

# ENERGY WORLD

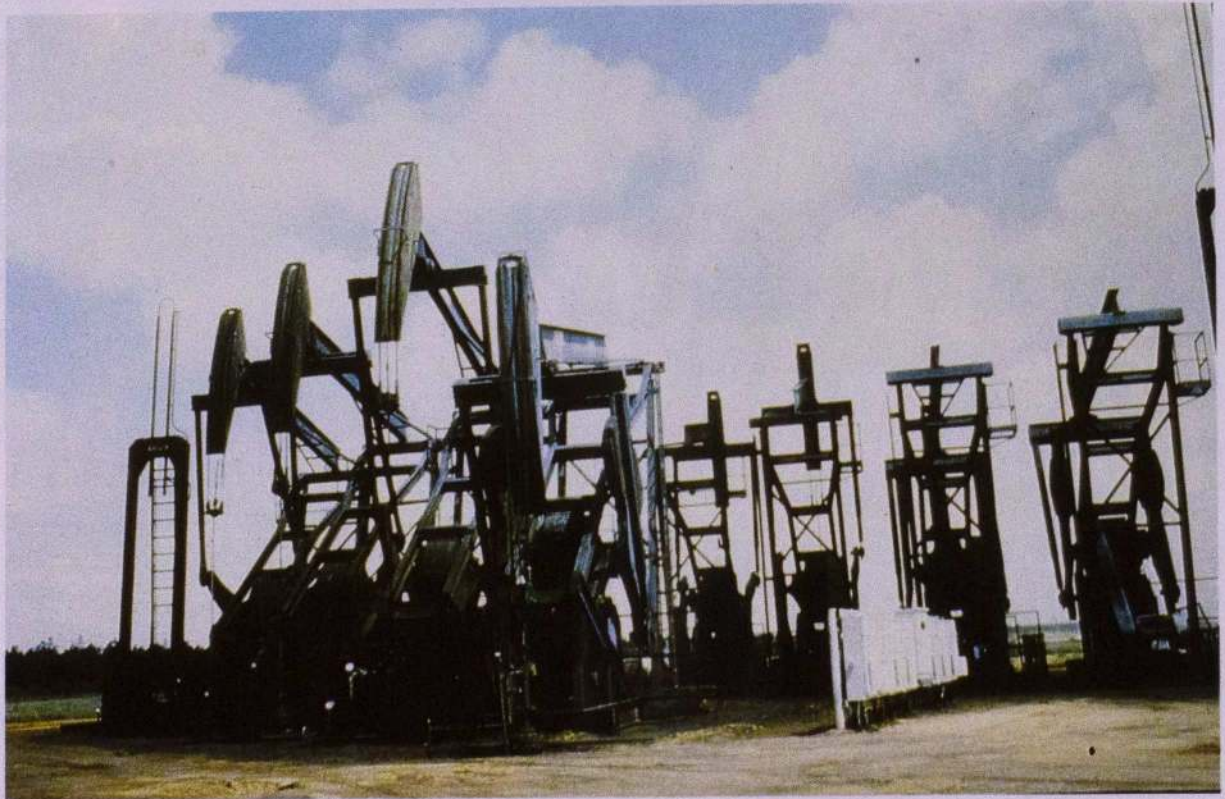
The magazine of The Institute of Energy

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October 1990

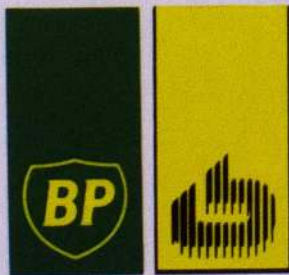


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1990 Idris Jones Memorial  
Lecture PLUS features on  
Flow Control

# ORIMULSION™



- A NEW FUEL FROM THE ORINOCO BELT, VENEZUELA
- A BITUMEN-IN-WATER EMULSION
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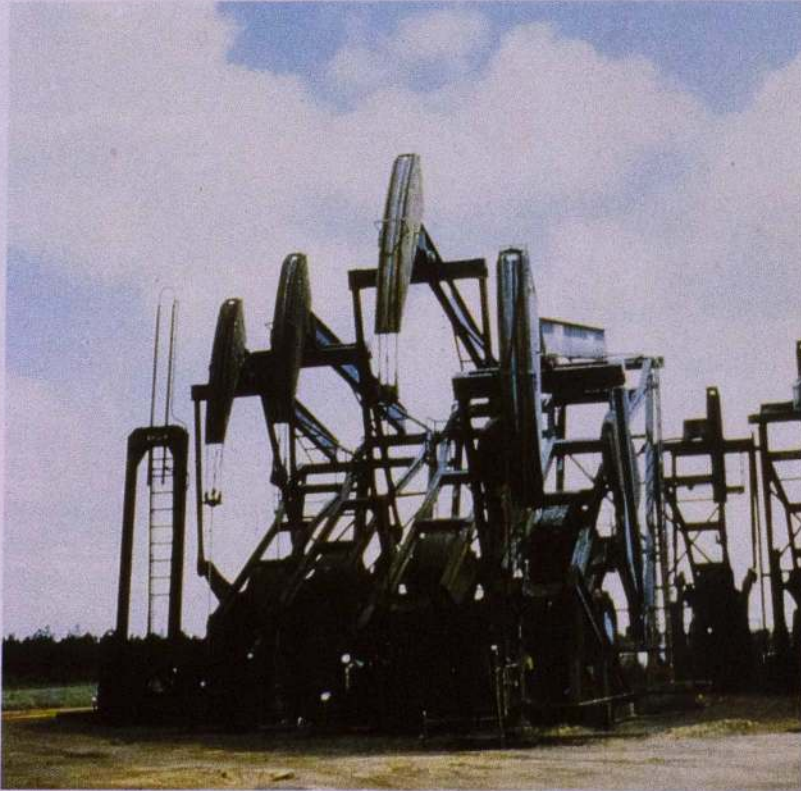
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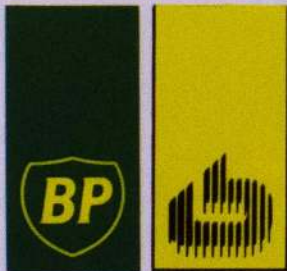
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## COVER STORY

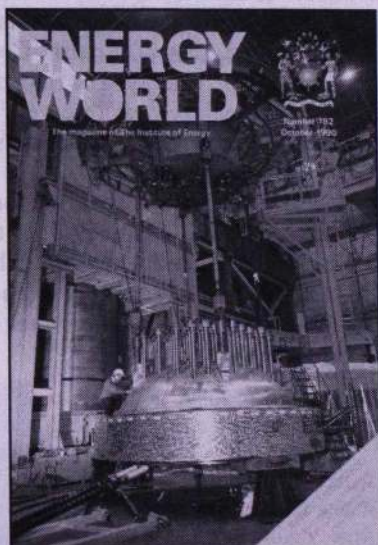
Our cover photograph this month shows the removable head of the reactor pressure vessel for the Sizewell 'B' Pressurised Water Reactor, sited in Suffolk, being prepared for lifting into place, on top of the main body, in preparation for the vessel's cold hydro test at the Framatome works in central France.

Earlier this year the completed vessel passed the test with flying colours.

The tubes protruding from the upper surface of the removable head are for mounting the control-rod drive mechanisms.

Each of the 53 drive mechanisms consists of an electromagnetically operated jacking device, which moves an individual control rod cluster assembly up or down in a series of small steps. The mechanisms are operated by energising, in sequence, electrical coils which are outside the primary circuit pressure boundary, so that no penetrations of the drive mechanism pressure envelope are required for its operation. An important feature of the mechanism is that it requires a continuous electric current to hold the control rods out of the core. If the supply is cut off, the rods fall into the core by force of gravity, tripping the reactor.

\*Cover photograph by courtesy of Nuclear Electric plc.



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## TERMS OF CONTROL

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# UK coal reserves — time for a thorough review

THE SUBJECT of UK coal reserves is probably one of the most vexed questions in coal debates in recent years. These debates have left participants and readers confused as to the size of the remaining UK coal reserves.

Since the early 1980s there have been several reports which have attempted to assess the extent of the nation's accessible coal reserves. The most recent report, commissioned from the British Geological Survey (BGS) by the Coalfield Communities Campaign, suggested that figures quoted by the coal industry were over-optimistic and were frequently based on the reports of the Royal Commissions on the Coal Industry (which were published in 1871 and 1905).

The BGS thought there was evidence that coal industry estimates for reserves are subjectively influenced, not only by changing views as to future markets for coal but also, perhaps, by poor forecasting with regard to changes in technology and the cost of coal extraction.

British Coal have frequently stated that the reserves will allow coal production to continue at the present rate of extraction for another 300 years. This time span would allow for decision-making as far ahead as any organisation can practically plan.

BGS suggested that British Coal's reserve estimates "suffered from a degree of ambiguity". Other analysts have argued that the "300 years" of coal reserves acted as a convenient cover story to deflect awkward questions, especially with colliery closures on economic grounds (as opposed to colliery closures caused by reserve exhaustion) sterilising large reserves of coal.

It is also worth noting that there have been few meaningful estimates made for the reserves of specialist coals, such as the coking coals and anthracite, and also for the coal accessible by opencast methods.

To overcome the confusion regarding UK coal reserve estimates the House of Lords Select Committee on the European Community pressed the Department of Energy in 1983 to produce an authoritative assessment of UK coal reserves on the same basis as is already done for oil and gas in the annual publication *Development of the Oil and Gas Resources of the United Kingdom* (referred to as the 'Brown Book' because of the colour of its cover).

When I recently questioned the coal minister, Rt Hon Tony Baldry MP, as to why such an assessment was not published by the Department of Energy, he told me that it was a matter for British Coal alone. Other meetings at the Department of Energy (plus other Government Departments) show the staff as being in almost complete ignorance as to the level of coal resources and reserves in this country.

How can any sensible review of a nation's energy future be carried out without a detailed knowledge of the energy resources that are available?

It is scandalous that there is currently more published data available about the coal resources and reserves from countries such as the United States and India than the United Kingdom.

It is hoped that if British Coal is to be privatised the Department of Energy will first carry out a thorough examination of the UK coal reserves, as it is usually prudent to undertake a review of a company's principle asset before it is sold.

I believe that now is the time for a new annual publication, 'The Black Book', which outlines the development of the UK coal resources. Perhaps we should have a 'Green Book' as well, covering the nation's renewable (and nuclear) energy resources.

I look forward to hearing what the Department of Energy have to say on this subject.



**Dr Andrew W Cox**  
Research Fellow,  
Department of Geography,  
University of Durham

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## Geothermal energy studies

RESOURCE assessments for low temperature, direct use geothermal projects in cities and counties throughout California are currently being carried out under grants from the California Energy Commission. Dames & Moore, the engineering and environmental consultants, are conducting these assessments.

The grant programme is designed to assist municipalities within the state in developing geothermal hot water systems for heating commercial and public buildings within their districts.

The geothermal resources for the heating systems are not hot enough for the production of electricity, but can be used directly for heat, at significantly lower cost than fossil fuels. Other direct uses of low-temperature geothermal resources include enhancing crop production and some industrial process applications.

## Hydro power generators for Nepal

SIEMENS' KWU Power Generation Group has supplied and installed three 30 MVA generators and all electrical equipment for the Marsyangdi hydroelectric power plant in Nepal. This plant, with a capacity of 69 MW and the largest in Nepal, raises the country's power system capacity to 270 MW. It is located on the Marsyangdi River 120 kilometres west of the Nepalese capital, Kathmandu.

It is anticipated that the plant's annual power generation figure will by 462.5 GWh.

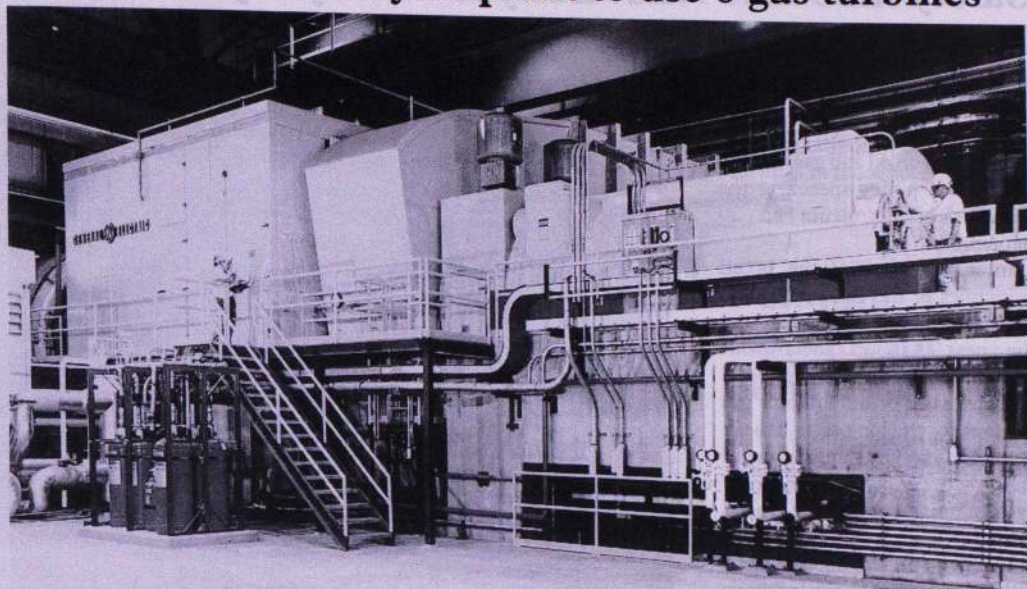
## Iraq/Kuwait conflict emphasises dependence on oil

THE IRAQ/KUWAIT conflict has served to bring home the uncomfortable extent of the world's continuing dependence on oil, John Wakeham, Britain's Energy Secretary, said in Jakarta on 19 September.

Speaking at the Indonesian/British Association lunch, Mr Wakeham said that "there is a close interrelationship between the availability and cost of energy and the pace of world economic development.

"But the OECD countries have

## Korean combined-cycle plant to use 8 gas turbines



GE's MS7001F gas turbine, the most powerful gas turbine in the world, is shown here installed at Virginia Power's Chesterfield Power Station near Richmond, VA. This 7F, part of the most efficient large thermal power plant in the US, has logged an availability of more than 99 per cent since commercial operation began in June.

GENERAL ELECTRIC of the USA have announced an order worth more than \$200 million for an additional four MS7001F gas turbines to Korea Electric Power Corporation (KEPCO) of the Republic of Korea. The new contract calls for the supply of gas and steam turbines for what will now be a 1,886 MW combined-cycle power plant to be built on Ildo, an Inchon Bay island west of Seoul.

GE announced in June that it had signed a first contract worth more than \$200 million with KEPCO to supply four STAG 107F combined-cycle units for a 943 MW power plant to be built on Ildo. This new contract doubles the size of the project, from four to eight CE STAG 107F combined-cycle units and brings GE's share of the entire project to more than \$400 million.

Each GE STAG 107F unit uses one 150 MW-class CE MS7001F gas turbine-generator and one GE reheat steam turbine-generator rated at 83 megawatts. All eight gas turbines will be equipped with dry low NO<sub>x</sub> abatement technology while burning natural gas, and this new order brings to 31 the number of GE "F" technology gas turbines sold worldwide.

All equipment is to be shipped in 1991, with the plant to begin combined cycle operation in December 1992.

The 7F recently exceeded its 150 MW rating during testing to become the most powerful 60-hertz gas turbine in the world. That unit is now in baseload combined-cycle operation at Virginia Power's Chesterfield plant (unit #7), with a combined-cycle rating of 214 MW and a plant efficiency level of more than 50

per cent.

The Ildo plant will be the first to utilise a GE three-pressure reheat steam turbine cycle, which is designed for greater efficiency. The steam turbines will be reheat single-flow, 33.5-inch last-stage bucket units.

The plant will operate at an efficiency greater than 50 per cent (on a lower heating value basis) using liquified natural gas, with distillate fuel as a back-up.

In addition to the supply of gas and steam turbines, GE will provide power plant engineering and project management for the power island, including procurement of power island controls and equipment such as a distributed digital control system, feed water pumps, bypass dampers, generator breakers and bus ducts. GE will also provide design data for the entire power island.

## US acquisition by Davenport

DAVENPORT Holdings Limited, the Bradford-based UK market leader in cooling tower design and construction, announces the acquisition of Cooling Technology Corporation of Kansas City, USA. The acquisition has been made through an asset purchase agreement and the new company will be known as Davenport Cooling Technology, Inc ("Davenport Inc").

also learned to use nearly a third less oil for each unit of output over the past decade. At the same time, progress towards increased economic liberalisation — which contributed to one of the longest and most sustained international economic upswings on record in the 1980's — should also have now put western countries in rather better shape to adapt to new external changes," he said.

Mr Wakeham pointed out that global consumption of oil has risen dramatically in the last 40

years. "In 1950, about 11 million barrels were consumed a day. By last year the total was almost six times that, at nearly 64 million barrels a day — the highest level for a decade.

"It is clearly vital that the international community should remain united. In this context, I particularly welcome Indonesia's own support for the UN Security Council resolutions, which include the imposition of sanctions and condemnation of Iraqi aggression."



## Safety first in Labour's new oil and gas policy

FRANK DORAN MP, Shadow Spokesman on oil and gas, made a major new policy speech at the Institute of Petroleum on 20 September.

In a statement of the broad principles of the Labour Party's oil and gas policy, Mr Doran said the next Labour government would seek "to manage the national asset of our oil and gas reserves for the long term benefit of the UK, by encouraging maximum recovery of hydro-carbons, by developing a strong UK based industry and technology and, above all, by preserving the safety of those who work in the industry and conserving our natural environment."

The emphasis of Mr Doran's speech was on safety aspects. Lord Cullen's report is expected at the end of October, and the Labour Party has committed itself to accepting the recommendations. In a major policy change Labour would remove all safety work from the Department of Energy, transferring it to the Health and Safety Executive.

Mr Doran also stressed that the next Labour government would also undertake a review of the environmental impact of the oil and gas industry.

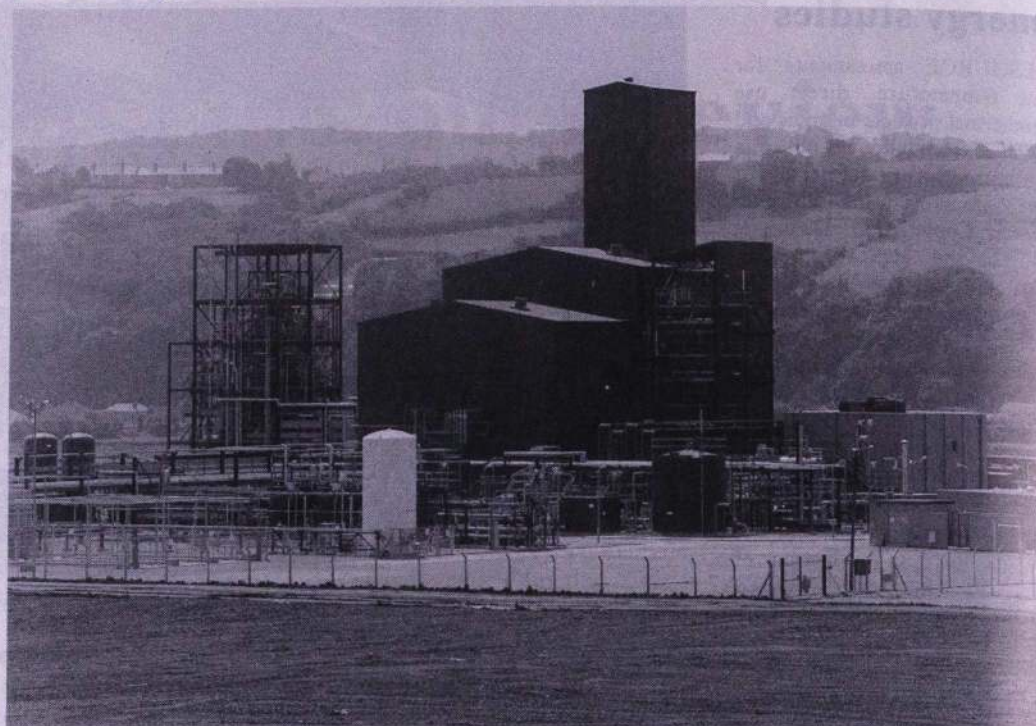
## Go-ahead for Bruce Field

JOHN WAKEHAM, Energy Secretary, has given the go-ahead for BP Exploration to begin development of the extensive North Sea Bruce Field, containing the largest gas reserves in UK waters.

The Bruce Field contains reserves of mainly condensates and gas, as well as crude oil.

First oil production is expected to commence by mid-1993 and reach a plateau rate of 15,000 barrels a day. Gas production should begin at a rate of approximately 430 million standard cubic feet a day, building to a plateau rate of around 530 million standard cubic feet a day during 1994. Associated condensate production rates will initially be around 40,000 barrels of condensate per day. The costs of development, at 1989 prices, were estimated to be £1.3 billion.

## Diversity is the key says Sec of State for Wales



British Coal's Point of Ayr Liquefaction plant. Recent economic assessments indicate that a plant similar in construction but several times larger could be economically viable, producing 50,000 barrels per day of finished products from approximately five million tonnes of coal per year.

SECRETARY of State for Wales, David Hunt MP, has stressed the Government's commitment to diversification in the energy supply industries.

He was speaking at the official opening of a coal liquefaction plant at British Coal's Point of Ayr site in Clwyd in August.

"Current events show us that we would be unwise to commit ourselves to a limited range of energy sources," he said, and

qualified his statement, saying there is an "obligation to use the nation's coal reserves in the most beneficial way, with due regard to the environment."

British Coal's Point of Ayr Liquefaction Project first got under way in 1986, with backing from the Department of Energy, the EEC and Ruhrkohle, the West German coal producer. The project received additional backing at a later date from the Amoco

Corporation.

The aim of the project is to produce liquid transport fuels from coal. The pilot plant is an integrated unit capable of continuous operation and will, over the next few years, provide tonnage samples for testing in automobile engines, and design data for commercial petrol-and-diesel-from-coal plants which could consume between five and six million tonnes per year.

## 'Renewables Order' laid before Parliament

THE FIRST Order setting a Non-Fossil Fuel Obligation (NFFO) for renewables was laid before Parliament in September.

The Order specifies the initial levels of renewables-sourced electricity generating capacity that the 12 regional electricity companies (TRECs) in England and Wales are required to have available from 1 October 1990 until 31 December 1998. They will build up to 102.25 MW declared net capacity at April 1995.

The responsibility for making appropriate arrangements to comply with the Order lies with the TRECs. The Department of Energy understands that the TRECs have concluded contracts for some 75 projects.

These have an installed capacity that will build up to

some 170 MW by early 1994. Over two thirds of this capacity is attributable to new projects that would not have been able to go forward without the support of a NFFO contract.

The overall level of the Obligation has been set in accordance with the advice of the Director General of Electricity Supply, to reflect the intermittent nature of wind power and in case some of the contracted projects should run into difficulties. It will increase, as new projects reach their expected commissioning dates, to reach a total of 102.25 MW declared net capacity (for the 12 TRECs taken together) from April 1995 until 31 December 1998.

September also saw the appointment of the UK Lead Underwriter for the flotation of

the TRECs. John Wakeham announced the appointment of J Henry Schroder Wagg & Co Ltd.

Mr Wakeham commented: "Following the launch of the retail marketing campaign this can be seen as the springboard for the institutional element of the offer for sale of the TRECs to be floated in November this year."

## CFC replacement plant

A CFC replacement plant was inaugurated by Colin Moynihan, Energy Minister, at the Conoco refinery at Killingholme on Humberside.

The new plant will have a capacity of 15,000 tonnes and will produce 'Dymel' A, currently being marketed by Du Pont, Conoco's parent company.



## Shell combines LPG operations



ShellGas import facility at Immingham.

SHELL have amalgamated their two bulk LPG operations — Shell Gas and Britannia Gas into one company, with Immingham as its Head Office.

The new company is one of the largest in the field and has the advantage of flexibility with import facilities at Teesside and Immingham and refineries at Stanlow and Shellhaven.

The expanded distribution network is making an immediate improvement to customer service with deliveries by Shell Gas vehicles backed up by Tank-freight on a contractual basis. In the short term orders can be placed through existing channels although plans are in hand for a

central ordering system through the Immingham Headquarters.

In the LPG industry safety has always been a high priority and must continue to be so. Shell have always placed a very high priority on safety in their operations, their records and initial installations. Technical Director, David Gelder has a team of 10 engineers on call nationally who will undertake all safety, maintenance and installation work throughout the UK.

The reorganised operation is under the directorship of John Tew and is named Britannia (LPG) Limited, trading as Shell Gas.

## Energy-saving project ten years on

KEEPING Newcastle Warm (KNW) — Newcastle's pioneering energy saving project — was ten years old in September.

Since it was launched in September 1980 KNW has brought extra warmth to 33,000 homes in and around Newcastle. Over 3,000 vulnerable households have been advised on how to make use of their energy. In addition, the scheme has created new work opportunities for over 500 previously long term unemployed people.

Keeping Newcastle Warm's founder and Chairman, David Green commented: "We set out to show what could be done to enable vulnerable households to improve their energy use. Through building a practical partnership between local and central Government and the community we have now shown what

can be done to ensure that we all become better users of energy."

Labour Party Energy Spokesman, Frank Dobson MP, added: "We need more of such initiatives; not only to help relieve the stress of fuel poverty, but also to tackle the growing threat posed by global warming."

The project was launched by the then Energy Minister John Moore MP in September 1980, when the first home was insulated in the Heaton area of Newcastle. Many leading public figures have since visited the project, and over 370 similar schemes have now been established under the aegis of the Newcastle based national charity Neighbourhood Energy Action.

To mark its tenth anniversary KNW outlined a five point action plan that lays the basis for its work in the 1990's.

## Greenhouse effect called into question by US scientist

AN EMINENT US scientist has warned against the danger of acting rashly in response to the greenhouse effect.

Dr Robert Balling, Director of the Climatology Laboratory at Arizona State University, was speaking at the Royal Society of Arts Auditorium in London, at the joint invitation of the Watt Committee and British Coal.

Dr Balling believes that there is no question that man-made gases are adding to the total of naturally occurring greenhouse gases. But models upon which predictions of future climatic changes are based often produce quite conflicting forecasts. "The models themselves are not at fault," says Dr Balling, "but there are not enough of them and their scope is too limited for the colossal task that has to be done before we can even begin to make accurate predictions of climatic changes in the long term."

He concluded: "There is growing scepticism about the future

greenhouse effect, and policies unnecessarily tied to it may lose popular support as confidence declines in the whole greenhouse issue."

## Planning consent for Hinkley C

THE UK Department of Energy has agreed in principle to the building of a new PWR at Hinkley Point in Somerset.

Energy Secretary, John Wakeham, stressed that the final go-ahead for the project would have to wait for the Government's review of nuclear power in 1994.

The Government's decision was heavily criticised by environmental groups, Greenpeace and the Council for the Protection of Rural England. Friends of the Earth described the decision as "bizarre, dated and irrelevant".

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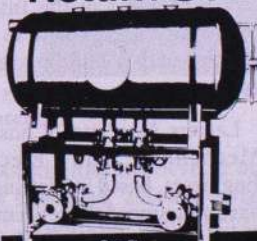
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**Costs of Flue Gas Desulphurisation: Institute conference a success**



Pictured above: President Doug Willis (front right) during the morning session of The Institute of Energy's conference *Costs of Flue Gas Desulphurisation*. Pictured left, from left to right (back row), are: John Cooper (National Power), Klaus Hein (Delft University of Technology), Bill Kyte (Power-Gen), all three speakers at the conference, and President Doug Willis. In the front row are Dr Anu Sanyal (Babcock Energy and Chairman of the Conference Organising Committee); Jan Vernon (centre) (KPMG Peat Marwick Consultants) and Michael Cooke (right) (British Coal) were also speakers at the conference.

**Directors appointed at BG**

BRITISH GAS has announced the key senior appointments in its new regional structure. Among those appointed are three members of The Institute of Energy. They are John Thomas, Director of Engineering, North West region; Reginald Leslie Dixon, Director of Marketing, North West region; and David Phelan, Director of Engineering, South East region. Mr Thomas and Mr Phelan both joined the Institute in 1963, Mr Dixon joined a year later in 1964. All three took up their new appointments on 1 September.

**Father to son**

A FELLOW of The Institute of Energy is to be replaced by his son, a Member of the Institute, following his retirement as senior partner with a building services company. Leivers Associates, Consulting Mechanical and Electrical Engineers, based in Nottingham, have announced the retirement of Peter F Leivers on 1 October, after a career of over 40 years in the building services industry. His place will be taken by his eldest son, Malcolm, whilst Mr Leivers senior will be retained as consultant to the practice.

**New members**

*Members*

- Robert George Galer**, Power-Gen, London.
- Anthony Bohun Lawrance**, McIlwraith McEacharn Ltd, Australia.
- Yiu Cheong Leung**, Hong Kong Electric Company.
- Glenn Albert Richards**, R M Consultants, Abingdon.
- Anton Frederick Squirrel**, Metroflex Grossventilbau, Switzerland.

Emmanuel Tagoe, Deutsche Babcock, West Germany.

*Associate Member*

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**Richard Crowder**, Taywood Engineering, Middlesex.

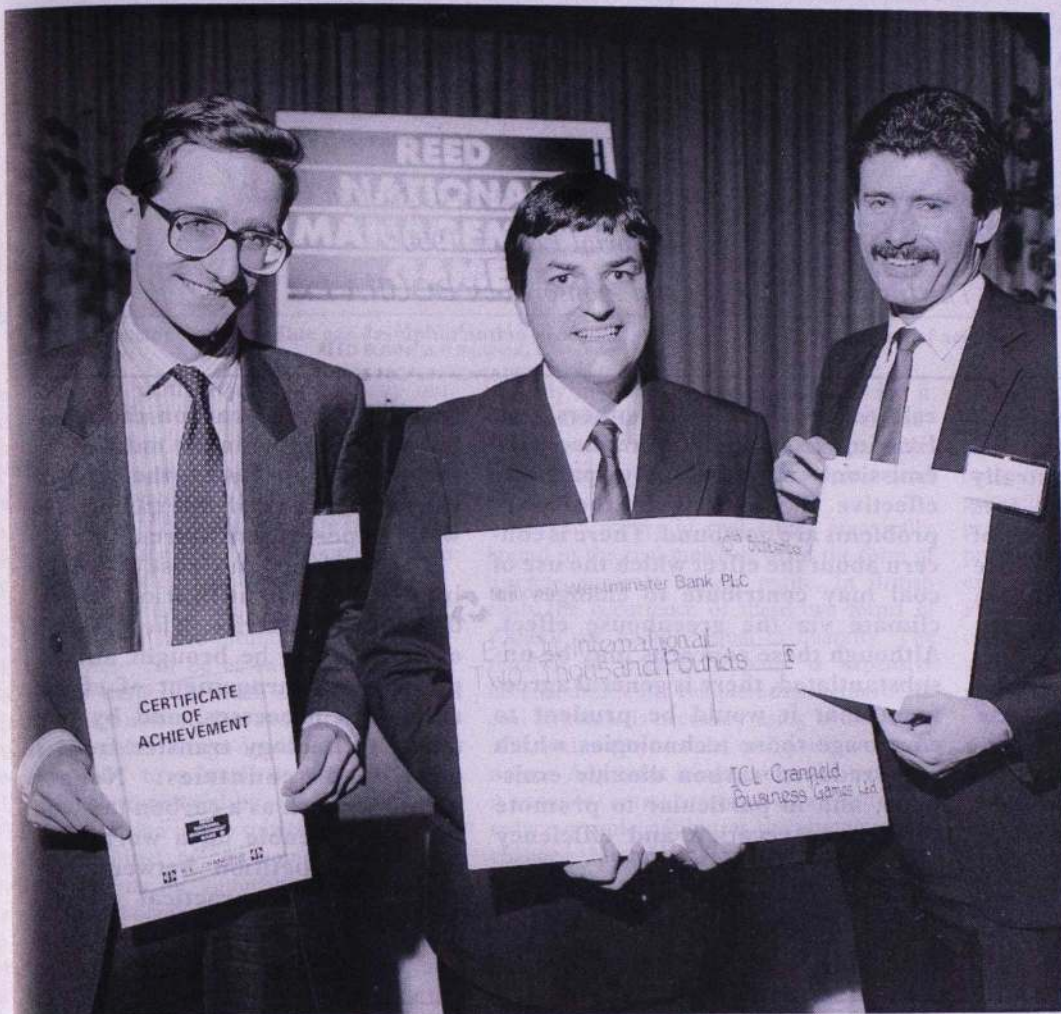
*Graduate*

**Adrian Charles Gray**, Jaros, Baum & Bolles Ltd, London.  
**Caroline Mary Louise Whitfield**, British Gas.



## Group Affiliates take 2nd and 3rd prizes in Reed National Management Game

## Fellow appointed TTCS chairman



The BP Oil team. From left to right, Jonathon Wake, Kevin Bell and Simon Lloyd.

BP OIL and British Coal teams have taken the second and third prizes respectively in the 1990 Reed National Management Game held on 9 and 10 September.

The BP Oil team, led by Kevin Bell, was presented with a cheque for £2,000, and certificates by Sir Trevor Holdsworth, chairman of National Power plc, who was the guest speaker at the awards lunch at London's Savoy Hotel.

The British Coal team, led by Nigel Byrne, was presented with a cheque for £1,500 and certificates.

The winners of the 1990 title were a team from Allied Irish Bank.

The Reed National Management Game is organised by ICL-Cranfield Business Games and co-sponsored by Reed Business Publishing Group and Nicklin Advertising. It is Europe's biggest business game and this



The British Coal team. From left to right, Peter Ashby, Nigel Byrne, Helen Paterson and Chris Webster.

year attracted 630 teams. The game is played on an elimination basis because of the large number of teams involved. All start off at the same position in round 1, when they are given a briefing pack which provides details about their 'company'.

Players then have to allocate

responsibilities and develop business strategies, allocate budgets and resources, and develop pricing policies. They run a simulated company in a competitive environment, the aim being to maximise profits. The game is genuinely interactive between teams and has the element of training value.

EUR ING Dr Norman A White (Fellow) retired as Chairman of KBC Advanced Technologies Limited at the company's AGM held in Weybridge.

Dr White has been Chairman since the company's formation in 1979. During this time he guided KBC's growth into a worldwide consulting and high technology organisation which was rewarded by the grant of the Queen's Award for Export Achievement in 1989.

He has been appointed the first Chairman of the Technical Transfer Centre Surrey Ltd (TTCS) as of July.

Dr White, who lives in Guildford, is a Chartered Engineer and businessman who established Norman White Associates in 1972 to specialise in the development and direction of technology based enterprises. Since then NWA has been involved in the creation of 15 companies. Dr White was a senior executive and director of companies in the Royal Dutch/Shell Group, latterly as chief executive, new enterprises division.

Dr White holds various public and professional appointments — national and international — concerned with technology, energy and education. He has been a Governor of the Royal Grammar School, Guildford, and Reigate Grammar School since 1976.

He joined The Institute of Energy in 1961.

## Freedom of the City for energy manager

ANN CONEY, the Chairman of the National Energy Efficiency Association (NEEA), an organisation closely associated with The Institute of Energy, has been awarded the Freedom of the City of London for her contribution to energy conservation.

Ann, who is the energy management officer with the London Borough of Bromley, was nominated for the award by colleagues from the London Boroughs Energy Group. Her nomination was inspired by her contributions to local bodies and national institutions promoting energy management.

# Coal Use in the Clean Environment

by James S Harrison, Director, Coal Research Establishment, British Coal

Based on the 17th Idris Jones Memorial Lecture 1990\*

\*Organised by The Institute of Energy and sponsored by BCURA Ltd

The use of energy in the world is steadily increasing, with the greatest rate of increase being in centrally planned economies and less developed countries. Reserves of coal are widely distributed and are several times those of oil and gas; thus coal can contribute to energy needs for many years to come. New technology can much reduce the environmental effects of coal use such as smoke, dust, and acid gases, and high efficiency techniques of power generation can reduce the production of carbon dioxide per unit of electricity generated.

Damage to lakes and forests results from combinations of the many factors involved, some of which are

related to fossil fuels, others not. Existing legislation to reduce acid emissions may be only partially effective if solutions to the other problems are not found. There is concern about the effect which the use of coal may contribute to changes in climate via the greenhouse effect. Although these concerns may be unsubstantiated, there is general agreement that it would be prudent to encourage those technologies which have reduced carbon dioxide emissions, and in particular to promote energy conservation and efficiency on a global scale.

It is wise now to examine the technical and economic feasibility and the environmental acceptability of

the collection of carbon dioxide, its enhanced uptake in the natural cycle including deep oceans, the use which might be made of the gas, and oil-wells as permanent stores.

There is, in any case a need to improve coal utilisation in less developed countries. The better use of coal should be brought about by positive encouragement of efficient and clean processes, and by facilitating technology transfer from the developed countries. Negative measures such as a carbon tax would be unenforceable on a world scale, distort competition between fuels, and have little practical effect on greenhouse warming.

**PUBLIC AWARENESS** about the environmental consequences of coal use is related to local, national, and international effects. Some of these factors such as acid rain, waste disposal and land use are universal. Other factors such as visual and noise problems in mining, and possible greenhouse warming are of more concern at present in advanced countries than in developing countries.

Established technology is available to prevent smoke emissions, and techniques for waste disposal are well advanced. Considerable efforts are being made to understand the mechanisms by which acid rain affects trees and lakes, and to establish whether greenhouse warming is occurring.

## World energy

Overall energy use in the OECD group of countries, centrally planned economies (CPEs) and less developed countries (LDCs) has nearly doubled in the last 20 years and may well double again in the next two decades. The

rate of increase is highest in the CPEs and LDCs and by 2005 their combined total use of energy will much outstrip that in the OECD.

The use of coal in the OECD group increased by over one billion tonnes per annum from 1967 to 1987 although its proportion of total energy use fell from 37 per cent to 31 per cent. Global reserves of coal are several times more than those of oil and gas combined, with large deposits in China, USA, USSR and India. Developing countries need coal to fulfil their energy needs, for example, the whole future development of China and India depends on electricity generated from coal.

In the OECD countries a much higher proportion of coal is used for electric power generation than elsewhere, and it is used at a thermal efficiency of about 35 per cent compared with levels nearer 25 per cent in less advanced countries.

A large proportion of coal burned outside the OECD countries is for domestic and industrial use which gives rise to different environmental problems. For example some 280 million tonnes/year are used for domestic heating and is burned very inefficiently, producing much smoke pollution.

In the UK, the development of smokeless fuels, and appliances that enable bituminous coal to be burnt smokelessly, has virtually eliminated domestic smoke pollution.

Table 1: Environmental Concerns (Coal)

Production		Countries	
		Developed	Developing
Local	Visual	*	?
	Noise	*	?
	Land use	*	?
	Waste	*	?
<b>Coal use</b>			
Local	Smoke	o	?
	Residue	*	?
National/ International	Acid rain	*	?
	Greenhouse	*	?

Key \* Important  
? Medium importance  
o Problem solved

A measure of the efficiency with which energy is used is given by the Gross National Product per unit of energy. This differs widely, from the most efficient group, including Japan and West Germany, with the UK and USA in the middle and the CPE's and developing world the most inefficient users.

In some respects low efficiency aggravates environmental problems. The need to improve efficiency and to reduce environmental problems are closely connected.

British Coal have developed technologies which have made a major contribution to

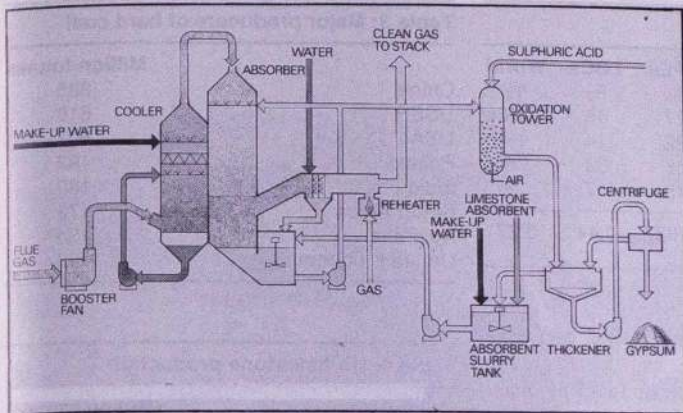


Fig 1: Limestone-gypsum flue gas desulphurisation process.

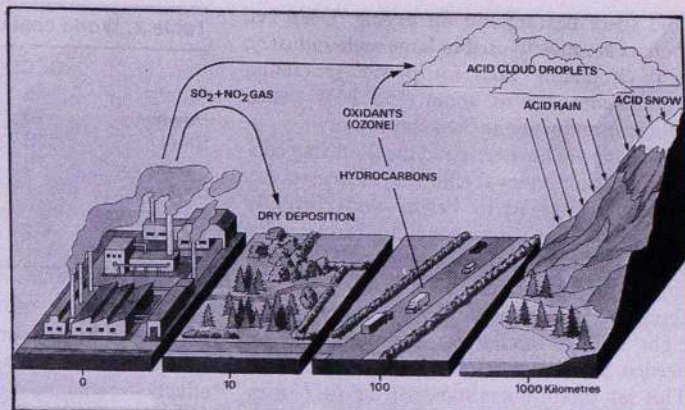


Fig 2: Formation of acid rain.

reducing air pollution and cleaning up our cities and towns. These technologies could help centrally planned and developing countries. The smokeless fuels for open fires, which were developed by British Coal with the support of Dr Idris Jones and were introduced in the UK in the 1960's as a contribution to clean air, are of interest overseas.

Another approach was to develop domestic boilers that will burn bituminous coal smokelessly. These can be of two types, either a downflow design in which smoke is made to pass through a hot firebed and refractory, or an underfed stoker design in which coal is fed mechanically to a small combustion zone. Emissions are reduced by some 90 per cent. The latter design is also suitable for the larger boilers required by the commercial market where systems for automatic coal feed, ash removal, and controls can be incorporated.

For industrial applications, many designs of boilers using fluidised bed, chain grate, and other grate types have been established in the market by British Coal in collaboration with manufacturers. These boilers can be equipped with cyclones or filters to reduce dust emissions to low levels. A recent example is the Cochran Coalmaster 2001 chain grate boiler which has a capacity of 0.1 to 1.2 MW, is fully automatic and has a high combustion efficiency.

Some concern has been expressed about the emission of trace elements from coal combustion. Levels of these substances in coal are similar to those in garden soil, and emissions from boiler plant fitted with modern gas cleaning equipment is found to be one hundred to one million times less than recommended exposure limits.

### Acid rain

The introduction to the EEC original draft directive, COM(83)704, produced in 1983 cites explicitly "the damage caused to forests, lakes, agricultural crops and monuments and other buildings" and elsewhere, "in view of the threat of the forest death phenomenon observed above all in the Federal Republic of Germany, the Stuttgart European Council called for drastic measures as a matter of priority in order to halt the damage in question." Five years later EEC limits were agreed for large plant. This legislation was based on the observation that a new form of damage to forests had become apparent par-

ticularly in Germany and Scandinavia and it was assumed that there was a simple relationship between tree damage and acid gas emissions, principally oxides of sulphur and nitrogen.

Sulphur occurs in coal either organically bound in the coal molecule or in the form of discrete minerals, mainly pyrite. In British coals the occurrence of these two forms of sulphur are roughly equal in quantity. The removal of organic sulphur is expensive because drastic and complete destruction of the coal structure is necessary using hydrofluoric acid, sodium hydroxide, or liquefaction techniques. At present it is uneconomic, but there is a need to continue research on ways that may reduce organic sulphur as the economics can change. Microbiological methods are at present slow and expensive. Physical methods used for coal preparation remove some inorganic sulphur. Costs and losses rise as the quantity is increased and the coal has to be finely crushed to release the pyrite.

Emissions of sulphur dioxide ( $\text{SO}_2$ ) can be

reduced by treating flue gases with absorbents — usually limestone. The flue gas desulphurisation process (FGD) most widely used results in the formation of gypsum. This technique is primarily employed at power stations; other processes, such as regenerative systems, can produce sulphur or sulphuric acid but are more expensive and less reliable. World capacity of FGD plant is increasing and these processes can offer an acceptable solution to  $\text{SO}_2$  emissions but with a penalty of 10 per cent to 15 per cent in the cost of electricity.

Other methods of reducing  $\text{SO}_2$  emissions particularly on smaller plant at lower cost involve the direct injection of limestone. In chain grate stoker boilers limestone can either be added with coal, or injected into cooler parts of the furnace to give reductions of about 50 per cent at reasonable limestone rates.

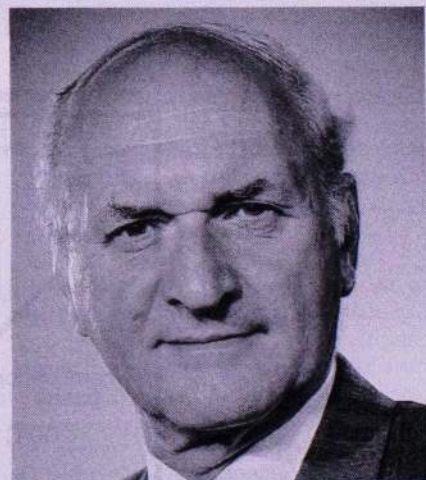
In shallow fluidised beds some 60 per cent to 70 per cent of sulphur can be captured by limestone, and in deep and circulating beds higher levels are practicable. Shallow fluidised beds are widely used in industrial plant for process

## The author

**James S Harrison** has qualifications in chemical technology (Loughborough College) and in chemistry (London University). He is a Fellow of the Royal Society of Chemistry, for which he was Chairman of the Process Technology Committee, and of The Institute of Energy which he has served as Member of Council and Chairman of Publications and Conferences Committee. He has recently been made a Fellow of the Institution of Chemical Engineers.

A Member of the Research Committee of the European Coal Producers, he has served on the Subcommittee of Energy R&D of the Commission of the Common Market, and on Advisory Committees of the IEA and of the UK Government. He is the joint founder, with Professor Marsh, of the Forum for Coal Science.

Joining the then National Coal Board from university he has led major projects on the development



and demonstration of processes involving carbonisation, smokeless fuel production, coal injection into blast furnaces and liquefaction, combustion and gasification of coal.

He is partly interested in the environmental aspects of energy production and has recently given evidence on the greenhouse effect to Select Committees of the House of Commons and the House of Lords.



and space heating and for drying. Deep bed boilers are mostly used in large scale industry, and circulating beds for power generation applications up to about 150 MW when efficient removal of SO<sub>2</sub> is important.

The type of limestone and the fluidising conditions affect removal efficiency. Limestone is widely distributed in Britain and currently over 100 million tonnes per annum are used for roadmaking and construction uses. If all coal fired power generation plant in the UK used fluid bed combustion with sulphur capture, eight million tonnes per annum would be needed producing 20 million tonnes of ash. This ash mixture has some setting properties and is easy to dispose of. It could substitute for freshly mined limestone in some uses and there might even be a reduction in net requirements.

Coal nitrogen is converted to free nitrogen or to oxides of nitrogen (NO<sub>x</sub>) on combustion. The free nitrogen reaction is favoured by low combustion temperatures, excess carbon, and low oxygen; the NO<sub>x</sub> formation reaction by the opposite conditions. About 80 per cent of NO<sub>x</sub> comes from nitrogen in coal and typically about 15 per cent of the coal nitrogen becomes NO<sub>x</sub>.

Low NO<sub>x</sub> burners are designed to produce the former conditions. The electricity industry's plans for burner replacement on existing power stations will progressively reduce emissions. For smaller plant using fluidised bed combustion, staged combustion can produce reductions but with some loss of

Table 2: World coal use

	OECD	CPEs	LDCs	World
	%	%	%	%
Power	73	27	46	46
Steel	16	22	14	19
Industry	10	36	33	26
Domestic	1	15	7	9
Total billion tonnes	1.2	1.63	0.44	3.27

efficiency. In pressurised fluidised bed combustion (PFBC) staging can have greater effects — reducing NO<sub>x</sub> by up to 75 per cent.

Overall EEC target reductions are 58 per cent SO<sub>2</sub> by the year 2000, and 30 per cent of NO<sub>x</sub> by 1998. The costs will be of the order of £2,000 million per year by 2003 for SO<sub>2</sub> and a once off cost of £1,000 million for NO<sub>x</sub>. This will add some 20 per cent to the cost of electricity and much more to industry if restrictions are applied to smaller plant.

In recent years experiments have been carried out to establish whether the type of acidic precipitation which is associated with the oxides of nitrogen and sulphur is in fact the main cause of plant damage. None of these studies has succeeded in reproducing any of the symptoms by artificial exposures to air pollutants singly or in combination; other factors must be involved.

Ozone which is formed by the reaction of nitrogen oxides with hydrocarbons may be a

Table 3: Major producers of hard coal

	Million tonnes
China	885
USSR	610
USA	607
Poland	192
India	180
South Africa	173
Australia	134
United Kingdom	103

Table 4: UK limestone production

Major usage	(Million tonnes)
Uncoated roadstone	34.2
Coated roadstone	11.4*
Construction use (ie fill)	31.7*
Concrete aggregate	11.9
Others	17.8

Total production	107.0
Potential limestone requirement for Power Generation	8.0
PFBC ash produced	20.0

\* could be partially substituted with PFBC ash

major contributor to the yellowing of leaves or needles and to foliar nutrient deficiency. Deposition of nitrogen oxides in excess of the normal requirements of the ecosystem may be a primary cause in some areas.

Another cause of tree damage is acidification of the soil. This can result in mobilisation of aluminium ions which may damage the fine roots of a tree, and thereby reduce its water uptake ability. Soil acidification can also cause leaching out from the soil of essential alkaline nutrients such as calcium, magnesium and potassium. Soil acidification is a natural process which is accelerated by forestry activities as well as by acidic precipitation. Reducing the acidity of rainfall will generally help to slow the progressive acidification of soil, but will not rectify the damage which is currently apparent without other measures such as liming the soil.<sup>1</sup>

Some years ago it was considered that the relationship between plant life and acid rain was straightforward. However, we now know that this is not so, and that many factors are involved in the decline of forests and lakes. If trees are otherwise healthy, acid rain will not normally harm them. Only if the trees are under stress from drought or disease or there is a shortage of trace elements will acid rain have any direct effect. Nevertheless legislation has been widely introduced to reduce acid rain, even though the benefits will be limited if cures are not found for the other factors.

### Greenhouse warming

The earth receives radiation from the sun, which is either absorbed at the earth's surface or reflected back into space. Certain gases in the atmosphere, such as carbon dioxide and water vapour, absorb this reflected radiation and blanket the earth which produces our present climate. Without this blanketing, mean surface temperatures would be some 30°C lower than at present. The global climate

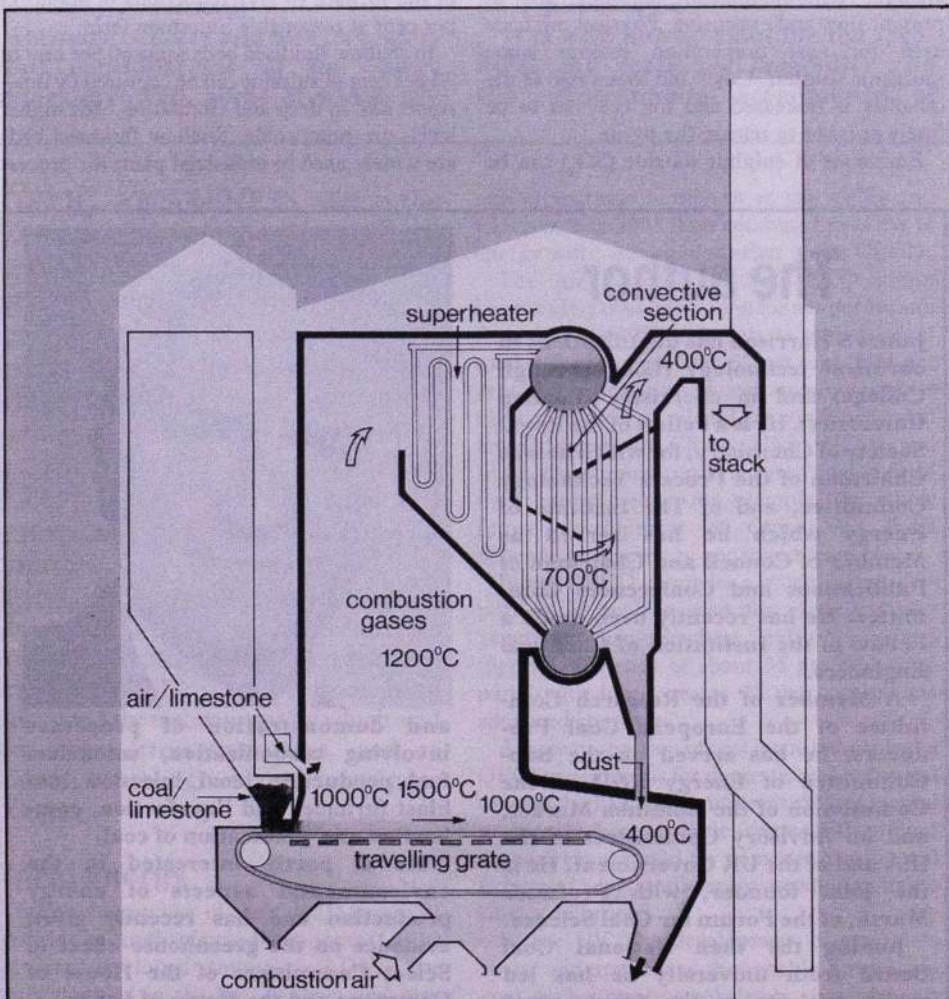


Fig 3: Travelling grate stoker fired boiler.



Water sampling at an acid lake carried out during a study of the factors effecting the water chemistry.

Photograph courtesy of CEGB

is related to the equilibria that exist amongst these gases in the atmosphere.

There is concern that the balance is being distributed by a build up of greenhouse gases such as carbon dioxide, CFCs, nitrous oxide, ozone and methane from man's activities. The effect, and lifetime in the atmosphere of these gases differs, but on a global basis carbon dioxide produces about half of the calculated man-made greenhouse effect.

Coal use produces 30 per cent of world carbon dioxide emissions and thus corresponds to about 15 per cent of the calculated man-made greenhouse effect. The current concern is that increasing concentrations of these greenhouse gases may give rise to global warming and changes in the earth's climate.

Global mean surface temperatures may have increased by about 0.5°C over the last 100 years although some doubts have been expressed about the past temperature record (because of the location of measurement stations and the monitoring techniques employed).

Even the best mathematical models of climate currently available have large uncertainties associated with them. As they become more refined the predictions of the models become less dramatic. For example, temperature rises of 2°C instead of the earlier 5°C

for a doubling of the concentration of carbon dioxide in the atmosphere, and sea level rises of 33 cm instead of the earlier five metres!

The potential greenhouse effect is nevertheless an international issue of major importance and the world's nations will have to respond appropriately. In order that they can do this we must find the answers to another series of questions.

- 1 Can we use the past warming as a guide to the future?
- 2 Why are the model predictions so uncertain and how can they be improved?
- 3 What measures should we take now while we are waiting for the science to become better established?

The first point worthy of note is that there is scientific consensus that the past temperature record does not prove the greenhouse effect. As the UK Department of Environment said in their evidence to a public inquiry, "the natural variability in the (observed temperature) record means that, statistically, the observed rise cannot be identified with any certainty as the greenhouse effect." A plot of recorded temperatures against those predicted from the build up of greenhouse gases in the atmosphere shows a number of discrepancies:

- it is clear that most of the 0.5°C rise occurred between 1880 and 1930, although only about one third of the increase in greenhouse gas concentrations is associated with this period;
- from about 1940 to 1970, while greenhouse gases continued to build up in the atmosphere, observed temperatures dropped substantially.

Some scientists have suggested that solar variations may go some way to explaining the past temperature record. A graph from the Marshall Institute<sup>2</sup> compares plots of average sunspot numbers (which are closely related to solar activity) and the temperature record over the period 1880 to the present day. The evidence points to changes in the sun's brightness as one contribution to global warming since 1880.

On a longer time-scale scientists have been able to provide evidence for correlations between past temperature trends and solar activity. The Little Ice Age of the 17th century occurred at a time of low solar activity. This shows that several factors can influence the temperature of our planet. There is an urgent need to identify those of greatest importance.

Predictions of the scale of the greenhouse effect are, in any case, very uncertain. Three

main areas where improvements must be made are:

- resolving the role of clouds in the greenhouse issue;
- obtaining a better understanding of how the oceans interact with the atmosphere and take up heat;
- increasing the quality of regional forecasts of greenhouse trends.

Even though there are major uncertainties surrounding the greenhouse effect, the issue is of such importance that prudent remedial strategies should be developed and applied while the scientific issues are resolved. These measures should be those which carry with them other benefits and which avoid major economic penalties. It is imperative that they are applied on a global basis and are backed by international agreements; and they must embrace the developing world.

With this in mind it is important that the following strategies are implemented:

- energy efficiency both in power generation and in end use;
- energy conservation;
- phasing out of CFCs;
- carbon dioxide removal and storage;
- halting deforestation and promoting the sustainable use of biomass fuel supplies in the developing world.

The major elements of this strategy as they apply to the use of coal must be to emphasise those techniques and practices which reduce emissions of greenhouse gases, to promote and develop processes of higher efficiency in conversion and use, and to evaluate means of capturing and storing carbon dioxide.

The first category of objectives is chiefly concerned with the encouragement of techniques which already exist, but which would have beneficial effects on emissions if their application were more widespread. For example, some colliery methane is presently collected and burned to generate heat. The

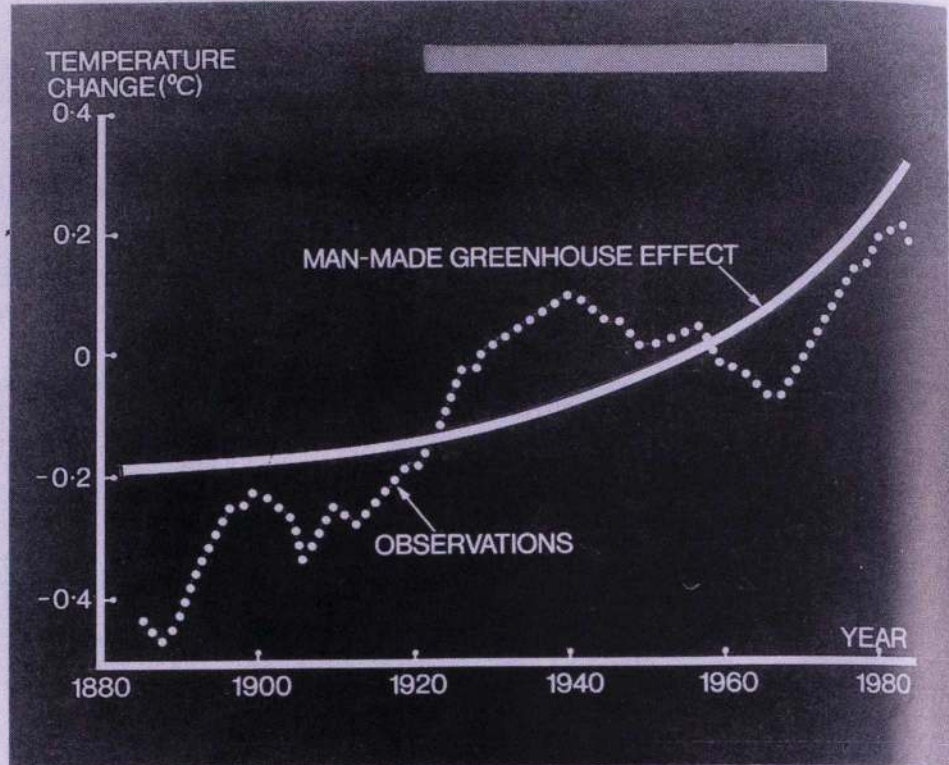


Fig 4: Global temperature change.

Source: George C. Marshall Institute

carbon dioxide produced has a smaller greenhouse effect than the original methane. It is therefore good practice from a greenhouse point of view to collect methane and burn it; making use of the heat generated will save fuel and carbon dioxide elsewhere. There is also scope for improving the efficiency with which coal is used, especially on the domestic and industrial scale — and even more importantly in the developing world. The more widespread use of up-to-date equipment would have many benefits in addition to the reduction of greenhouse gases, and we should be seeking means to encourage it.

We should also be encouraging the use of combined heat and power systems, which could have major benefits from a greenhouse

point of view. For example, combining a separate heating system with an efficiency of 90 per cent with a power generation system of 39 per cent efficiency would result in an overall efficiency of 77 per cent and carbon dioxide savings of about 22 per cent.

In the power generation applications in this country and in other industrialised countries we should be applying more efficient means of converting primary energy into electricity. Combined cycles of gas and coal are available now and could improve conversion efficiencies by some 10 per cent compared with pulverised fuel systems. In developing countries even present day conventional systems would show considerable advantages.

For the immediate future we should be

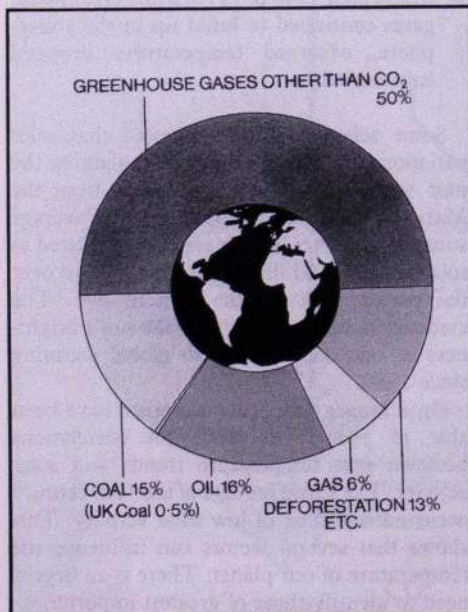


Fig 5: Man-made causes of the greenhouse effect.

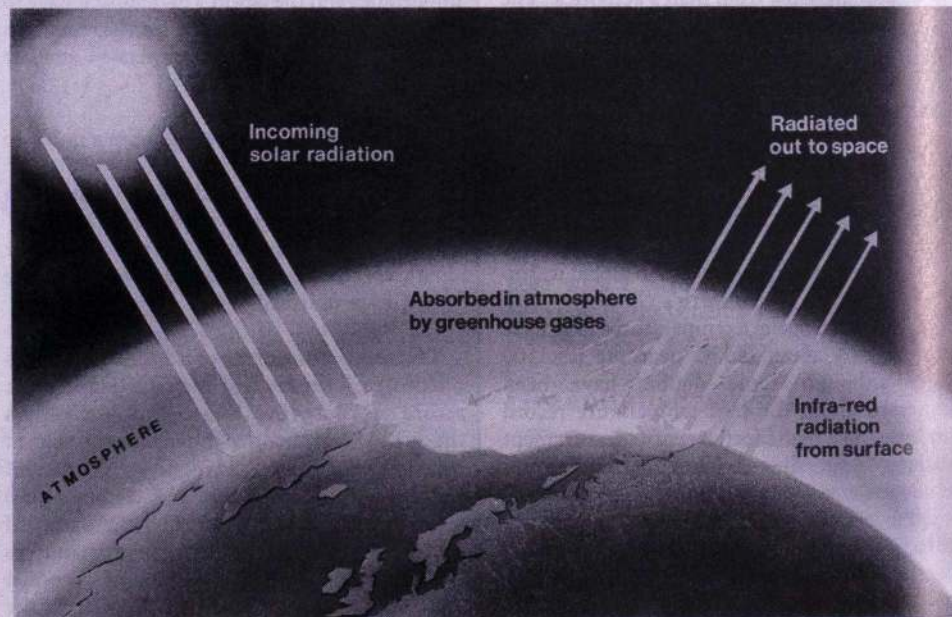


Fig 6: The greenhouse effect.



promoting and developing technologies with bigger savings in efficiency, and hence with reduced emissions. In steelmaking, for example, the direct use of coal injected into the tuyeres of a blast furnace might save some 10 per cent of overall carbon dioxide emissions, which is an additional advantage of this technique to those of reduced coke requirements and smoother blast furnace operation.

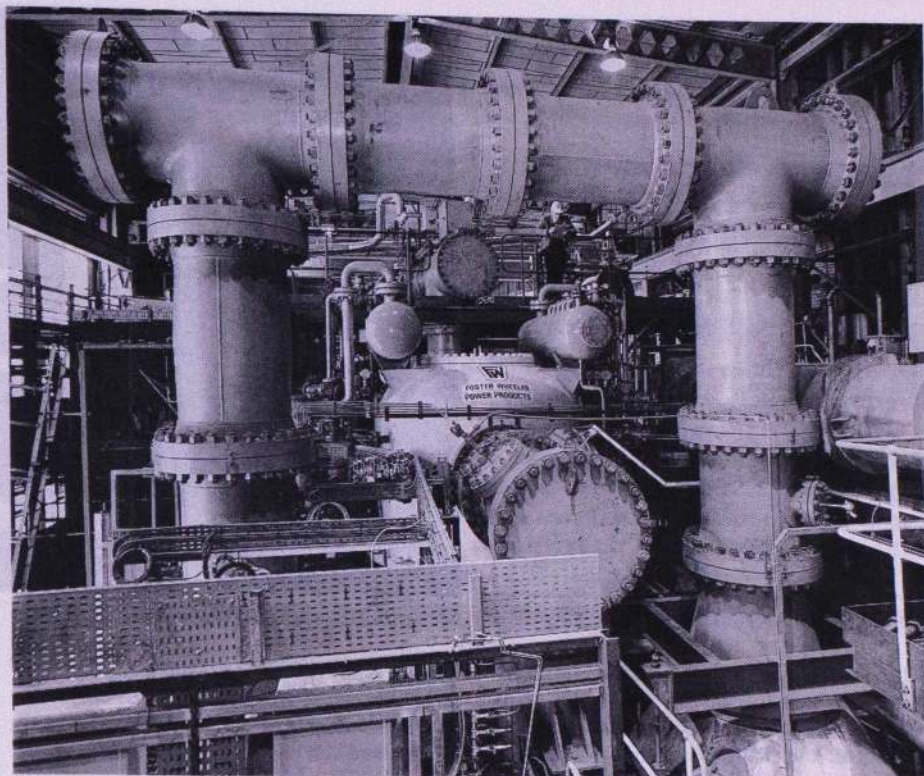
In furtherance of the improvement of electricity generation, British Coal have been promoting and supporting the development of a coal-based combined cycle plant based on the use of pressurised fluidised bed combustion (PFBC).

This technology has been developed at the Coal Research Establishment (CRE) and at the 80 MW combustion test rig at Grimethorpe. High combustion efficiencies over 99 per cent have been demonstrated on this plant, and good sulphur capture achieved at moderate limestone addition rates. Nitrogen oxide levels were low, and could be reduced still further by staging the combustion air. The reliability of components, and commercial service life were demonstrated. The first commercial plants using the technique are being built in the US and Europe and will be commissioned in 1990.

While the PFBC combined cycle has a substantial generating efficiency advantage over conventional pulverised fuel plant with flue gas desulphurisations, further improvements are limited by the temperature at which the combustion bed, and hence the turbine can operate. This in turn limits the cycle efficiency.

In a topping cycle, part of the coal is converted to a hot gas which is burnt to provide high turbine inlet temperatures. Any coal not gasified is burnt and the heat incorporated into the cycle. This provides:

- a 20 per cent reduction in electricity generating costs compared with conventional plant;
- a 20 per cent reduction in carbon dioxide production per unit of power generated;
- low capital costs;
- low emissions of sulphur and nitrogen oxides.



Grimethorpe PFBC test facility.

For generating capacities of around 350 MWe, technical and economic evaluations indicate that the topping cycle has substantial economic advantages over conventional stations and other competing technologies. Pressurised fluid bed and circulating bed variants of the topping cycle have been evaluated and give similar results. The development programme now under way in the UK includes the operation of a pressurised combustor and gas turbine at Grimethorpe, and a pressurised gasification rig at CRE. Large scale demonstrations are planned at Grimethorpe for the mid 1990's.

This type of technology can make a real contribution to the global environment, has no adverse effects, and hence merits development.

Government support for developing this technology is much preferable to a carbon tax which will be unenforceable over most of the

world, inequitable between fuels and impossible to quantify in its effects.

## CO<sub>2</sub> removal and storage

A number of schemes have been considered for the removal of carbon dioxide from combustion gas and its storage in ways that prevent it reaching the atmosphere. Water, methyl ethanolamine, lime, and caustic soda have been suggested as agents for removing carbon dioxide, and liquefaction of the gas is a possibility particularly if an oxygen-carbon dioxide combustion gas mixture is used.

Possible storage methods for carbon dioxide include dissolution in deep oceans (which have sufficient capacity), storage as liquid carbon dioxide under deep oceans or in caverns, or as plant material, although in the latter case areas of land would be needed.

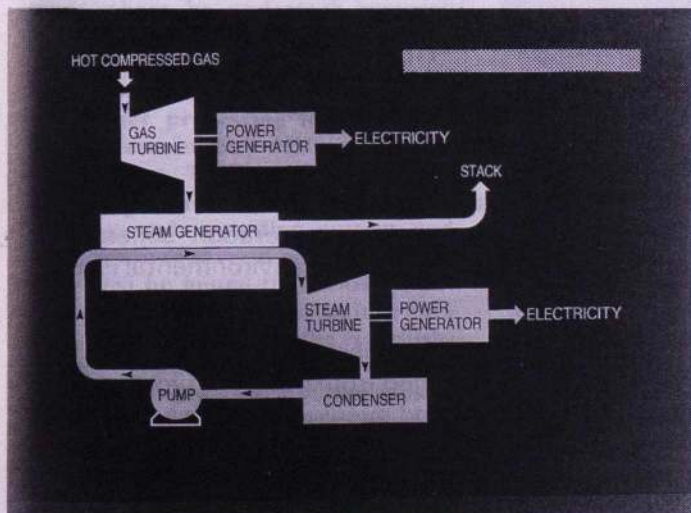


Fig 7: Typical combined cycle.

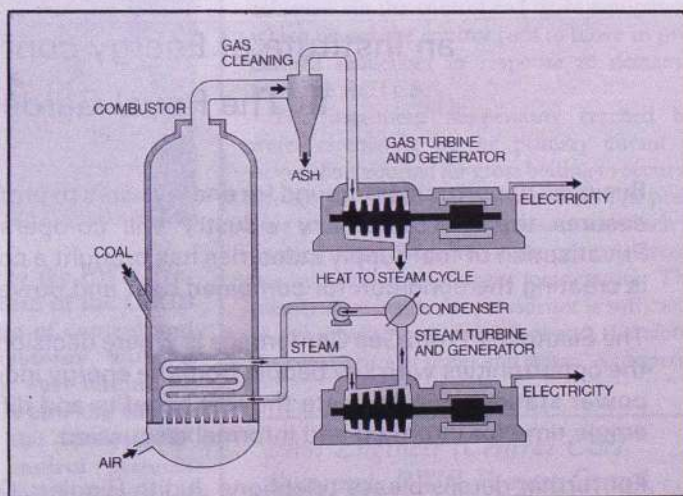


Fig 8: PFBC system for power generation using a combined cycle.

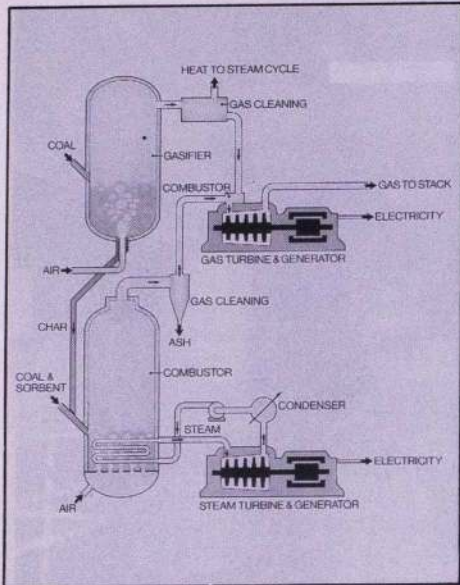


Fig 9: Topping cycle.

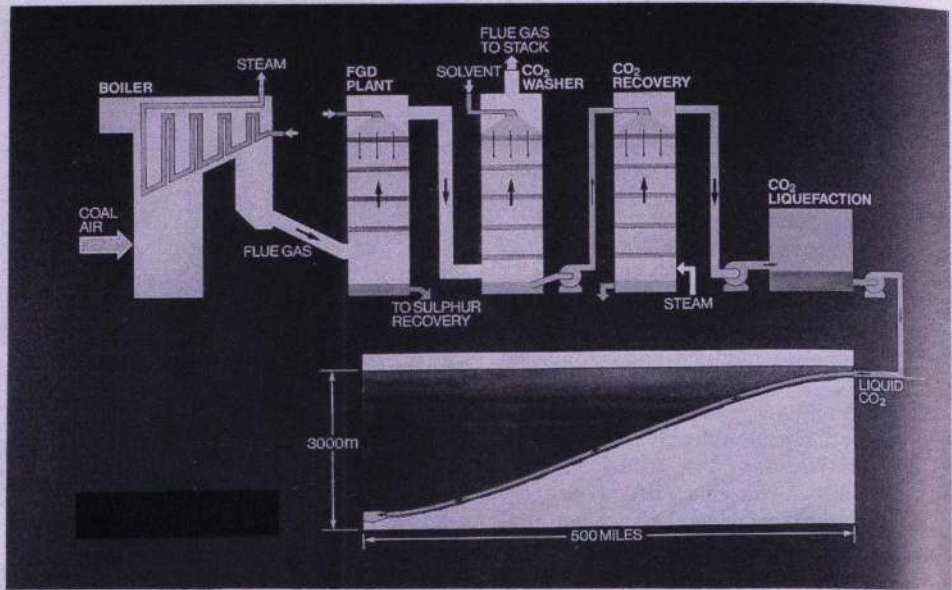


Fig 10: Deep sea disposal of liquid CO<sub>2</sub>.

British Coal are taking the lead in an international re-examination of all these possibilities. We wish to obtain further understanding of the natural carbon cycle, and to explore the possibilities for enhancing the natural uptake of plant and animal life on land and in the seas. We will assess the potential for storing carbon dioxide in exhausted reservoirs of gas and oil as well as in the deep ocean itself.

The first objectives will be to identify the most promising solutions and then to collaborate in an international demonstration of carbon dioxide collection, transport and storage. We need to establish the technical feasibility and the economic costs involved in such schemes and we have to demonstrate that they are acceptable environmentally. Exchanging one environmental problem for another would not be a sensible way of solving a carbon dioxide problem. This is a large project involving many research institutions and university departments in this country and

abroad. It must be undertaken now, so that if and when remedial steps prove to be necessary, the technology will be available, the costs known, and the environmental consequences fully appreciated.

### Conclusion

There are problems with achieving high environmental standards in coal use, but there are technical solutions to them. Energy conservation is a very worthwhile goal with many advantages and no potential regrets. It would be very unwise for nations to rush into spectacular major policy shifts like the introduction of carbon taxes, or a massive expansion of nuclear power, without fully understanding the consequences or the international nature of the problem.

A far more realistic solution is to find means of promoting new technology with higher efficiency and lower emissions of all

pollutants, including sulphur and nitrogen oxides and carbon dioxide. We also need to evolve means of introducing these technologies into Eastern Europe and the Third World. In helping them to overcome their environmental and energy problems we shall be helping to solve the world's environmental problems and hence be helping ourselves. British Coal are taking the lead in bringing together the international community to evaluate and demonstrate the technical feasibility, costs, and environmental acceptability of means of capturing and storing carbon dioxide.

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- 1 *Acid Deposition — Soils and Forests*. P Harter. IEA Coal Research 1989.
- 2 *Scientific perspectives on the Greenhouse Problem*. George C Marshall Institute, Washington 1989.

# ELECTRICITY FROM GAS

an Institute of Energy conference — 31 October 1990  
at The Royal Garden Hotel, London W8

Business opportunities abound for energy users to profit from combined heat and power. The 1983 Energy Act ensures that the electricity industry will co-operate with customers' electricity generation schemes. Privatisation of fuel supply industries has brought a competitive edge to fuel pricing. The environmental issue is creating the condition for combined heat and power to flourish.

The Electricity From Gas Conference is where decision makers in industry and commerce can hear and debate the opportunities with key people from the energy industries. Case studies ranging from hotels to factories to power stations will illustrate the real benefits and difficulties. An exhibition and evening reception will give ample time for informed and informal discussion.

For further details please telephone Judith Higgins, Conference Manager on 071-580 0008.



# Sizewell 'B': a review of modulating control strategy

THE PRESSURISED Water Reactor (PWR) nuclear power station under construction at Sizewell is the first such reactor of this type to be built and operated by Nuclear Electric plc.

The basic design is similar to the Westinghouse/Bechtel Standardised Nuclear Unit Power Plant System (SNUPPS) although a number of modifications have been made in order to satisfy Nuclear Electric's requirements in terms of station operation, safety and availability. Not least among such work has been the development of the station control systems. This paper summarises the basic operation of these control systems and explains the procedures which have led to their present form.

The mechanical arrangement of the Sizewell 'B' PWR is shown schematically in Figure 1 together with the major Station Automatic Control Systems (SACS). The PWR takes its name from the use of pressurised water as the primary coolant to transfer the heat from the reactor to the steam generators. The water is

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The following article examines the development of the modulating control systems for the UK's first Pressurised Water Reactor, currently under construction at Sizewell in Suffolk. Although the design of Sizewell 'B' is based upon the Westinghouse/Bechtel Standardised Nuclear Unit Power Plant System (SNUPPS), many changes have been made to the basic design to satisfy UK licensing and operational requirements. One result of this has been that control strategies have needed modification or validation before they could be applied with confidence to the UK design of PWR.

circulated around the reactor primary circuit by means of primary pumps, being heated as it passes through the reactor core and discharging heat in the U-tube heat exchangers of the steam generators. A single coolant circuit is shown in Figure 1 for simplicity, in reality there are four such circuits although only one is attached to the pressuriser.

In the secondary coolant circuit, steam from the steam generators passes into a common steam header and then on through the two turbines to the condensers. Condensate is pumped from the condensers into the

deaerators from where it is extracted by the main feed-pumps and pumped back into the steam generators.

A summary of technical data relating to Sizewell is presented in Table 1.

The basic principles of the SACS are similar to the equivalent systems of the SNUPPS design and an overview of their operation follows.

## Basic control principles

The SACS are divided into two main groups controlling the primary and secondary coolant circuits. The primary circuit systems control the pressuriser (water level and pressure) and reactor whereas the secondary circuit systems control the feed-water (steam generator level and feed-pump speed) and steam (turbine load and steam dump) systems.

The coolant inlet temperature to the reactor is held nominally constant by the operation of the Reactor Coolant Temperature Control System (RCTCS) whereas, since the primary coolant flow rate is constant, the outlet temperature is allowed to rise as reactor power increases. The inlet temperature and reactor power are controlled by regulation of the insertion of the control rods into the reactor. This is achieved via the control rod drive equipment which causes the control rods to move in pre-defined sequences in response to demands from the RCTCS.

The maximum temperature reached by water circulating in the primary circuit is below that required for gross boiling to occur at the normal primary circuit pressure. The pressure is maintained via the pressuriser which is a sealed vessel connected to the primary circuit but maintained at a higher temperature. The temperature inside the pressuriser is sufficient to sustain saturation conditions and, therefore, the coexistence of water and steam. A property

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Born in Kirby, Nottinghamshire, Andrew Johnson attended Ashfield Comprehensive School before going to Nottingham University in 1978 from where he graduated with a First Class BSc (Hons) degree in Electrical and Electronic Engineering.

In 1981 he joined the Central Electricity Generating Board as a Research Officer in the North Western Region Scientific Services Department where he undertook research activities related to non-destructive testing. During this time he specialised in the application of signal and image processing technology to the ultrasonic inspection of mechanical plant. This culminated in the development of a real-time ultrasonic imaging and recording system and publication of several papers.

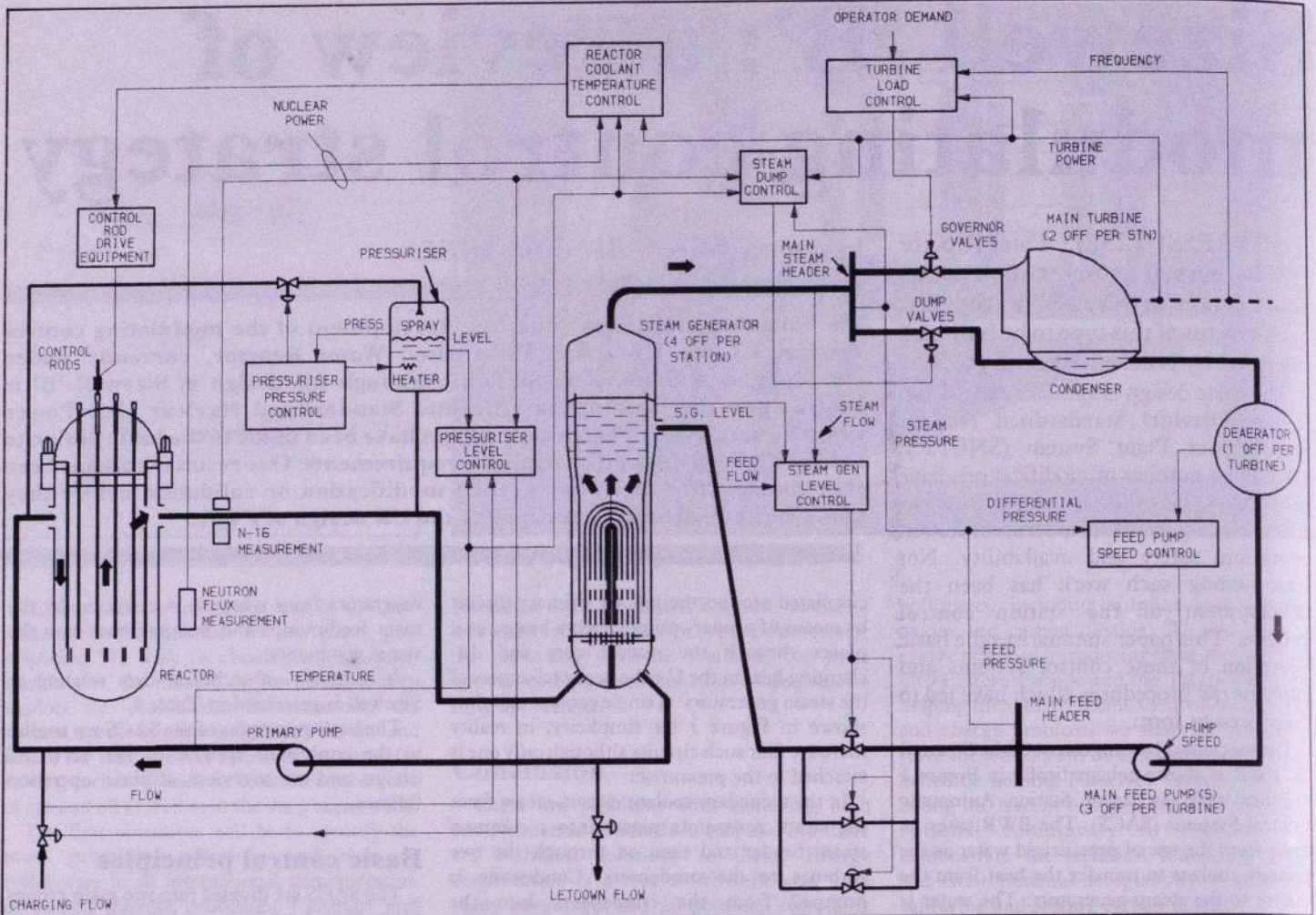
In 1985 he joined the CEGB South Western Regional Engineering Department working on the refurbishment of control and instrumentation systems of Magnox nuclear power stations. During this time he contributed to the design of the replacement burst fuel can detection system at Berkeley Power Station and undertook boiler control studies at Oldbury



Power Station.

In 1987 he moved to the PWR Project Management Team of the CEGB to work on the design of control and instrumentation systems with a specific interest in the automatic control systems. He is now the Engineer responsible for the Sizewell 'B' Station automatic control systems within the PWR Project Group of Nuclear Electric.

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**Fig 1: Schematic of the PWR primary and secondary coolant circuits showing the main Station Automatic Control Systems (SACS).**

of the saturated water/steam is that its temperature and pressure are uniquely related — reducing one reduces the other and vice versa. It is this property which forms the basis by which the Pressuriser Pressure Control System (PPCS) controls the primary circuit pressure. Immersion heaters in the pressuriser (1800kW capacity) are progressively energised when the pressure is too low increasing the temperature and hence raising the pressure. If the pressure is too high then relatively cool water from the reactor inlet is sprayed into the pressuriser causing a reduction in temperature and hence a reduction in pressure.

There is a continuous letdown flow of coolant water out of the primary circuit, the clean-up and volume control purposes, which is normally balanced by the charging flow into the primary circuit. By regulation of the charging flow in response to deviations of the pressuriser level from the desired level the Pressuriser Level Control System (PLCS) is able to maintain the pressuriser water level. The desired level is not constant but is increased as the water in the primary circuit expands due to rising average temperatures as the reactor power increases. The pressuriser and its control systems are designed so that the normal expansion of the water can be accommodated within the pressuriser without the need to change the mass of water in the primary circuit. Consequently, there is only minimal change in the charging flow during normal

operation although the system has the capacity to replace inventory lost through minor leaks should this be necessary.

The secondary circuit water in the steam generators must be maintained at an appropriate level to avoid uncovering the heat exchangers or passing water into the turbines as a result of load changes. This is achieved by the action of the Steam Generator Level Control System (SGLCS) adjusting the feed-water flow to the steam generators. Unlike the primary circuit flow the feed flow rate must be increased as reactor power increases. Each steam generator is equipped with three feed-valves of varying capacity which are used at different power levels, changeover between the valves occurring automatically. This ensures that sufficiently sensitive flow control is available at all feed flow rates. Although the principal measurement used to regulate the feed-valves is the steam generator level, other measurements are used to improve the per-

formance of the SGLCS under conditions of rapid change such as load rejections. One such measurement is the difference between the steam and feed-water mass flows, which is used to regulate the valves in anticipation of a level error developing — since under equilibrium conditions the mass flow into and out of the steam generator will be the same.

The flow through the feed-valves is determined not only by the opening of the valve but also by the pressure difference across the valve. This parameter is maintained at an optimal value by the Feed-pump Speed Control System (FSCS) which measures the steam header to feed the header differential pressure and varies the speed of the feed-pumps in response to pressure changes.

The optimal pressure drop is the minimum required to give acceptable control and by minimising the pressure drop, wear on the valve is reduced as is the power consumption of the electrically driven feed-pumps.

There are three feed-pumps allocated to each of the turbines and normally two out of the three will be operational with the third on automatic standby. All of the feed-pumps respond in parallel to changes in differential pressure. However a bias speed demand is applied between operating groups so as to draw more or less feed-water from one deaerator. The bias demand is derived from the difference in level of the two deaerators and is arranged to maintain the same water level in each deaerator —

**Table 1: Summary of Sizewell 'B' main operating conditions — full power.**

Reactor thermal output	3411 MW
Primary circuit pressure	155 bar
Reactor inlet temperature	293°C
Reactor outlet temperature	325°C
Primary circuit flow	19139 kg/s
Secondary circuit flow	1911 kg/s
Steam pressure (full load)	69 bar
Turbine generator output	1258 MW



even when the turbines are operating at different loads.

Station electrical output is adjusted by the operator selecting a target load on the Turbine Load Control System (TLCS). The TLCS then regulates the opening of the turbine governor valves so as to admit the amount of steam required to achieve the desired electrical output. The change in primary coolant temperature and electrical output following a change in steam demand is sensed by the RCTCS which makes the necessary adjustments to the control rod positions so as to control the reactor temperatures and match the reactor power output with that of the turbines. This principle of 'reactor follows turbine' control is the basis for all station load manoeuvres.

In the event of a sudden load rejection or trip of the reactor and/or turbines, there is an immediate need for an alternative path for the steam generated by the steam generators. This is provided by the Steam Pump System which opens dump valves connected directly to the turbine condensers (or to atmosphere) and thereby provides an alternative path for the steam, bypassing the turbines. The bypass path is maintained in operation until the reactor power output has been reduced or has decreased sufficiently to match the new conditions. The Steam Dump System comprises two sub-systems: the Steam Dump Interlock System (SDIS) which actively inhibits dumping until required by plant conditions and the Steam Dump Control System (SDCS) which regulates the precise amount of steam dumped. The two sub-systems combined are able to accommodate a loss of all load external to the station without a trip of either the reactor or turbines. The Steam Dump System can also be used to control the steam header pressure to a value selected by the operating staff. This mode of operation is used to hold conditions stable prior to turbine loading and during plant cooldown.

Much of the philosophy of the control described above is based on the experience gained from operating PWRs and the basic SNUPPS design. Since the Sizewell design has developed beyond the basic SNUPPS design then it has been necessary to undertake a programme of work to validate the control schemes for Sizewell use and optimise or extend their operation. This is now discussed.

## Development and validation

The principal objectives of the SACS are to enable the plant to be operated in a safe and efficient manner. In order to achieve these objectives three main strategies have been followed in the formulation of the control principles; control system modelling, Probabilistic Safety Assessment (PSA) and 'human factors' analysis.

As stated earlier, changes to the basic SNUPPS design of PWR have been made at Sizewell and, consequently, it has not been possible to simply replicate the control of an existing power plant. SNUPPS control systems were based on hard-wired analogue technology whereas direct digital control

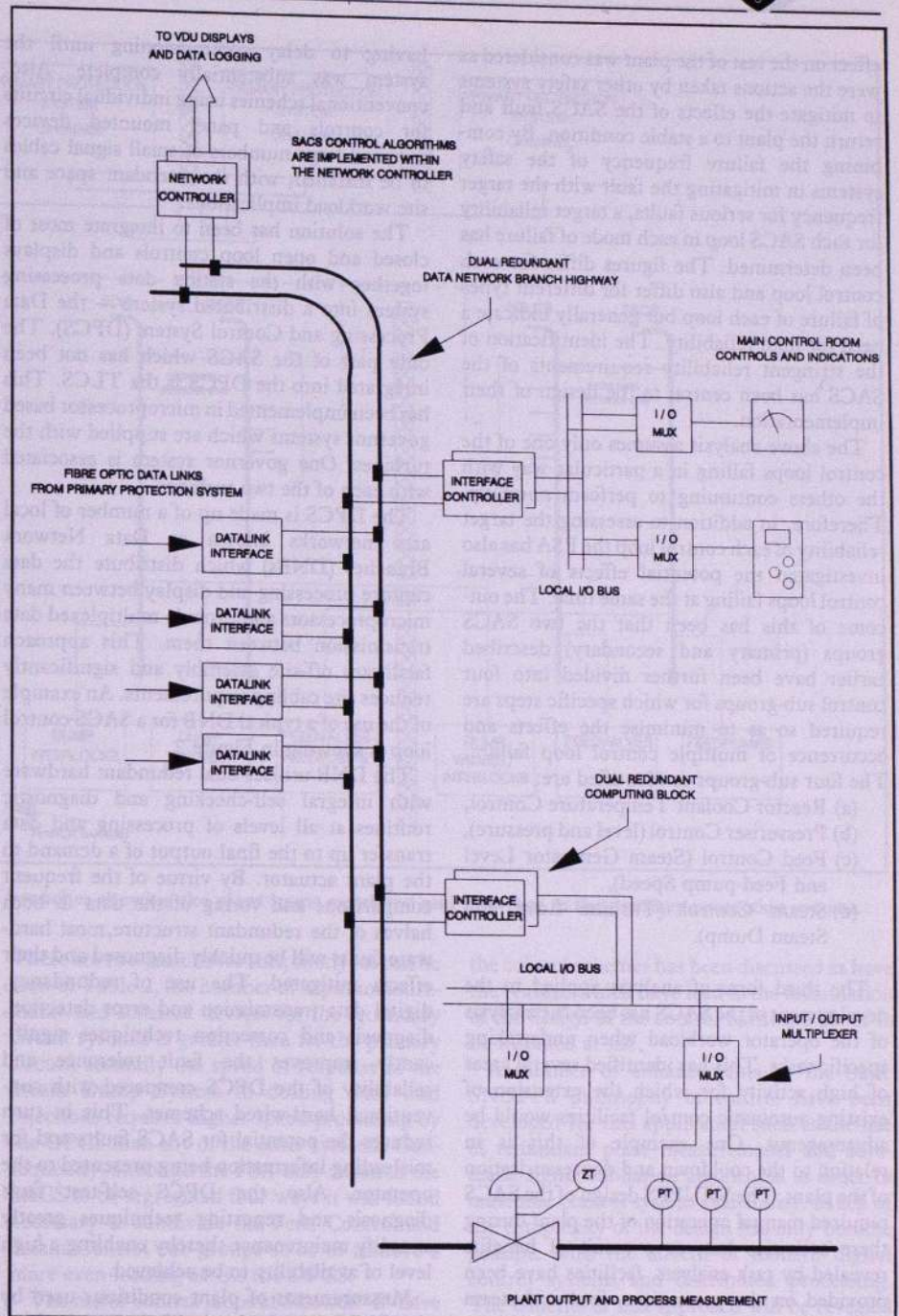


Fig 2: Utilisation of data network branches showing the plant items regulated and interface to the primary protection system.

systems are to be employed at Sizewell. In order to investigate the behaviour of the control systems, a mathematical model of the Sizewell plant was developed and validated using data from an operational SNUPPS PWR (Wolf Creek, USA). This established the model as a good representation of the Sizewell plant which could therefore be used to develop and test various control strategies.

The use of the model has enabled the effects of changes from the SNUPPS design to be investigated and optimal solutions adopted. For example, because Nuclear Electric has adopted a twin turbine design at Sizewell several modifications to the SNUPPS load control and Steam Dump Systems have been made and reassurance of the performance of the plant, in both single and double turbine modes of operation, has been obtained by using the plant model. The use of the model had also allowed known problems of PWR control to be

investigated and improved upon. Many generating utilities throughout the world have reported difficulties in the control of the steam generator water level, particularly at low loads, due to difficulty in measuring feed and steam flows and the large fluctuations in water level experienced. The problems have been addressed by other utilities in various ways — typically by the use of additional instrumentation for the measurement or estimation of flow, steam generator level or both. The modelling work revealed which of the additional instruments was likely to be most beneficial at Sizewell 'B' and how best to employ their measurements.

The second strategy employed has been PSA to determine the maximum permissible frequency of faults within the SACS. This was done by considering the effects of the individual SACS control loops failing in a variety of ways. For each mode of failure the



effect on the rest of the plant was considered as were the actions taken by other safety systems to mitigate the effects of the SACS fault and return the plant to a stable condition. By combining the failure frequency of the safety systems in mitigating the fault with the target frequency for serious faults, a target reliability for each SACS loop in each mode of failure has been determined. The figures differ for each control loop and also differ for different types of failure of each loop but generally indicate a need for high reliability. The identification of the stringent reliability requirements of the SACS has been central to the design of their implementation.

The above analysis assumes only one of the control loops failing in a particular way with the others continuing to perform normally. Therefore, in addition to assessing the target reliability of each control loop the PSA has also investigated the potential effects of several control loops failing at the same time. The outcome of this has been that the two SACS groups (primary and secondary) described earlier have been further divided into four control sub-groups for which specific steps are required so as to minimise the effects and occurrence of multiple control loop failure. The four sub-groups so identified are:

- (a) Reactor Coolant Temperature Control,
- (b) Pressuriser Control (level and pressure),
- (c) Feed Control (Steam Generator Level and Feed-pump Speed),
- (d) Steam Control (Turbine Load and Steam Dump).

The third form of analysis applied to the development of the SACS has been the analysis of the operator workload when undertaking specific tasks. This has identified several areas of high activity for which the extension of existing automatic control facilities would be advantageous. One example of this is in relation to the cooldown and depressurisation of the plant. The SNUPPS design of the SACS required manual operation of the plant during these activities but, as a result of benefits revealed by task analysis, facilities have been provided on the pressuriser, feed and steam control systems to permit coordinated automatic operation during cooldown and depressurisation, and so reduce operator burden.

Having thus described how the SACS design has been enhanced beyond the principles of SNUPPS the next section will describe the realisation of the complete scheme and how the principles determined above have been addressed.

## Control implementation

In considering the implementation of the SACS a number of shortcomings of earlier, conventional control schemes were identified. The adoption of the SNUPPS civil design imposed space constraints such that a conventional hard-wired scheme which incorporated the necessary level of redundancy for each control system could not be accommodated. Experience of large centralised control and data processing systems on other projects has revealed problems due to lack of expansion capability and difficulties caused by

having to delay commissioning until the system was substantially complete. Also, conventional schemes using individual circuits for controls and panel mounted devices required large numbers of small signal cables to be installed, with the attendant space and site workload implications.

The solution has been to integrate most of closed and open loop controls and displays together with the station data processing system into a distributed system — the Data Processing and Control System (DPCS). The only part of the SACS which has not been integrated into the DPCS is the TLCS. This has been implemented in microprocessor based governor systems which are supplied with the turbines. One governor system is associated with each of the two turbines.

The DPCS is made up of a number of local area networks known as Data Network Branches (DNBs) which distribute the data capture processing and display between many microprocessors and provide multiplexed data transmission between them. This approach facilitates off-site assembly and significantly reduces site cabling requirements. An example of the use of a typical DNB for a SACS control loop is showing in Figure 2.

The DNB utilises dual redundant hardware with integral self-checking and diagnostic routines at all levels of processing and data transfer up to the final output of a demand to the plant actuator. By virtue of the frequent comparisons and voting of the data in both halves of the redundant structure, most hardware faults will be quickly diagnosed and their effects mitigated. The use of redundancy, digital data transmission and error detection, diagnosis and correction techniques significantly improves the fault tolerance and reliability of the DPCS compared with conventional hard-wired schemes. This in turn reduces the potential for SACS faults and for misleading information being presented to the operator. Also the DPCS self-test fault diagnosis and reporting techniques greatly simplify maintenance thereby enabling a high level of availability to be achieved.

Measurements of plant conditions used by the SACS are obtained either directly from plant measurements or via the Primary

Protection System (PPS), see Table 2. The PPS is a microprocessor based protection system the main function of which is to initiate a reactor trip should any of the principal plant operating parameters move outside the normal operating envelope. Many of the parameters monitored by the PPS are used by the SACS and high speed fibre optic data links have been provided to transmit this data to the DPCS. The use of this form of data link ensures electrical isolation between the two systems, furthermore the data links are unidirectional so that no data can be passed from the DPCS to the PPS. Consequently, complete independence of the PPS and SACS is maintained such that the PPS can mitigate SACS faults which may occur at frequencies up to those dictated by the PSA. The possibility that the common sensors used by the PPS and the SACS could fail and affect both control and protection simultaneously has been considered. For single sensor failure, other lines of protection remain available, whereas multiple sensor or PPS failure is addressed by the provision of a diverse protection system which has its own separate dedicated sensors.

Any control system can only be as good as the data it receives in the form of plant measurements and for this reason each parameter used by SACS (either from plant or the PPS) for control is measured by several different sensors. The PPS consists of four independent channels and so four measurements of each parameter are obtained; other inputs (not obtained via the PPS) are three-way redundant. Each redundant measurement enters the DPCS via a separate current loop or data link interface and a signal validation algorithm is applied for each parameter which:

- (a) checks that each input value is within the expected range,
- (b) checks that all of the input values are consistent and,
- (c) forms an average value from good measurements for control use.

If the checks at (a) or (b) result in a 'bad' measurement being detected then it is automatically discarded and control will continue with the remaining 'good' measurements. In the event of insufficient 'good' measurements

**Table 2: Summary of the allocation of analogue measurements from plant and the PPS to each of the SACS and of devices regulated.**

Control System	Inputs from PPS	Inputs from Plant	Regulated Devices
Reactor Coolant Temperature System (RCTCS)	24	8	53 control rods (via CRDE)
Pressuriser Level Control System (PLCS)	24	4	1 valve 1 valve
Pressuriser Pressure Control System (PPCS)	12	4	2 valves 5 heaters
Steam Generator Level Control System (SGLCS)	72	12	12 valves
Feed-pump Speed Control System (FSCS)	4	15	6 pumps
Steam Dump Control System (SDCS)	20	23	28 valves
Steam Dump Interlock System (SDIS)	0	6	16 valves
Steam Dump Control System (TLCS)	0	14	20 valves

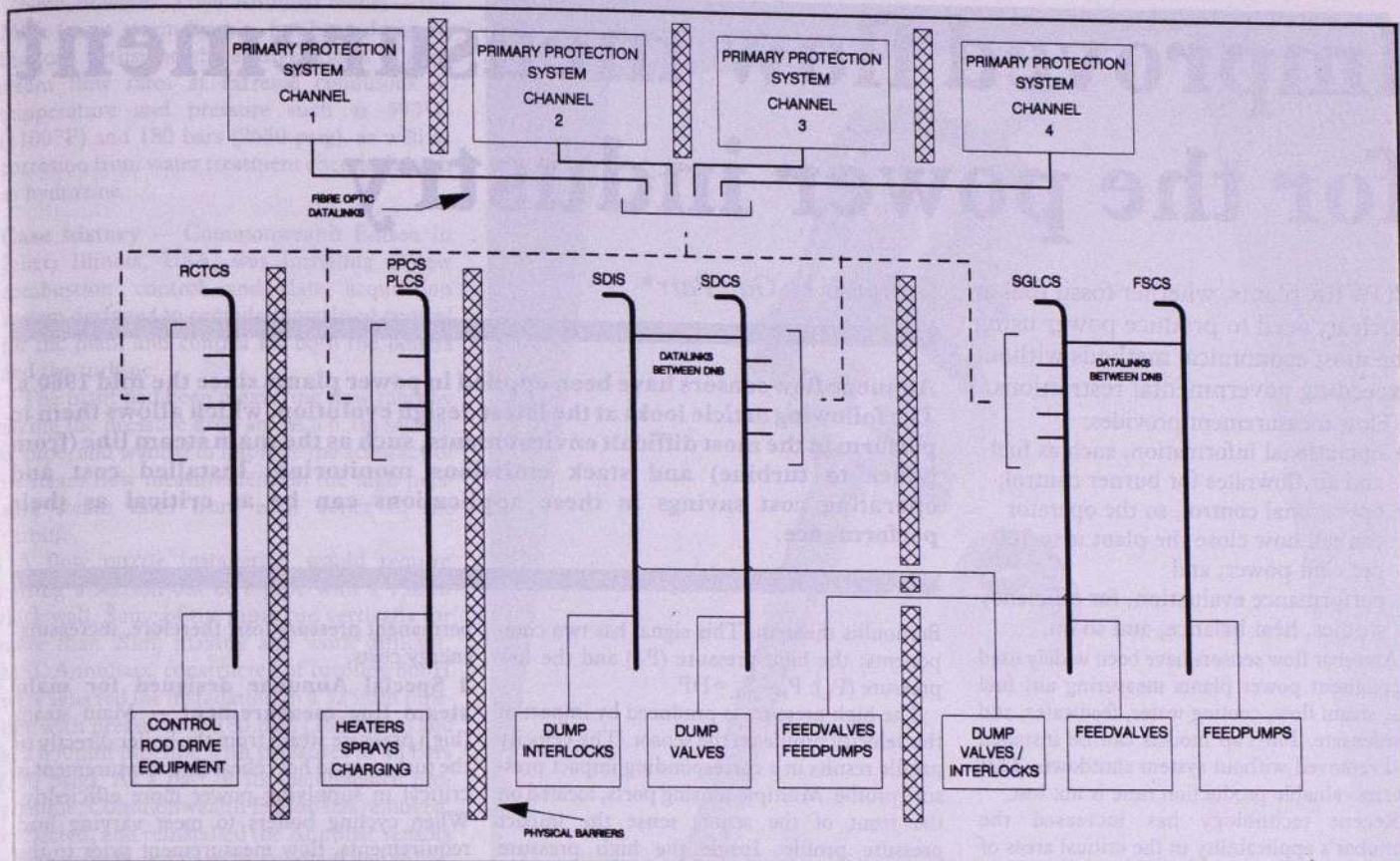


Fig 3: Allocation of the SACS to data network branches showing the plant items regulated and interface to the primary protection system.

being available then the SACS reverts to manual control. It should be noted that many of the SACS control loops (eg, Steam Generator Level) are not easy to control manually and so prolonged operation with one or more control loops in manual is likely to lead to a reactor trip with the associated loss of electrical output. Thus the use of redundant input measurements, which makes such an eventuality unlikely, not only improves the reliability of the control system but also improves the availability of the power station generated output.

The description above explains how the features of the DPCS have been used to achieve the individual loop reliability targets required by the PSA. Defence against the failure of multiple control loops is gained by distributing the four control sub-groups amongst different DNBs which are physically separated and have independent power supplies. Thus hazards such as fire, which have the potential to simultaneously affect more than one DNB and hence cause multiple control system failure have their effect limited by the physical barriers. Figure 3 shows how the SACS have been allocated to different DNBs and identifies which of the DNBs are physically separated.

The complexity of the SACS control algorithms and the use of three- or four-way redundant measurements imposes a significant processing burden on the DNBs performing SACS functions. A comparison of the relative processing requirements for each of the SACS systems is shown in Figure 4 and from this it can be seen that the requirements for the secondary circuit loops are considerably greater than those for the primary circuit.

There are two reasons for this; firstly, as can be seen in Table 2, the number of input measurements and actuated devices for the secondary circuit systems is greater than for the primary circuit; secondly the speed of response of the Steam Dump System in dealing with load rejections requires higher speed processing by the DPCS than any of the other systems. Consequently, although the PSA only required the SACS to be segregated four ways it was found necessary to subdivide the Feed Control and Steam Control sub-groups so as to achieve a more even loading across the DPCS.

The major control loops at Sizewell 'B' have been briefly described as have some of the main changes from the SNUPPS design which have required additional design effort from the PWR construction project. The benefits of the application of off-line analysis to the design of

the control schemes has been discussed as have the reasons which have led to the formulation of the design of the control hardware about to be installed at site.

A number of enhancements to the basic SNUPPS philosophy of control have been developed for this application such as the use of redundant plant measurements and automatic signal validation algorithms in order to maximise control system availability. Much of the complexity of the design has only become possible with the advent of modern digital control systems and distributed processing. The benefits of this approach will be revealed over the lifetime of Sizewell 'B'.

## Acknowledgements

The author wishes to acknowledge the work of the departments within the PWR Project Group and National Nuclear Corporation Ltd which have contributed to the development of the SACS design.

The description of the DPCS uses project rather than product based terminology. The DPCS is being supplied by GEC Power, Instrumentation and Control Ltd using the P-20 Controbloc product developed by CEGELEC of France.

Finally, thanks are expressed to the Chief Executive of the PPG for permission to publish this paper.

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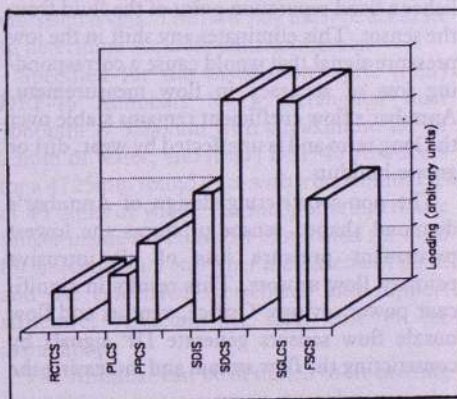


Fig 4: Comparison of the processing requirements for each of the SACS implemented in the data processing and control system.

# Improved flow measurement for the power industry

POWER plants, whether fossil fuel or nuclear, need to produce power using the most economical methods without exceeding governmental restrictions.

Flow measurement provides:

- operational information, such as fuel and air flowrates for burner control;
- operational control, so the operator can tell how close the plant is to 100 per cent power; and
- performance evaluation, for efficiency studies, heat balance, and so on.

Annubar flow sensors have been widely used throughout power plants measuring air, fuel gas, steam flow, cooling water, feedwater, and condensate. Flo-Tap models can be installed and removed without system shutdown. This means valuable production time is not lost.

Recent technology has increased the Annubar's applicability in the critical areas of main steam line measurement (high pressure steam from the boiler directly to the turbine) and emissions monitoring. Annubar's increased applicability, coupled with the fact that its design results in lower installation and operating costs, puts the Annubar on the leading edge of flow measurement technology for the power industry.

## How Annubar works

The Annubar is a differential pressure (DP) primary flow sensor designed so that a single probe spans the internal diameter of the pipe without restricting the flow. The Annubar produces a DP signal proportional to the square of the flow rate, in accordance with

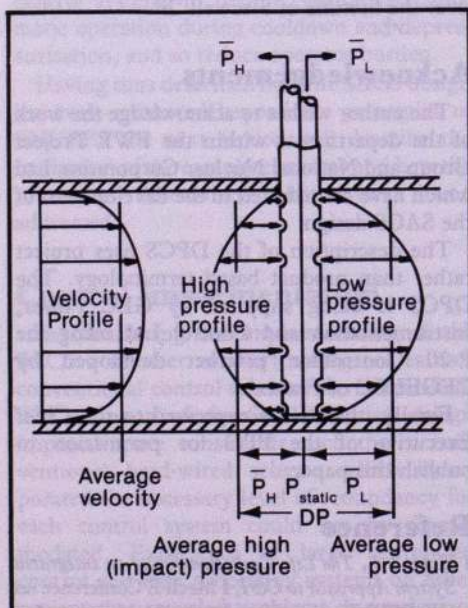


Fig 1: How Annubar works.

Compiled by Gay Parr\*

**Annubar flow sensors have been applied in power plants since the mid 1960's. The following article looks at the latest design evolution, which allows them to perform in the most difficult environments, such as the main steam line (from boiler to turbine) and stack emissions monitoring. Installed cost and operating cost savings in these applications can be as critical as their performance.**

Bernoulli's theorem. This signal has two components: the high pressure ( $P_H$ ) and the low pressure ( $P_L$ ):  $P_H - P_L = DP$ .

The high pressure is produced by impact of the velocity profile on the sensor. The velocity profile results in a corresponding impact pressure profile. Multiple sensing ports, located on the front of the sensor, sense the impact pressure profile. Inside the high pressure chamber, the average velocity pressure is maintained by the proportionality of the sensing port diameters to the chamber cross-sectional area. The velocity profile continues around the sensor and creates a low pressure profile. The low pressure profile is sensed by ports, located downstream and opposite the high pressure ports. Working on the same principle as the high pressure side, an average low pressure is maintained in the low pressure chamber.

Since larger pipes are most susceptible to dynamic distortions of the velocity profiles which can affect the stability and accuracy of the flow device, the Annubar is engineered so the number of sensing ports is a function of the pipe size. The additional sensing ports provide a stable DP signal that is a better average of the velocity profile.

## Measurement accuracy

The diamond shape of the Annubar establishes a fixed separation point of the fluid from the sensor. This eliminates any shift in the low pressure signal that would cause a corresponding loss of accuracy in flow measurement. Annubar's flow coefficient remains stable over the long term and is unaffected by wear, dirt or grease buildup.

The non-constricting design of Annubar's diamond shaped sensor produces the lowest permanent pressure loss of all intrusive primary flow sensors. This results in significant power savings. Orifice, venturi and flow nozzle flow sensors generate DP signals by constricting the flow stream and increasing the

permanent pressure loss, therefore, increasing energy costs.

**1 Special Annubar designed for main steam line measurement** — Main steam (high pressure steam from the boiler directly to the turbine) and hot reheat line measurement is critical in supplying power more efficiently. When cycling boilers to meet varying load requirements, flow measurement prior to the turbine gives operators better control information and allows faster, more efficient start up.

Flow measurement can also detect boiler or pump inefficiencies by comparing fuel consumption with kilowatt hours produced. When efficiency drops, an intermediate measurement of steam can detect if the boiler or the turbine is causing the inefficiency. An Annubar located in the steam lines to the turbine can provide this critical information to plant operators.

The severe temperature and pressure conditions characteristic of main or hot-reheat steam lines found in a fossil-fired plant have restricted the installation of flow measurement equipment in the past.

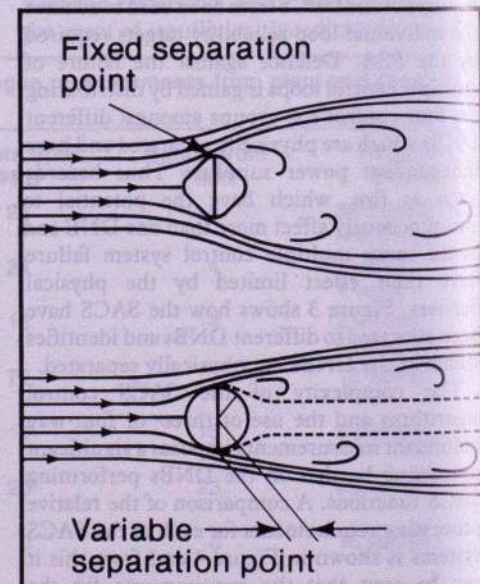


Fig 2: Fixed separation point increases measurement accuracy.

\*Freelance Technical Writer.

Now, however, a new Annubar model — the MSL (main steam line) — has been designed that can withstand the erosive effects of high steam flow rates at extreme conditions of temperature and pressure such as 593°C (1100°F) and 180 bars (2650 psig), as well as corrosion from water treatment chemicals such as hydrazine.

**Case history** — Commonwealth Edison in Joliet, Illinois, USA, was installing a new combustion control and data acquisition system designed to provide centralised control for the plant and control for both the boilers and the turbine.

The plant had been measuring flow rates by taking the pressure drop across a 6.1m section of pipe, and wanted to improve the accuracy of its steam flow measurement on the high pressure steam lines from each boiler to the turbine.

A flow nozzle installation would require cutting a section out of a pipe with a 75mm thick wall. Some of the pipes run vertically for more than 20m, making any work difficult. MSL Annubars, constructed of Incolloy 800H were selected for installation in a 325mm pipeline with pressures to 180 bars (2650 psig) and in a 650mm pipeline with pressures to 48 bars (700 psig). As a part of its maintenance programme, Commonwealth Edison has removed, inspected, and reinstalled the Annubar sensors which were found to be in excellent condition.

The MSL Annubar can be machined from 316SS, Monel, Alloy 20, Incoloy 800, and Incoloy 800H. Ports and passages are gun-drilled in solid metal to avoid welds and joins in high temperature areas. The MSL Annubar flow sensors are designed to span the full pipe diameter up to 2 meters and are supported by welded fittings at both ends.

**Installed cost savings can be significant** —

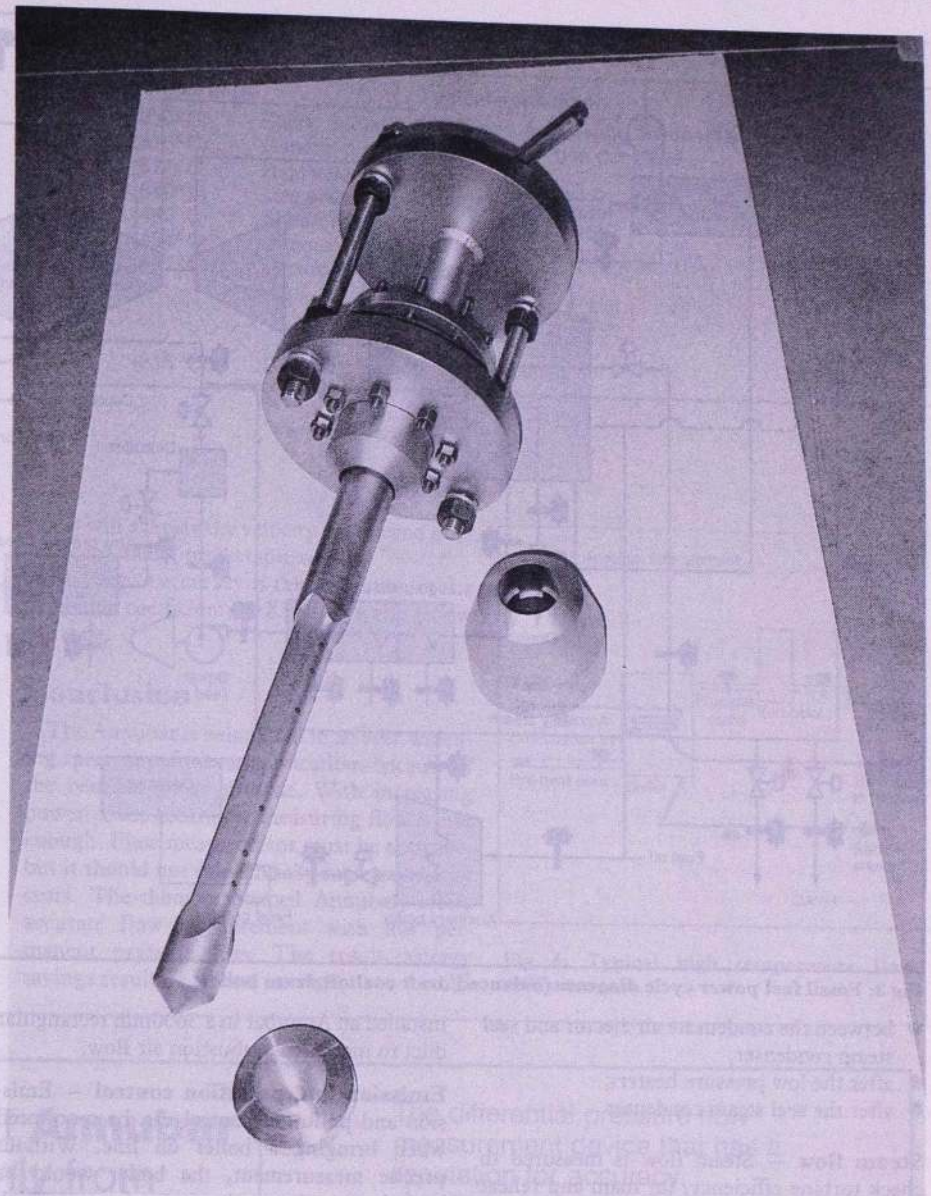
Since installation involves only cutting ports on both sides of the pipe and welding on necessary fittings, installation and future retrofitting are cost-effective. NDE requirements for the line are usually greatly reduced, overall installation time is reduced, and cranes and other heavy lifting equipment are not required. Minimal welding around each mounting coupling is all that is required, in contrast to multiple passes around the circumference of the pipe.

**2 Measuring exhaust emissions** —

The current focus on clear air legislation has led to new requirements for the measurement and control of exhaust emissions. The measurement of exhaust type gas flow presents several difficulties: high temperatures, suspended solids (ash), high moisture content, and corrosive gases. The DSF-46 Annubar is the latest generation of averaging pitot tube technology which has been designed for flow monitoring systems in stacks or ducts up to 10 meters.

**Case history** — Kansas City Power and Light (Kansas, USA) is being required to measure emissions on their 850 MW plant in LaCygne, Kansas.

The plant burns high sulphur and ash content coal from a local source and has one of



**MSL Annubar.**

the largest wet scrubbers in the world. Accurate flow measurement of the emissions is critical. If the plant runs out of tolerance, the company is subject to a high penalty. The company needed to measure the duct flow exhaust from the boiler. This measurement is critical because Kansas City Power and Light uses the flow rate readings of the exhaust in combination with gas analysers to arrive at emission levels. The flow rate must be accurate to determine accurate emission levels.

Specified for the installation were: (four) DFF-46 Annubars for a rectangular duct 3660mm x 3200mm with a maximum DP of 23mm of water; and (four) DSF-46 Annubars for a 4725mm round duct with a maximum DP of 45.2mm of water. An integral temperature sensor inside the Annubar eliminated the need for a second duct entry per measurement point and the associated thermowell and support structure, reducing the total cost of the installation.

The Annubar can be designed to fit existing flanged instrument ports in the exhaust stack, or can include the appropriate mounting hardware for new or retrofit installations. To accommodate the severity of the corrosive

nature of the gas, the DSF-46 Annubar can be manufactured out of 316SS, Kynar or Hastelloy C.

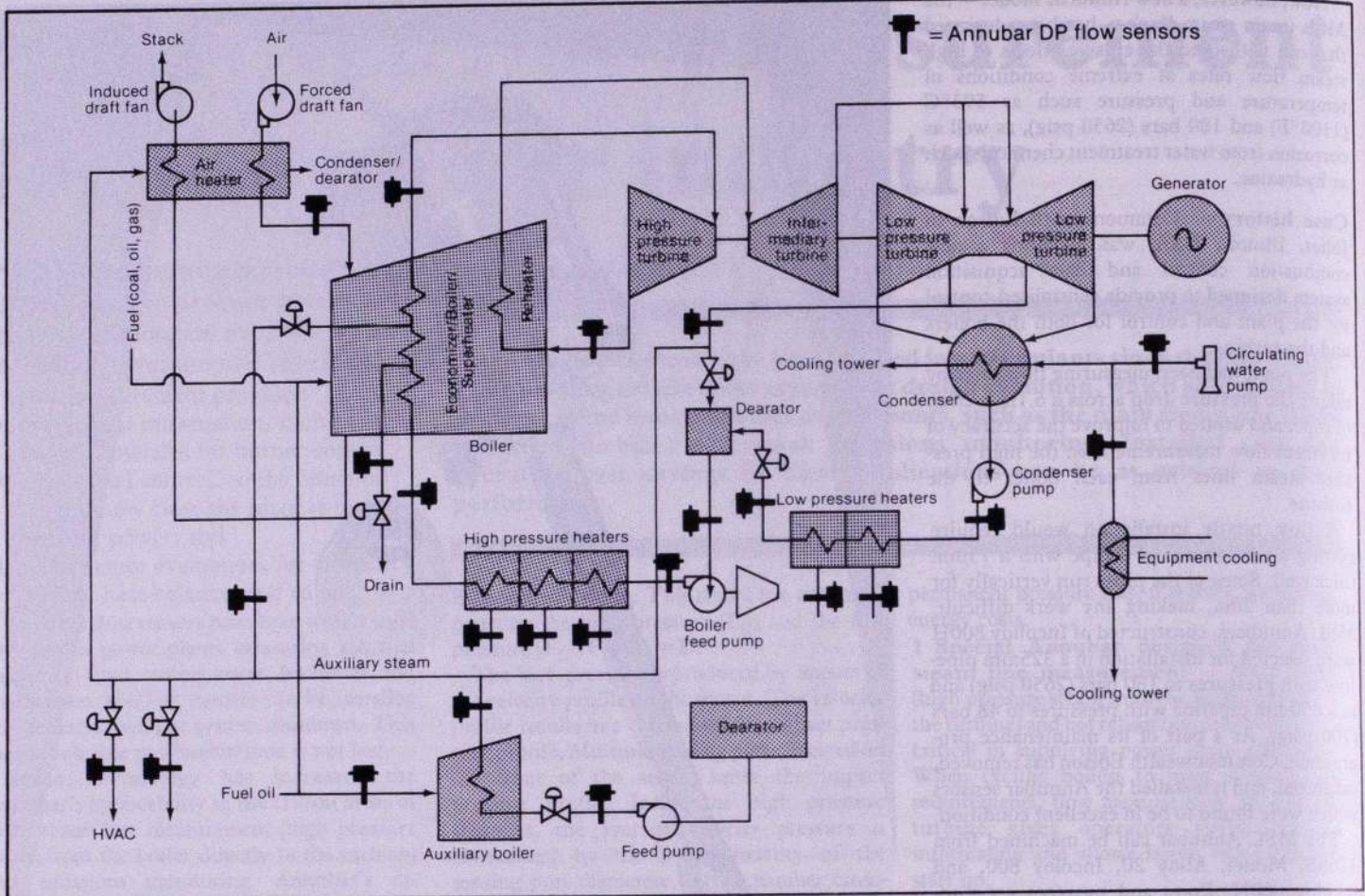
**3 Typical power plant applications for flow measurement** —

Flow measurement is important in a variety of power plant applications. The Annubar advantages can also be obtained in these less challenging applications.

**Feedwater** — Feedwater is measured on both the suction side of the boiler feed pump and after the discharge side in order to distribute flow for the boiler feed pump or heaters, although sometimes it may be measured at the high pressure heaters or at the economiser inlet.

**Condensate** — Condensate is measured for flow recording, or condensate recirculation control and for test purposes. It is generally measured:

- between the condensate pump and the deaerator;
- between the condensate pump and the steam packing exhauster;



**Fig 3: Fossil fuel power cycle diagram (balanced draft coal/oil drum boiler).**

- between the condensate air ejector and seal steam condenser;
- after the low pressure heaters;
- after the seal steam condenser.

**Steam flow** — Steam flow is measured to check turbine efficiency, for main and reheat steam lines, and for auxiliary steam supplies.

**Cooling water** — Cooling water is measured on cooling loops for equipment cooling, and for cooling tower efficiency studies. At Niagara Mohawk Power Corporation in Oswego, New York, USA, cooling water is drawn from Lake Ontario into the plant for steam generation. A flanged Model 86 Annubar was mounted in the 3350mm TD underground concrete lined pipe to measure this cooling water. The flow exceeded 1,551,850 LPM with a velocity exceeding 3.3 meters per second. Including the flanged extension, the Annubar had a total unsupported length of 4172mm. The flow rate, as measured by the Annubar, agrees within 1.0 per cent of the flow rate as determined by the pump performance curve.

The Potomac Electric Power Company installed four Annubars at the Chalk Point Generating Station in Aquasco, Maryland to measure turbine cooling water flowing at 529,900 LPM through a pipe that is buried 4115mm underground.

**Air measurement** — Air measurement is used for heating, ventilating and air conditioning throughout the plant, and in process areas such as the mixing of air and fuel to the boiler. A thermo-electric power plant in Vienna has

installed an Annubar in a 3600mm rectangular duct to measure combustion air flow.

**Emission and pollution control** — Emission and pollution control can be monitored when bringing a boiler on line. Without precise measurement, the boiler would be brought up on line with a surge of power which would result in a surge of pollutants being released into the atmosphere.

Other applications within the power industry which benefit from flow measurement are waste disposal, river water, service

water, fire protection, boiler control, cooling tower, and load balancing.

**4 Nuclear installations** — For nuclear power plant applications, the Annubar has been designed to handle the measurement of steam flow, cooling water, boiler feedwater, condensate return, air flow, and lubricant flow. Annubar flow sensors hold the NPT Stamp (piping subassemblies) in accordance with the requirements of the American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section III, Class 1, 2 and 3.

**Case histories** — The Trillo Nuclear Power Plant in Madrid, Spain, installed a Monel Annubar weighing 188kg, designed to measure seawater flow through a pipe that is 3200mm in diameter. The Annubar was installed through a manhole cover and is mounted to a concrete pipe with a steel core. A unique mounting was designed for this installation which involves a support on the inside of the opposite wall.

Arizona Public Service, USA, installed three 1525mm Annubars at the Palo Verde Nuclear Generating Station in a thin wall duct to measure exhaust air. Larger model 86's were specified because of the stringent seismic qualification requirements.

Annubars have been installed at the Heysham II unit in Lancashire, and the NPT Stamp has allowed Annubars to be provided on such critical jobs in the United States of America as TVA Watts Bar Nuclear Plant and Sequoyah Steam and Electrical Generating



**The DSF-46 Stack Annubar.**

Power Plant in Tennessee; Susquehanna Steam Electric Station in Allentown, Pennsylvania; Catawba Nuclear Power Plant in Newport, South Carolina and the WPPSS Hanford Unit near Richland, Washington.

## Annubar benefits

**Installation without shutting down the system** — Flo-Tap Annubars can be installed, removed, and reinserted without system shut-down. This is an advantage that eases retrofit of flow measurement.

A gear-driven mechanism cuts the insertion or retraction time to a minimum under flowing conditions. The gear drive is a worm gear design that can be powered by hand crank, heavy duty electric drill, or available line pressure.

**Elbow mount installations** — To obtain published accuracy of  $\pm$  one per cent with an Annubar or any other flow device, adequate straight run of piping must be available for installation. Where straight run is not available, the elbow-mounted Annubar can provide a  $\pm$  three per cent accuracy solution. This is particularly useful in retrofit installations into existing plants where flow measurement was not initially planned.

Although a pipe elbow distorts fully developed flow, it acts as a flow conditioner resulting in a predictable flow profile immediately downstream of the discharge of the elbow.

When an Annubar is installed, two pipe diameters downstream of the centreline of the

**Table 1: Application summary**

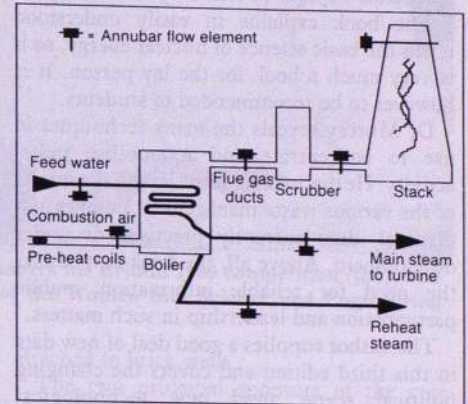
Maximum temperature	Typical application	Material
1850°F (1010°C)	Stack, exhaust, flue gases, & oxidising environments	330SS
1500°F (816°C)	General purpose high temp — non corrosive	316SS
1250°F (677°C)	High velocity & steam flows	Incolloy 800 HT
1200°F (649°C)	Low pressure — hot air & gasses — low cost	316SS
900°F (482°C)	Steam with chlorides & contaminants	Monel
850°F (454°C)	General purpose — high temperature	316L
800°F (427°C)	Corrosive applications	Monel
		Alloy 20
		Hastelloy C
		Inconel 625
		Titanium
600°F (316°C)	Organic chemicals — corrosives	

elbow will average the velocity profile and provide repeatable, predictable results.

The key to accuracy is the prediction of the discharge coefficient, or K-value in this elbow position.

## Conclusion

The Annubar is being used in an ever widening spectrum of power applications because of the benefits it can provide. With increasing power costs, accurately measuring flow is not enough. Flow measurement must be accurate, but it should not substantially increase energy costs. The diamond-shaped Annubar, offers accurate flow measurement with low permanent pressure loss. The result, energy savings resulting in cost savings. □



**Fig 4: Typical high temperature flow measurement.**

## The Diamond II Annubar available only from **KDG MOBREY**



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- Sensors available for pipe sizes from 13mm to 1800mm.



## A highly charged topic

**'Understanding Radioactive Waste'**  
by Raymond L Murray  
Battelle Press, third edit, 1989  
184 pp. \$18.95 (H/B); \$12.50 (P/B)  
Plus \$3.50 shipping and handling

Dr Murray, Professor Emeritus at North Carolina State University, has published widely on nuclear engineering topics. The book under review, the third edition, contains many new features.

Notable amongst these are topics covering radon in buildings, new estimates for America's annual radiation exposure from all sources, an enlarged perspective on environmental issues and the accomplishment of the spacecraft *Voyager* powered by radioisotopes.

The book explains in easily understood terms the basic science of nuclear energy, so it is very much a book for the lay person. It is however to be recommended to students.

Dr Murray reveals the many techniques in use to concentrate and immobilise radioactivity. He discusses at some length the merits of the various waste management policies and disposal ideas currently practised or under development. Above all, the book emphasises the need for reliable information, public participation and leadership in such matters.

The author supplies a good deal of new data in this third edition and covers the changing political scene amid new technological improvements. The importance of the effect of these aspects for the future of nuclear power is examined.

The book is thoroughly recommended. The contents supply the knowledge needed to form responsible opinions that assist in making sensible and logical decisions in what is a highly charged topic in many countries.

*F John L Bindon*

## An excellent review

**'Combustion of Liquid Fuel Sprays'**  
by Alan Williams  
Butterworths, 1990  
289 pp. £35.00

The object of this book is to "outline the fundamentals of the combustion of sprays in a unified way" at a level suitable to those entering the subject and students. This it achieves admirably, being easy to read, clearly presented and aiming for breadth and simplicity rather than depth.

The first chapter sets the scene with a brief review of fuel science relevant to spray combustion, in particular relating to sources of oil and the fuel combustion properties. The next two chapters are concerned with the science of sprays, discussing the basic mechanisms of spray formation and measurement techniques.

The book then moves on to consider the combustion first of individual drops, and then of sprays. Perhaps group combustion does not receive the emphasis that it deserves in the latter case. At least typical values of the group combustion number in sprays could have been quoted to emphasise the extent to which the

sprays must be modelled as a group, and when single drop combustion may be presumed.

There follow sections on the production and control of pollutants and deposits from spray combustion. Two-phase fuels are discussed in a most interesting chapter devoted to this relatively new field. Emphasis is given to the economics of these fuels, which injects a useful perspective.

Theoretical modelling is touched upon in a rather short chapter. Given that this is a major area of activity, the book could possibly be criticised for not treating the subject in more depth. However, the basic principles are covered with the governing equations, and, given the intended nature of the book, the level of coverage is about correct.

Finally, the practical uses of spray combustion in furnaces and engines are discussed. Here the properties of atomisers and burners are reviewed and their influence on furnace aerodynamics and performance. Applications to a number of industrial processes are examined briefly, including boilers for steam raising. The chapter on engines is short but provides an interesting taste of the subject.

The book is produced by direct reproduction of typescript. It is clear and well presented. Unfortunately, the decision to group all the figures at the end of each chapter results in a minor irritation, as the reader has continually to go searching and then return to the text.

Inevitably in such a wide overview at the level intended, some aspects of the subject will not be covered in the depth that they may warrant. Occasionally there is a tendency to gloss over material where only a very short addition would help. The example of group combustion number was mentioned previously. In another case CARS is mentioned as a means of temperature measurement. However, it would have been worth adding one sentence to say how this is actually achieved. On the whole, however, the book is an excellent short review and will well serve the market for which it is intended.

*Dr A R Jones*

## Evaluation techniques

**'Environmental Policy Benefits: Monetary Valuation'**  
OECD, 1988  
83 pp. £11.50

Following an OECD Conference on Environment and Economics held in 1984, it was decided to prepare a comprehensive survey of studies on the collection and analysis of data on the economic evaluation of the benefits of environmental measures. This report is the result of that decision. The first chapter begins with a clear statement of its scope, being concerned solely with monetary evaluation techniques and the associated procedures needed to engage in monetary evaluation. The importance of environmental policy is stressed and a number of basic concepts are introduced, eg, benefit, willingness to pay, markets and uncertainty. The final section, on time and discounting, will trap the unwary, as a \$1 million of cost in 50 years time "... at a 10 per cent

discount rate ... is viewed as being worth now ... less than one cent"! Let us hope that our decision-makers don't get hold of this one!

The second chapter outlines the types of framework used in decision-making, eg, Cost-benefit Analysis, Cost-effective Analysis, Multi-criteria Analysis, Decision Analysis and Environment Impact Assessment. This is followed in the third chapter by a brief description of Total Economic Value. This includes values that are placed on natural environments and which are not associated with any specific use, eg, a fine landscape view. It also includes the existence of environmental assets for future generations.

Direct valuation techniques are dealt with under four headings in the fourth chapter: Hedonic Property Prices (the value of a piece of land is related to the stream of benefits to be derived from that land); Wage Risk Studies and the Value of Life; Contingent Valuation (asking how much people are prepared to pay for a benefit, and/or what they are willing to receive by way of compensation to tolerate a cost); and Travel Cost Models. Indirect valuation procedures are discussed in the next chapter under the headings of pollution and health, materials corrosion and vegetation damage.

The sixth chapter looks in detail at a few examples of benefit estimation, including the analysis of the Gordon River Dam project in Tasmania. The approaches outlined in the text are clearly summed up in the final chapter, which includes a matrix of benefit techniques by environmental sector. Eight brief annexes illustrate some of the techniques and there is a comprehensive bibliography.

This is a useful book for those who wish to examine the background literature and the economic theories which have recently been applied to environmental issues. The authors have rewritten some of the text in a simplified version in *'Blueprint for a Green Economy'*, with a co-author, Edward B Barbier; this is published by Earthscan Publications.

*Dr Cleland McVeigh*

## Recently published

**'Solar Energy Conversion A Photoelectrochemical Approach'**  
by Yuri V Pleskov  
Springer-Verlag, 1990, 163 pp. DM 178.00.

**'Bretherick's Handbook of Reactive Chemical Hazards'**  
by Leslie Bretherick  
Butterworths, 1990, 2056 pp, £120.00.

**'Labour's New Policies: Strategies for Business'**  
Public Policy Unit, 1990, 100 pp, £65.00 (net).



## Schoolboy's 'Cookmate' wins Young Engineer for Britain title

A 13-YEAR-OLD schoolboy has carried off the title of Young Engineer for Britain 1990.

Ben Scammell, of Trent College, Nottingham, won the coveted trophy and £1,250 for his college — for the purchase of equipment for the encouragement of young engineers — with his invention called 'Cookmate' — an electronic device that indicates when a barbecue is at the correct temperature for cooking.

Ben's invention — which gives audible signals and actually speaks the warnings — has great potential for a wide range of applications, in industry and the home, to warn of changes in heat, resistance and speed.

Ben, of Guilsborough, Northampton, was one of 42 national finalists, aged 11 to 19, competing in the competition organised by The Engineering Council — the leading event of its type in Europe — at the National Westminster Hall in the City of London. They had been selected from 400 young people at 11 regional finals staged throughout the country.

The winning projects also included: a fog density monitor, a bicycle ride simulator, a clamp for pulling a caravan on to the ball-hitch of a car, a low-cost device to hygienically clean a baby's mouth and an appliance to help with physiotherapy of a patient's arms.

Runners-up received prizes of study visits to companies in the United Kingdom and abroad, cash prizes up to £600 for themselves and their schools and the opportunity to discuss projects and career prospects with highly-qualified people in the field of engineering.

The Engineering Council's Women into Science and Engineering (WISE) award of £250 for the best project by a girl was won by Victoria Barrett, aged 19, of Harrogate, Yorkshire, with her invention 'Silent drum kit' which enables the musician to practise without



Ben Scammell, 13, winner of The Young Engineers for Britain 1990 competition (left), and pictured right, Victoria Barrett, 19, winner of the Women Into Science and Engineering Award.

disturbing the neighbours. The device provides a realistic drum feel and sound but is only heard by the drummer.

A special £600 prize, awarded by the Department of Education and Science for the school entering the competition for the first time with the most imaginative project, was won by Bishop Bell Church of England School, Priory Road, Eastbourne, for 'Alter climb' by Andrew Phillips (13) and Stuart Wyllie (13). Their invention was a climbing system that can be

attached to brick walls.

The two principal sponsors of the competition are Lloyd's Register, one of the world's leading marine, offshore and industrial technical inspection and advisory organisations, and the National Westminster Bank. Other major sponsors include: BP plc, GEC plc, ICI plc and Shell (UK) Limited.

Prizes and other support are also provided by industrial companies, professional engineering institutions and educational bodies.

## Environment engineers can lead the way

THE 1990 Engineering Assembly was held in July at Surrey University.

The 114 nationally elected engineering delegates drew up their plans for the protection of the environment, calling for professional engineers and technicians to take action to improve the environment, and to help reduce pollution and risk to the public.

The Assembly also called on The Engineering Council to press the Government for national policies on energy, transport and waste management. Speaking on the second day of the Assembly, Mr David Heathcoat-Amory MP, Parliamentary Under-Secretary of State at the Department of the Environment replied that new provisions would be introduced in the Environmental Protection Bill to minimise waste production, but increasingly the Government was looking towards using the market to provide the necessary environmental signals.

Sara Parkin, the Green Party speaker, gave her backing to The Engineering Council's programme of engineering solutions to environmental problems.

"Environmentally sound design of all future technology is the most important area. From

now on, everything we do must be checked against one criteria — is it biologically sustainable?" she said.

"The engineering heroes and heroines of the next century will be those who have done most to shift human progress along a development path which minimises our use of energy and raw materials in everything we do."

Speaking on the first day of the proceedings, HRH The Duke of Kent, President of The Engineering Council, took a worldwide view, broadening the discussion to include the third world and the eastern bloc.

"Less developed countries are often the ones with the greatest pollution problems, because they are using old fashioned, dirty and energy inefficient methods," he said.

"If we are to transfer technology to countries in eastern Europe and the third world, as we must, then it is absolutely incumbent upon us to ensure that it is the appropriate technology from an environmental point of view. Transferring technology that is obsolete or obsolescent will only negate the actions we take to reduce environmental damage. As Chernobyl reminded us, we all share the same atmosphere and breathe the same air."

## ACostE affiliation

THE ENGINEERING COUNCIL has announced that the Association of Cost Engineers (ACostE) has become one of its institution-affiliated bodies.

The Association of Cost Engineers was formed in 1960 in London as the British Group of the American Association of Cost Engineers (AACE). It promotes the technical study and development of cost engineering with the objectives of furthering the application of scientific principles and techniques to the problems of cost estimating, cost control, profitability and investment appraisal.

This new status for the ACostE means that those of its members who are suitably qualified can apply to become Chartered Engineers (CEng). The arrangement will be operated through an institution-affiliated agreement, approved by The Engineering Council, with the Institution of Chemical Engineers (IChemE) with whom the ACostE has had close links for many years.

The ACostE will now be a member of The Engineering Council's Executive Group Committee 4 and so promote even closer links.



## October 1990

**Electricity Privatisation  
— Effect on User  
Industries**

National IEEIE lecture by Dr D R Helm & I J Blakey. 22 October, London.

Details from IEEIE, Savoy Hill House, Savoy Hill, London WC2R 0BS. Tel: 071-836 3357, fax: 071-497 9006.

**Electrical Aspects of CHP**

Colloquium, 26 October, London.

Details from Christina Dagnall, IEE Press Office. Tel: 071-240 1871 ext 272.

## November 1990

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

Conference, 6 November, London.

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

**Futures and Forward  
Markets — Swaps and  
Options**

Conference, 16 November, London.

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

**The Human Factor in  
Safety: Implications for  
the Chemical, Process &  
Offshore Oil & Gas  
Industries**

International conference, 20-21 November, Manchester.

Details from Katie Lye, IBC Technical Services Ltd. Tel: 071-236 4080, fax: 071-489 0849, tlx: 888870.

**Offshore Safety — The  
Way Ahead**

Conference, 22 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.

**Petroleum Technology  
Australia '90**

International oil & gas exhibition, 22-24 November, Perth, Western Australia.

Details from PTA '90, 103 Scarborough Beach Road, Mount Hawthorn, Perth, Western Australia. Tel: (09) 443 3400, fax: (09) 242 1811, tlx: AA9531.

**Installation &  
Maintenance of Security  
Equipment**

Symposium, 27 November, Solihull, UK.

Details from The Conference Office, IEEIE, Savoy Hill House, Savoy Hill, London WC2R 0BS. Tel: 071-836 3357, fax: 071-497 9006.

**Oxygen Enrichment in  
Combustion Technology**

Symposium, 28 November, Leeds, UK.

Details from Mrs Dianne Taylor, Department of Fuel & Energy, University of Leeds, LS2 9JT. Tel: 0532 332511/332508.

**Man's Influence on the  
Climate II**

Conference, 28-29 November, Neuss, FRG.

Details from VDI-Gesellschaft

Energietechnik, Postfach 11 39, D-4000 Düsseldorf 1, FRG. Tel: \*211/6214-363.

**Implications of the Piper  
Alpha Disaster for the  
Onshore and Non-Oil  
Industries**

Conference, 30 November, Edinburgh, UK.

Details from Dr John Christy (Hon Sec), Dept of Chemical Engineering, University of Edinburgh, The King's Buildings, Mayfield Road, Edinburgh EH9 3JL. Tel: 031-667 1081 ext 3364/3650.

## December 1990

**Gas Appliances and the  
Consumer: What Price  
Quality & Safety?**

Conference, 3 December, London.

Details from ICM Marketing, tel: 0483 37557.

**Gastech 90**

International conference & exhibition, 4-7 December, Amsterdam, The Netherlands.

Details from Gastech Ltd, 2 Station Road, Rickmansworth, Herts WD3 1QP. Tel: 0923 776363, fax: 0923 777206, tlx: 924312.

**Subsea 90**

International conference, 11-12 December, London.

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

**Robotics in the Power  
Generation Industry**

Conference, 11-12 December, London.

Details from Katie Lye, IBC Technical Services Ltd. Tel: 071-236 4080, fax: 071-489 0849, tlx: 888870.

## January 1991

**Lighting Developments &  
Appliances**

Conference & exhibition, 16 January 1991, London.

Details from Miss Linda Jelly, Conference Organiser, ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA.

**14th Energy-sources  
Technology Conference &  
Exhibition**

20-24 January 1991, Texas, USA.

Details from Frank Demarest, ASME, 1950 Stemmons Freeway #5037C, Dallas, Texas, USA 75207. Tel: (214) 746 4901, fax: (214) 746 4902.

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### FIRST ANNOUNCEMENT & CALL FOR PAPERS

The Fifth International Fluidised Combustion Conference, organised by the Institute of Energy, will provide a review of fluidised bed combustion developments worldwide. At the present time there is much publicity on the potential impact of fossil fuel combustion upon the environment. The conference organisers will, therefore, particularly welcome papers that describe developments and demonstrations of systems with a high environmental impact, for both industrial and utility applications.

#### PAPERS

Papers are invited covering:

- **Fundamentals** – particularly mechanisms for formation and control of pollutants.
- **Emissions Performance and Control Developments** – SO<sub>x</sub>, NO<sub>x</sub>, particulates, combustion modifications, additives, gas clean-up equipment.
- **Economics** – prospects for advanced cycles, efficiency, capital/operating costs, systems analysis.
- **Advanced Combustion Programmes** – PFBC, CFBC, topping cycles, pyrolyser-combustor.

- **Experience** – large plant performance, long-term operating experience, component reliability.

#### ABSTRACTS

Abstracts in English of 300 to 500 words should give a clear understanding of the scope of the paper and be submitted by 31st January 1991, to: Conference Department, The Institute of Energy, 18 Devonshire Street, London W1N 2AU. Tel: 071-580 0008. Fax: 071-580 4420. Notification of acceptance will be given at the end of February 1991. Final drafts must be received by April 1991.

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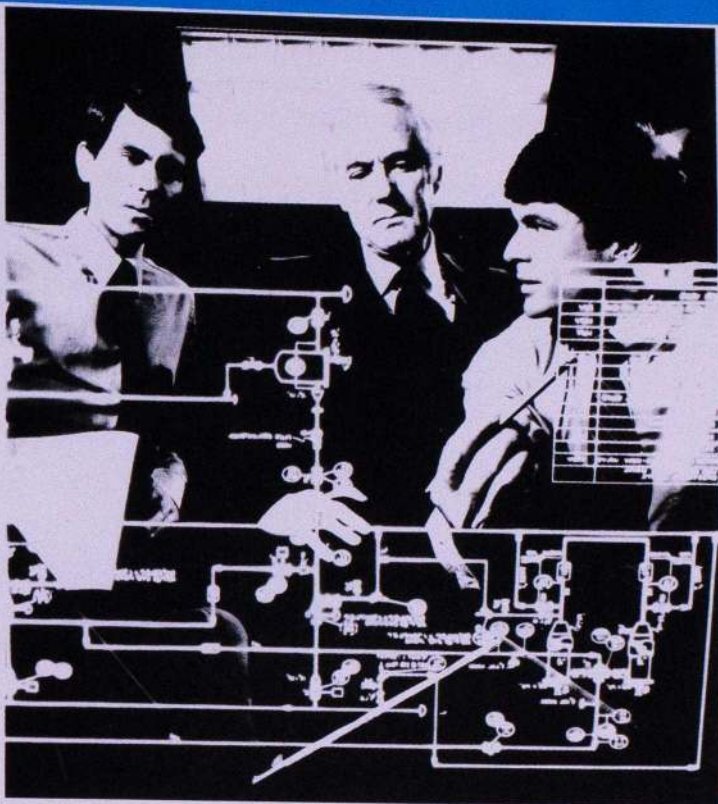


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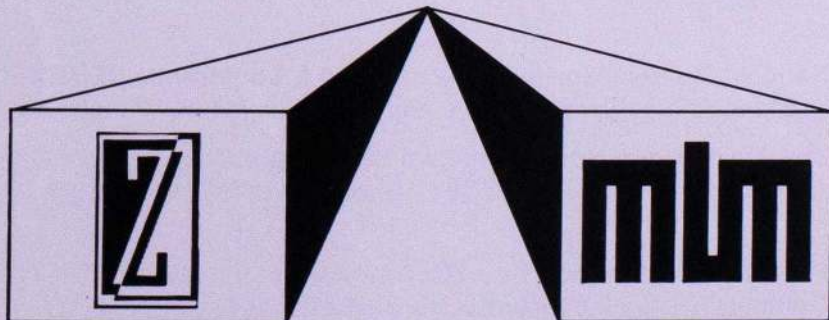
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# INSTITUTE OF ENERGY CONFERENCES

The following programme is currently being organised by The Institute of Energy.

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

## In 1990

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

## In 1991

February **MANAGING LONG TERM RISKS IN THE ENERGY BUSINESS**  
**Venue:** to be confirmed  
**Chairman:** Mr D M Willis (Institute of Energy)

13 March **WHERE ARE WE NOW ON NUCLEAR POWER?**  
**Venue:** to be confirmed  
**Chairman:** Mr C E Pugh CBE (Institute of Energy)

30 April-1 May **FIRE & EXPLOSION HAZARDS: ENERGY UTILISATION**  
**Venue:** Fire Service College, Gloucestershire  
**Chairman:** Mr P G Redpath (British Steel)

17-19 May **THE INSTITUTE OF ENERGY ANNUAL CONFERENCE**  
**Venue:** Bournemouth  
**Chairman:** Mr D M Willis (Institute of Energy)

Autumn **ENERGY FROM WASTE** (provisional title)  
**Venue:** to be confirmed  
**Chairman:** Mr B Lees (Institute of Energy)

Autumn/Winter **5th International Fluidised Bed Combustion Conference:  
FBC TECHNOLOGY TO MEET THE ENVIRONMENTAL CHALLENGE**  
**Venue:** to be confirmed  
**Chairman:** Mr J S Harrison (British Coal)

## Conferences co-sponsored by The Institute of Energy

### In 1990

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

12 December **The Reactions of Nitrogen in Coal Combustion**  
**Contact:** Institution of Chemical Engineers on (0788) 578214

### In 1991

Jan/Feb **Practical Solar Energy: New Opportunities in Europe**  
**Contact:** The Solar Energy Society on (071) 333 4314

20-25 March **2nd International Conference on Desulphurisation**  
**Contact:** Institution of Chemical Engineers on (0788) 578214