from £6.4 billion in 1986 to £0.7 billion in 1989. The latter figure was offset by payments of £0.3 billion to France for electricity imported via the Channel link. The surplus for the first three months of 1990 totalled just £0.09 billion.

Commenting on the figures, Mr Dobson said: "These figures show what a mess the Government has made of their handling of Britain's precious natural resources. An island built on coal surrounded by seas rich in oil and gas manages to have a fuel trade deficit. Government recklessness has curtailed our self-sufficiency in fuel to just eight short years.

"It is clearly Government policies which have caused this. They have encouraged coal imports. They have allowed the oil companies to 'flare off' natural gas so we have had to import it.

"All this is bad enough. But it's going to get worse. To avoid cleaning up power station chimney emissions the Government are encouraging the electricity



Analysis of the UK balance of trade in fuel, 1973-89, as presented by the Shadow Energy Secretary, Frank Dobson.

generators to import low-sulphur coal (having closed 49 low-sulphur British pits in the last decade). Now British Gas have announced that they intend to step up gas imports. On top of that the electricity generators have started burning more oil in power stations.

"This is economic madness. Energy Secretary John Wakeham doesn't want to know and Trade Secretary Nicholas Ridley doesn't seem to care. Both have acquiesced in proposals to build coal importing plant on Humber-side and are now actually promoting the building of gas fired power stations. The latter pose two threats to the balance of payments — possibly having to use imported fuel and certainly being built by overseas companies," he added.

Responding to these comments, Energy Secretary

John Wakeham said that Mr Dobson had apparently failed to notice that shutdowns and work to improve offshore safety — which remains the Government's over-riding concern — had the effect of reducing the UK's oil output last year.

"The continuation of this work will probably mean that the recovery in production this year — and even into next — may only be relatively modest. But thereafter factors like last year's record number of significant discoveries on the UKCS, the recent record levels of exploration and appraisal activity, and continued buoyant levels of investment, are expected to result in a second peak in oil output by 1993/94," he explained.

"Because oil largely dominates our total fuel trade, that should mean that there is every chance that our fuel trade will return to

an increased overall surplus within the not too distant future.

"It is true of course — though Frank Dobson disingenuously fails to mention this — that since North Sea oil output reached its first peak in the mid-1980's when oil prices were extremely high, some subsequent decline — in both value and volume terms — became virtually inevitable. But North Sea oil still produced a not insubstantial surplus of £1.5 billion on our balance of payments last year," commented Mr Wakeham.

In the case of gas, Mr Wakeham argued that the 20 per cent of UK supplies which are currently imported from Norway are expected to decline rapidly within the next few years, and the recent high rates of development activity within the UK sector mean that we now have sufficient reserves to meet the whole of UK demand at competitive prices for the foreseeable future.

"Coal imports are still a relatively small contributor to the fuel trade position. It remains possible that low-sulphur coal imports may rise as one of the means of meeting our EC commitment to reduce sulphur dioxide emissions, but that is a matter for the electricity generators to decide," he stated.

Referring to the recent writing off of British Coal's debts under the capital reconstruction of around 6½ billion, Mr Wakeham said that this should have the effect of making the industry more competitive against coal imports.

## £2m power station conversion

BABCOCK ENERGY Limited, part of Babcock International Group plc, has been awarded a contract worth £2 million for new combustion equipment at the North of Scotland's Hydro-Electric Board's Peterhead power station in Grampian, Scotland.

The work will form part of the conversion of the station's two 660 MW boilers to burn gas from the Miller field due to be brought ashore in 1992. Babcock Energy's contribution involves modification to the existing gas burners and associated gas handling equipment.

The two boilers at Peterhead, which were originally designed, supplied, erected and commissioned by Babcock in 1980 and 1982, have been in service since then, firing oil and gaseous natural gas liquids as required to meet load demands. The new fuel will be burnt continuously to match the supply over any 24 hour period.

The new gas burners are based on the latest Babcock designs.

Modified boiler management, together with start-up and venting arrangements, also forms an important part of the package.



## Energy spending by local authorities 'still excessive' — Audit Commission reports

LOCAL authorities in England and Wales could save £100m in annual energy costs and more in the long term, according to an Audit Commission study published on 10 May.

Substantial cost savings were identified in a Commission report in 1985, but following energy audits in over 300 authorities the Commission was disappointed to find that by 1989 savings of only £23m had been achieved.

A small number of authorities had implemented all the potential savings identified by auditors but progress at the majority of those surveyed is very slow.

Most authorities do not invest enough in measures to reduce energy consumption, energy is not managed as well as it could be and proper monitoring could better identify problem areas says the Commission.

However, outside factors such as the limitation of capital controls and more particularly the gas 'tariff trap' are major barriers. (Under the British Gas tariff system, unit prices rise by as much as 30 per cent when a building's consumption falls below 25,000 therms a year, thereby penalising efforts to conserve energy). The report describes the tariff system as 'a serious impediment to energy efficiency'.

## Solar energy sun-day

MORE than 30 venues either using or researching solar energy will be open to the public on 24 June in an exercise named Solar Energy Sun-day.

Members of the Solar Energy Society, and other enthusiasts, will be on hand at various solar houses, wind turbines, wave energy devices, small hydro-electric plants and bio-mass schemes. In addition there will be exhibitions, demonstrations and literature on sale.

The Solar Energy Society runs four conferences each year, and encourages membership from researchers, students, and prospective consumers.

For further details, send an sae to: The Solar Energy Society, King's College London, Campden Hill Road, Kensington, London W8 7AH.

Successful energy authorities commonly display:

- a committed and organised approach to energy
- an adequate, sustained investment in conservation measures
- good systems and monitoring arrangements
- encouragement for users to save energy
- effective property management.

During the forthcoming year district auditors will be reviewing energy management at many of the larger energy using authorities to help them identify and overcome the barriers to further and faster reductions in consumption. (In addition auditors, under the Commission's guidance, are reviewing energy efficiency in Health Authorities using similar methodology).

One recommendation is that authorities should invest ten per cent of the value of total energy

expenditure in conservation measures as the initial investment is likely to be recouped within five years.

"In view of the relatively short payback of many efficiency measures and the long term returns, it is sad to find authorities, and particularly those under most financial pressure, reducing or eliminating their energy investment budgets," said Howard Davies, Controller of the Audit Commission.

"But it is encouraging that many authorities are now developing 'environmental audits'. Energy should play an important part in these initiatives," Mr Davies said.

The report also draws attention to the fact that local authorities are significant users of energy — in total they spent some £930m in 1989 (over 40 per cent of energy expenditure in the public sector), of which £740m went on non-domestic buildings such as schools and offices.

Table 1: Typical expenditure for some common types of building

Building Category	Annual Energy Expenditure (£)
Primary school	9,000
Secondary school (with pool)	40,000
Secondary school (no pool)	30,000
Library	5,000
Elderly persons' home	12,000
Leisure centre (with pool)	65,000
Main office	80,000

Source: Auditors' reports

## Approval for UK's first privately-owned wind farm

PLANNING permission has been given by North Cornwall District Council for what is destined to become Britain's first privately-owned commercial wind generator farm.

The approval for erection of ten 400 kW wind turbine generators at Deli Farm, Delabole in Cornwall, has been granted to organic farmers Peter and Simon Edwards on the recommendation of North Cornwall's planning officer, Tony Philp.

The planning permission has been granted despite opposition from local objectors who claimed that the wind turbines would create a noise nuisance, would have a detrimental effect on the landscape, devalue property,

affect television reception, and affect the holiday industry. However, a visit to Danish wind farm sites by a delegation of the North Cornwall councillors helped to allay fears.

However, the approval for the wind generator scheme is subject to a legal agreement that would control the environmental impact of the development to the planning authority's satisfaction. Restrictions on the development will include limiting the number of turbines on the site to ten, the siting of the machines at not less than 350m from any nearby dwelling, limiting noise emissions to ensure that, at low speed operation (32 rpm), the combined effect of all operating machines

## Market forces not enough warns RIBA

THE Royal Institute of British Architects (RIBA) has warned the Government that market forces alone will not produce energy efficient buildings.

In written evidence to the House of Commons Select Committee on Energy, the Institute warns that: "Architects who propose to clients that they should go beyond the insulation standards of the current Regulations are usually met with the instruction to comply with the Regulations and no more. The majority of clients are unimpressed by both the ecological and medium term economic arguments.

"The Government seems committed to the belief that energy conservation can be adequately realised through the operation of market forces. This, in our view, reveals a failure to recognise the urgency of the global problem and the realities of commercial self interest. It is the view of the Institute that Government intervention is necessary," continues the Institute.

Amongst the Institute's proposed regulations are: raising the standard of insulation in domestic, commercial and public buildings to current Danish levels by the mid 1990's; new housing to be graded according to a national rating of energy efficiency; and financial inducements to retro-fit insulation to existing buildings.

will be no greater than 39dBA at a distance of 350m, and during high speed operation (48rpm) the combined effect will be no more than 45dBA at the same distance.

The threshold for operating the wind turbines at low or high speed is related to prevailing wind speed. The changeover from low to high speed operation takes place when the prevailing wind speed reaches eight metres/second at hub height (25m above ground level).

Wind Energy Group Ltd have been chosen as the supplier of the wind turbine generators, which will be their MS3 type. Manufacture of the machines is due to begin later this year and site installation is expected to begin early in 1991.

## Royal visit

HRH The Duke of Edinburgh, an Honorary Fellow of the Institute of Energy, visited a 'hot rocks' geothermal site near Falmouth, Cornwall in May.

Camborne School of Mines, backed by Department of Energy financing, has now been working on the project for 14 years — at a cost, so far, of more than £33 million. The next stage, a prototype power plant, is expected to cost a further £50-£60 million.

Technically, Mr Roy Baria, assistant project director, believes there are no problems the project cannot overcome: 'We could built a power station right now, but the technology we are developing is really for the next century. Quite a lot of us may not be here to see it finally work as a power station.'

The Cornish project team is already winning the world race to tap energy from within the earth, with the Americans now judged to be three or four years behind, while engineers from Japan, France and Germany concede that Britain is now well in the lead.

The potential advantages offered by the system are immense, says Mr Baria. For instance, the hot rocks contain the only known renewable energy source that remains constant 24 hours a day. And the earth's crust is so vast that man could never use all its energy.

According to Government sources: "Unlike solar heating, the potential energy produced by the geothermal 'hot rocks' project will cost far, far less than it saves."

## IEE measurements prize

APPLICATIONS are now invited for the 1990 Measurements Prize awarded annually by the Institution of Electrical Engineers (IEE) for achievements in the science, art and practice of electrical measurements. The £500 prize is donated by CEE Relays Ltd.

Applications for the 1990 award should be submitted to the IEE by 29 June 1990.

Application forms are available from Miss Moira Hatherley, IEE, Savoy Place, London WC2R 0BL. Tel: 071-240 1871 ext 207.

## New Companions of the Institute



Dr Elliot Finer, pictured above left, and Mr Alf Tyson, below left, receiving their special awards, conferring Companionship of the Institute of Energy upon them. Both Dr Finer and Mr Tyson are pictured with Professor Brian Brinkworth, the then President, at the Institute's annual luncheon in April.



## Fellow receives further distinction

JASPER MARDON (*Fellow*), President of Omni Continental Ltd, Vancouver, Canada, has been honoured by the Finnish Paper Engineer's Association with the Stenbäch Plaquette.

As reported in the February issue of *Energy World*, Dr Mardon was presented with TAPPI's Gunnar Nicholson Gold Medal Award earlier this year.

The Stenbäch Plaquette was founded in 1967 and it is awarded for outstanding service to the Finnish Paper Engineers' Association. Over the years, it has been awarded to 45 outstanding

persons in the pulp and paper industry.

Within the Finnish pulp and paper industry Jasper Mardon has contributed much know how and expertise in research and development, most of all in the area of papermaking. He has organised courses on different themes in Finland and has been a frequent lecturer at meetings of the Association. Dr Mardon is a corresponding member of the Finnish Association.

The plaquette was presented to Dr Mardon at a special ceremony during the 24th EUCEPA Conference in Stockholm in May.

## Obituary

### Ian N Merrill

IAN N MERRILL died on 30 December 1989, aged 85. He had been a Member of The Institute of Energy for many years.

Born in Jarrow he moved with his father — a gas engineer — to Sutton in Ashfield, Nottinghamshire, where he was apprenticed at Stanton & Stavely Iron Works. Qualified in Chemical Engineering he took on sales agencies for Audco Valves and Labour Pumps.

But his inventive, restless mind saw the potential in inhibitors for the steel industry and began analysing formulas leading to his setting up of his first company — Rapax Ltd, later known as Merrill Chemicals Ltd.

His pioneering work brought him in touch with Amchem — the American Paint and Chemicals Company, Pennsylvania — and he secured the licences to manufacture their inhibitors and Rodine products here in the UK. After more than 30 years he sold the business.

His other major interest was chemical pumps for handling special sensitive liquids. In time he designed his unique Merrill Pump, which he patented worldwide along with his valves, forming another company — Merrill Pumps Ltd. The pump was exported all over the world as well as being extensively used in Britain at major plants such as ICI, British Rail, Esso Fawley, atomic power stations, and numerous chemical manufacturers and steel plants. It is a tribute to their robust simple design that most are operating 25 years later.

He later sold the business in his mid 70's and moved to Devon to enjoy a peaceful retirement. He continued to be very active in the chemical engineering field and still designed pumps up until his death. His chemical pump remains a fitting memorial to his ingenuity and relentless devotion to his work.

## Appointment

DR OLINGA TA'EED (*Graduate*) was appointed head of the central R&D division of Molyntx Holdings plc earlier this year.

Dr Ta'eed will continue in his role as acquisitions investigator for the company.



## Our incoming President — a profile

FOLLOWING The Institute of Energy's annual general meeting in Scarborough on 19 May, Doug Willis has taken over as President from Prof Brian Brinkworth.

Doug Willis retired in February 1989 after 40 years in the coal industry. His career began in 1949, after serving in the RAF, when he joined the National Coal Board's then newly set-up Central Research Establishment at Stoke Orchard as a laboratory assistant.

In 1950, enabled by an ex-service grant, Mr Willis left Stoke Orchard to attend University College, Cardiff, graduating in Fuel Technology in 1953.

On his return to Stoke Orchard, following his academic career, he was involved in the early work on the fluidised bed carbonisation of coal.

In 1955 he moved to the NCB's National Fuel Efficiency Service, becoming involved in all aspects of energy efficiency, including the generation and usage of steam, electric power and compressed air, which was then widely used underground as a safe power source.

In 1962 he moved into the newly formed Technical Services branch of the marketing department in the West Midlands, dealing with a wide range of industrial and commercial users of coal. He was particularly involved in group and district heating schemes.

Having moved to Nottingham in 1968 when marketing regions were merged, he became the first operations manager of the Nottingham District heating and incineration scheme, which was set up in the mid 1970's.

Then followed two years as



Doug Willis BSc CEng FInstE.

Deputy Head of the industrial sales and service branch in the Midland region before he moved back to Stoke Orchard in 1978 as Chief Industrial Development Technologist, being very much involved in the commercial development of fluidised bed combustion.

He was promoted to the NCB headquarters at Hobart House in 1985, first as deputy manager of the industrial sales and technical service, and then manager.

Doug Willis has been an active member of the Institute for many years. He was Chairman of Midland branch in 1969-70 and then Chairman of the East Midlands branch in 1975-76. He was elected to Council and served two 'stints' as well as having been on membership committee for about 15 years.

In 1986 he was given the Institute's Services Award in recognition of his hard work, and all that he has contributed to The Institute of Energy.

## Prof Sergeant to serve on ACMTC

PROF GEOFFREY SERGEANT (*Fellow*) is now a member of the Australian Coal Marketing and Technology Council (ACMTC).

His appointment was announced earlier this year by the acting Ministry for Primary Industries and Energy in Australia, Senator Peter Cook.

The ACMTC was established in 1988 to advise the Minister on measures to enhance Australia's export coal trade.

Prof Sergeant, Head of the Department of Technology at the

University of New South Wales, replaces Prof Ming Leung, who died at the beginning of the year.

The Minister stated: 'Prof Sergeant's qualifications and experience should enable him to make a valuable contribution to the Council's work.'

### Next edition

The next scheduled issue of *Energy World*, will be in August, to allow for holidays taken by editorial and printer's staff.

## New members

### Fellow

**Rohan Amarasinghe**, Colombo Gas & Water Company, Sri Lanka (*transfer*)

**Leigh Jonathan Carless**, T M Energy Ltd, London (*transfer*)

**Jeffrey Chapman**, Allott & Lomax, Manchester

**David Alan Hutchison**, HLM Architects Ltd, Avon

**Ernest Alexander Rowland**, (*transfer*)

### Members

**Clifford Roy Bassett**, Briar Associates, Stourbridge

**David Anthony Carter**, Eng Dept, General Hospital, Jersey, CI

**Bryan William Gladstone**, Sheffield Polytechnic

**Pradeep Herath**, Cremer & Warner, London (*transfer*)

**Wing Yeung Li**, Hong Kong & China Gas Company, Kowloon

**Robert William Whitelaw**, Emstar Limited, Glasgow

**Yigzaw Goshu Yohanis**, University of Ulster Jordanstown

### Associate Member

**William Wilkinson**, Royal Mail Letters, Croydon

### Graduate

**Neale Andrew Jackson**, KRJ Consultants, Maidstone, Kent

**Richard John Tabberer**, PowerGen, Marchwood, Southampton

### Student

**Nicholas David Reid Gardner**, Cranfield Institute of Tech

**Mustafa Husain**, University of Liverpool

**Owden Robert Mwaikondela**, University of Reading

**Sina Pachenari**, The Polytechnic of the South Bank

**Kevin Roberts**, University of Leeds

## Annual Report and Accounts — corrections

Page XIV. Statement of Source and Application of funds for year ending 31 December 1989: application of funds should read £5,845, not £(5,845).

Page XVII. Institute Award Funds, Less: Awards section, column nine, the figure £250 should be inserted.



## A.K. WAUGH LTD.

Formed in 1940 by Mr A. K. Waugh, our Company celebrates 50 years in business this year. Over this period we have remained specialists in producing custom manufactured heating equipment for heating Industrial Fuel Oils. We also manufacture for other applications involving any fluid type.

### IMMERSION HEATERS

Single tube immersion heaters with various means of connection are manufactured in accordance with current British Standards with loadings from 200 watts-6000 watts in varying lengths according to requirements. The heating element is removable for repair or replacement without draining the system. Multi tube assemblies cover a standard range of 6 kW-54 kW, with special units up to 180 kW.

Flameproof single tube immersion heaters are also manufactured in a similar range to the single tube units described above. Special units can be manufactured for particular applications.

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We manufacture electric, combined steam and electric and steam only units. Our standard range is from 3 kW to 75 kW, with special units to 300 kW. Heating elements are replaceable without draining the system. Hot water and thermal oil units are manufactured also.

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In-line heaters are supplied in a standard range of 3 kW to 72 kW with an extension of the range up to a maximum of 315 kW in a single shell. Heaters can be arranged for two tier mounting when required and once more there is the option of utilising different methods of heating, such as steam or hot water.

### NEW PRODUCTS

With the advent of Orimulsion (Bitumen emulsion) as a fuel for use within the power generating industry, we have designs for heaters which will be able to heat this fluid without degradation of the fluid. Please contact us for further details.

**AK Waugh Ltd**

FUEL OIL HEATING EQUIPMENT MANUFACTURERS

Abbotsburn, Inchinnan Industrial Estate, Renfrew PA4 9RW

Tel: 041-812 0131/041-812 1961, Fax: 041-812 0157, Telex: 779466





IT IS very unusual to see a completely new fuel introduced to the market, but BP Bitor, a new 50/50 joint venture company set up by BP Oil and Bitumines Orinoco SA, have taken the initiative to introduce the bitumen-based emulsion fuel known as Orimulsion.

The Institute of Energy's conference on the subject provided a good opportunity to assess the results of trials in which the combustion characteristics of the fuel and the performance of the fuel in power station boilers and other applications were studied. The presentations and discussions yielded a useful introduction to the potential of the fuel although it was felt that a number of intriguing questions remain to be answered before the fuel is fully accepted by the market.

The more detailed introduction to the characteristics of Orimulsion was given by Dr Manuel F De Oliveira, managing director of BP Bitor, who began by giving a very clear and illuminating account of the discovery and assessment of the enormous reserves in Orinoco, Venezuela, of an extra heavy crude oil or natural bitumen.

The recoverable reserves are comparable in energy content to 64,000 million tonnes of coal and could sustain production of 200 million tonnes of coal equivalent pa for 300 years. The

*\*Independent fuel and combustion consultant*

# Orimulsion—review of combustion and handling tests

by Byrom Lees MSc, CEng, SFIInstE\*

The world of fuel and energy experienced a very unusual event when the results of initial trials in combustion and handling of a completely new fuel—Orimulsion—were presented at an Institute of Energy conference in London on 19 April. The uniqueness of the occasion attracted approximately 150 leading fuel specialists to assess for themselves the potential of the new fuel. In the following article one of these specialists, Byrom Lees, a Senior Fellow of The Institute of Energy, gives his impressions and summarises the results of the early trials based on data provided at the conference.

reserves were described in 1983 as the largest untapped reservoir in the world.

Petrole de Venezuela made a comprehensive exploration of the field and studied different steam injection systems for obtaining the product. A combination steam injection and cluster project have already achieved good outputs so that the bitumen fuel could now be marketed after passing through a simple degasification, dehydration and desalting process.

In 1982 an agreement was reached with BP Research Centre, Sunbury, to assess whether a suitable fuel oil could be produced by emulsifying Orinoco Bitumen in water to prepare a fuel which could be stored, handled and transported satisfactorily and have good combustion characteristics. In 1986-87 the fuel was prepared on a laboratory scale, in 1987-88 it was prepared on a pilot scale and in 1988-89 it was produced on a commercial scale.

This report is concerned only with the tech-

## The author

Byrom Lees began his career in fuel technology at the Fuel Research Station, Greenwich in 1937. He worked with Dr Crossley on boiler availability problems, classifying coals according to their fouling and corrosive characteristics when used in power station boilers. He took the opportunity to take an external MSc at London University.

From 1949 he worked in the CEGB as a combustion technologist, London Division, controlling the fuel quality and studying the effect of fuel quality on boiler availability. The use of combustion control, that is operation with a low concentration of excess air in the flue gases, was introduced at Bankside Power Station to reduce sulphur trioxide formation and low temperature corrosion in oil fired boilers.

In 1957 he joined BP and introduced the ammonia process, which had been developed in the BP Sunbury Research Laboratories, into the flue gases in power stations to reduce air



preheater corrosion problems, again with notable success at Bankside Power Station.

Aluminium cladding and insulation of steel chimneys was introduced to reduce corrosion and acidic smut

emission problems with oil fired boilers. BP received the Arnold Marsh Clean Air Award from the National Society for Clean Air (NSCA) for this development.

Magnesium based additives were introduced into oil-fired boilers to overcome both high temperature and low temperature corrosion problems. This technique is now finding an important application with the introduction of Orimulsion and the scientific assessment methods used in the past will undoubtedly be applied again in the applications of this new fuel.

He has been a member of The Institute of Energy (formerly the Institute of Fuel) since 1949 and was elected to become a Senior Fellow in 1965. In 1975 he received the Institute's Lubbock-Sambrook Award.

Part time consultancy on corrosion and pollution problems associated with combustion has been undertaken since 1975 after he retired from BP Technical Services. He has been chairman of the Institute's Publications and Conferences Committee and still serves on this committee and on the Technical Committee of the NSCA.

nical aspects of trials carried out by ICL and Babcock Energy to assess the combustion and handling characteristics of the fuel and trials at Dalhousie and Ince B power stations with the new fuel. Combustion trials have also been carried out in Japan and gasification trials using the Texaco process in California.

## Chemical/mechanical characteristics

The manufacture of Orimulsion is a two stage process. This is illustrated in Figure 1. In the first step an emulsion of nine parts of bitumen and one part of water containing the surfactant in solution is passed into a low shear industrial mixer to blend the first stage emulsion. In the second stage a further 20 per cent water is added to the emulsion and the product passed through the second mixer.

The water ends up evenly distributed throughout the mixture so that the bitumen is carried in a detergent medium. The emulsion has the ability to flow through pipe lines and remains unaffected by constant recirculation. The bitumen droplets are so small (the mean droplet size is less than 30 microns) that the emulsion remains stable in storage and can be burned as a fuel. The characteristics of the two fuels, Orinoco and Orimulsion are shown in Table 1. It was realised that the surfactant should not contain salts such as alkalis which would accentuate corrosion and deposition in boilers or other plant using the fuel. A magnesium organo-based surfactant was chosen and sufficient introduced to finish with a concentration of approximately 350 ppm magnesium in Orimulsion.

**Table 1: Orimulsion characteristics**

	Typical values
Water content, % W/W	29.0
Median droplet size, $\mu\text{m}$	20
Maximum viscosities, mPas	
5°C	1200
10°C	2000
20°C	700
30°C	600
70°C	300
GVC, $\text{MJkg}^{-1}$	29.7
NCV, $\text{MJkg}^{-1}$	27.5
Sulphur, % W/W	2.7
Vanadium, ppm	300
Sodium, ppm	70
Magnesium, ppm	350
Ash, % W/W	0.25
Flash Point, °C	130

It is well-known that the addition of magnesium based additives into the fuel oil in oil fired boilers reduces deposition and corrosion associated with sodium vanadyl vanadates particularly in the superheater and reheater zones. They also bring about a reduction in the formation of sulphur trioxide from sulphur dioxide in the flue gas steam as it passes through the boiler. Low temperature corrosion and acidic smut emission problems are reduced or eliminated, enabling plant to be designed to operate at high efficiency.

A paper by Jim Struthers of Babcock Energy Ltd described an extensive programme carried out at Renfrew to study the handling characteristics of the new fuel and to determine the



**Dr J Allen, of NEI International Combustion, delivering his paper entitled Combustion of Orimulsion, at the Institute's Orimulsion conference.**

modifications which would have to be made when introducing the fuel to an existing oil fired boiler.

The storage temperature need not exceed 40°C so that, in transit from Venezuela, it is generally not necessary to apply heating providing the fuel is supplied to the tanker a few degrees above this temperature, the oil is circulated and the journey is not too long. In one trial run, the fuel was satisfactory after travelling for 45 days.

The fuel is not compatible with all other liquid fuels handled in normal power stations. In order to avoid deterioration the level of contamination should never exceed 3 per cent on Orimulsion.

Emphasis was placed on the need to ensure that capitation at the pump section does not occur. Orimulsion is sensitive both to turbulence and to shear rate, with excessive levels of either causing damage such as coalescence or an increase in droplet size. The types of pumps used to transfer the fuel have to be carefully selected to avoid an excessive shear rate and the pumps recommended by Babcock Energy Limited have been used satisfactorily in trials on boilers converted from fuel oil firing. Care must be taken to ensure that heaters in storage facilities should not have surface temperatures in excess of 90°C to avoid local overheating of Orimulsion.

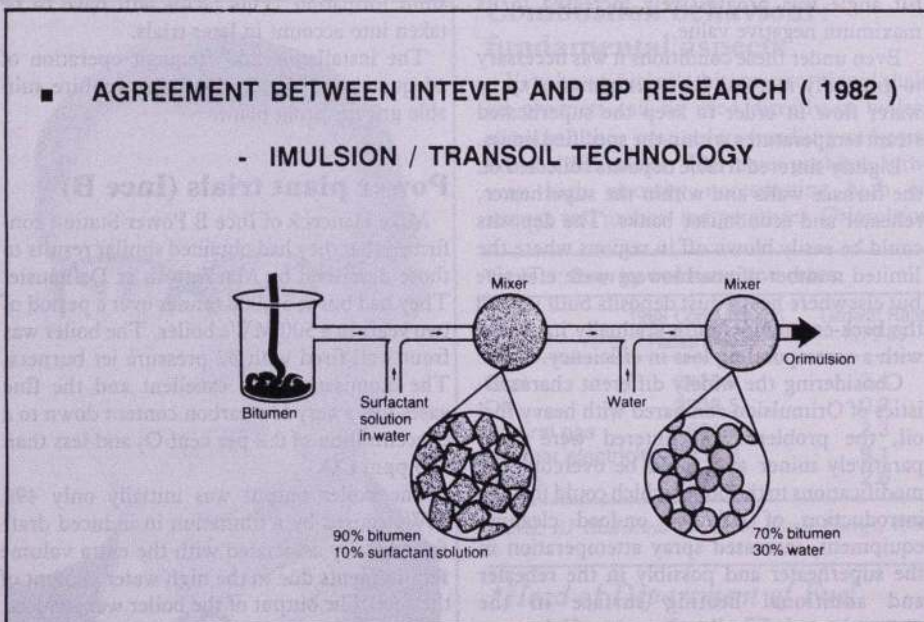
## Burner trials

Trials carried out at Derby on the NEI International Combustion test rig showed that the new fuel could be used with standard fuel oil burners and in most cases combustion characteristics were better than when burning heavy fuel oil. The flames were slightly shorter and carbon emissions were exceptionally low even with very tight combustion control with excess oxygen well below 1 per cent. Carbon monoxide concentrations in the flue gases were also low and the fuel can be used with low  $\text{NO}_x$  registers.

## Power plant trials (Dalhousie)

Brian Mackintosh described in detail the results of very comprehensive trials carried out in a 100 MWe power station boiler at Dalhousie.

Due to the water in the fuel, there is an increase in combustion gas weight of some 2.5 per cent and a reduction in efficiency of some 2.3 per cent when operating with similar excess air and flue gas exit temperatures as with fuel oil firing. Other factors also added to a reduction in efficiency but straight-forward



**Fig 1: Development of the Orinoco Belt emulsions project.**



Pictured from left to right, Eugenia Vasquez, Marketing Manager with BP Bitor; Dr Manuel De Oliveira, Managing Director, BP Bitor; Ian Hole, Sales and Supply Manager, BP Bitor; and Fernando Carvello, Assistant Technical Manager, BP Bitor. Both Ms Vasquez and Dr De Oliveira were speakers at the conference.

modifications to the boiler design should eliminate these factors.

As has been experienced in the past with oil firing, when the magnesium additive is introduced, a white soft friable deposit forms in the combustion chamber in contrast to the black fused deposit which forms in an oil fired boiler not using an additive. The change in the heat transfer characteristics resulted in the flue gases having a higher temperature at the exit from the combustion chamber and an increase in the superheater and reheater steam temperatures when the burners were operated with the same tilt angle with fuel firing. The burner tilt angle was progressively increased to its maximum negative value.

Even under these conditions it was necessary to gradually increase the attemperating spray water flow in order to keep the superheated steam temperatures within the specified limits.

Lightly sintered friable deposits collected on the furnace walls and within the superheater, reheater and economiser banks. The deposits could be easily blown off in regions where the limited number of sootblowers were effective but elsewhere heavy dust deposits built up and the back-end temperature gradually increased with a corresponding loss in efficiency.

Considering the widely different characteristics of Orimulsion compared with heavy fuel oil, the problems encountered were comparatively minor and could be overcome by modifications to the boiler which could include introduction of effective on-load cleaning equipment, increased spray attemperation in the superheater and possibly in the reheater and additional heating surface in the economiser or air preheater.

The fly ash concentration was said to be 250

mg/Nm<sup>3</sup> and the particle size of the dust was 91 per cent below 5 microns and 50 per cent below 0.3 microns. A high proportion of this dust will be magnesium and vanadium oxides. The plume from the stack is much more visible than with fuel oil firing and he considered that it will require most large boilers using this fuel to be fitted with electrostatic precipitators.

The magnesium oxides present in the flue gases will counter any tendency to form acidic smuts due to the high sulphur content of the fuel. Removal of the magnesium oxides by electrostatic precipitation may be counter productive relative to the reduction in acidic smut formation. This factor will have to be taken into account in later trials.

The installation and frequent operation of adequate soot blowing will also require suitable grit arresting plant.

### Power plant trials (Ince B)

Mike Hancock of Ince B Power Station confirmed that they had obtained similar results to those described by Mackintosh at Dalhousie. They had burnt 50,000 tonnes over a period of two years in a 500 MWe boiler. The boiler was front wall fired with 32 pressure jet burners. The atomisation was excellent and the flue gases had a very low carbon content down to a concentration of 0.2 per cent O<sub>2</sub> and less than 300 ppm CO.

The boiler output was initially only 490 MWe caused by a limitation in induced draft fan capacity associated with the extra volume requirements due to the high water content of the fuel. The output of the boiler was reduced still further to 450 MWe as the boiler fouled up due to the dust burden. The compressed air

soot blowers were inadequate to deal with this high deposition problem as they were designed to deal with the different type of deposit associated with fuel oil firing.

The NO<sub>x</sub> concentration in the flue gases fell from 560 ppm to 480 ppm compared with oil firing.

Collected dust contained Mg, V, Na and Ni and was of low acidity. The particle size was in the range 1-5 microns and a persistent plume was observed.

It is proposed to fit better sootblowing facilities and electrostatic precipitators. It is important to ensure that removal of alkaline dust does not bring about acidic smut emission particularly as this station has a common flue chimney (152 m high) for the two 500 MWe boilers.

Both papers indicate that the deposits on the superheater, reheater and furnace wall tubes are soft and friable and that there was no evidence of high temperature corrosion. It would appear that the magnesium to vanadium ratio of 1.3-1 in Orimulsion is adequate to prevent high temperature corrosion. With fuel oil firing it was necessary to use a higher magnesium to vanadium ratio. It is possible that this lower ratio is adequate because of the low sodium to vanadium ratio in Orimulsion.

However, it would be advantageous for those marketing the product to have factual data on the rate of wastage of superheater and reheater tubes. Measurements can be carried out using a micrometer gauge in a standardised method, which is both quick and accurate and has yielded conclusive results in the past, which have been confirmed in practice after some 20 years' operation at Amer Centrale power station in Holland. □



# Primary energy sources: the role of Orimulsion

by Professor Alan Williams, BSc, PhD, CEng, FInstE, FRSC\*

OVER the last hundred years or so the growth in energy consumption has risen at a rate of 1.9 per cent pa. During the late nineteenth and early part of this century coal was the dominant energy source being supplanted by oil and gas in the 1960's.

Cheap oil resulted an increased consumption and the energy consumption growth rate over the period 1960-70 was ca 3 per cent, ie, energy requirements doubled over the period of ten years or so.

This led to worries of the creation of an energy gap, the difference between supply and consumption, but the OPEC oil shocks of 1973 and 1979 slowed down growth so that between 1979 to 1989 the growth rates for the various energy sources were reduced as shown in Table 1. This, together with down-turn in the world economy, has led to a current glut in energy supplies and low energy prices.

The current world energy consumption is shown in Table 1.

Of the fuels specified in Table 1 natural gas must be considered to be the best fuel on grounds of convenience and combustion performance as well as containing virtually no sulphur or fuel-nitrogen compounds and having the lowest CO<sub>2</sub> emission factor. The demand for it is reflected in the growth rate in Table 1. However the lifetime of natural gas is only three years or so if the world were fuelled by it alone. Low sulphur fuel oils or low sulphur, low ash coal are also desirable fuels

**The recent attention focused on Orimulsion as a potential major new primary fuel on world markets has prompted thoughts of what the role of the new fuel might be: in the context of its particular characteristics compared with other conventional fuels, and its position against the emerging fuel supply/demand trends expected in the next decade and beyond. Professor Williams presents his analysis of the factors that will determine the new fuel's role and its degree of success on world markets.**

but their availability is also limited.

Nuclear and alternative energy sources are seemingly incapable of providing the world's energy requirements at the present time and their role over the next two or three decades is seemingly not a major one. The search must therefore be focused on fossil fuels as the major energy sources for perhaps 30 to 50 years or so.

The future energy demand is difficult to assess and future predictions have often been revised downwards over the last decade as shown in Figure 1. The present energy consumption per capita in the world is 1.58 toe and this averages the high energy consuming countries (US, Europe) and the low energy consuming countries (developing countries). This figure has remained unchanged over the last decade when both the population and energy consumption increased at a rate of 1.9 per cent pa respectively. Estimates have been made of the world population over the next 30 years and are as shown in Figure 2. If the

present energy consumption per capita is maintained this implies a vast increase in energy consumption, although some (eg, Thring, *Viewpoint, Energy World*, April 1990) have put forward an alternative strategy.

The world energy reserves are shown in Table 2 and coal is seen to be the most abundant fuel as well as being geographically more uniformly distributed than oil. Clearly it will be a long term major energy source.

Rational analysis suggests that in the future natural gas and fuel oils must be used for premium purposes such as heating, transportation, etc. In the short term both natural gas, low sulphur fuel oils and low sulphur, low ash coal will be used for power generation in many instances when pollutant emission legislation has to be met. However, in principle large integrated power plants with pollution offer the most economic methods of using low grade fuels whether by conventional combustion or by gasification.

## Combustion behaviour: fundamental aspects

Very heavy fuel oils, bitumens or liquid shale oil products can be used directly in boilers although they pose severe handling and combustion difficulties. The major problem is the very high viscosity necessitating high oil storage and preheat temperatures. Orimulsion

## The author

Professor Alan Williams has been the Livesey Professor and the head of the Department of Fuel and Energy, University of Leeds since 1973. His major interests are in the combustion of fossil fuels and environmental pollution control.

He has been a vigorous and active supporter of a number of professional institutions for many years. He is a Fellow of The Institute of Energy, the Institute of Gas Engineers, the Royal Society of Chemistry and of the Institute of Petroleum.

Professor Williams is also a Past President of The Institute of Energy and is currently its honorary secretary. He has written a total of 140 papers on energy, combustion and pollution control.

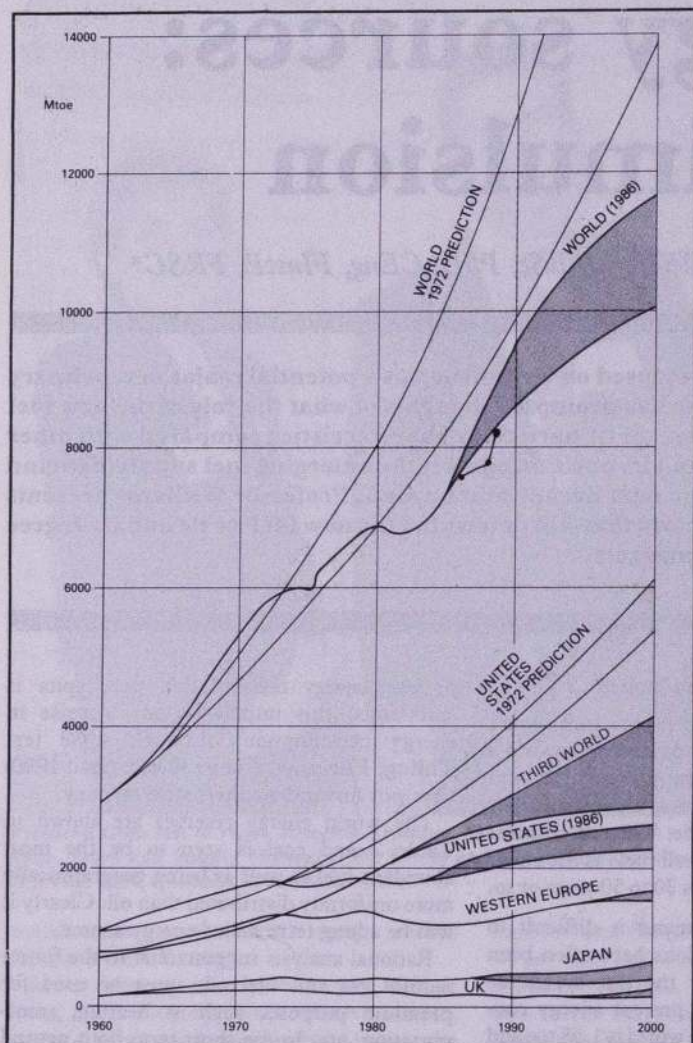


Table 1: Energy consumption rates

	1988 Consumption Rates (mtoe) <sup>x</sup>	Growth Rate 1979-89
Coal	2428.0	2.4
Oil	3038.5	0.2
Natural gas	1631.0	2.3
Nuclear electricity	438.8	9.1
Hydro	537.2	2.6

Source: BP Statistical Review of World Energy, 1989

\*Head of Department of Fuel and Energy, Leeds University



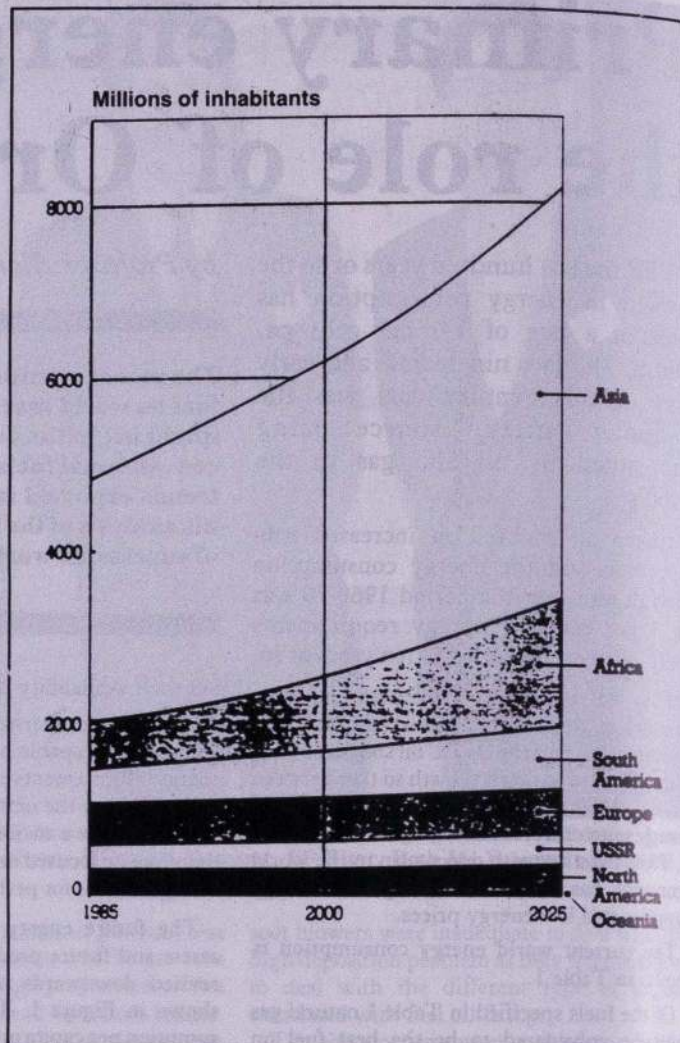
Source: *Energy for the Future*, Institute of Energy, 1986.

**Fig 1: World energy consumption trends in 1972 and 1986, actual world energy consumption.**

consisting of a bitumen particles (70 per cent) — water (30 per cent) emulsion overcomes this problem because it has a viscosity (70°C) of ca 100 cPas (100 s<sup>-1</sup>) compared with a value of 100 cPas for the bitumen alone and is thus readily atomised like a normal liquid fuel. The bitumen particles which have particle sizes of ca 20 μm also enhance atomisation because the liquid sheet formed during atomisation breaks up more readily giving a spray with a smaller mean droplet size than for an equivalent fuel oil.

Orimulsion burns as a spray of liquid fuel and the flames look like conventional oil flames although they are slightly more radiant. The

essential steps are illustrated in Figure 3. The droplet enters the flame and evaporates exposing bitumen particles to the flame gases causing them to melt and subsequently evaporate, decompose and ignite. This stage occurs very rapidly producing a highly reactive carbonaceous particle which burns initially via disruptive combustion then forms a char particle but burns away and fragments. The droplets burn more like a medium fuel oil rather than a coal-water slurry and consequently avoids many of the problems associated with coal-water slurry combustion (significant derating, atomiser wear). However the water content of Orimulsion results in a



Source: *World Population Projections 1987-8*, World Bank.

**Fig 2: Regional distribution of world population.**

**Table 2: World fossil fuel reserves (1988)**

	Reserves	Lifetime ie (years) at current production rates (reserves/production)
Natural gas	111.9 × 10 <sup>12</sup> m <sup>3</sup>	58
Crude oil	123.8 Gt	41
Coal	579.4 Gt hard coal 444.3 Gt lignite	218
Biomass	450 Gt	indefinite
Nuclear	3.6 Mt Uranium	1000 years, or at least very large
Hydro	very large	indefinite

small energy penalty (flue gas losses) and less easy ignition compared with a fuel oil.

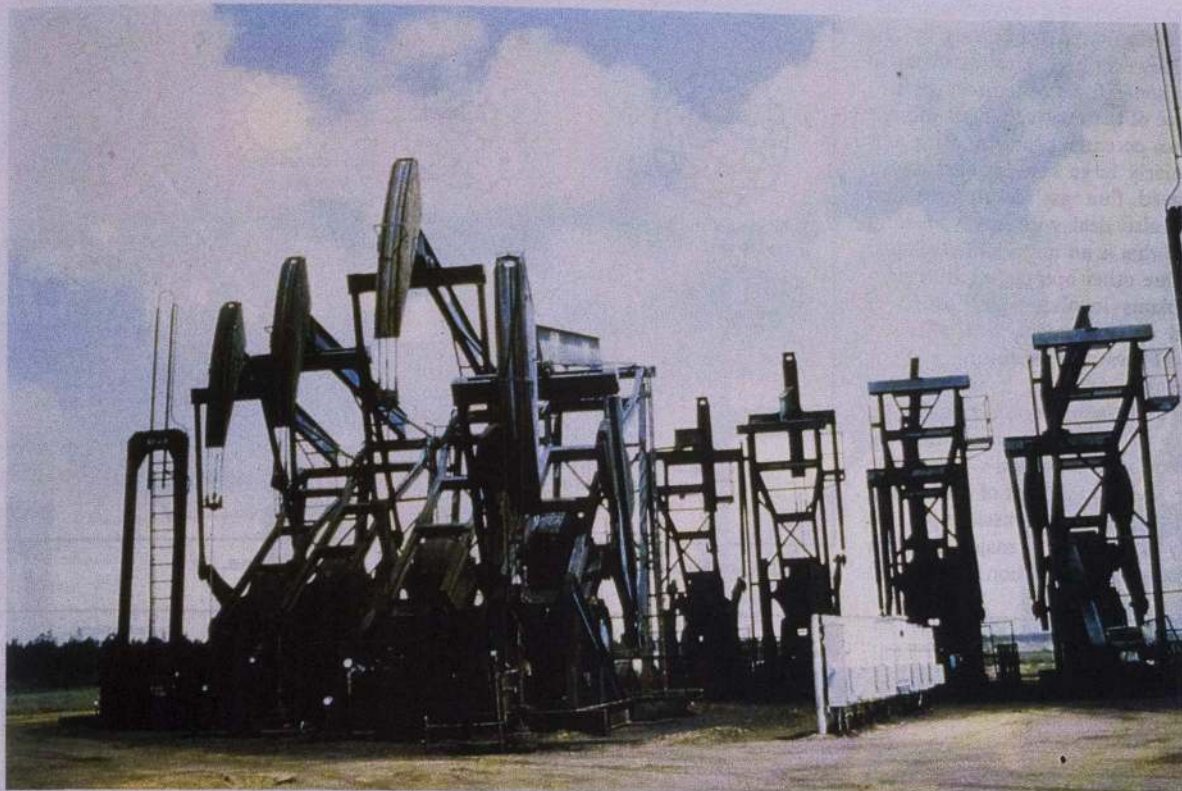
The formation of the carbonaceous residue is more significant than in the case of fuel oils but the presence of finely dispersed metals (vanadium and Mg from the organo-magnesium stabiliser compounds) results in its rapid burn-out and fragmentation.

## Economic factors

Orimulsion can be handled and burned in a way similar to oil and can be used by conventional oil burning plant with little modification. Clearly Orimulsion can be rapidly commercialised in competition with heavy fuel oil or in the longer term with coal with a market price determined by the fuel properties such as calorific value as well as the sulphur and vanadium contents. The fact that it is single sourced at present however is also another factor to be taken into consideration.

The relatively high vanadium content means that electrostatic precipitation (or equivalent) must be used to minimise flue gas solids emission levels. In addition vanadium (together with sodium) can cause corrosion but the presence of magnesium in the Orimulsion will reduce this tendency by modifying the

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composition of the vanadium deposits. Vanadium also catalyses the conversion of  $\text{SO}_2$  to  $\text{SO}_3$  but is inhibited (poisoned) by the magnesium. However high vanadium content fuels result in some direct or indirect costs.

The presence of the relatively high sulphur content is also a potential problem. Most new plant, particularly large conventional power plant, will need flue gas desulphurisation (which would also deal with any vanadium emissions) and this is an important economic factor. There are other options, such as combined cycle plants involving gasification of emulsion and this approach can offer an important way forward in the future.

Clearly, Orimulsion is an important new energy source and the increasing pressure on the availability of other fuels over the next decade will require Orimulsion's large scale development. The requirement of controlling sulphur (and vanadium) emissions in an economic way is however a major problem although not only for Orimulsion. □

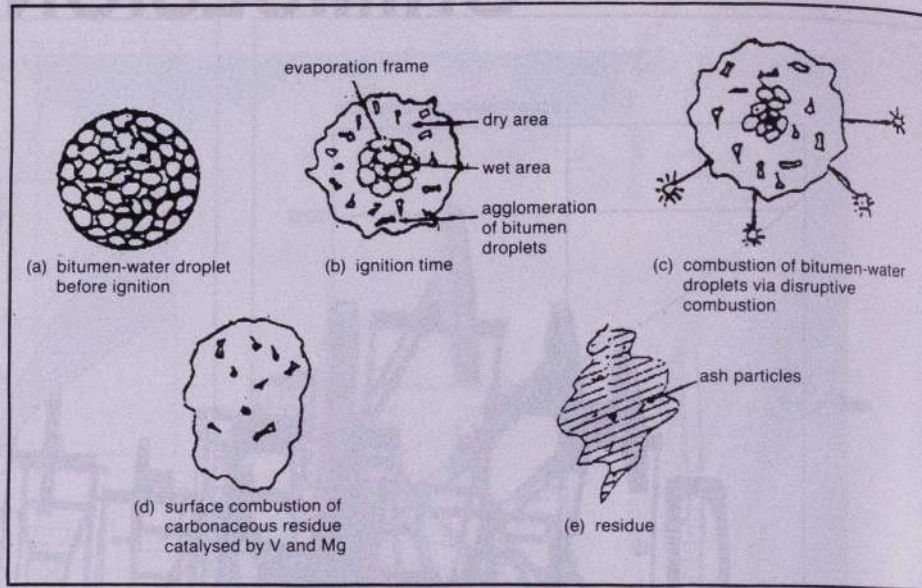


Fig 3: Combustion processes of spray droplets of Orimulsion.

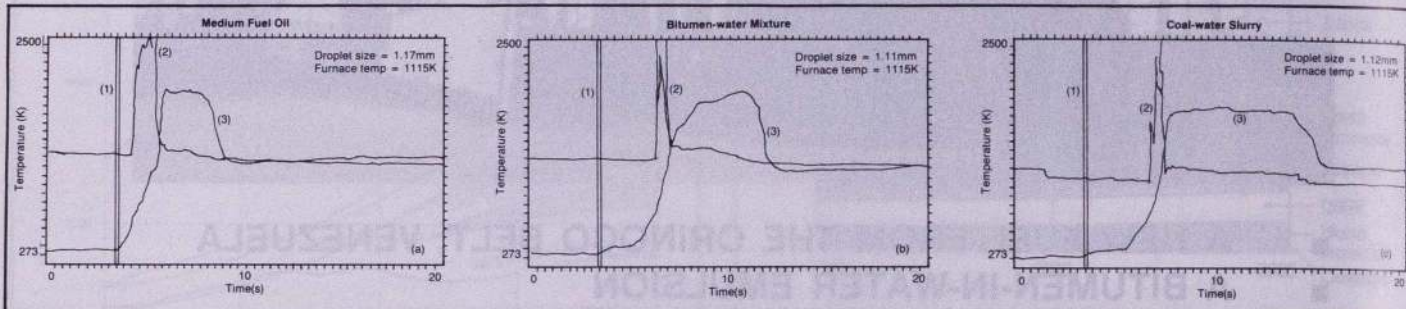


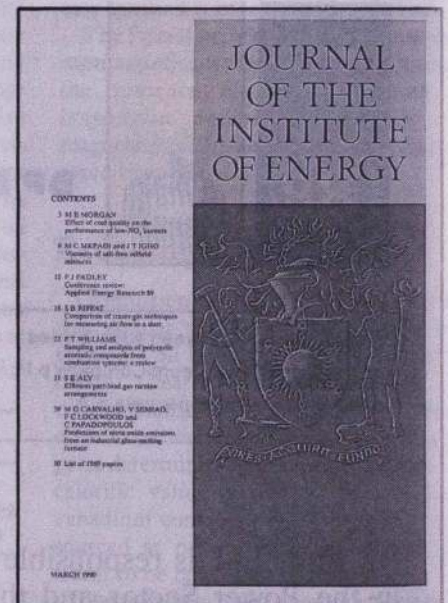
Fig 4: Typical temperature-time history for droplets of medium fuel oil, bitumen-water mixture and coal-water slurry. (1) Moment droplet is exposed to furnace atmosphere; (2) visible flame duration; and (3) droplet temperature history.

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Examples of papers recently published include: *The burning velocities of methane and SNG mixtures with air* (MS Haniff, A Melvin, DB Smith and A Williams); *Optimisation of the design and operation of coal flames in cement kilns* (TM Lowes and LP Evans); and *Pulverised-coal-fired dilute-phase hybrid boilers: a new concept* (P Basu, EAM Gbordzoe and A Sett); *Comparison of tracer-gas techniques for measuring air flow in a duct* (S B Riffat); *Viscosity of salt-free oilfield mixtures* (M C Mkpadi and J T Igho); *Predictions of nitric oxide emissions from an industrial glass-melting furnace* (M G Carvalho, V Semiao, F C Lockwood and C Papadopoulos).



# ENERGY WORLD

The Magazine of The Institute of Energy

Special Energy World supplement  
The 1989 Robens  
Coal Science Lecture

# IT SEEMS ONLY NATURAL THAT AN ELECTRICITY COMPANY SHOULD GENERATE A FEW BRIGHT IDEAS.



Killingholme power station.



Pickerill gas field.



Pipeline joint venture.



Toyota deal.



New technology centre.



Orimulsion, a new fuel.

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For instance, work is starting on our new energy-efficient power station at Killingholme, South Humberside.

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THE FUTURE GENERATION.

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# Coal in the 21st Century

by Kurt E Yeager

**EXPERIENCE** in attempting to forecast the future suggests that 'vision' is less a matter of creating new ideas than accepting and applying that which is already visible. Thus dusting off old ideas whose time has come, not generating new ones, is the principal aim of this paper.

Moreover, it is likely to be significant issues or events we can't identify today, like Three Mile Island and Chernobyl, tankers running aground, oil supply interruptions, and environmental politics, that will be the larger determinants of the future. We can't predict what will happen or when, but, if past is prologue, their occurrence is a certainty. Nevertheless, such events are likely to strengthen this vision of the importance of coal in the new century.

This vision encourages redoubling current efforts to publicly advocate the enlightened use of coal in both the electric power and industrial sectors of the world economy. In order for this effort to achieve its goal of obtaining maximum future benefits from coal's important potential, it will be necessary, on a worldwide basis, to:

- aggressively foster our one unlimited asset — technology — to resolve the historic conflict between coal use and the environment and, in turn, provide the energy foundation for continued global economic development.
- recognise that public opinion is a major factor in deciding which energy options are pursued and that coal is currently perceived by a large segment of the public to be an environmentally unsatisfactory fuel. This image of coal can and must be transformed through technical advances and an effective, long-term programme of public advocacy.

Success on these two fronts is critical because the importance of coal is in direct proportion to its ability to fuel world economic development while stewarding natural resources. Far from being in conflict, world economic development is the most important strategic environmental protection step because, ultimately, environmental protection depends on economic well being. The level of development of societies will increasingly be measured by their ability to achieve high individual welfare with minimum use of all resources. As a result, the challenge of the 21st Century will be to use the tools of economic development to control and balance population growth in a manner that best utilises the world's natural resources.

## Cover photograph

A dramatic night time view of the 50 t/h multi-solid fluidised bed boiler plant at Listowel, Republic of Ireland. Photograph courtesy of Foster Wheeler Power Products Ltd.

## Based on The 1989 Robens Coal Science Lecture presented at The Royal Institution, London 2nd October 1989

As the world grapples with this challenge between now and the middle of the next Century, we can conservatively expect nearly a tripling in global energy consumption. Figure 1 indicates the remarkable importance of coal in meeting this challenge as it is expected to become the world's principal source of energy again, thus resuming its pre-World War II dominance after an oil 'interlude' of half a century. This critical future role for coal reflects the fact that it represents nearly 90 per cent of the world's known, recoverable, fossil energy resources. Factors which bear on coal as it faces the challenge of resuming dominance are:

- the pace of global electrification,
- synthesis of coal-derived fuels at competitive prices,
- resolution of ecological constraints,
- geopolitical management of coal resources (USA, USSR, and China hold about 70 per cent of the world's total as shown in Figure 2).

Two centuries ago coal launched the Industrial Revolution in the United Kingdom. One century ago, coal launched the Electric Era. Proper management of the innovative technical programmes we must conduct will allow coal to propel similar waves of progress across the globe in the second electrical century. That can only be assured if coal is protected from well-meaning, but short-sighted, political pressures which threaten its utilisation or, at the other extreme, the environment in which it is utilised.

In this regard, it is evident that human society has a complex energy ecology woven

into its fabric. Any one change in this total system of energy relationships affects all its component parts. Our ignorance of these matters has led to many simplistic notions concerning the role of energy in the quality of life, ranging from the poetically idyllic notion that the less energy used the better the life, to the opposite extreme of the need for unlimited abundance. Both extremes have little evidence to support their validity. The fragility of our delicately balanced energy ecology was put in sharp perspective during the oil supply interruptions of the 1970's when temporary reductions in supply of just five per cent created major dislocations throughout the western world.

The means of protecting coal's usage as the key element in the global energy ecology of the first half of the 21st century are fully within our technological capability. The historic conflict between coal use and the environment can be resolved, and that resolution must be convincingly demonstrated to opinion leaders and the general public throughout the world. Indeed, it is this elevation of the environmental performance criterion to a level equivalent to the classical engineering criteria of economic performance and reliability which has marked the recent advances in coal utilisation technology.

If these technology and public advocacy programmes are not successful, then the interlocking economic progress of both the developed and developing worlds will be seriously threatened by wasted energy resources, policy indecision created by endless debate over environmental issues, and increasing energy costs that will damage the viability of a broad spectrum of industries. We can avoid this situation by recognising, to paraphrase Winston Churchill, that through technology we are not at the 'beginning of the end' of the coal era but rather at the 'end of the beginning'. Figure 3 summarises the array of new coal utilisation technology, collectively known as the Clean Coal Technology (CCT)

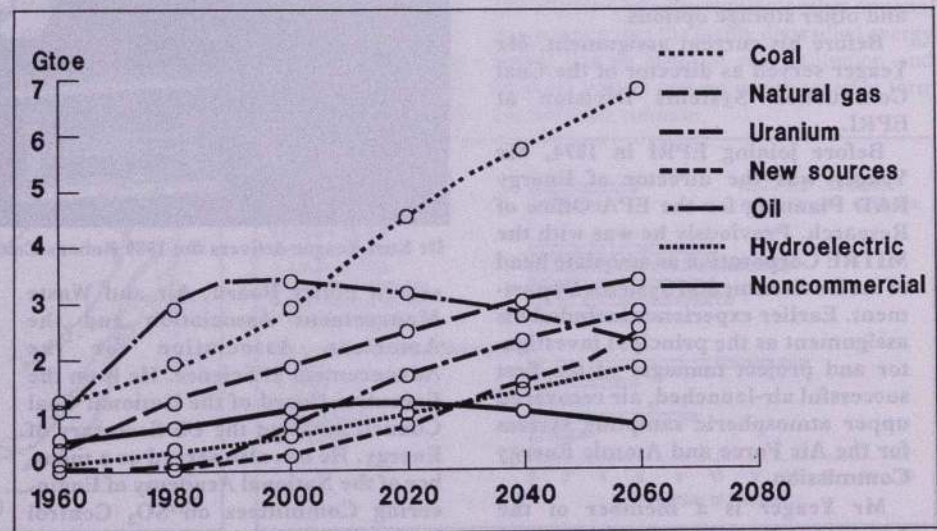


Figure 1: Evolution of world energy utilisation, 1960 to 2060. (Source: WEC Conservation Commission 1986).



initiative, which is providing the building blocks to revolutionise the world's use of coal.

I believe the fully integrated 'Coal Refinery' concept is the essential capability we must expedite in achieving this resolution. It is the most productive conclusion of the CCT development efforts being implemented today, and it makes environmental and economic sense for both the developed and developing worlds by extracting the greatest value and leaving the least waste from the coal resource.

## Coal & electricity

In addition to its abundance, a major attribute of coal that has enabled its use to grow rapidly is the fact that it can be transformed into a versatile energy form, electricity, at relatively low cost. Not often appreciated is the fact that, with increasing electrification, the overall energy efficiency of the world economy has been improving.

This seems counter-intuitive at first. Electricity generation is sometimes perceived as a wasteful process, since about two-thirds of the primary energy available is rejected as low-temperature waste heat at the power plant. However, electrical end-use processes are generally very efficient, so total system efficiency (fuel to end-use) is typically higher than direct fuel energy use. Electrically-based

Billion tonnes

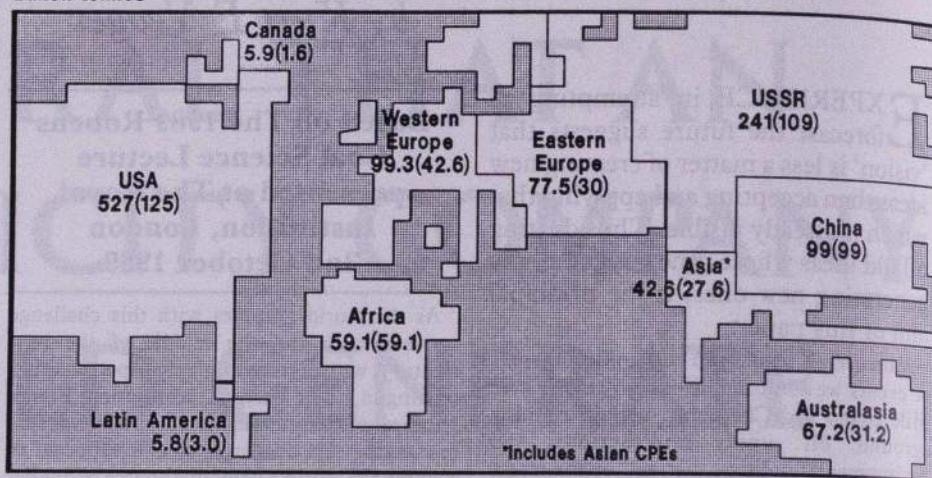


Figure 2: World coal reserves at end of 1985. (Source: BP Statistical Review of World Energy).

technologies have served to raise the net economic productivity from all factor inputs, including energy. This phenomenon can be attributed to the unique qualities of electricity, which have been described as 'precision in space, in time, and in scale'.

Future global economic growth, particularly in the developing countries, will bring large increases in electricity generation and, correspondingly,

coal usage. If the present world population approached the per capita electricity consumption of today's industrial regions, world electricity use would be about 3.4 times as great as at present. Given the historical time constant of a half century for substantial changes in the mix of large-scale energy systems (and a similar time characteristic for potential global climate changes), such

## The author

Kurt E Yeager is Vice President in charge of the Generation and Storage Division of the Electric Power Research Institute (EPRI), Palo Alto, California. He is responsible for a \$110 million per year R&D programme on fossil and renewable electric power generation and storage for the electricity utility industry. This work includes programmes in environmental control, plant performance and reliability, fluidised bed combustion, coal gasification, combustion turbines, photovoltaics, renewable fuels, hydroelectric power, batteries, and other storage options.

Before his current assignment, Mr Yeager served as director of the Coal Combustion Systems Division at EPRI.

Before joining EPRI in 1974, Mr Yeager was the director of Energy R&D Planning for the EPA Office of Research. Previously he was with the MITRE Corporation as associate head of the Environmental Systems Department. Earlier experience included his assignment as the principal investigator and project manager of the first successful air-launched, air recovered upper atmospheric sampling system for the Air Force and Atomic Energy Commission.

Mr Yeager is a member of the American Society of Mechanical Engineers, and has served on its Re-



Dr Kurt Yeager delivers the 1989 Robens Coal Science Lecture at The Royal Institution.

search Policy Board, Air and Waste Management Association and the American Association for the Advancement of Science. He is on the Executive Board of the National Coal Council advising the US Secretary of Energy. He has also served as a member of the National Academy of Engineering Committees on SO<sub>2</sub> Control Technologies and Accessory Elements in Coal, and on the Energy Research

Advisory Board to the US Department of Energy.

He has authored over 140 technical publications on energy and environmental topics.

Mr Yeager received a Bachelor's degree in Chemistry from Kenyon College and a Master's degree in Physics from the University of California. He did additional graduate work in Chemistry at Ohio State.

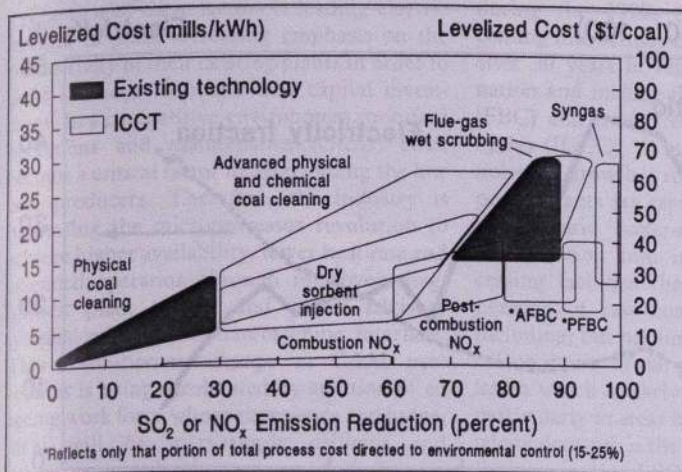


Figure 3: Cost-effectiveness of Clean Coal options versus existing technology.

an increase in electricity generation over three-quarters of a century is not a far-fetched speculation. The corresponding GNP growth rate of less than two per cent per year is modest by both historical standards and the consensus of current forecasts.

Historically, the cost and availability advantages of coal have overcome the fact that it has never been the most desirable fossil fuel. It contains less energy per unit weight than natural gas or oil, it is difficult to transport, and it has created a variety of environmental issues. Today, environmental requirements have joined cost reduction as primary considerations in the design and operation of coal-fired power plants, and they are a major driving force behind the new technological directions for coal utilisation.

Two key trends have historically characterised coal plant design: increases in efficiency and increases in capacity. Figure 4 shows that the thermal efficiency of coal-fired steam electric generation rose from five per cent in the late 1800s to nearly 40 per cent in the late 1960s. This resulted in an 85 per cent reduction in fuel consumption per kilowatt (kW) of power produced. During the same period, boiler size increased from 50 kW to 1,200 megawatts (MW). As a result, the cost of new generating capacity dropped from \$350 per kW in 1920 to \$130 per kW in 1967 (constant 1967 dollars), and average residential service cost dropped from 25 cents per kWh to 2 cents per kWh.

By the 1970s the diminishing performance returns from the Carnot Cycle were joined by

new economic and institutional forces, namely rapidly escalating capital costs, slow growth of demand, stricter emission-control requirements, and extended licensing and construction schedules. The result has been an abrupt end to the historic trend of declining real cost of electricity from coal. Indeed, a kilowatt of new US generating capacity costs more today (in constant dollars) than it did in 1920. Although the USA has probably led in this regression, similar trends exist throughout the developed world as it grapples with new societal demands on power production. It is precisely this challenge which the new technology for coal utilisation must address.

### A sense of urgency

The importance of this effort is underscored by the fact that in the USA a new, large, pulverised coal-fired power plant may typically cost \$1.5 billion, with more than 30 per cent of the cost driven by environmental controls (Figure 5). Moreover, these controls have a major impact on plant efficiency and reliability.

It is important to note that this programme for action must be conducted with a sense of urgency. In fact, the new Clean Coal Technology must be commercially proven and made broadly available in order to meet the requirements of existing and proposed environmental policies in the developed world, and to serve the developing world's emerging power supply and industrial capability needs. The urgency is underscored by the expected commitment of

110,000 MW of new coal-fired power generation capacity in the Asia/Pacific region alone in the next decade.

The principle guiding Clean Coal Technology development is that sustained environmental improvement will only be effectively achieved when emission reduction and cost reduction complement each other. This responds to the environmental consensus of society while controlling the cost of energy and keeping its supply secure. Simply stated, the goal is to resolve the policy conflict between coal use and environmental quality.

In order to achieve this goal, the US electric utility industry and EPRI have spent more than \$2 billion and plan to spend at least \$3 billion more in a collaborative, national joint venture with the federal and state governments to bring Clean Coal Technology to commercial maturity by the beginning of the 21st century. This investment is being made because coal is, and will remain, the nation's primary fuel source. It also positions the US to remain a major player in a world-wide coal technology market valued at \$50 billion per year by the turn of the century and growing rapidly.

These technologies are not the result of a single nation's or industry's initiative; rather, they are the fruit of the combined efforts of an international community of coal and power generation technology developers (Figure 6). The objective is not to eliminate other options, but to assure that the highly diversified energy market has an array of coal utilisation and emission control options which together form the least-cost solution.

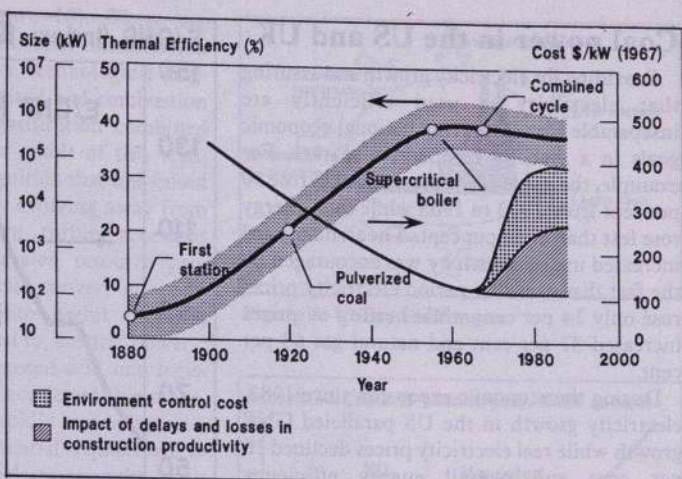


Figure 4: Coal-fired power plant evolution.

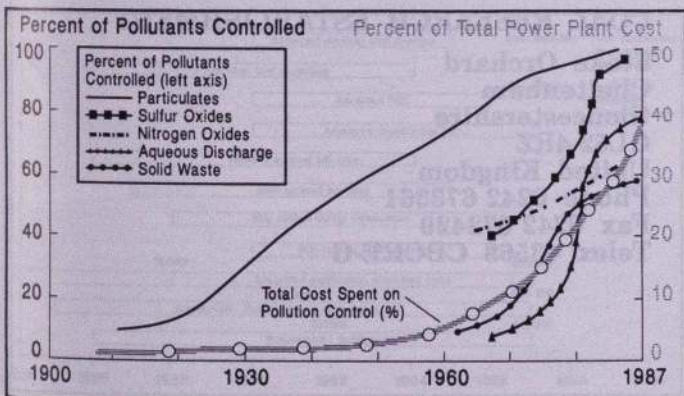


Figure 5: Percentage of power plant cost spent on pollution control as percentage of pollutants controlled increases. (Source: Scientific American, September 1987).

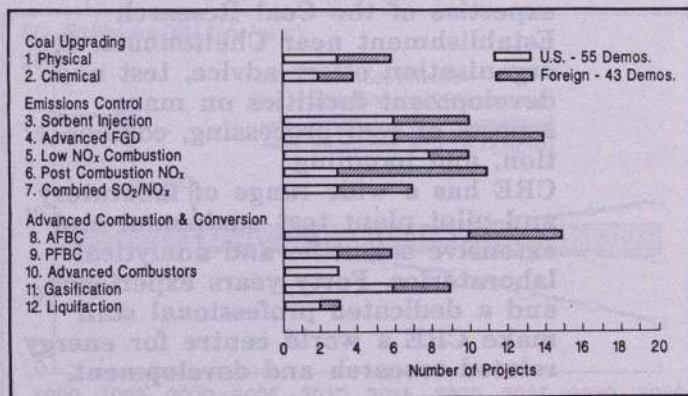


Figure 6: Clean coal demonstrations.



### Coal power in the US and UK

Providing for electricity growth and assuring that electricity is used efficiently are inseparable from achieving national economic goals in a globally competitive market. For example, the use of electricity in the US rose 50 per cent from 1973 to 1988 while total energy rose less than eight per cent. The trend toward increased use of electricity was encouraged by the fact that over that period electricity prices rose only 14 per cent while heating oil prices increased 37 per cent and natural gas 68 per cent.

During the economic expansion since 1982, electricity growth in the US paralleled GNP growth while real electricity prices declined 16 per cent and overall energy efficiency improved 11 per cent. Economic progress, energy efficiency, and increased electrification have proceeded hand-in-hand and continued economic growth is expected to continue to raise electricity use (Figure 7). Thus, electricity will confidently remain a growth business among the relatively static energy industries.

At the same time, the electric power industries of both our nations are undergoing fundamental restructuring in order to respond to new, much more competitive, markets for electricity. Because they are starting from different points and have different institutional settings, they are moving along different paths at different rates toward a competitive energy supply industry. However, both nations'

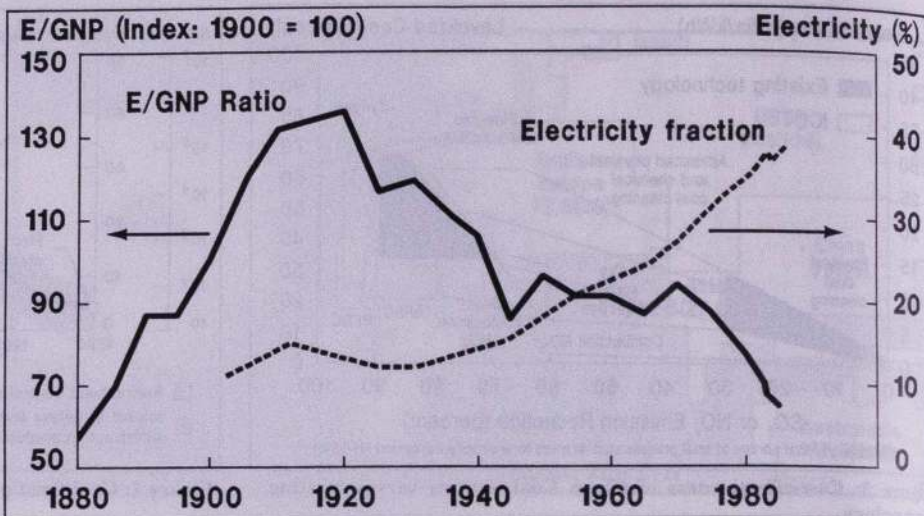


Figure 7: US Energy/GNP ratio and electricity fraction, 1880-1985.

evolving electric power industries will provide new opportunities for technological innovation and diversification in the use of their primary fuel source, coal, to achieve competitive advantage.

Against this backdrop, electricity planners are increasingly adopting new criteria better suited to the changing circumstances of electricity supply and use that are likely to prevail. Instead of only seeking economies of scale in ever-larger specialised plants, system planners are emphasising economies of time and efficiency including smaller, modular plants and increased fuel flexibility. Such plants can

be ordered, constructed, and bought on line quickly in order to match demand growth within a plausible forecasting horizon, and to generate cash-flow comparatively quickly. It is these conditions which also nurture new technology approaches.

The root causes creating this change are, paradoxically, the uncertain economic policies governing electric power producers, the pressure of increasingly stringent environmental control requirements, and the internationalisation of the power equipment supply base. These reflect the challenges facing the electric utility industry today (Figure 8).



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The first of these factors is leading electric utilities to place increasing emphasis on the productivity of their existing plants in order to defer the need for major new capital investment. In a competitive environment, non-fuel operations and maintenance (O&M) costs become a critical factor in determining the low cost producers. Therefore, the industry is harnessing the microprocessor revolution to achieve higher availability, lower heat rate and extended operation through improved diagnostics, plant control and expert advisory systems guiding the man/machine interface. This revolutionary change in O&M procedures is being accelerated by attrition of an ageing work force whose experience and judgement will be increasingly difficult and expensive to replace.

It also sets the stage for the equally revolutionary change in power generation technology and operating demands that will follow. As someone succinctly put it, '80 per cent availability, 60 per cent capacity factor, and 30 per cent efficiency are not the figures of merit you would choose to succeed in a competitive environment.'

Initially, as increased capacity is needed it is being added marginally through gas turbines, plant repowering and independent power production — all intended to forestall financial exposure but, in a derivative manner, also ushering in a new diversity of electricity supply.

The fundamental change in the technology for power production, particularly from coal, is being driven primarily by environmental control requirements and is being realised through Clean Coal Technology. The importance of this initiative can be gauged by the flexibility it provides to reduce the annual cost of proposed US acid rain legislation from about \$7 billion to \$4 billion. This will achieve a nominal 50 per cent, or nine million tons per year, SO<sub>x</sub> reduction from coal-fired power production and a 30 per cent NO<sub>x</sub> reduction (Figure 9). Clean Coal Technology has also become the centrepiece of deliberations over the timing of these new control requirements which are targeted for the year 2000 and could affect some 300 coal-fired US power plants with a total generating capacity of over 150,000 MW by that date.

One positive outcome is a diversity of new technology options for coal-based power generation and emission control maturing

during the 1990s (Figure 10). These are coming into serious commercial consideration after 30 years of relative technological stagnation and include fluidised bed combustion (FBC) and integrated gasification combined cycles (IGCC). A major result of this technological growth is recognition that coal-based power plants are rapidly evolving away from the historic boiler-steam turbine-generator configuration into integrated resource processing facilities that can convert all components of raw coal into useful products including, but not limited to, electric power.

One aspect of the proposed acid rain legislation which is likely to accelerate this move, particularly in areas of rapidly increasing electricity demand, is the potential requirement to limit or cap local SO<sub>x</sub> emissions at the levels controlled in 2000. Figure 11 indicates, for example, that the SO<sub>x</sub> cap is likely to require, on average, about a 95 per cent level of SO<sub>x</sub> control for new US coal-fired generating capacity.

The third root cause — the rapid consolidation of nationally oriented boiler, turbine/generator, and emission control suppliers into several integrated, multinational, corporations is forcing electric power producers and their supporting engineering/construction community to rethink the whole process of designing, specifying, purchasing and constructing power plants. The economic feasibility of individually customised power plants is being superseded by ever-larger and more standardised shop fabricated modules, taking advantage of international competitive supply opportunities. The results reduce the cost and time of field work in progress while improving both quality control and the integration of the new, clean coal utilisation technologies entering the commercial arena. The competitive, value-added opportunities for the engineer and supplier result less from the steel or manhours involved and more from the 'smart parts' which increasingly differentiate construction costs as well as plant operability and maintainability.

Another aspect of this globalisation trend is that parts, products and services are being intermingled and exchanged in ways that render meaningless the question of national origin as a smaller number of large corporations organise their operations on a worldwide scale. It is this environment of increased international corporate flexibility and quest for

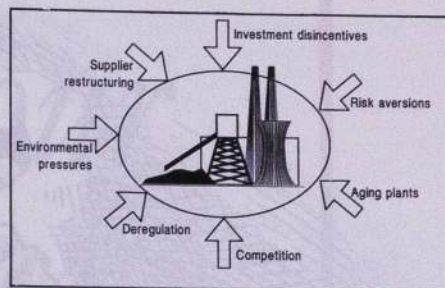


Figure 8: Utility challenges.

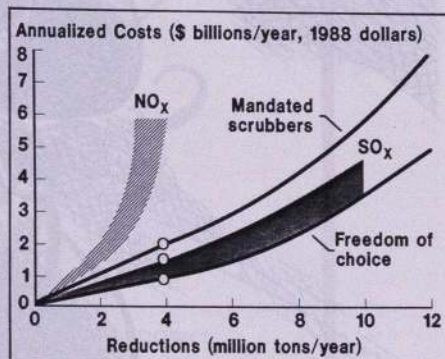


Figure 9: Comparison of Utility Control Costs.

economic advantage that also encourages collaborative national enterprises focusing public and private resources and risk sharing for advantage in the international competition to attract and build the corporate base.

In the US, for example, the opportunity for such a 'national arsenal of energy innovation' is expected to depend increasingly on alliances between the power industry and technological areas where US innovation and production advantages can be commercially exploited. These areas of new emphasis include: gas turbine, silicon microprocessor and coal processing technologies. It is interesting to note that in each case, technological and commercial leadership does not depend on the power industry today. For example, gas turbine leadership results principally from defence and aerospace markets, microprocessors from the broad-based electronics industry and coal processing technology from the strategic R&D investments of the petroleum and chemical industries who control the bulk of the US coal resources.

The combination of these three effects

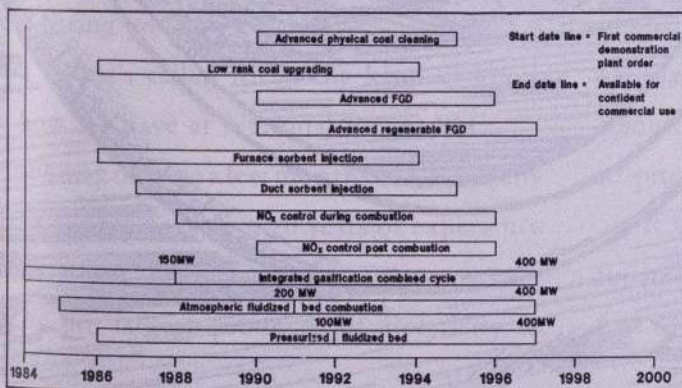


Figure 10: Estimated commercial availability dates of Innovative Clean Coal Technologies. (Source: National Coal Council, November 1988).

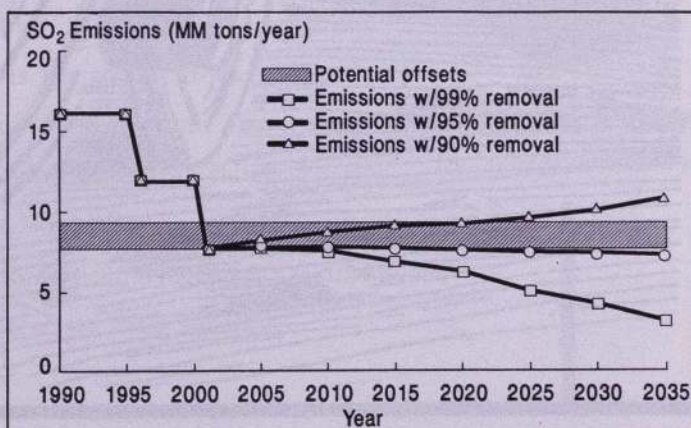


Figure 11: National capacity expansion — SO<sub>2</sub> control implications.



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signals a fundamental transition in the power generation business as we enter the new century. This transition is likely to be marked by the following overriding trends:

- an increasingly competitive electricity supply market where the low-cost producer is the only assured survivor. The message of the last two decades is that electricity demand *is* dependent on price. This message also remains the promise of the future.
- increasing emphasis on coal, not only as the primary fuel for electric power production but also as the strategically secure hydro-carbon base for transport fuel.

The first of these trends has become sufficiently clear to have already gained a measure of political orthodoxy. The second, in an era of seemingly abundant low-cost oil and gas, unfortunately remains beyond the horizon of popular acceptance. As a result, the former is likely to proceed with relatively greater predictability and fewer crises than the equally assured latter trend which will, nevertheless, inevitably serve to accelerate this process of change.

The organisations which are likely to survive such a transition, in terms of staying in the power generation business, are those that come out the other end best able to maximise the value-added to their invested capital and purchased fuels. These organisations will be characterised by their successful adoption, directly or through commercial alliances, of a process methodology for coal utilisation.

When the opportunities for phased construction are coupled with escalating emission

control requirements and projected gas and oil prices, more and more electric utilities in the US are incorporating the advanced clean coal option of IGCC as the most economic approach to their capacity expansion plans (Figure 12). This is likely, ultimately, to lead to integrated energy facilities capable of translating coal-derived synthesis gas into a variety of products including, but not limited to, electricity (Figure 13). In addition to coal, such facilities could similarly process carbonaceous refuse and biological wastes — both increasingly difficult by-products of our urbanised and industrialised societies.

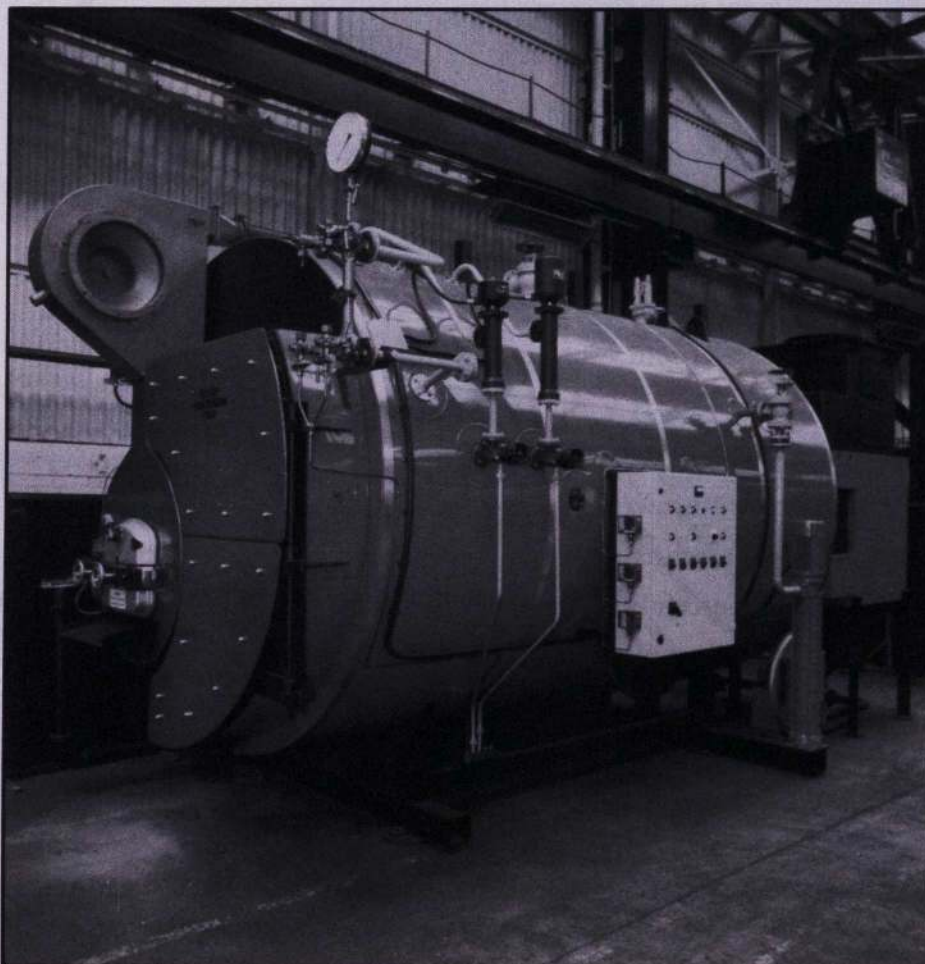
Such a co-production, integrated 'Coal Refinery' approach appears to be the key to lowest-cost electricity generation and transport fuel production from coal in an economy increasingly limited in its energy source options and by the environmental constraints to their use. The result is likely to be an electricity generation industry that is integrated with overall energy production. The US goals which will measure success in this progress require little vision. They are (1) providing 200 to 300 GW of new electrical generating capacity, and (2) replacing 10 million barrels per day of oil imports. The US should be prepared to realise these goals by 2010 and recognise that they are not simply desirable but essential to our national economy and security.

The fully integrated Coal Refinery could be adapted to produce a mixture of electricity, heat, fuels and marketable products. This achievement would present an opportunity to expand coal use beyond conventional operations — for example, to reduce petroleum use

in the industrial, residential, commercial and transportation sectors. Development of such plants depends upon the successful blending of a variety of clean-coal technology building blocks. Such a facility could ultimately move beyond the efficiency constraints of the Carnot Cycle by integrating fuel cells, for example, as the electricity production process.

Each unit process building block incorporated into the integrated Coal Refinery would be linked by electronic diagnostic and control systems. This 'smart' instrumentation, based on microprocessor technology, would create integrated monitoring systems for temperature, pressure, flow rate, and chemistry of liquid and gas streams for operating product mixes as well as sensors and feedback elements in robotic systems for plant maintenance and inspection. Syngas would be used as fuel for electricity generation and the production of chemicals. Coal ash could find use in highways and railroads, cement and concrete, and as a source of high value trace metals. The enhanced efficiency of primary energy utilisation could make a significant contribution to decreasing emissions of CO<sub>2</sub>. This is particularly true if fuel cells are ultimately integrated to achieve efficiencies of 50 per cent or more.

As an example of the potential economic benefits attributable to such a scheme, it has been shown that an integrated Coal Refinery designed to generate electric power at a 65 per cent capacity factor (using existing IGCC technology), while co-producing transportation fuels from excess syngas at a 25 per cent capacity factor, would have the potential to reduce the cost of generating electric power by

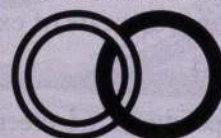


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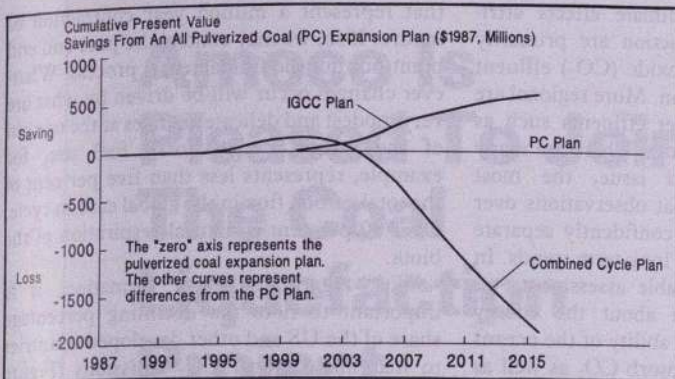


Figure 12: Florida Power and Light's potential expansion plan comparison.

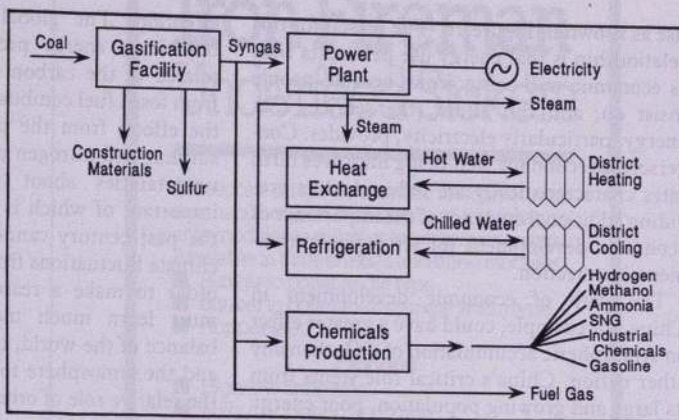


Figure 13: Integrated coal refinery.

as much as 25 per cent from its nominal cost of approximately 5.4 cents/kWh (Figure 14). This estimate is based on a delivered coal price of \$1.62/MMBtu, a fob price of \$1.20/gallon for the transportation fuel and typical US utility economic accounting principles.<sup>24</sup>

With regard to Clean Coal Technology and the ultimate goal of the fully integrated Coal Refinery, there is a characteristic learning curve associated with the development and commercial deployment of these and other new technologies (Figure 15). Today, the various technology options under consideration have reached, or are approaching, first commercial demonstration. It is this 'commercial demonstration' step where the size and cost of the facility necessary to assure reliable operation is the greatest. As the learning curve continues, each succeeding installation entails less risk and therefore less engineering margin and redundancy until full commercial maturity is reached. Recognition of the risks inherent in this learning curve is essential to the successful development of new technologies.

As a result, probably the single most important step taking place today, in terms of advancing the concept of the large scale, integrated coal refinery, is the 250MW integrated gasification combined cycle (IGCC) power plant to be built in the Netherlands by Demkolec, a subsidiary of the SEP electric utility. This facility is scheduled to begin operation in 1993 and will use the Shell coal gasification process to gasify 1900 tons per day of Australian Drayton bituminous coal. The design efficiency is 42 per cent, higher heating value (HHV), or 8200 Btu/kWh.

The increased use of coal in this manner will

be critical for the industrialised democracies in the 21st Century. The threat of a major decline in coal imports is not a serious problem because of the number and diversity of external suppliers. In this regard, it should be noted that Europe expects to increase its coal imports by about 75 million tons per year between now and the year 2000. In contrast, diversifying future sources of oil supply will be difficult as countries outside the Middle East deplete their reserves and/or increasingly limit petroleum exports so that their resources can be used domestically.

Oil dominates energy markets, accounting for 38 per cent of commercial energy consumption. Dependence on imported oil strains the economies of both the less developed and industrialised world. In 1987 the US imported \$40 billion worth of oil, an amount equal to one-third of the nation's trade deficit. During the same year, the Pentagon spent \$15 billion to protect those oil supply lines. Development and implementation of the integrated coal refinery concept would also significantly lower the energy vulnerability of Europe and would be responsive to:

- the Council of European Communities' resolution to further develop indigenous resources as well as diversify sources of supply and forms of energy used;
- the International Energy Agency's desire to achieve improved energy security for all its members through a more balanced energy economy and less dependence on oil.

Industrialised countries with ageing infrastructure will also have a major impact on future energy consumption and carbon emis-

sions unless they too begin the process of converting to such high efficiency coal utilisation techniques. Energy intensity (energy used per unit of Gross National Product) in the Soviet Union, for example, is twice the average of nations belonging to the OECD and shows no sign of improvement.

## Coal in the developing world

Although one-fifth of the world's population consumes 70 per cent of the world's commercial energy, the industrialised world's energy intensity fell by 20 per cent between 1973 and 1985. By comparison, the most rapid growth in energy consumption now occurs in developing countries where about 75 per cent of the world's people use less than 30 gigajoules per person, about one sixth the energy use in Europe and one-sixteenth that of North America.

As they sought to industrialise, raise standards of living and accommodate population growth between 1980 and 1985 alone, these countries, such as China, Mexico and India, increased energy consumption by 22 per cent. The importance of this trend is underscored by the United Nations projection that in the century 1975-2075 the population of Europe will increase by one-quarter, North America and the USSR by about one-half each, East Asia by three-quarters, Latin America and South Asia fourfold, and Africa more than fivefold. At this rate world energy consumption would have to grow at 1.3 per cent per year just to keep per capita levels from dropping.

These less developed countries face hard choices since there is a close coupling between the level of economic development and energy

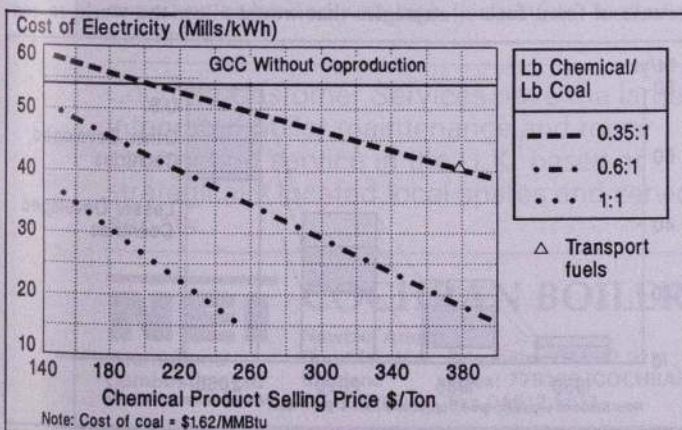


Figure 14: Cost of electricity versus chemical byproducts from a 400MW GCC.

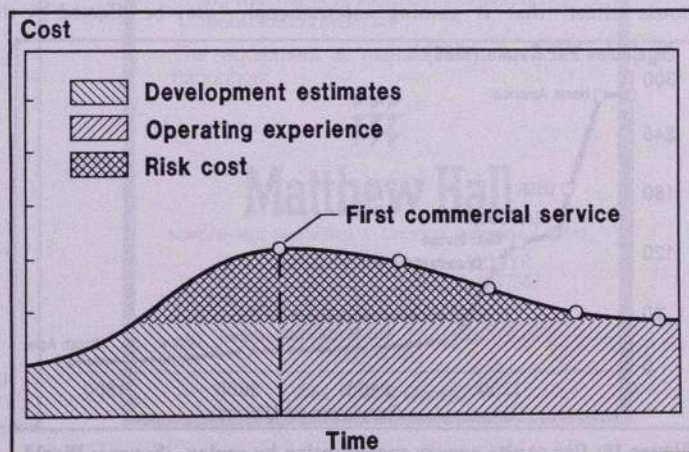


Figure 15: Technology learning curve.



use as shown in Figure 16. The reason for this relationship is that energy use per capita rises as economic well-being grows because people insist on, and can afford, the services that energy, particularly electricity, provides. Conversely, as economic well-being improves birth rates characteristically are reduced, thus providing additional evidence of the importance of economic development for strategic environmental protection.

The path of economic development in China, for example, could have a greater effect on atmospheric accumulation of CO<sub>2</sub> than any other nation. China's critical role stems from its large and growing population, poor energy efficiency and massive reliance on coal. Between 1980 and 1986, China's manufacturing sector grew by 12 per cent a year, the fastest growth in any large nation in the world. Indeed, the potential for improved efficiency is China's chief future energy resource.

Technological ingenuity can dramatically reduce the amount of energy required to provide a given level of goods and services while simultaneously cutting down on energy-driven problems. It is the collective response of developing countries to these new opportunities for efficient resource use in their economies that will determine humanity's ultimate success in slowing the deterioration of the global environment. New technology can help less developed countries to leap over the undesirable practices of the past and follow new energy paths for development.

For example, the cost of coal-based electric power in the US averages 4 to 6 cents/kWh. By comparison, it runs as high as 50 cents/kWh in urban areas of developing countries and \$1/kWh or more in rural areas. At these costs, even powering a simple light bulb may exceed the per capita income of underdeveloped countries. Under these conditions, the introduction of the integrated Coal Refinery would serve not only to fundamentally reduce these costs but concurrently process the total value of indigenous solid fuel resources into an array of products providing the essential foundation for economic development and environmental protection.

## Technology and climate

Technology can also play an essential role in helping to relieve concern about possible global climate modification and the 'greenhouse effect' that is gaining international

attention. The global climate effects attributable to energy production are primarily related to the carbon dioxide (CO<sub>2</sub>) effluent from fossil fuel combustion. More regional are the effects from the other effluents such as sulphur and nitrogen oxides. There are many uncertainties about this issue, the most important of which is that observations over the past century cannot confidently separate climate fluctuations from long-term trends. In order to make a reasonable assessment, we must learn much more about the energy balance of the world, the ability of the oceans and the atmosphere to absorb CO<sub>2</sub> as well as the relative role of other so-called 'greenhouse gases'.

In spite of limited scientific understanding, the political process is rushing to fill the vacuum in the area of climate modification raised by this sudden public attention. The process unfortunately tends to use this opportunity to justify various long-standing special interests. These typically *no not* address the essential, but less politically comfortable, realities of potential climate modification.

Based on previous experience, we must consider, however, that the outcome of this issue will ultimately be determined by public opinion and political perception. Science will likely play only a supporting role to guide those perceptions and opinions. How important that role will be depends on how effectively government and industrial opinion leaders support the development of the necessary knowledge base and use the results to guide public policy.

Compared to other environmental issues, the greenhouse effect is distinct in that it is, first, a global issue ultimately affected by, and affecting, every nation; and second, any consistent climate change pattern may not be seen for decades. As a result, policy responses proposed to date include both mitigation and adaptation, since there is a chance that naturally occurring or anthropogenic factors will not fully counter the effects of increasing atmospheric carbon concentration. Given the uncertainties and importance of this emerging environmental issue, it is essential that coal users and producers participate actively in the scientific, technology, and policy development process at both the national and international level.

Although there is no clear correlation today between CO<sub>2</sub> emissions and temperature change, it may be prudent to consider the possibility that the dynamics of the biosphere may be affected by the release of fossil fuels

that represent a million year contraction of nature. If so, we may control the pace and end point but not the fundamental process. Whatever changes occur will be driven by what are very modest and delicate changes at the margin of the carbon cycle. Fossil fuel use, for example, represents less than five per cent of the total carbon flux in the global carbon cycle. Over 90 per cent is natural respiration of the biota.

With regard to policy formation, it is important to note the declining percentage share of the US and other developed countries to man-made global CO<sub>2</sub> emissions (Figure 17). The rapidly growing role of the lesser developed countries and their resulting importance in any strategic CO<sub>2</sub> mitigation strategy should also be noted. It is important to stress again that it is not a question of whether these countries will use their domestic coal resource to fuel their economies, but rather *how* they will use the resource.

To the extent technology provides increased efficiency in the conversion of coal to usable energy, it will have a beneficial global impact on CO<sub>2</sub> and N<sub>2</sub>O generation. In the event that greenhouse warming is substantiated and reducing CO<sub>2</sub> growth becomes a policy imperative, this will provide a powerful additional argument in favour of more rapid development and global deployment of the new clean coal technology for coal use. The most important contribution can again be made by the integrated Coal Refinery in terms of its energy conversion efficiency potential which, depending on the specific combined cycle conditions used, would range from 42 to 60 per cent.

If indeed it is shown that it is in the best interest of the world community to control the future emission of anthropogenic CO<sub>2</sub>, extreme caution must be exercised to prevent precipitous over-reaction at such high cost that the economies of both developed and developing nations are at risk of being destabilised. It has been shown by EPRI, for example, that the short-term requirement to reduce US CO<sub>2</sub> emissions 20 per cent by the year 2000 could result in costs to the US electric power industry alone exceeding \$90 billion and could more than double the annual consumption of natural gas by that industry. Such an urgent diversion of resources would have essentially no impact on reducing global CO<sub>2</sub> concentration trends.

A more rational approach would be to seek strategies that would allow the world to con-

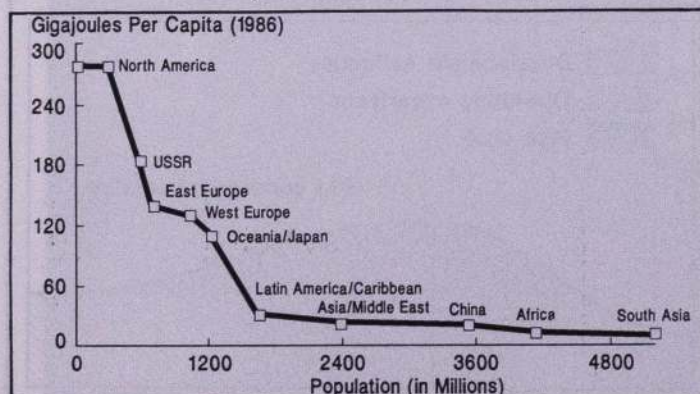


Figure 16: Per capita energy consumption by region. (Source: World Resources 1989).

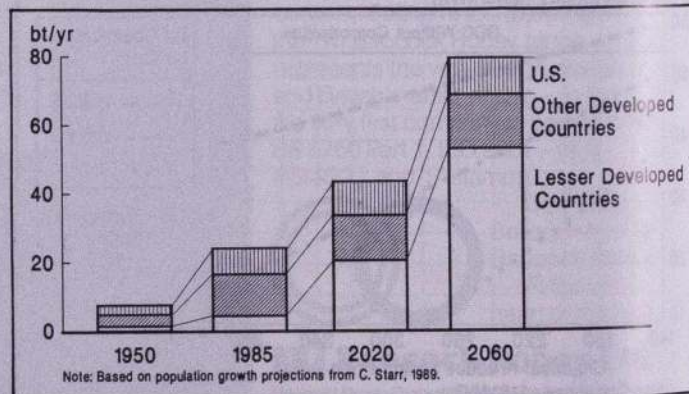


Figure 17: Contribution to global man-made CO<sub>2</sub> emissions.

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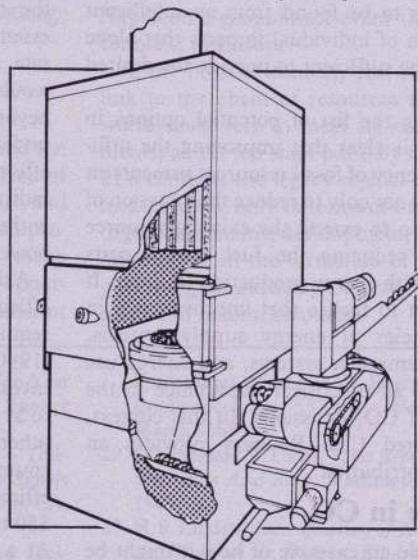
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tinue to depend on the use of abundant and low-cost fossil resources by employing emission mitigation strategies that do not impair economic growth and that can be implemented on an international basis. Although the potential requirement to control CO<sub>2</sub> emissions appears at first sight to represent a significant economic threat, it is possible that the situation could be considered from a different viewpoint; ie, it might provide significant opportunities for economic and market development if the policy decision is made to focus investment in the developing world where the greatest energy efficiency improvement opportunities exist.

A variety of options exist that could contribute to the stabilisation of global CO<sub>2</sub> emissions (ie, minimising the rate of increase of annual CO<sub>2</sub> emissions) that would not only allow the continued use of fossil fuels, but could also contribute to the economic well-being of both the developed and the developing nations. A partial listing of such options is presented in Table 1.

As is the case for all problems that confront humanity, there is no single 'perfect' solution to the CO<sub>2</sub> emission reduction issue. The 'solution' is to be found from an intelligent combination of individual impacts that alone would not be sufficient to provide the desired effect.

Examining the list of potential options in Table 1, it is clear that improving the utilisation efficiency of fossil resources presents an opportunity not only to reduce the emission of CO<sub>2</sub> but also to extend the existing resource base while reducing the fuel related costs associated with energy production facilities. It is important to realise that improvements in the efficiencies of energy supply systems, energy transmission systems, and energy use systems are all of critical importance to the reduction of CO<sub>2</sub> emissions. In this context, the Integrated Coal Refinery provides an essential contribution.

## Increase in CO<sub>2</sub>

To provide an example of how it might be possible to stabilise the emission of CO<sub>2</sub> from fossil plants by a combination of approaches listed in Table 1, it has been assumed (for the purposes of illustration) that the world's appetite for energy will grow at an average annual rate of 1.5 per cent between now and the year 2050 (midway between the high and conservative projections in reference 16). This

rate of increase would result in an energy demand at the date about 2.5 times greater than the current demand. In this same time period, without technological improvement, fuel use efficiency will probably decline based on the fact that the bulk of the growth will be in the lesser developed countries where fuels will be consumed at relatively poor efficiencies. This could result in an increase in the production of CO<sub>2</sub> by the year 2050 that is more than three times higher than it is today. This exponential growth is demonstrated in Figure 18.

If it is assumed that the efficiency of use can be increased 35 per cent by a combination of mechanisms such as those listed in Table 1 (ie, Coal Refinery-based energy supply systems, more efficient appliances, electrification of certain industries, more efficient and electrified automobiles, etc) the growth in the rate at which CO<sub>2</sub> is generated could be reduced from an increase of 3.3 times to 2.5 times what it is today as shown in Figure 18. Further, if it is assumed that in addition to the 35 per cent increase in the efficiency of the use of fossil fuels an incremental 10 per cent of the *new* CO<sub>2</sub> generated each decade is absorbed by a growing world-wide reforestation programme, the future generation rate of CO<sub>2</sub> can be essentially stabilised at about 1.7 times today's rate, as also shown by Figure 18. Such a target would buy the essential time necessary to move beyond a carbon-based global energy and/or understand and accommodate the greenhouse effects. This simplified illustration purposely indicates the control potential available even without the likely contribution of nuclear power and other non-fossil energy sources.

Achieving a global 35 per cent energy efficiency improvement by 2050 is likely to require in the order of 25 trillion US dollars (1990 \$). This expected annual global investment increases from \$90 billion in 2000 to \$1.25 trillion in 2050 (all 1990 \$US). On the other hand, the corresponding total, undiscounted, energy cost savings from that efficiency improvement would amount to some \$50 trillion (1990 \$US) over that same period. At a six per cent real annual discount rate, these estimates result in a probable payback period of five to 20 years after the initial investment. Stated another way, these estimates indicate a broad range in rates of return depending on the specific circumstance. Some efficiency improvements are extremely cost-effective (particularly in certain end use applications) and already are being financed pri-

vately all over the world. Other improvements necessary to the global efficiency objective are at the low end of the profitability scale and will require a change in public policy to encourage private investment with longer term paybacks and in less developed regions where risks are greater.

## Prime determinant

This analysis also indicates that the efficiency of capital investment, defined as the ratio between energy cost savings and capital investment requirements, is higher for both electric supply and end-users than for non-electric energy consumption. Furthermore, the less developed countries are likely to have higher capital investment efficiencies than the developed countries. For example, in the less developed countries, the efficiency of capital use is forecast to be greater than 7 to 1 for the conversion of certain industrial processes to electric energy, and in excess of 4 to 1 for improving the efficiency of electric power production. This result is reasonable since capital shortages have caused less developed countries to lag behind developed countries in adopting capital-intensive technologies, even when these technologies are more energy- and cost-effective. As their growth accelerates, this capital availability issue will be the prime determinant of global economic and environmental progress.

Although the complementary reforestation programme described in the above example has been simplified (ie., it has disregarded changing growth rates as a function of age, differences in land productivity and displacement of other biomass from land to be reforested), it has been employed to demonstrate the essential contribution that a reforestation programme provides to a comprehensive global CO<sub>2</sub> control strategy. Approximations of the land area required by the above example, in the 1990-2000 time frame, result in roughly nine million acres/year for a total 10-year requirement of 90 million acres (ie., 4.3 per cent of the area of Brazil or 1.2 per cent of the area of Africa). The 'cost' of the 90 million acres required for a 10-year reforestation programme would be approximately \$18 billion (1988 \$) based on estimates made by Sedjo in 1988. These estimates include the establishment costs for forest plantations but do not include the cost of land procurement. Land procurement costs would, in degraded tropical regions

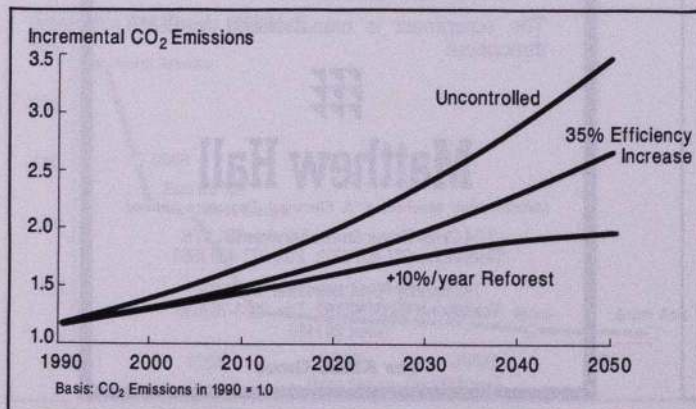


Figure 18: Incremental CO<sub>2</sub> emissions, illustrative situation.

1. Improved efficiency (supply, transmission, and demand-side)
2. Integrated energy systems producing electricity, heating, cooling, fuels and chemicals from coal
3. Reforestation
4. Nuclear Power
5. Deployment of renewable energy systems in lesser developed countries (LDC's)
6. Biomass fuels
7. Solar/fossil hybrids where appropriate

Table 1: Some options for global control of CO<sub>2</sub> emissions.



having little other economic uses, most likely be lower than the plantation establishment costs cited above.

Carrying this programme through to the year 2050 would require a total land area for reforestation of approximately four billion acres, representing somewhat more than 10 per cent of the earth's surface at an estimated total cost over the intervening 60 year period, including land procurement, of some \$200-\$400 billion (1988\$) depending on the regions utilised. Since only growing plants absorb CO<sub>2</sub>, the forests would be harvested and replaced at maturity.

In addition to building materials, the resulting biomass cycle could provide energy without adding to the atmospheric greenhouse burden. This biomass 'proto-coal' resource, based on the previous reforestation estimates and with a practical photosynthesis conversion efficiency to dry fuel of one-half per cent, could provide some 10 trillion kWhrs by 2050 — about the same as the world's electricity demand today. In addition to electricity, this biomass also has the potential to be a renewable chemical resource for the reforested regions of the globe utilising technology analogous to the integrated coal refinery. Thus, these regions would be afforded the same opportunity for resource self-sufficiency and sustainable economic development as the coal rich regions today.

It is also useful to put this investment in efficiency and reforestation in perspective. For example, the escalating cost of imported oil now exceeds \$60 billion per year in foreign trade deficit and supply line defence cost to the US alone. Even more dramatic is the realisation that the global commitment to

military defence already exceeds \$1 trillion per year, or about six per cent of the global GNP. By comparison, the necessary annual global financial commitment to energy efficiency improvement in the Second Electrical Century would be about one per cent of the expected global GNP, and with a far greater assurance of investment return by most nations.

This simplified illustration has been provided not to suggest that the solution will be either easy or inexpensive, but to indicate the potential the world has to stabilise CO<sub>2</sub> emissions, if necessary, in a responsible manner through technology while not stunting the economic development of any nation. No single means is likely to be adequate, rather the optimum mix of options used will be determined by the wisdom of our economic and political considerations.

These policies and investments are justified only if the time gained is used to technologically and culturally expedite a post-carbon global energy economy. The harder issue implicit in this illustration may prove to be the political will to focus the necessary technology investment in a developing world unable to do so itself. That is likely to be the major energy-environmental policy challenge of the 21st century.

## Conclusion

The last decade of the 20th century and the first decades of the 21st will pose a period of major economic, technical, organisational, and cultural changes for world coal users and producers. While these changes pose many challenges, they also bring even greater opportunities. Whether it will be the best of times or

the worst of times will, to a large measure, be dependent on how technology is used to respond to these changing circumstances.

What ever else may be said of the concepts advanced here, they should not be stigmatised as novel. It is hoped that collective experience will allow everyone to perceive the same recognisable trends in events and to act with the decisiveness needed. In this case, technological innovation is providing the utilisation remedies necessary for coal to continue to meet society's needs while satisfying the geopolitical trends which everyone is now beginning to appreciate. History is full of such circumstances.

For example, 18th century French armourers discovered a method of casting cannon barrels that not only improved their accuracy but made them much lighter. To the pedestrian officer, the latter advantage was a convenience. But to a certain Corsican Corporal of Artillery with a sense of history, the change provided an entirely new utilisation of the weapon. It was not to be towed across the plains by oxen, but quickly across the Alps by horses. Forests were to be bypassed and fire-power concentrated. What was to the man on the street a metallurgical convenience was to Napoleon a geopolitical event that led to the conquest of Europe.

In the broader context, coal represents one link in the chain of resources on which the world must rely to meet its energy requirements, and it too shall pass. By the end of the 21st century, the legacy of coal could well be measured not only in terms of its contribution to global economic development, but also by its critical role in the formation of global policy governing stewardship of economic development and natural resources. □

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# Energy conversion through coal gasification

by Keith R Tart BSc MSc PhD CEng MIChemE\*

**Dr Keith Tart of British Gas Midlands Research Station assesses the role to be played by gas in the coming decades. He envisages a role largely shaped by environmental concerns, in which he sees natural gas fired combined cycle plant having a major part to play, particularly in the short to medium term, while renewable sources of energy are still being developed. In the medium term, however, he considers that GCC plant appear to be the most acceptable method of deriving power from high sulphur coal.**

THERE IS worldwide interest in demonstrating power generation technology that not only has good economics but that also meets the increasingly high environmental and safety standards expected by the public. It is clear that the combined influences of nuclear accidents, feared climatic changes and acid rain damage will profoundly influence the choice of power generation technologies in the 1990's.

For several decades conventional coal fired and nuclear power stations have provided the majority of the world's power. Some countries have acted promptly to ameliorate sulphur oxides (SO<sub>x</sub>) emissions by fitting flue gas desulphurisation (FGD) processes to existing coal fired plant. Owing to the large volume of low pressure gas needing purification this is a very expensive option, only normally considered if it allows continued operation of a station that would otherwise be forced to shutdown.

While it is clear that there is an expanding role for wind, wave, hydro and geothermal power generation, these alone will not be able to replace stations that have reached the end of their life and also meet the expected growth in demand for power.

In the short to medium term natural gas fired combined cycle plant will play a major role. Such plants have the benefits of relatively low cost, short construction time and excellent environmental characteristics, particularly low CO<sub>2</sub> and negligible SO<sub>x</sub> emissions.

In the medium term gasification combined cycle (GCC) offers a safe and economic solution to the above problems. The Cool Water plant in the USA<sup>1</sup> has demonstrated the technical feasibility of this technology. Several gasification processes are available for immediate use in GCC plants, including the British Gas/Lurgi (BGL) Slagging Gasifier. This article reviews recent developments in GCC technology, as exemplified in the BGL process.

## Principal features

Gasification offers a very attractive way of converting a relatively low grade fuel into clean gas. This can be used to generate power using a combination of gas and steam turbines, with minimum environmental impact. Coal prepared to the appropriate size distribution is gasified at pressure by reacting it with oxygen and also usually steam. The hot product gases

are cooled and condensate and particulates are removed prior to purification of the gas in an absorption process.

The clean fuel gas feeds a gas turbine, the hot exit gas being cooled in a heat recovery steam generator (HRSG). This raises superheated steam at several pressure levels which drives a steam turbine. The use of a combined cycle, rather than the less efficient Rankine cycle used in conventional coal fired plant leads to efficiency increases of over 5 percentage points.

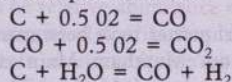
## The BGL gasifier

Following pilot scale development work at the Midlands Research Station in the early 1960's a 1.8 m gasifier was operated at the British Gas Westfield Development Centre (WDC) between 1975 and 1981. Over 100,000 tonnes of UK and US coals were gasified<sup>2</sup> culminating in an extended run of 90 days duration to demonstrate the durability of its components. In 1984 a new 2.3 m diameter gasifier, with a throughput of up to 500 tonne/d coal, was commissioned at WDC.

The BGL gasifier is an advanced derivative of the well established Lurgi dry ash gasifier upon which over 90 per cent of the world's

gasification capacity is currently based.

The BGL gasifier is characterised by its exceptionally high thermal efficiency which results largely from the counter-current flow of the solid and gaseous streams in the reactor shaft and also from the economic use of gasification steam. Coal enters the gasifier through a lock hopper and is evenly spread on top of a bed of coal by a distributor device. A stirrer ensures smooth flow of the coal down the bed. During its descent the coal is first dried by the hot ascending gas and then devolatilised. Devolatilisation yields mainly hydrocarbon products such as methane, tar and oil. The resulting coal char continues to be heated as it progresses downward eventually reaching the raceway, a very high temperature region, where the following gasification and combustion reactions predominate:



The steam and oxygen required is injected, at high velocity, through nozzles called tuyeres situated near the base of the reactor. Unlike the Lurgi dry ash process which limits temperatures by addition of much excess steam, the BGL process minimises steam consumption by



## The author

**Dr Keith Tart is a principal engineer at the British Gas Midlands Research Station, and leads a group of process engineers in the process development division.**

**Since joining MRS in 1975, he has worked on a wide range of energy conversion technologies, including oil and coal gasification projects. He has played a leading role in identifying the most desirable process configuration for the BGL gasifier in both SNG and power generation applications, and is the author of several British Gas papers on these topics.**

\*Principal Engineer,  
British Gas plc, Midlands  
Research Station



allowing temperatures of about 2000°C in this region. This results in the mineral matter content of the coal being released as a liquid slag, the viscosity of which is controlled by a small amount of flux addition to the top fed coal. Molten slag is automatically removed through the bottom of the reactor via a slag tap device and is immediately quenched in water prior to removal as a solid frit through the bottom lock hopper.

The crude gas leaves the top of the bed at typically 400°C and is immediately quenched with hot recycled aqueous liquor in order to remove particulates and tar. The major components of the crude gas are always carbon monoxide and hydrogen. The BGL process can gasify a variety of liquids by injection through the tuyeres including tar and oil from the cooling train, thus these undesirable by-products can be eliminated.

## Recent gasifier trials

UK coal consumed in power stations is predominantly smaller than 25 mm size, typically 50 per cent being less than 6 mm size. The BGL process can gasify the 6.25 mm size fraction directly, but the major part of the .6 mm fraction needs to be prepared for gasification. There are two broad options either to agglomerate the fines; eg, by briquetting, or to inject crushed fines through the gasifier tuyeres either as a dry powder or as a coal water slurry. Both options have been successfully demonstrated on the 2.3 m gasifier.

A slurry containing up to 65 wt% (dry coal basis) has been manufactured in a plant alongside the 2.3 m gasifier and gasified at rates of up to 120 tonne per day. Stable slurries were produced without any special additives. This option results in a slightly increased oxygen consumption, but reduced steam consumption owing to the contribution from water in the slurry.

2000 tonnes of briquettes have been manufactured off-site from Markham Main coal using both bitumen and pitch binders. These briquettes have been successfully gasified admixed with +6 mm coal. A plant has recently been commissioned at WDC capable of screening power station fuels psf and manufacturing briquettes at a rate of 300 tonne per day. During 1990 trials will be carried out for Powergen and National Power with financial contributions also from the UK

**Table 1: Fines handling options — performance data for 2.3 m gasifier**

Coal handling option	Slurry	Briquettes
	Markham Main psf	Markham Main psf
Coal type		
Steam/oxygen ratio, (molar)	0.60	1.09
Steam consumption, kg/kg DAF coal	0.20	0.34
Oxygen consumption, kg/kg DAF coal	0.60	0.55
Coal to top of gasifier, tonne DAF/h	9.0	
Coal fed a slurry, tonne DAF/h	3.3	
Crude gas composition, % molar		
CO	58.3	56.7
H <sub>2</sub>	29.1	26.6
CH <sub>4</sub>	5.3	6.8
CO <sub>2</sub>	3.8	5.9
N <sub>2</sub> + Ar	2.7	3.0
H <sub>2</sub> S + COS	0.4	0.4
Trace	0.4	0.6
Gasifier offtake temp, Deg C	435	285

**Table 2: Comparative cost and performance estimates for 400-500 MWe IGCC power plants (3) (Based on high sulphur Illinois coal)**

	Net system heat rate kJ/kW.h	Equivalent availability %	Total capital requirement S/kW.h (a)
Conventional pf + FGD	10,390	75	1,280
BGL	9,180	85	1,350
Shell	9,390	85	1,480
Texaco	9,500	85	1,450

(a) Includes working capital, start-up costs, spare parts and royalties. Constant 1987 dollars. IGCC plants rated at 31 Deg C.

Department of Energy, British Coal and the Commission of the European Community. A major aim will be to demonstrate the ability of the gasifier to run for extended periods with typically varying power stations fuel (psf) supplies. It is planned to gasify simultaneously briquettes and the separated coarse coal by operating the briquetting plant on line.

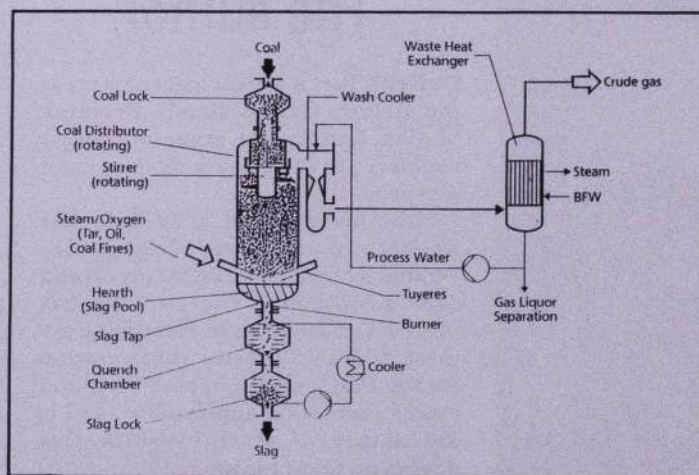
To date over 180,000 tonnes of UK and USA coals have been gasified in the 2.3 m gasifier. The ash and moisture contents of these coals were in the range 1.23 per cent and 3.28 per cent respectively. These trials have demonstrated that the BGL gasifier can be scaled up without difficulty. Gasifier throughput was limited by site utility supply rates and not any intrinsic gasifier constraints. Tests carried out for the Electric Power Research Institute (EPRI) on the former 1.8 m gasifier demonstrated its excellent load following ability. The BGL gasifier has been turned down to 30 per

cent of its normal output without problems and can be held at near zero output on hot standby, if so desired for two shift operation.

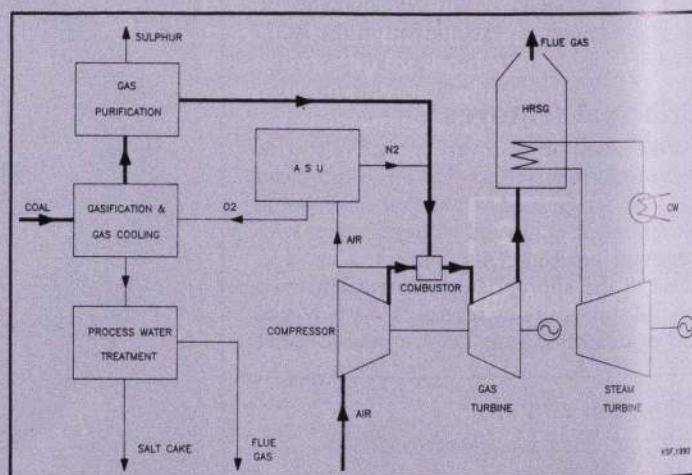
## BGL gasification combined cycle route

The overall performance of a GCC plant depends both on the performance of the gasifier itself and the downstream process steps in the production of conditioned gas for the gas turbine. The choice of turbines and the thermal design of the HRSG play an equally important role especially their optimal integration with the upstream stages. British Gas and Lurgi have developed an optimised GCC design for the BGL gasifier.

The conceptual design of such a 250 MWe IGCC plant is shown in Figure 2. Graded coal, together with any fines agglomerated as briquettes, are supplied to two 4 m diameter



**Fig 1: BGL gasifier.**



**Fig 2: BGL GCC route.**

BGL gasifiers operating at 30 bar pressure. Oxygen of 85 per cent purity is used for gasification. It is obtained from an air separation unit that receives high pressure air from the gas turbine compressor. After it has been purified to remove more than 99 per cent of the sulphur, the fuel gas is blended with high pressure nitrogen returned from the air separation unit. This reduces the calorific value and flame temperature of the fuel gas to minimise NO<sub>x</sub> formation when burned in the gas turbine, while maximising the mass flow of gas. Aqueous liquor from the gasifier cooling stage is stripped of dissolved gases and combusted in a proprietary Lurgi incineration process to yield a salt cake and clean combustion products.

Numerous studies involving contractors have indicated that power generation costs for the BGL GCC route are equal to or slightly lower than conventional coal fired stations fitted with FGD. Using this process route overall power generation efficiencies of 42 per cent (HHV basis) are obtainable. This is based on the incorporation of presently available gas turbines operating with a turbine entry temperature (TET) of 1050°C. Use of the General Electric Frame 9F machine expected to be in service in 1992 would increase this efficiency by about 1.6 per cent points.

Power generation from coal within urban areas is already under threat in some areas of the world. There could be advantage in some locations in concentrating coal handling and conversion in large plants away from populated areas and then piping the clean fuel gas to small local power generation units. This is particularly advantageous where combined heat and power distribution is practised. The BGL process, as distinct from other GCC options, can produce fuel gas at a very high efficiency (ca 83 per cent HHV basis) without having to simultaneously use surplus steam for power generation. Local generation could be either by combined cycle plants or, in the longer term, by fuel cells which are actively under development and hold the promise of coal to power conversion efficiencies up to 60 per cent or more. The relatively high methane content of the BGL gasifier gas makes it particularly attractive for this second application.

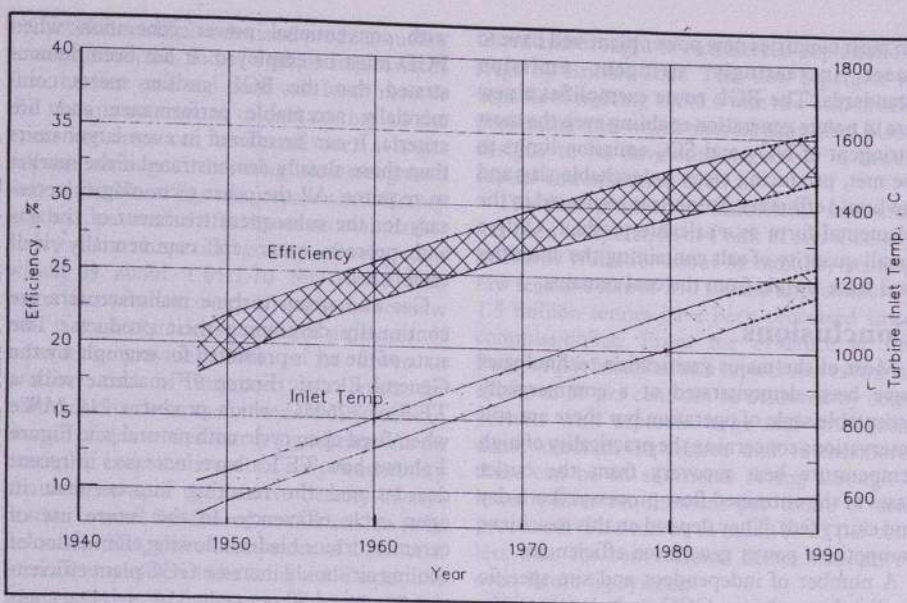


Fig 3: History of increasing turbine entry temperature and resulting open cycle efficiency.

## Coproduction

The clean gas produced by gasifying coal is suitable not only as a fuel but also as a raw material for the synthesis of other chemicals and fuels. In this respect coal gasification, unlike the alternatives, offers a means of load following with the combined cycle plant whilst maintaining the gasification plant base-loaded. This can result in considerably reduced capital charges. Examples of the way in which this could be achieved are by the synthesis of Substitute Natural Gas (SNG) or methanol. SNG, which is interchangeable with natural gas, can be stored during turnaround periods, taking advantage of capacity in the high pressure pipeline system. British Gas has developed and demonstrated the HICOM catalytic methanation process specifically for SNG manufacture. Using this technology SNG could be manufactured at efficiencies of up to 75 per cent. Alternatively, synthesised methanol can easily be stored and could be used for supplementary firing of the combined cycle plant to meet peak demands.

Situations exist where, although a significant proportion of the life of a power plant may remain, the emissions are no longer acceptable owing to more stringent environmental legis-

lation. One option is of course to use fluidised bed combustion or install FGD. However, since generally only 90 per cent desulphurisation can economically be achieved by these methods, the remaining emissions may still be unacceptable in some specific cases.

Coal gasification can remedy this situation by using two configurations. First and simplest, the coal can be gasified and the clean fuel gas used to fuel the steam raising boiler. Alternatively, a higher efficiency can be achieved by firing the clean fuel gas in a gas turbine to generate power. The exhaust is used to raise steam in the existing boiler or to provide pre-heated oxidant for combustion of further clean fuel or coal.

## Environmental aspects

The relative abundance of coal and its wide geographical distribution have been important factors in its adoption as the major energy source for power generation world-wide. This has exposed a variety of environmental issues, particularly damage resulting from gaseous discharges. FGD is a very costly remedy that only partly solves the problem. The proportion of SO<sub>x</sub> that can be economically removed is limited to about 90 per cent and secondary effluents are produced. Consequently most observers regard FGD as only an interim measure that will buy time and allow more satisfactory long term solutions to be demonstrated. There is also worldwide concern about the consequences of the release of carbon dioxide increasing the so called 'greenhouse effect'. Unfortunately FGD increases the amount of CO<sub>2</sub> produced by lowering the power station efficiency. GCC is an attractive alternative which achieves lower NO<sub>x</sub> and SO<sub>x</sub> emissions, and through its higher efficiency 10-20 per cent less CO<sub>2</sub> production per kW station output. Its ability to almost totally remove sulphur also eliminates the inherent disadvantage that UK coal, with its generally high sulphur content, normally suffers.

The increasing public awareness and concern about acid rain, solids waste disposal and liquid effluent discharges will ensure that

Table 3: The predicted performance of a 250 MWe IGCC plant

Plant output, MWe	250
Number of gasifiers	2
Gasifier pressure, Bar	30
Gasifier diameter, m	4
Oxygen purity, % v/v	85
<b>Power plant</b>	
Gas turbine	KWU — Siemens V94
Temperature, °C	1090
Steam turbine, °C	510
Steam pressure, Bar	100
Consenser pressure, Bar	0.03
<b>Efficiency</b>	
Coal to electricity, % (HHV)	42
<b>Emissions</b>	
Sulphur discharge	< 1% of sulphur in the coal
NO <sub>x</sub>	5 to 15 ppm v (15% O <sub>2</sub> )
Slag	Inert, non-leachable

in most countries new power plant will have to meet increasingly stringent emission standards. The BGL route exemplifies a new era in power generation enabling even the most stringent of NO<sub>x</sub> and SO<sub>x</sub> emission limits to be met, producing clean unleachable slag and no liquid effluents. Sulphur is recovered in the elemental form as a saleable product. Only a small quantity of salt containing the chlorides and trace metals from the coal remains.

**Conclusions**

Most of the major gasification technologies have been demonstrated at a commercially acceptable scale of operation but there are still reservations concerning the practicality of high temperature heat recovery from the outlet gases of the entrained flow processes (both dry and slurry fed). They depend on this to achieve competitive power generation efficiencies.

A number of independent and site specific studies have shown GCC to be competitive

with conventional power generation when FGD must be employed. It has been demonstrated that the BGL gasifier meets commercially acceptable performance and life criteria. It can be offered in even larger units than those already demonstrated if the market so requires. All the other technologies necessary for the subsequent treatment of the gas and process water are commercially well established.

Gas and steam turbine manufacturers are continually developing their products. The state of the art is presented for example by the General Electric Frame 9F machine with a TET of 1260°C which produces 212 MWe when fired open cycle with natural gas. Figure 3 shows how TET's have increased in recent decades and the resulting improvement in open cycle efficiency. In the future use of ceramic turbine blades, allowing elimination of cooling air should increase GCC plant efficiencies to around 50 per cent.

GCC technology offers the most environmentally attractive means of generating power from coal, especially high sulphur coals such as found in the UK. This combined with the firm prospect of the presently high efficiencies rising substantially as turbine technology develops further has prompted many utilities around the world to actively consider its role for future generating plant.

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THE UK Coal Industry is in the process of dramatic change, possibly far greater than experienced by any other organisation in this country. Although much press coverage has been given to the number of mines which have been closed in the last two to three years perhaps less has been said about new commitments. For example, there are the new mines at Selby, Asfordby and Hawkhurst Moor, and the high investment being made at other large producing units, all directed to make British Coal competitive with solid fuel from elsewhere in the world.

The competition is largely from coal produced from opencast sites in South America, South Africa and Australia where mining costs are very low. Even with the added shipping charges by bulk carrier products can still be financially attractive on the European market. The evidence is, however, that fortunately UK coals are of better quality and consistency and provided the cost per tonne can be reduced, possibly by about one per cent per annum over the next three to four years. UK coal would provide the better commercial deal. The economy of the country could soon be adversely affected if too much reliance was placed on imports, even if initially of lower cost.

Current practices in this country are, therefore, directed towards two main objectives to reduce costs.

- 1 Centralisation of output from fewer faces.
- 2 Higher utilisation of capital plant.

*\*Chief coal preparation engineer, British Coal Corporation*

# Coal preparation practices

by Peter Cammack\*

**In the current political climate of greater consideration to environmental issues, such as global warming and acid rain, the UK coal industry is examining all possible options for more acceptable methods of coal treatment and combustion. In this article, Peter Cammack, a chief engineer with British Coal, examines the technical advances made by the Corporation over recent years. He paints a picture of an industry undergoing far-reaching changes in order to be competitive in the world market for solid fuel.**

The concentration of output from fewer faces can assist the coal preparation engineer in that there should be less variation in the quality of the raw coal feed from the mine. However, with intensive mining and the cumulative effects of underground transport and bunkering and then surface stocking of the coal prior to the preparation plant, the amount of fines minus 0.5 mm in run of mine coal is unfortunately still very high. Although typically about 15 per cent of the coal feed to the washery is of this size, for particular coals it is not unusual to have to design plants for peak quantities up to 20 per cent, and this is the costly part of coal preparation.

The raw feed will also become wetter as a result of the application of water sprays underground to reduce dust concentration levels to less than 6 mg/m<sup>3</sup>. While developments are in hand to offset some of the problems it is unlikely that there will be any significant improvement in the quality of deep mined run of mine coal within the foreseeable future.

Associated with the development of new mines has been the rationalisation of output at existing mines and this has resulted in a joining

of some neighbouring collieries underground with common delivery of raw coal to the surface via a new drift conveyor. Quite obviously the seams mined at adjacent collieries are generally the same, but for the coal preparation engineer these changes do mean that the input feed rate to the preparation plant is often considerably higher than when the mineral was lifted via the shaft in skips or mine cars.

If geological and economic conditions are unfavourable for joining neighbouring collieries underground, raw coal is sometimes transported overland from one pit to another which again increases the need for preparation plant facilities of higher capacity than hitherto for deep mined coal in the UK. In some cases, therefore, plants will have to be designed to handle input feed capacities of 1,200-1,500 t/h or even 2,000 t/h.

Apart from ensuring that the quality and consistency of products meet customer needs, while at the same time achieving maximum proceeds for British Coal, coal preparation philosophy has five main aims. These are:



- correct choice of plant for raw coal treatment,
- maximum utilisation of high cost capital equipment,
- simplification of plant,
- where possible a reduction in manpower with control of plants being maintained automatically by computer systems,
- concern for the environment, particularly in respect of the disposal of tailings and effluents.

In general, and particularly for the next 10 years or so, no major changes are envisaged in the main processing units to separate run of mine coal into clean coal, middlings and reject. Dense medium processors and Baum jigs and froth flotation for the fines will still be used. Recent plant performance tests have indicated a high degree of efficiency of separation for these processors when they are correctly applied within their feed capacity limits.

How, therefore, are the five main aims for coal preparation in the UK to be achieved?

## Correct choice of plant

Customer demands for coal, whether in the larger quantities for power generation or small consignments for industrial use, will be for improved consistency of quality, and this means as small as possible standard deviations in ash, moisture and other quality criteria. To meet this demand it will be imperative that the best system or combination of systems is selected for the treatment of the raw coal to produce the necessary quality of products. In order to assist the selection of plant, therefore, and to allow 'searches' to be made of the raw coal washability data, British Coal has developed computer programmes to enable predictions to be made, quickly and reliably, of the practical performance in all the major cleaning processors.

These programmes have been prepared from the wealth of data available within British Coal of actual plant performance tests and it has been proved that the information obtained is truly factual, inclusive of the actual errors of separation of the plant. A special test wash of a South American coal was carried out in a Baum jig plant in the North East of England, for example, and the difference between the predicted and actual yield and sulphur content of a clean coal product of predetermined ash was 0.6 per cent and 0.05 per cent respectively. The computer prediction is not, therefore, purely an academic exercise.

Naturally from the results of computer analysis of the raw coal data and information on the operating costs per tonne incurred by the various processes, taking into account the interest and depreciation charges, comparative assessments can be made of the annual profits from each system or combination of systems. The latter technique is comparatively new but is beginning to be applied and with significant benefits at an early stage in the design of all new preparation plants for British Coal. The uniqueness of these facilities have been recognised worldwide and quite a number of contracts for coal cleaning performance predictions have been undertaken on a consultancy basis.

Customers will also demand product quality at minimum cost, and as a major step towards this the first essential need will be to recover the maximum amount of coal so that all the operating costs can be shared over a larger saleable tonnage. It has long been recognised that whilst Baum jigs can prepare a satisfactory product, particularly for the steam coal market at the natural specific gravity of separation which is about 1.65-1.70 for 12-0.5 mm material, overall recovery is less than when raw coal is treated in dense medium processes. If separating gravities have to be lower to produce coal of improved ash levels for particular markets, then the yield difference in favour of dense medium is significant. As an example, even for a coal of easy washability characteristics, if the relative density of separation to meet the desired market ash has to be below 1.5 RD, then a minimum of 1 per cent increase in yield could be achieved. To put this in perspective, an increase in the yield of 1 per cent from a plant treating 500 t/h raw coal with, say, 50 per cent reject, would provide an annual gain of 10,000 tonnes, and this provides a significant contribution to reduce costs.

The application of dense medium washing will, therefore, in the future assume greater application. This is borne out by the fact that a higher proportion of preparation plants include a bath of a drum-type separator for large coal, say, 125-12.5 mm, and a centrifugal dense medium separator for the material 12.5-0.5 mm. There are a number of large coal separators, Wemco Drum and Drewboy Bath for example, equally acceptable for cleaning British coals containing peaks in excess of 60 per cent sinks material. Similarly there is little to choose in performance efficiency between the DSM cyclone and British Coal's Vorsyl separator for the minus 12.5 mm sizes.

There are, however, disadvantages in having two dense medium processes, one for large and one for small coal, and recently a new separator, the Larcodems, has been developed,

tested and brought to commercial exploitation stage by British Coal. This new separator is capable of treating 100-0.5 mm raw coal in one processing unit which enables simplified plant designs to be developed to result in lower capital and operating costs.

The first production Larcodems separator has been in operation at Point of Ayr Colliery in North Wales for about 20 months, treating raw feed at a rate of 250 t/h and approximately 1.5 million tonnes have been processed since commissioning. From the evidence at the Point of Ayr installation a capital cost saving in excess of 30 per cent can be achieved by comparison with separate large and small coal dense medium separators and furthermore, there can be an additional saving through a lower power requirement per tonne of coal processed. This can be as much as 25 per cent less than for conventional dense medium or even Baum jig systems.

Yet a further enhancement of the Larcodems separator is now at the prototype providing stage and this includes a facility to produce three products — clean coal, middlings and reject, from one separator and with one feed medium. This development enables the reject extraction section of the primary Larcodems to be replaced by an integral second separating chamber which allows the primary sinks material to be further treated to produce middlings and the final reject at a higher separating gravity. For example when testing a pilot size 10 t/h three-product Larcodems in the laboratory, two separating densities 1.43 and 1.83 were achieved with a single feed medium of relative density 1.45. The same kind of differential between the first and second separating densities has so far been proven over a relative density range for the feed medium of 1.3-1.6. Typical performance from the separator in the laboratory produced an Epm (Ecarte probable moyen) at the primary cutpoint of 0.028 for coal of size 25 mm-0.5 mm and 0.094 at the secondary output.

## The author



Born in Boston, Lincolnshire, Peter Cammack attended the Grammar School until 1951 when he went to Kings College, University of Durham. Here, he obtained a BSc (Hons) degree in Mining and then undertook university research in Coal Preparation, Chemical Engineering and Fuel Technology, to be awarded an MSc in 1957.

In 1960 he joined the National Coal Board and after DPT was appointed project engineer at the Central Engineering Establishment in 1960. After progressing through posts of varying responsibility he was appointed deputy chief coal preparation engineer (R&D) in 1975.

Throughout this time he has been the author of in excess of 40 technical papers presented and published to Societies, International Congress, Journals and so on. He is a Chartered Engineer, and is also listed in *Who's Who* in the Commonwealth.



## Baum jigs

Whilst greater emphasis will be, therefore, towards the use of dense medium processes, it would be wrong not to highlight recent developments which have been made to improve Baum jig operations and performance. Two new systems for the control of reject extraction electronically from the Baum jig have reached commercial application stage and through a better understanding of what is happening in the jig bed, improved performance has been obtained. For example, at a colliery in South Wales a new 300 t/h jig has been equipped with British Coal/Unifloc electronic extraction controls. A visual display remotely sited in the plant control room shows:

- the setpoint for the jig,
- the actual bed position,
- the position of the extraction valve opening.

Any reject overload into the primary compartment of the jig is immediately seen as an increased actual bed depth. When the extraction valve has responded, if the actual level doesn't soon return to the setpoint level, transfer of reject from the primary to the secondary compartment will occur. The control room attendant will see this reflected in the visual display of the second compartment, and has, therefore, a far better appreciation of conditions in the jig to take the appropriate action.

The Berman automatic control from Simon-acco Ltd is another new development. This reject extraction control device can be supplied with an in-built facility to monitor the relative density of the wash water, and to feed the signal into the Baum reject extraction control system. The controller would then ensure that the setpoint from the Baum jig controls were altered automatically to suit any variation in the relative density of the water.

In both cases the basic operation of the jig has not changed but the performance and consistency has been improved the operator being better informed.

## Timber removal bath

Almost without exception, all coal preparation plants are adequately equipped with permanent magnets to collect and remove ferrous metals from coal flows.

Wood, on the other hand, presents an entirely different problem. Having a relative density of about 0.8 compared with coal at 1.3-1.5, in any density separation it almost always reports with the clean coal product. Despite wood being combustible it can present difficulties in rotary valves and feeders, in injection furnace situations, and so on. It has, therefore, to be removed and a simple effective system has recently been developed by the staff at Mansfield Colliery to provide a solution.

The timber extraction unit comprises a simple water bath in which the clean coal settles to a conveyor for removal and the separated timber is automatically discharged from the surface by a pneumatically operated pusher blade having an adjustable timer and speed control. Of importance to British Coal, manpower is eliminated, the total cost of the unit is as little as £4,500, and it is a simple process to improve product quality.

In most coal preparation plants there is blending of different coal qualities which may simply be of two washed components, such as washed smalls and filter cake, or washed and untreated components, as is the normal practice in the UK in the preparation of power station coal. The usual control of these mixing/blending operations is on a ratio basis whereby plant operators change the ratio in response to integrated ash or moisture values from the results of laboratory analysis. However, where there is variance in the untreated fines ash content, and if this is a major component of the power station blend, for example, then the blend consistency could be inaccurate on a short term basis. In other instances, and where there is a high ratio of washed to untreated coal in the blend, it could be the washed fraction which has biggest influence on product consistency for ash or moisture, due to the variation in the inherent coal quality, which cannot be changed by coal preparation.

In spite of this where blend quality consistency over long periods is required, then this method of control is simple and satisfactory, but a reduced variation in quality and from a load to load basis is necessary. Fundamental to this requirement is also the need to know coal quality, ash and moisture, particularly on-line, although in spite of the intensive research and development effort worldwide, it cannot yet be said that totally satisfactory instruments are available to measure these qualities to an acceptable 10 per cent relative level of accuracy.

Perhaps, however, technical excellence is

being sought when the correct application of equipment already tried and proven, although maybe of lower accuracy, could make significant contributions to blend consistency. For example, the addition of dry fines on the basis of its reciprocal bulk density would improve the short term stability of the blend. Bulk density meters have been available for some time capable of an accuracy in the region of  $\pm 1.5$  to  $\pm 2.0$  per cent of ash. There could also be improved control of the blending ratio by using integrated ash and moisture readings from, say, the BC/AERE phase 3A ash meter or equivalent.

It is true that wet coal creates handling problems with the phase 3A monitor system but the monitor does examine a true sample. Equally on-belt ash instruments 'look at' so small a percentage of the material on the conveyor belt that they too are not totally satisfactory. In some particular colliery trials, it has been demonstrated that the use of a phase 3A ash monitor signal to monitor the blend ash and provide a feedback control signal to adjust the blending ratio, has improved the blend consistency by a factor of two, relative to when produced on a fixed ratio basis. In this case, for example, the actual blend variance was reduced by about 40 per cent from the time before the monitor was used to an equivalent period afterwards. Further improvement could be achieved by using either an input signal to the blending equation of the untreated component from a bulk density meter, or from a radiometric ash monitor measuring the washed



The new Larcodems separator.



coal component, and as feed forward control signals.

Opportunities exist for control system engineers to introduce automation, using the signals from the monitors currently available, to improve the consistency of coal mixtures. As the accuracy and reliability of ash and moisture monitors improves, so these opportunities will expand to allow universal computation of calorific value as has already been done at two sites in Scotland. In these examples the accuracy was approximately  $\pm 400$  kJ/kg on a shift-by-shift basis.

## Pelletisation of fine coal

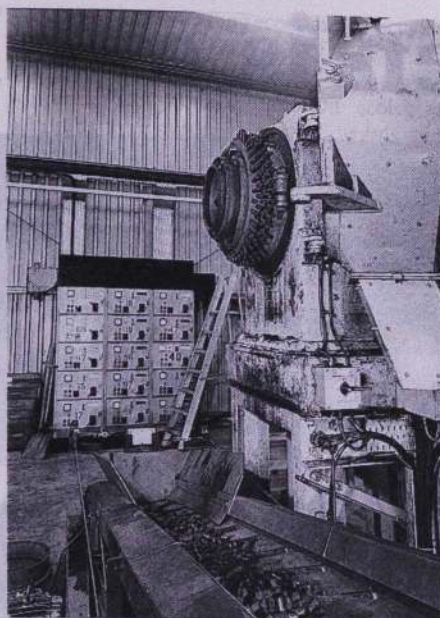
Where vacuum filtered from coal concentrates are added to other products, in order to maintain unhindered flow through the handling plant associated with the combustion or carbonisation of the coal, a limit on the amount of minus 3 mm material may be imposed. Other, but perhaps minor difficulties associated with coal handlability, such as freezing in wagons, can also be more easily overcome by reducing the amount of fines.

Obviously stocking or discarding unhandlable fines does not allow a competitive situation since all the mining and preparation costs have already been incurred. All the coal which has been produced has to be sold, and it was essential to consider how coal fines might be extruded into coarser granules, capable of withstanding shear in storage and handling, possible flame contact on entering a combustion chamber without complete breakdown to dust, thereby to overcome the handlability difficulties.

After extensive laboratory and pilot plant trials where all the pelletising parameters were examined for different coal types, the pelletisation of bituminous coal fines has been shown to be one method whereby the problem of handlability may be reduced or eliminated. Similarly 25 mm diameter pellets of anthracite duff have also been proven satisfactory for certain domestic markets and thereby provide a means of maximising the sale of fine coal which might otherwise be put to ground. Whilst the technical solution for pelletising coal fines has been demonstrated it is also clear that because of low machine throughput rates and high associated operating charges the pelletisation of coal will be costly. Typically the add-on costs could be up £12/tonne for bituminous pellets added directly to a power station blend and up to £18/tonne for anthracite, bagged and palletted in 25 kg packages.

## Simplification of plant

Improvements in process design are being made to keep pace with present day requirements and to ensure that the same standards of performance can be maintained with larger machines. Although in the past views have differed as to whether it is better to use one large capacity of two or more smaller capacity units, it is generally accepted now that process performance and engineering standards can be maintained with larger machines. For example, in the UK while at one time it was thought that the maximum washing width for



Pelletisation of coal fines.

a conventional Baum jig was about 2.6 m, a number of machines 3.6 m wide are now working perfectly satisfactorily. The capacity per unit machine has, therefore, been increased with a reduction in capital cost per tonne created.

The advantages of one 3 m wide screen compared with two 1.6 m wide units is clear from Table 1 and there is the added economic advantage of reduced space requirements.

As another example a 2 m wide  $\times$  3.5 m long feeder, capable of discharging 1,200 m<sup>3</sup>/h costs about £20,000 compared with about £13,500 each for two feeders, 1.2 m wide  $\times$  3.5 m long discharging 600 m<sup>3</sup>/h. Again a clear advantage in using the large single feeder.

The same pattern applies when considering centrifuges for the dewatering of small coal, and indeed for froth flotation cells. Flotation machines three to four times the capacity of earlier units and up to 14-15 m<sup>3</sup> in size, have been installed in the UK and operated continuously and satisfactorily on an hour-by-hour and day-by-day basis. It will be appreciated that not only can plants be simplified by the use of larger capacity machines, but problems can be lessened and even avoided in reducing the division of both solid and liquid flows to multiple streams. Loss of plant availability is probably caused more often by the division of flows and cross-over streams than for any other cause. When the problems of the division of feed have been reduced measurements for the control of the process is considerably simplified. This makes for better and more consistent quality product.

## Environmental issues

**Disposal of tailings and effluents** — The problems of tailings disposal from large tonnage inputs are severe. For coarse discard

greater than 0.5 mm size secondary screening to remove as much water as possible is always carried out and typically the free moisture content in this material discharged to the tip is about 2 per cent. Civil engineers have agreed that it is preferable in many cases for the coarse discard and tailings to be delivered separately to the tip, where better control of layering and/or mixing can be carried out.

**Coal desulphurisation** — On account of the serious, costly and cumulative environmental damage which appears to be attributable to sulphur dioxide, there is considerable pressure for restrictions to be placed on the sulphur content of coal used for power generation. As far as European coal resources are concerned in view of the dearth of indigenous low sulphur coal, this implies some form of treatment. Depending on economic, technical and political considerations, countries with large reserves, containing relatively high amounts of sulphur, will opt for fuel cleaning and/or emission control.

Because coal varies so much in its characteristics it is not possible to give overall figures for the reduction of sulphur achievable by the application of coal preparation techniques. It could be as little as 4 per cent or, in exceptional cases, may be as high as 20 per cent. It must be stressed, however, that in practice coal preparation does not remove very much sulphur, it simply moves it, and this invariably results in a high sulphur middlings which must then be crushed, retreated, or burned in a non-polluting manner. In either case the level of sulphur would not be reduced low enough to comply with the emission regulations being considered for Europe, and some form of stack gas treatment after combustion would still be necessary.

There has been the greatest collaboration between the CEBG and British Coal to explore all avenues of reducing sulphur dioxide emissions from power stations. The conclusions are that FGD equipment to remove 90 per cent of all the sulphur dioxide is at present the best technical and economic solution. To achieve maximum benefit, however, it will be important that the highest sulphur coals are routed to those stations equipped with FGD, leaving the lower sulphur coals for combustion at conventional stations.

This conspectus of coal preparation practice, whilst basically UK orientated, identifies typically the processes and systems used throughout the world to prepare coal for the market. There is no doubt, however, that there are strong challenges to coal and particularly for deep mine operators. Perhaps this review will prompt thought for research, development and application of preparation techniques to maintain coal as a competitive form of energy. □

Table 1.

Size	Power	Approx cost
3 m wide $\times$ 4.5 m long	2 $\times$ 20 HP	£34,000
1.6 m wide $\times$ 4.5 m long	2 $\times$ 10 HP	£20,000



# How Green is our Energy?

HOW GREEN is Our Energy? was the title of the Institute's first annual conference — a one day event — which preceded the annual general meeting and the installation of the new President for 1990-91 on 19 May, and held as part of a three-day weekend of business and social events in the Yorkshire coastal resort of Scarborough.

As might be expected, the question posed by the conference title proved to be an over simplistic one. For beneath this lurked a vast array of complex issues which were further confused by variable perceptions of present and future energy needs, to what degree environmental and social considerations should prevail over economic forces, and — presuming that the essential prerequisite of a global consensus is ever achieved in relation to these two factors — then what actions would be the most effective in dealing with the phenomena known as the *greenhouse effect* or, alternatively, *global warming*.

An appeal against the confusion caused by the use of such terms as "green" and "energy" as metaphors was made by Walter Patterson, the conference chairman and presenter of the keynote address. He argued that the use of these terms as metaphors can be dangerous if it confused an argument, adding that society at large had fallen into the habit of using the word "energy" as a metaphor, imprecisely and often inaccurately, and the consequent confusion is leading mankind badly astray.

## Unrealistic concepts

Mr Patterson, who has achieved prominence as an independent analyst, writer and broadcaster on energy and the environment, and who also described himself as a 'lapsed nuclear physicist', asserted that the institutionalisation of the *energy supply* infrastructure over the course of this century had led to concepts about the purpose of energy which were increasingly divorced from reality and the real needs of society.

Public consciousness of the need for conservation was at risk of being undermined through the entrenched culture of the energy supply planners, who had become accustomed to a work ethic based upon notions of the inexorable rise in demand for fuels and electricity, but paid little attention to what fuel and electricity are actually used for.

This kind of mind-set, he argued, had led to the situation whereby energy demand forecasts had moved further and further away from reality. More optimistically however, by the mid 1970s Mr Patterson had discerned the beginnings of an alternative approach, when people began studying what users actually *do* with fuel and electricity. This led in turn to a focus on whole systems for energy conversion, the most efficient use of energy to provide services, and energy conservation.



Delegates in session during the conference on 'How Green is Our Energy?'

## Integrated approach

Mr Patterson concluded by asserting that at least part of the solution to problems associated with mankind's energy use and harmful environmental effects lay in the proposition of institutionalising a more integrated approach towards fuel use, energy conversion and end use, so as to produce maximum efficiency across the whole cycle. This led him to reintroduce the concept of the energy services company — a concept originally advanced by Thomas Edison more than a century ago — plus the notion of creating an Institute of Energy Services.

Another proposition advanced by Mr Patterson, and others who spoke at the conference, was the concept of tax incentives for energy conservation. In his keynote address, Mr Patterson drew attention to what he felt was an anomaly in the UK whereby there was no tax on domestic electricity or gas consumers, but there is no similar incentive for consumers to invest in energy efficient appliances and equipment because Value Added Tax is applied to this sector.

However, the idea that the traditional fuel and energy suppliers were not already involved in the promotion of integrated schemes for efficient energy use as well as production, was obliquely rejected by Allan McKay, the North Eastern Regional Chairman of British Gas plc. He referred in his address to a number of integrated energy management schemes in which his company had participated with impressive results, in terms of improved energy efficiency and minimal effects on the environment.

An attempt to put the UK contribution to the so-called greenhouse effect into a realistic

perspective, was made by Graham Hall, the Divisional Director of Energy Supply for Yorkshire Electricity Group plc. Addressing the issue of carbon dioxide emissions, the biggest contributor by volume to the 'greenhouse' gases, Mr Hall said it had been estimated that CO<sub>2</sub> emissions from the UK accounted for three per cent of world emissions of this gas; but within the UK, electricity generation is responsible for about one third of this, or one per cent of total world emissions.

However, as one of the few speakers brave enough to attempt any kind of prognosis on what may realistically happen in the future, Mr Hall said that, as far as the UK is concerned, energy *efficiency* will continue to replace *conservation* as the main focus of activity because of straight economics. He believed that the new electricity distribution companies would have a major part to play in this, and would be helping industry improve its energy efficiency in terms of energy usage per unit of productive output.

On a more pessimistic note, he commented that the environment will continue to have a high profile in political exchanges but will fail to dominate technology because of the cost.

## Profound analysis

Probably the most profound analysis of the current state of the global debate on energy and the environment was contributed by the final speaker of the conference, Malcolm Edwards, the Commercial Director of the British Coal Corporation. A sceptical but very direct answer to the question posed by the conference was given by Mr Edwards when he commented: "In all the publicity of the past year, the facts remain stubbornly, exasperatingly unclear."

Questioning the premise that the phenomena of global warming was itself attributable to man-made causes, Mr Edwards added: "Over the past century, global temperature it has been said, may have risen by 0.5°C — that itself is no longer universally accepted but in any case it falls within natural variations. More important, variations within that period have not been what you would expect if greenhouse gas emissions was the dominant influence. Most of that rise in temperature is said to have occurred between 1880 and 1930 when only a third of the total increase in greenhouse gases took place. From 1940 to 1970, when greenhouse emissions rose sharply, temperatures dropped. The result — the 1970s were rife with predictions of a new ice age. All this suggests that other natural factors predominate."

Mr Edwards also drew attention to what he described as "a weight of analysis and interpretation . . . which casts some doubt on the greenhouse theory in its state of primitive innocence. He cited works of Professor Labitske, the studies of Kuo, Lindberg and Thomson as published in *Nature* earlier this year, and the report of the Marshall Institute as identifying variations in the activity of the sun as a most important factor for the temperature of the earth.

Despite these uncertainties, Mr Edwards observed that the public who elect politicians are not willing to sit around to see whether the earth does warm up to provide the irrefutable scientific evidence that something should have been done 20 years before to turn down the heat in the greenhouse. Acknowledging that political expediency would be the principle propellant of action on the environmental front, Mr Edwards considered that a real effort is being made by many in government to get the right balance amidst all the pressures and uncertainties. "We all have to do the best we can to ensure that the public pressure does not cause the politicians to do things which could be both ineffective and leave us all a lot poorer," he warned his audience.

One of the options that Mr Edwards evidently felt would be ineffective was the much-publicised notion of a carbon tax, adding that: "It makes no sense to tax half the greenhouse gases but not the other half despite the fact that these may be more long lived."

Developing this theme, Mr Edwards went on to assert: "It makes no sense if the whole of the relevant activity — energy production and processing — is not tackled as a whole. If it is

not, then a sheaf of wrong economic choices are not at risk — they are a certainty."

Doubts about the capability of governments worldwide to produce the right ecological solutions were raised when Mr Edwards said: "I submit that wrapped up in this parcel labelled Global Warming, there is a great array of quite different problems separately and together of a scale and extent and as yet a lack of definition that governments have not experienced before. The institutions are very simply not yet in existence to deal with problems of this quality. This is clearest even where the problem is most clearly recognised and, we should expect, most simple to solve such as CFCs and deforestation."

### Practical steps

Turning to the potential practical steps that could be taken to minimise greenhouse gas emissions, at least on a regional or global level, Mr Edwards advanced the theory that no single development could do more to reduce CO<sub>2</sub> emissions in the electricity part of the energy cycle than the establishment of a reliable low cost combined cycle system with coal combustion. He claimed that combined cycle power generation would have the potential to reduce both the emission levels from coal fired power stations and the cost of electricity generation by 20 per cent.

Observing that transport contributes more of the greenhouse gases than coal fired power stations — around 10 per cent — Mr Edwards noted that attempts to reduce the motor vehicle population through increased taxation would prove to be politically unattractive, but if greater public transport were to make any real inroads then the provision would have to be positively lavish, even in cities, where the motor cars is at its most inefficient.

He drew some comfort from the initiative taken by the US state of California, which is to ballot this November on a wide range of severe environmental restrictions. One of the principle objectives is to achieve a 40 per cent reduction in carbon monoxide emissions over the next 20 years. The Californian plan tackles the pollution problem from the internal combustion engine head on by establishing high occupancy vehicle lanes, requiring companies to increase the average occupancy of cars parking on their property and even restricting the use of petrol driven lawn mowers. "Despite all this, the conclusion is emerging that only a determined switch from petrol to battery transportation of around 10 per cent can get the total

emissions within target," Mr Edwards commented.

The issue was considered of how the natural process of photosynthesis could be assisted to rectify, what Mr Edwards believed to be, a small imbalance in the natural cycle so far as the processing of CO<sub>2</sub> is concerned (3GT of carbon when the photosynthesis of the forests alone removes 50GT a year from the atmosphere).

Mr Edwards suggested this could be done directly by planting India, or its equivalent, with forest and then ensuring that when the trees reached maturity, they were turned into furniture, not firewood. Alternatively, the sea provided a potentially much greater sink for carbon if mankind could find a way of using it. Mr Edwards was careful to qualify his proposal with the assertion that he was not considering some kind of dumping exercise — rather a way of helping the natural process there to work a shade harder by enhancing the growth of ocean organisms.

He also announced that British Coal is willing to participate in efforts to find cheaper and better ways to extract CO<sub>2</sub> at the power stations than is available through existing technology. He suggested that one way would be to combust fossil fuels in a CO<sub>2</sub>/oxygen mixture. Another means could be partial gasification in oxygen, with the oxygen then separated, a shift conversion to increase the hydrogen content and the CO<sub>2</sub> removed by scrubbing.

No doubt the delegates were grateful for at least this elucidation of the options for solving some of the greenhouse problems. However, the abiding sense of frustration over society's failure to produce a coherent and well-defined plan of action were neatly summed up by Mr Edwards when he said: "This greenhouse of ours is more full of undefined and unsolved problems than any other part of our global property that I can identify. It is something that every self-respecting corporation should help address . . . It costs effort and management and money, but self interest is there beckoning because the more that those in business help, the better the advice that will be available to the bemused politicians and the fewer mistakes business is likely to suffer as a result."

Whether this strategy succeeds in producing the kind of global consensus and coordinated action to effectively deal with the popular perception of current environmental problems, it appears that only a strictly limited amount of time will tell . . .

**KBH**

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## Environment agenda

BRITAIN'S professional engineers and technicians are taking a close look at environmental matters.

"Engineers and the environment" is the theme of the 1990 Engineering Assembly — consisting of 114 elected delegates from the whole of the United Kingdom — to be held on 16 and 17 July at the University of Surrey.

There is an impressive line-up of speakers for the debate on the subject. Speakers include: the Rt Hon Christopher Patten, Secretary of State for the Environment (on political issues); Sir John Mason FRS, former Director General of the Meteorological Office (on the 'greenhouse effect'); Sara Parkin, Speaker for the Green Party (*The greenview of the role of engineering*); Mr Robert Malpass FEng, Chairman of PowerGen (*The challenge to the engineering profession*).

Mr Denis Filer FEng, Director General of The Engineering Council, said: "Engineers have always been conscious of the environment because we are involved in so many aspects of life — right across the spectrum from making aircraft to producing medical care equipment. This year we are asking all our engineers and technicians — through their elected members at the Assembly — to concentrate on the environment and to see what future steps we should be taking to safeguard it. Our leading speakers at this year's Assembly will be giving us their views and we shall take their opinions into account when we agree on the action we should take as professionals."

## Government funding for Neighbourhood Engineers

THE DEPARTMENT of Trade and Industry is offering up to £612,000 to The Engineering Council as initial pump-priming money to help the national launch of the Council's Neighbourhood Engineers project.

Neighbourhood Engineers links three or four engineers and technicians to each secondary school to work — for three or four hours a week — in teams with teachers. It aims to provide young people, their parents and teachers with a friendly and informal source of practical support on matters relating to engineering. It is currently helping teachers deliver the national curriculum and engender an awareness among pupils of the importance that engineering plays in their lives.

The Engineering Council, which already has six secondees from industry working on Neighbourhood Engineers, will be seeking major additional contributions from industry.

The scheme is being set up initially in eight regions (Merseyside and North Wales, Scotland East, Kent and Sussex, South West, Northern, South Wales, Devon and Cornwall and the Midlands) of the Council's 19 regions. It is currently active in 450 schools, involving 1,500 engineers, and eventually it will link 24,000 engineers to 6,000 secondary schools.

## How companies are helping schools create the future



Photograph by courtesy of The Engineering Council.

The cover photograph for The Engineering Council's brochure, *Creating the Future*.

SMALL and medium-sized companies throughout the country are being encouraged in a new brochure to become involved in supporting the teaching of technology in schools.

The brochure, *Creating the Future*, aims to stimulate employers to find ways in which they can help their local schools to teach technology as part of the national curriculum.

*Creating the Future* has been produced by The Engineering Council, which represents Britain's professional engineers and technicians, and The Standing Conference on Schools' Science and Technology (SCSST), which promotes the development of science and technology in schools.

The brochure — sponsored by the Department of Trade and Industry and Unilever and being sent to 25,000 firms — describes some of the ways companies are already helping teachers present the subject to the five to 16-year-olds. In fact, five-year-olds at a London school had their first taste of technology when they dressed up as professional engineers, in white coats, safety helmets and protective glasses, to pose for the brochure's eye-catching cover photograph.

The brochure highlights case histories of companies who have worked with schools to introduce practical examples from industry into their course work so that technology becomes relevant and interesting.

Mr Denis Filer FEng, Director General of The Engineering Council, who was a member of the national curriculum working party on design and technology, said: "The future well-being of industry and commerce is dependent upon the health of the education system in the technology field, so the importance of making the subject interesting and appealing to young people is vital. That's why we want companies to help in the schools."

## Official visit

HIS Royal Highness The Duke of Kent, KG GCMG GCVO ADC, who became the first President of The Engineering Council in November last year, made an official visit to the London offices of The Engineering Council in April.

The Duke of Kent was welcomed by Sir William Barlow FEng, Chairman of The Engineering Council. His Royal Highness then attended the full meeting of the Council and had lunch with Sir William, Members of Council and Council staff.

## EMA survey highlights engineering skill shortages

ALARM at the growing shortage of those entering the engineering profession led the Engineers' and Managers' Association to undertake its own survey of the situation. Among its 41,000 members the EMA represents 15,000 Chartered and Incorporated Engineers working in British industry.

The report *An engineering vacuum: How a shortage of engineers and technicians is crippling British industry* has just been published, with a foreword by Dr Kenneth Miller, first director of the Engineering Council.

The report finds that over the decade 1978-88 the demand for engineers and scientists with degree type qualifications in the engineering industry had risen by 55 per cent while the number of students applying for engineering courses at polytechnics and universities had fallen by more than 30 per cent between 1982 and 1988.

In February 1989 some 5,000 engineering firms were estimated by a joint Training Agency/Confederation of British Industry survey to be experiencing shortages of skilled staff which prevented them from developing new products or raising output to meet increased demand.

A comparison of international statistics shows that the number of qualified professional engineers leaving British universities and colleges each summer is only two-thirds of the output for West Germany and the USA and half the output in Japan (the figures were adjusted to take into account the much larger populations in these countries). For craftsmen and women there is an even greater disparity, the number qualifying each year in this country being only 40 per cent of the number in France and 30 per cent of the German output.

The most important of the recommendations that the EMA proposes on how to resolve this situation, which is already having a drastic effect on British manufacturing industry, is that there must be a marked improvement in the pay, status and career prospects for engineers.

Copies of the report, price £2.50 + postage, are available from the EMA, Station House, Fox Lane North, Chertsey, Surrey KT16 9HW.



## An update

**'Coal Liquid Mixtures'**  
**Institution of Chemical Engineers**  
**Symposium Series No 107**  
**Hemisphere Publishing**  
**Corporation, 1988**  
**409 pp. £32 plus £3 (p&p)**

The 28 papers published in this book were presented at the Third European Conference on Coal Liquid Mixtures, held in Malmo, Sweden (October 1987). They provide an update of international developments in this technology together with evidence of adaptation to the currently challenging economic pressures.

The book is divided into four main sections: CWM Preparation and Properties (laboratory or intermediate scale); Atomisation and Combustion; Commercial Application; and Commercial Production and Future Prospects.

The topics covered in the text range from coal pretreatment (before slurry preparation) and the use of biocides to the containment of particulate emissions following the combustion process. As to slurry preparation, both pilot-scale studies and updated commercial plant are described.

Slurry atomisation behaviour continues to attract attention, with emphasis on mechanisms of drop formation and the effect of dispersant addition. Progress in fundamental aspects of slurry combustion includes an assessment of mineral matter transformations in flames and work relating to the reaction kinetics of slurry droplets prepared from relatively coarse coal.

Developments in commercial burner technology are discussed and it is encouraging that slurry combustion programmes have continued on converted utility and industrial boiler plant. Such work will give confidence to commercial suppliers of coal liquid mixtures poised to offer slurries prepared with the advantage of economy of scale.

New initiatives aimed at enhancing the competitiveness of slurry fuels are described. These include the use of coal washery fines and low-grade fuels of high ash content, rather than premium grades of coal. Examples are given of integrated systems which provide for slurry preparation at the point of use in order to take advantage of reduced preparation costs or local economic factors which favour a change to a coal-based fuel.

The latter part of the book contains papers which cover development in various applications for coal liquid mixtures. These range from the commercial (small premises) boiler sector to aggregate drying, cement kiln firing and open hearth furnaces. Process heating applications may offer the prospect of a variety of slurry formulations each tailored to suit specific process requirements.

This is an excellent selection of papers. The knowledge and skills required for the commercial implementation of coal liquid mixtures have become increasingly comprehensive and are now ready to respond to market opportunities.

*Dr Andrew W Cox*

## Well researched

**'Carbon Fibers'**  
**by J-B Donnet and R C Bansal**  
**Marcel Dekker Inc, second edit, 1990**  
**496 pp. \$125.00 (USA and Canada);**  
**\$150.00 (all other countries)**

This subject is now of significance to the field of energy, as world demand is at the level of 8,000 tonnes per annum and knowledge has increased in the eight years since the first edition of this book was published.

Carbon fibres are normally used in a matrix, in epoxy resin, but ceramic, glass, metal or plastic matrices have been used; also some hybrid matrices have advantages. Carbon materials are brittle and have poor impact resistance. They are highly anisotropic and expensive, but the price has come down. In the future they are expected to reinforce light metals such as aluminium and magnesium.

The fibre is a brittle low density material with great resistance to fatigue failure, which improves the payload economics and makes it attractive in transportation. Its use in sports equipment has been recognised for many years. High thermal conductivity and low coefficient of linear expansion enhance heat dissipation in gears, brake pads and bearings. Reinforcement of carbon heat exchanger tubes by fibres reduces cracking and leakage in those applications where carbon is essential.

While petroleum-based carbon is the main source of this material, development may proceed to the use of pitch-based carbon, probably at the expense of lower purity and consequently lower strength.

The authors, both professors, have produced a well-researched text with 890 references and 101 tables. The quality of the transmission and scanning electron micrographs among the 210 figures is remarkably good, also the clear diagrams demonstrating organic chemical structures. The first edition has been considerably revised. The first chapter deals with the preparation of fibres; the second refers to structures. Chapter 3 deals with the gas and liquid phase, also electrochemical oxidation treatments on composite properties. Chapters 4 to 6 concern the surface, mechanical, and electronic, magnetic and thermal properties, respectively. The last chapter refers to the applications of carbon fibres. There are good author and subject indexes.

*Dr D N Gwyther*

## How safe is nuclear?

**'The Safety of Nuclear Power Plants'**  
**The Uranium Institute, 1988**  
**66 pp. £10.00**

This is an excellent, albeit short book on the concern of the public over the safety of nuclear power plants. It is admirably presented and well laid out and includes an informative section of 13 'Questions and Answers'. These should be a considerable assistance to those who wish to gain some introductory knowledge of the subject. They cover a range of matters of most concern to the general public, but for

some inexplicable reason no mention is made of nuclear waste.

The book is an assessment by an international group of senior nuclear safety experts. Their views have been edited and presented by a staff member of the Uranium Institute, Mary Acland-Hood.

The book focuses on the risk to safety, specific to nuclear power stations. The key safety aspects are dealt with in an early chapter which covers the design of such plants. Important safety principles covering redundancy, diversity, cooling and the system characteristics, together with the human factors involved, are well explained.

Basic preventive measures taken against the release of radioactivity by building a series of leak-tight barriers are excellently portrayed for three levels of prevention, which, in these sort of plants, are required. The chapter explains that despite a high degree of automation and protective devices, adverse human factors cannot be entirely excluded.

The reader is presented with a chapter which carefully explains operational safety, the role of operators and their responsibility and training; it also includes maintenance, testing and surveillance of equipment. Two further chapters cover emergency planning and accident management, risk analysis and risk comparison.

These matters constitute about half of the book, the remainder being the very informative 'Questions and Answers' section, included because it was felt to be a most useful contribution towards improving communications with the public.

The expert group concludes that the risk associated with electricity production from nuclear power stations is and can be kept very low. The general approach has to be that although the overriding priority is to prevent accidents, the possibility always remains and therefore the three principles of accident management, containment and emergency planning must always be implemented.

The Uranium Institute is to be congratulated on this presentation. The price of the book is about right, but it may still be too high for purchases by educational establishments. It is in schools where this book would be of the greatest benefit for the understanding of nuclear energy by tomorrow's adults.

*F John L Bindon*

## Recently published

**'Who's Who in the Environment: England'**  
**Compiled and edited by Sarah Cowell**  
**The Environment Council, 1990, 317 pp. Free**  
**of charge**

**'Calder Hall and Chapelcross Nuclear Power Stations'**  
**Health and Safety Executive**  
**HMSO, 1990, 23 pp. £4.00 net**

**'Combined Heat and Power — an Annotated Bibliography'**  
**The Building Services Research and Information Association, 1990, £15**

## Largest ever gas turbines to go offshore

RUSTON Gas Turbines Ltd, a UK subsidiary of GEC Alsthom's European Gas Turbine Company, has just secured contracts worth over £40 million to supply the largest ever gas turbines offshore.

Ruston is to supply three 33 MW RLM5000 gas turbine generating sets for the Scott platform in the North Sea operated by Amerada Hess, and three RLM 5000 gas turbine compressor sets for the East Brae platform, also in the North Sea, operated by Marathon Oil UK Ltd.

For Ruston, a world leader in offshore gas turbine electrical power generation and mechanical drive applications, the contracts represent a number of historic achievements: the first offshore application of the RLM5000 gas turbine, the gas generator of which is manufactured in America by GE who have a 10 per cent shareholding in the European Gas Turbine Company; the largest power generation sets to be installed on an offshore platform; the first mechanical drive application for the RLM5000; and the largest gas turbine driven compressor sets in the world.

Build and test of the units will take place at EGT's Ruston plant in Lincoln for delivery in 1991.

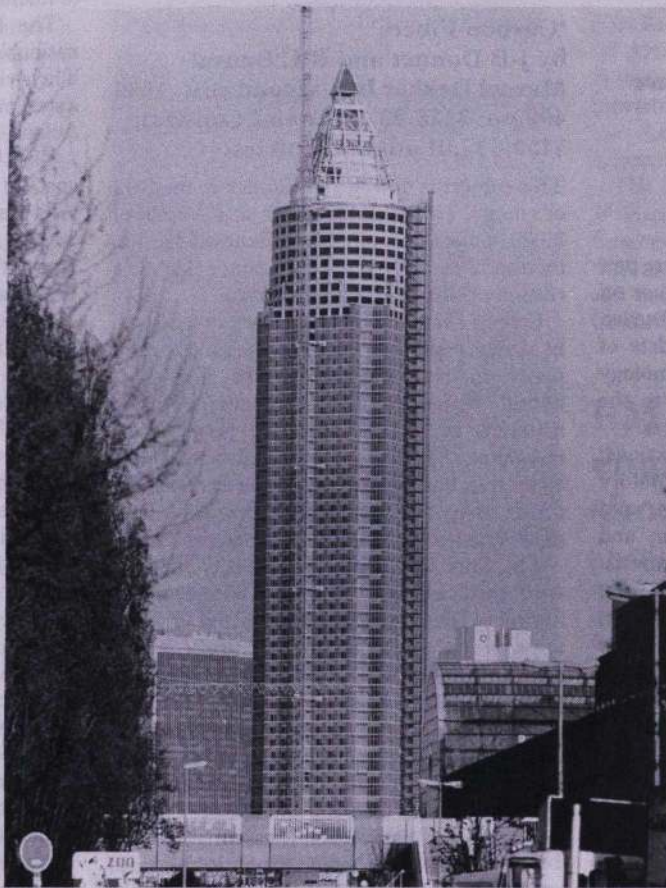
These contracts are subject to final confirmation and the Annex B requests for both fields have been submitted to the Department of Energy by the operators and are currently under discussion.

## Transmitters for hazardous oil and gas environments

A NEW family of four BASEEFA EEx certified pressure transducers, which are designed for use within the oil and gas industries, have been introduced by TransInstruments.

Designated as part of the BHL-4260 series, the new instruments are available in intrinsically safe, flameproof or non-incendive versions, with each being suitable for a variety of environments including oil and gas production platforms, petrochemical plants, refineries, pipelines and compressor stations.

## BEMS for Europe's tallest building



**ENVIRONMENTAL control will soon be provided for the 'Messeturm', Europe's tallest office building in Frankfurt, by Landis & Gyr's Visonik building energy management system (BEMS).**

**The 70-storey building, scheduled for completion in August this year, is 256 metre high with 62,000 square metre of office space.**

**The 'Messeturm', pictured above, is part of Messe Frankfurt, the city's vast exhibition and trade fair complex, home to the biennial heating and air conditioning exhibition, ISH.**

**The Visonik system incorporates computerised supervision of all heating, ventilating and air conditioning plant and will ensure a high level of environmental comfort throughout the building with the minimum of energy consumption.**

**For further information contact Sue Murphy, Landis & Gyr Building Control (UK) Ltd, Victoria Road, North Acton, London W3 6XS.**

Each of the new transducers has very high burst pressure rating, is manufactured using the latest sputtered thin film sensor technology, offers 5 to 1 rangeability, plus long term stability without the need for frequent recalibration.

The BHL-4262 is a high performance, flameproof pressure instrument with either a NACE compatible Inconel or stainless steel casing. The transducer has a pressure range of 0.2.5 to 0.400 bar, adjustable down to 0.625 mbar or up to 0.500 bar or equivalent.

The three other pressure transmitters: BHL-4261, BHL-4263 and BHL-4269-20/30, are all intrinsically safe and range from 0.1 to 0.690 bar. The accuracy and operating range are plus or minus 0.15 per cent and  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  respectively. The BHL-4261 has a DIN plug electrical connection, the BHL-4263 a M20 gland electrical connection and the BHL-4269 a 1m waterproof electrical cable.

For further information contact TransInstruments, Lennox Road, Basingstoke, Hampshire RG22 4AW.

## 'Maintenance-free' battery

A MAJOR manufacturer of nickel-cadmium (NiCd) batteries for industrial and commercial applications, Alcad Ltd, has introduced the Solar Vantage range of NiCd batteries that is designed specifically to meet the needs of photovoltaic system users.

The maintenance-free technology works upon the gas recombination principle in which gas given off during operation is recombined within the cell. Consequently, a negligible amount of water is lost so the need for maintenance is eliminated, thereby allowing the battery to operate, typically, without topping up, for 20 years.

The battery has an operating temperature of  $-40^{\circ}\text{C}$  to  $+55^{\circ}\text{C}$  and a significantly longer life at high temperatures (15 years at  $40^{\circ}\text{C}$ ) than lead-acid batteries.

It is designed to give 95% charge efficiency and excellent charge retention (less than 5 per cent loss per annum when 80 per cent charged) in specified operating conditions.

Solar Vantage is available with rated capacities of 33-250 Ah and can be assembled into battery units with voltages of 2.4-12 V.

For more information contact Alcad Ltd, Union Street, Smallwood, Redditch, Worcestershire B98 7BW.

## Noise problems

THE PROBLEM of additional motor noise, caused by standard PWM drives, which can be highly undesirable in quiet environments, has been overcome by MTE with their Blue Range ac drive type SD.

The drive operates at a switching frequency of 20 kHz which is above the audible frequency range and therefore suitable for applications such as heating, ventilating and pumping.

0.75 kW and 1.5 kW models are available in either open or enclosed form with optional reversing.

Standard features include isolated control inputs, low-speed torque boost, torque limit adjustment, adjustable current trip delay and minimum speed setting.

For further information contact MTE Ltd, Leigh-on-Sea, Essex SS9 5LS.



- Title:** **Chemical engineering for engineers.**  
**Location:** Bradford.  
**Duration:** 2 days.  
**Starting:** 27 June 1990.  
**Content:** What is chemical engineering? Material balances. Energy balances. Reactor design. Basic mass transfer. Gas absorption. Binary distillation.  
**Contact:** Conference section, IChemE on 0788 78214.
- Title:** **Introduction to oil industry operations.**  
**Location:** The Institute of Petroleum, London.  
**Duration:** 3 days.  
**Starting:** 27 June 1990.  
**Content:** Changing perspectives in the international oil industry. Exploration for oil and gas. Basic concepts of drilling. Petroleum production. Marine transportation. Supply. Refining. Petrochemicals. Research activities. Introduction to marketing and distribution. The retail market.  
**Contact:** Miss Caroline Little, InstPet 071-636 1004.
- Title:** **Introduction to petroleum economics course.**
- Location:** The Institute of Petroleum, London.  
**Duration:** 3 days.  
**Starting:** 2 July 1990.  
**Content:** Development of the major oil companies. The national oil companies. The role of the independents. USA. OPEC/Middle East. Centrally planned economics. North Sea Basin. The changing pattern of trade. Crude oil markets. Product markets. Oil price information. Oil futures market. Oil supply and price — the outlook.  
**Contact:** Miss Caroline Little, InstPet on 071-636 1004.
- Title:** **Radioactive waste management.**  
**Location:** Oxford.  
**Duration:** 4 days.  
**Starting:** 2 July 1990.  
**Content:** Radiological standards and health implications. Management of waste arising from the UK nuclear programme. Decommissioning. Use of radionuclides. Legislative control. Proposals for underground disposals in the UK and abroad. Public acceptance or radioactive waste management.  
**Contact:** Louise Coote, IBC Technical Services Ltd on 071-236 4080.
- Title:** **Radiological protection.**  
**Location:** Cambridge.  
**Duration:** 4 days.  
**Starting:** 16 July 1990.  
**Content:** An update on the concepts of radiological protection. The implications of recent developments in the understanding and assessment of radiation effects.  
**Contact:** Liz Hide, IBC Technical Services on 071-236 4080.
- Title:** **Effective marketing in the international coal trade.**  
**Location:** Oxford.  
**Duration:** 4 days.  
**Starting:** 23 July 1990.  
**Content:** International coal trade: history and current status. Coal quality and the environment. Shipping and freight. General contractual terms. Coal supplier marketing and contractual requirements. Coal customer contractual requirements.  
**Contact:** The Registrar, The College of Petroleum Studies on 0865 250521.

## THE COSTS OF FLUE GAS DESULPHURISATION

a one day conference organised by The Institute of Energy

19 September 1990

at The Scientific Societies Lecture Theatre, London W1

The removal of sulphur oxides from the flue gases of power stations and large industrial plants has been a frequent topic of conferences and seminars. The discussions have, however, mostly centred on the means of removal and assessment of the possible environmental effects of such removal. The costs of removal and associated aspects have hardly figured in these conferences.

The practice of sulphur dioxide removal from both pulverised fuel and stoker fired plants are well established on the Continent representing the worldwide practice.

The Institute of Energy's conference will include speakers from the European operators, designers and suppliers of the various systems: wet, semi-dry and dry for pf firing, and dry systems for stoker-fired plants who will present their experience of costs of installing and operating their units.

The conference will also include speakers from: British Coal Corporation, KPMG Peat Marwick McLintock, Stadtwerke Dusseldorf AG, Tampella Ltd, Delft University of Technology, Volland Energisystemer A/S.

With the imminent implementation of the EC Directive requiring flue gas desulphurisation from large combustion plants of UK power stations, industries and refineries, this conference will provide an ideal opportunity for delegates to obtain first hand information on the costs of flue gas desulphurisation from those who have already designed and supplied these systems and are operating them.

For further details please contact: Judith Higgins, The Institute of Energy, 18 Devonshire Street, London W1N 2AU, or telephone on 071-580 0008.



### June 1990

#### Energy and the Environment

Seminar, 20 June, Cambridge, England.

Details from Rex Bowen, tel: 0992 555120, or Robert Bilbie, tel: 0603 629571.

#### The New UK Energy Market — How Will You Benefit?

Two-day conference, 21-22 June, Edinburgh, Scotland.

Details from Henry MacDermot, Conference Organiser, Professional Studies Scotland, 21 Lansdowne Crescent, Edinburgh EH12 5EH, tel: 031 226 2830/031 313 2360, fax: 031 313 2337.

#### Mechanical Systems for Wind Turbines

One day discussion, 26 June, Harwell Laboratory, England.

Details from Dr Mays, tel: 0442 233444, or Dr Page, tel: 0235 433513.

#### Experimental Heat Transfer, Fluid Mechanics and Thermodynamics

Conference, 23-28 June, Dubrovnik, Yugoslavia.

Details from Professor J F Keffer, tel: (416) 978-4948, or Professor Ganić, tel: (71) 512-149.

#### Pneumatic Conveying Technology

International conference, 26-28 June, Glasgow, Scotland.

Details from the Powder Advisory Centre, PO Box 78, London NW11 0PG. Tel: 081 455 0011, tlx: 8954242 (POWDER G), fax: 081 458 2278.

### July 1990

#### Minerals, materials and industry

14th congress of CMMI, 2-6 July, Edinburgh, Scotland.

Details from IMM Conference Office, 44 Portland Place, London W1N 4BR. Tel: 071-580 3802, tlx: 261410 IMM G, fax: 071-436 5388.

#### The Environmental Protection Bill: The Way Forward

One day conference, 16 July, London.

Details from Elaine Hendry on 071-236 4080.

### August 1990

#### SynOps 90

International symposium and exhibition, 28-30 August, North Dakota.

Details from Dawn Botsford, University of North Dakota, Box 8277, University Station, Grand Forks, North Dakota 58202. Tel: (701) 777-2663, fax: (701) 777-3650.

### September 1990

#### Into the 1990's — The decade of energy and environment

Congress, 23-28 September, Reading, England.

Details from Professor Sayigh, tel: 0734 318588.

### October 1990

#### 2nd Hellenic Aerospace Conference

7-9 October, Athens.

Details from Hellenic Aerospace Engineers Society, Lykourgou 9, Athens 10551, Greece.

#### Hydrocarbons 90

International conference, 9-10 October, London.

Details from Themedia Ltd, Hydrocarbons 90, International Conference, PO Box 2, Chipping Norton, Oxon OX7 5QX.

#### Advances in Heat Treatment Technology

Conference, 31 October, Birmingham, England.

Details from the Conference Administrator, Wolfson Heat Treatment Centre, Aston University, Aston Triangle, Birmingham B4 7ET. Tel: 021-359 3611, tlx: 336997 UNIAST G, fax: 021-359 8910.

### November 1990

#### Safe Road Transport in the Petroleum Industry — The Way Ahead

Conference, 6 November, London.

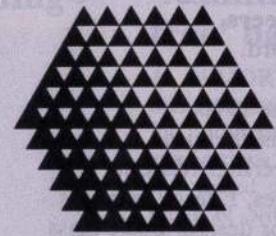
Details from Caroline Little, The Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR. Tel: 071-636 1004, tlx: 264380, fax: 071-255 1472.

### April 1991

#### Coal in the Environment

Conference, 3-5 April 1991, London.

Details from Dr Nicole Williams, World Coal Institute, tel: 071-376 0454.



## WORLD COAL INSTITUTE CONFERENCE

# COAL IN THE ENVIRONMENT

3-5 April 1991, London

The World Coal Institute's first conference — 'Coal in the Environment' — will take place at the prestigious Queen Elizabeth II Conference Centre in London between April 3 to 5 1991.

The conference will discuss coal as a clean and environmentally acceptable source of energy. Coal's suitability as the premier fuel for the large scale and long term generation of electricity will be emphasized.

The conference programme includes the following sessions:

- Coal in the Global Energy Economy
- Coal and Clean Air Issues
- Global Climate Change
- Current and Prospective Technical Solutions
- Advanced Coal Power Technologies
- Coal: Clean Power to Fuel Development

The conference will be accompanied by an exhibition of state-of-the-art clean coal technology.

All those interested are welcome to address their enquiries for further information to the following:

World Coal Institute  
Conference & Exhibition Secretariat  
8 Cotswold Mews  
Battersea High Street  
London SW11 3JE  
United Kingdom

Telephone +44-71-228 8034  
Facsimile +44-71-924 1790  
Telex 917712 POLYBS G

# INSTITUTE OF ENERGY CONFERENCES



The following programme is currently being organised by The Institute of Energy, and its associated overseas societies, and other UK societies 'in association'.

For further details please contact Judith Higgins on 071-580 0008.

## In 1990

19 September **The Costs of Flue Gas Desulphurisation**  
**Venue:** Scientific Societies Lecture Theatre, London W1  
**Chairman:** Dr A Sanyal (Babcock Energy)

31 October **Electricity from Gas**  
**Venue:** The Royal Garden Hotel, London W8  
**Chairman:** Mr J Masters (British Gas)

## In 1991

30 April-1 May **Fire & Explosion Hazards: Energy Utilization**  
**Venue:** Fire Service College, Gloucestershire  
**Chairman:** Mr P G Redpath (British Steel)

## Conferences with which the Institute is in association

### In 1990

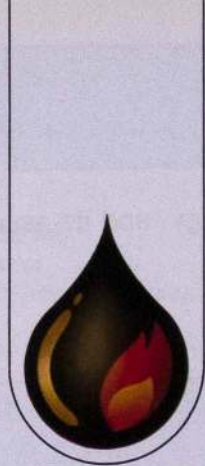
July **Comadem 90 International**  
(Congress on Condition Monitoring and Diagnostic Engineering Management)  
**Contact:** Dr Raj Rao, Birmingham Polytechnic on 021-331 5441

17-18 July **3rd International Conference on Small Engines and their Fuels for use in Rural Areas**  
**Contact:** Mrs P Harris, Reading University on (0734) 875 123

26-27 September **Piper Alpha - Lessons for Life-Cycle Safety Management**  
**Contact:** Conference Office, Institution of Chemical Engineers on 0788-78214

15-18 October **3rd International Conference on Circulating Fluidised Beds**  
**Contact:** Professor Hira Ahuja on (902) 439-8300 ext 2014 (Canada)

4-5 December **NEMEX '90 — National Energy Management Exhibition and Conference**  
**Contact:** Energy Systems Trade Association on 0453 873568



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## A fuel for the future

**O**RIMULSION is an important new fuel, a fuel for the future, providing energy for tomorrow's world. Orimulsion is a bitumen-in-water emulsion which has all the convenience of a liquid fuel. It is ideal for both power generation and industrial sectors.

Orimulsion can be used with only minor modifications, in most oil and coal designed industrial water-tube boiler plants. It can be handled and stored in a similar manner to heavy fuel oil. It is ideal for industrial circulating fluidised bed technology.

The vast reserves of the natural bitumen resource mean supply is guaranteed for centuries to come.

The handling, combustibility and flue gas properties associated with the use of Orimulsion have been fully evaluated and the fuel has undergone extensive tests on rigs operated by major boiler manufacturers around the world.

With Orimulsion, full plant capacity can be achieved; boiler deposits due to the ash content are light, friable and easily removed by normal soot blowing.

BP Bitor Limited is marketing Orimulsion in the EEC, Austria, Switzerland and Turkey. In the UK BP Bitor is marketing the fuel to the power generation industry, while BP Oil UK is selling to the UK industrial sector.

BP Bitor Ltd. is responsible for the marketing of ORIMULSION™ in the EC, directly in the Power Sector and through the BP National Affiliates in the Industrial Sector.



*Orimulsion flame on the Combustion Test Rig at NEI International Combustion Limited, Derby, England. Picture courtesy of NEI.*

For more information on the use of Orimulsion in industrial applications post this coupon to:

Jack Liebeskind, BP Oil UK Limited  
BP House, Breakspear Way,  
Hemel Hempstead, Herts HP2 4UL.

Alternatively phone him on 0442 225237  
or fax to 0442 224873

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