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ENVIRONMENTAL IMPACT OF NUCLEAR POWER

WHAT FUTURE FOR THE 'BREEDER'?

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ATOM contents

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Front cover: Electricity to power industry and homes has to come from somewhere. In this issue, reports on the environmental impact of nuclear power, and on the future of the breeder

THE ENVIRONMENTAL IMPACT OF NUCLEAR POWER

The public debate on the acceptability of nuclear power has been characterised by many misconceptions and distortions of the scale and nature of its possible effects. The British Nuclear Energy Society, supported by the UKAEA, set out at a conference in London in April to review the scientific and technical facts, to assist "all concerned with the rational and balanced assessment of the impact of nuclear power on the environment." James Daglish reports

Mr Norman Lamont, Under-Secretary of State for Energy, in his opening address made one criticism of the agenda of the conference: there was nothing about the benefits of nuclear power [see box]. "Yet the benefits of nuclear power are real; nuclear power is indeed a friend of the earth," he said. "I wonder whether you might not have turned the theme of the conference the other way round and talked about the impact of environmentalism on nuclear power. That is a subject which has not always in all countries had beneficial results. . . .

"The debate on nuclear power is going to go on. It must be based on scientific evidence; it must be based on facts; it must be a debate which takes place with the industry vigorously putting forward its case in public. It is as a contribution to that vital role that the industry has that I particularly welcome this conference."

The topics covered in the two days of the conference, which attracted the better part of 200 delegates, ranged from radiation protection philosophy and the radiation dose to the population from nuclear industry effluents, through the environmental aspects of transporting radioactive materials, UK disposal of solid radioactive waste into the Atlantic ocean and its environmental impact, and the assessment of the environmental consequences of reactor accidents; to the comparative risks of different fuels in electricity generation, the local impacts of nuclear power stations, and the nuclear fuel cycle and proliferation, concluding with papers on a strategy for the development of a UK radioactive waste management scheme and the management of high level waste and its environmental impact.

I will not here review each paper in detail: some covered well-worn ground, and all are available in a volume of *Proceedings* from the BNES. The fundamentals of radiation protection philosophy were spelled out in a presentation by Pamela Bryant, of the National Radiological Protection Board. To comply with radiation protection objectives and principles, two fundamental but contrasting courses of action in radioactive waste management were available:

- the containment of radionuclides in order to achieve the required degree of isolation from the environment by suitable storage of disposal methods; and
- dispersion and dilution of radionuclides through the release of effluents into the environment.

The first course of action resulted in little or no radiation exposure of the public as long as the isolation was maintained, although it might result in exposure of future generations as a consequence of the eventual release of activity to the environment. Almost all the activity in wastes generated in the nuclear fuel cycle was currently isolated from the environment by storage until radioactive decay had reduced the activity to non-hazardous levels or pending the implementation of disposal procedures. The second course of action could be adopted when release of the radioactive waste would lead to radiation exposure consistent with radiation and environmental protection principles.

The International Commission on Radiological Protection had recommended a system of dose limitation resulting from exposure to sources of radiation in its report No. 26, published in 1977. This system could be summarised as:

- No practice shall be adopted unless its introduction produces a positive net benefit (justification of the practice);
- All exposures shall be kept as low as reasonably achievable (the ALARA principle), economic and social factors being taken into account (optimisation of the protection); and
- the dose equivalents to individuals shall not exceed the limits recommended for the appropriate circumstances (compliance with dose limits).

Thus, justification and optimisation were now as important as compliance with dose limits.

Miss Bryant recalled that the NRPB had expressed the view in its first statement giving advice on standards of protection that the system of dose limitation recommended by the ICRP was a satisfactory basis for controlling the exposure of persons to ionising radiation in workplaces and in the general environment, though the Board considered that the detailed recommendations and supporting argument and data called for the interpretation of many specific points—particularly as they related to various practical applications. The Board had therefore published comments and views on these from time to time.

How did the system work in practice? G.N. Kelly and M.J. Clark of the NRPB reviewed the radiation exposure of the UK population from nuclear industry effluents, drawing on two recent studies undertaken by the Board to assess the radiation exposure of the UK population resulting from routine discharges of radionuclides by the industry. These studies formed part of a broader and continuing review of the exposure of the population from all sources of ionising radiation, including artificial, technologically enhanced and naturally occurring sources; the doses resulting from the quantities of radionuclides discharged from nuclear installations were in general very small and the exposure of the population, or of sub-groups within it, could rarely be determined by measurements. Extensive use was therefore made of mathematical models which described the transfer of activity through the environment to man.

The full paper contains considerable detail; here, it is sufficient to reproduce the accompanying table, showing the maximum individual or critical group dose from effluents from each establishment in the UK as percentages of the appropriate ICRP dose limit in 1978. Almost all the dose estimates in the table were quoted as upper limits, owing to the conservative assumptions adopted in their derivation; in reality the actual doses received were likely to be significantly lower. In most cases the maximum individual or critical group doses were small fractions of the dose limit, the exception being liquid effluents from Windscale, where the average critical group dose had been conservatively estimated as 26 per cent of the dose limit. Discharges of caesium-137 were mainly responsible for this dose, which resulted from the consumption of fish and shellfish caught in the vicinity of the plant. Measures were currently being taken to reduce the discharges of caesium-137 and other nuclides in liquid effluents from Windscale, and the levels of caesium-137 in airborne effluents. Both individual and collective doses from this source in the future might therefore be significantly less than those estimated for 1978.

Any estimate of the radiological impact of effluent discharges from the nuclear industry in future must be uncertain, and qualified accordingly. Given a number of assumptions about the size and type of the future UK nuclear programme, the authors concluded that the predicted collective dose from discharges in the year 2000 would not be markedly different from that from discharges in 1978: the absence of an increase in dose commensurate with the expected size of the nuclear programme at the turn of the century was largely a consequence of reduced liquid discharges of caesium-137, these being predominantly associated with Magnox fuel reprocessing which was expected to have ceased by that time.

The paper concluded by contrasting the collective dose commitment from effluents discharged in 1978 with the annual collective doses to the UK population from other sources of exposure, as shown in the second table (over). The collective dose from effluents could be seen to be a very small fraction of that from other sources. Nevertheless, such a comparison could not be used to conclude that these doses were "as low as reasonably achievable": the collective dose was but one of the many parameters which needed to be considered in reaching judgments. The measures being taken to reduce the discharges of some of the more significant radionuclides discharged in 1978 were an illustration that comparisons with other sources of exposure must be confined to giving a broad perspective.

Transport

J.C. Chicken, Head of Safety Services at the UKAEA Culham Laboratory, E. Goldfinch (CEGB) and W.G. Milne (BNFL Risley) discussed the environmental criteria that the transport of radioactive materials had to satisfy in the UK, describing the regulatory framework and the way requirements were met.

The basic criteria were the IAEA Regulations for the Safe Transport of Radioactive Materials (IAEA Safety Series No. 6, 1979), applied through a variety of international and UK regulations and codes of practice. There were two primary aspects of concern in examining the environmental impact of transporting radioactive materials: the accident-free situation, and the effect of accidents.

Control of the environmental effects was achieved through the control of package contents, of external radiation and of the leakage of package contents. [A full discussion of measures taken to ensure the safe transport of radioactive materials appeared in ATOM No. 270, April 1979—available as a reprint.] The authors concluded that over the past 20 years the transport of radioactive material had been carried out with care and responsibility, and had not endangered public health. This finding, they said, endorsed the view that compliance with the IAEA regulations had given the public adequate protection, and there was no reason to doubt that it would continue to do so.

In the discussion following this paper Mr Goldfinch noted that the public came into contact with two aspects of radioactive materials transport: that of radiopharmaceuticals, and that of nuclear fuel. The transport of radiopharmaceuticals would clearly increase over the next 20 or 30 years, but the rate of increase in nuclear fuel movements would depend very much on the reactor type used in the future nuclear programme. If the reactors were predominantly PWRs nuclear fuel transport would not increase significantly, because the fuel flasks used for PWR fuel transport contained more than the relatively small quantity accommodated in flasks used for Magnox fuel transport.

Establishment	Airborne Effluents		Liquid Effluents	
	% of ICRP Dose Limit[a]	Exposure Pathway	% of ICRP Dose Limit[a]	Exposure Pathway
UKAEA				
AERE Harwell	< 1	Inhalations	Very small	–
	< 3	Ingestion: milk		
DNPDE Dounreay	< 6	Ingestion: milk	< 1	External – salmon nets and sludges
	< 0.2	External		
AEE Winfrith	< 4	Ingestion	< 0.2	Ingestion: Shellfish
	< 1	External		
BNFL				
Capenhurst	Very small	–	Very small[c]	–
Springfields	Very small	–	< 2[b]	External – River banks
Windscale & Calder	< 2	Inhalation	26	Ingestion: fish and shellfish
	< 4.5	Ingestion		
	< 3	External	~4	External – sediment
Chapelcross	< 1	Ingestion	< 1	–
	< 0.6	External		
CEGB/SSEB				
Power Stations	< 0.1	Ingestion: milk	< 2	Ingestion: fish
	< 3[d]	External		

a) See text: the dose limits in some cases refer to those recommended in ICRP Publication 9 and in others in Publication 26.
b) Major contribution from Windscale rather than Springfields discharges.
c) Levels of activity in the local environment commensurate with Windscale discharges.
d) Includes only the dose from effluents; at some stations direct irradiation from the reactors is the major contributor to the maximum individual dose.

Table 1. Maximum individual or critical group doses from effluents discharged in 1978

Sea disposal

Dr N.T. Mitchell and Dr J.G. Shepherd, of the Ministry of Agriculture, Fisheries and Food, Lowestoft, looked next at the UK disposal of solid radioactive waste into the Atlantic Ocean and its environmental impact. The authors recalled that packaged low-level solid radioactive wastes were first disposed of from the UK into the deep waters of the north-east Atlantic in 1949. Further use was made of this procedure in 1951 and in subsequent years, and it became ultimately an annual operation. Except for isolated instances in 1960 and 1962, when some Belgian waste had been included in otherwise solely UK consignments, other European countries had not begun to use the ocean disposal route for solid wastes until 1967, when the first experimental collaborative exercise organised by the Nuclear Energy Agency of the OECD took place. Joint disposal operations became an annual undertaking from 1971, although member states had reverted to taking a greater individual responsibility from 1977 to conform to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping Convention, or LDC).

All kinds of radioactive waste were potential candidates for sea disposal provided that they satisfied the terms of the LDC in respect of both their radioactive and their non-radioactive content. Waste disposed of by the UK in recent years had come from a variety of sources, mostly from the nuclear industry – R&D establishments, reprocessing facilities and nuclear power stations – and radioisotope production. The sea disposal route also served smaller users of radioactive materials.

Current UK practice was to produce waste in a limited range of package sizes, all of them drum shaped (a steel drum was usually the outer container) and using a small range of methods of fabrication. The fundamental principles underlying package design, manufacture and other aspects of disposal, were those normal to good radiological protection practice, including strength, shielding, density, sealing and containment. Special restrictions were applied to buoyant materials and liquids: buoyant materials were allowed but only if they had been so conditioned that either their return to the surface was precluded or, on return, they would neither constitute a radiation hazard nor interfere with the legitimate use of the sea. Liquids must be either solidified or absorbed in a solid substrate.

The aim had been to produce packages which, as a minimum, would reach the sea bed intact. In so doing, it was very likely that containment would extend longer than this. It was considered that this requirement honoured the basic principle of the ICRP, ensuring that doses to the public were kept as low as was reasonably achievable.

The radiological assessment of sea disposal posed a number of complex and difficult problems, particularly if the objective was to make accurate (rather than pessimistic) estimates of population radiation exposure. The principal reason for this was that concentrations of radioactivity attributable to the waste in relevant materials such as foodstuffs were too low to permit direct measurement, so that conventional monitoring procedures were of no direct use. This was largely a reflection of the quantity of radioactivity involved relative to the scale of the receiving environment, together with factors such as the timescale of return of activity to man after it had escaped from the packages.

The answer to the problem lay in the use of mathematical modelling techniques. By making a series of simplifying but intentionally conservative assumptions it became easier to make dose estimates, although these were therefore upper limit values rather than the accurate values which would be preferable. Nevertheless, they did provide a basis for regulatory authorities to decide whether authorisation for a proposed disposal could be granted.

Source	Annual collective effective dose equivalent to the UK population (man Sv)
Natural background[a]	104 000
Medical irradiation	28 000
Fallout	560
Miscellaneous sources	450
Occupational exposure	500
Total	134 000
Effluents from the civil nuclear programme in 1978	160[b]

[a] Including exposure to radon daughters
[b] Collective dose commitment equated with the annual collective dose

Table 2. Comparison with other sources of exposure

It could be concluded that doses from current practice would not reach as much as 1·5 per cent of the ICRP recommended dose limits. The radiological impact of current UK solid waste disposal to the sea was therefore very small. In future, it was likely that more attention would have to be turned to unpackaged waste, for such intractable items as the heat exchangers from decommissioned nuclear power stations and other similar large plant. Whatever the form or quantity of the waste proposed for dumping in the future evaluation of its radiological impact would be necessary.

Dr Mitchell acknowledged in the discussion following this paper that there were those who did not want the sea used for disposal of radioactive wastes at all. If they were to adopt that view, "you must put the waste somewhere else."

"I know of no material which is so toxic that we cannot allow some small rate of release of that material into the environment," Dr Mitchell said. "The problem stems largely from emotive fears about radioactivity in itself. . . . [In considering sea disposal] one can't say as exactly as one can with a river or a small part of the coast exactly what will happen; this I think feeds fear and fear feeds emotion. But philosophy is not my subject, and I think I had better stop."

Reactor accidents

Thus far the conference had been considering the operations of the industry day to day. J.R. Beattie, of the UKAEA Safety and Reliability Directorate, turned next to consider the effects of reactor accidents. Nuclear power reactors were well-established in the UK, he said; no serious incident having any environmental consequences had ever occurred, because of the extraordinary measures taken in design, construction and operation and in safety supervision and licensing procedures.

"The nuclear industry has spared no reasonable expense to ensure that accidents do not happen; nevertheless, scenarios for such accidents have been envisaged and thoroughly investigated, since it is acknowledged that accidents causing significant radioactive environmental impact could be realised with a very low probability as a result of a highly unlikely combination of what are individually highly unlikely events in the reactor system."

Certain human activities were attended by a high degree of risk that something would go badly wrong, resulting in damage, injury or death as a consequence: no human activity could be free from the risk of injurious consequences arising from error or malfunction of some kind. So if anything worthwhile was to be accomplished some degree of risk must be accepted.

"To determine the acceptability of a risk one has to compare it with other risks in life," said Mr Beattie. "To try to put this item in focus I will select from some figures of everyday risk covering various multiple fatality accidents in the United States: passenger aircraft crashes leading to multiple fatalities. There is a passenger aircraft crash that kills about 100 passengers on average once a year. Yet curiously enough this does not seem to diminish the popularity of air travel. . . . I can only conclude that what is acceptable to the community seems to depend on more than mere numbers. The worst reactor accident might kill 100 people once in 10 million years. Perceived risk for some people seems to differ widely from the assessed risk, calculated and stated in numerical fashion. I can't tell you why: I wish I could."

Mr Beattie concluded: "Perhaps through a continued process of learning about the realities of nuclear power, and through time, a more rational view may be taken of nuclear power by most people and the perceived risk will become equal at least to the real or calculated risk: if the calculated risk *is* the real risk, which I cannot say."

Professor G.R. Bainbridge, of the Department of Energy Studies at the University of Newcastle upon Tyne, next morning presented a paper reminding delegates that other energy industries had similar "environmental" problems. "Caveats and conditions, doubts and uncertainties, keep entering assessments of comparative risks of different fuels in electricity generation," he wrote. "Establishing the terms of reference, the ground rules, for such exercises can be a major difficulty. There are gaps to be filled in methods and data, there are limitations to be understood.

"The risks from electricity generation are small for all fuel types compared with those experienced in many other fields of human activity. Claims may be made that between coal, oil and nuclear types of electricity generation, when taking into account the whole of the associated activities from extraction of fuels through transport, fuel processing and power station operations to waste disposal, there are numerical differences in the level of risks. They are however small differences between small numbers, and the whole argument can be demolished by a single accident of lesser magnitude than many which have been experienced in similar industrial activities in earlier days. It would be a brave forecaster who would say such an accident could never happen again. When, however, the normal total risk is a small one, as it is for the electricity generating systems irrespective of fuel type in Britain, the benefits from electricity are such that the prospect of very low probability larger accidents can be accepted."

To give perspective to his conclusion, Prof. Bainbridge pointed out that the risks which loomed large in news headlines were the "world defeating killers": earthquakes, floods, famine, plague; man-made disasters such as water storage dams which burst, jumbo jet aircraft which lost engines or collided, hotel fires, chemical plant explosions. Yet one of the largest electricity generating systems in Europe, that of the UK, scarcely figured in the major risk charts: it had a capacity of 75 gigawatts at about 250 power stations, converting at present coal, residual fuel oil, uranium, water power, diesel and gas to more than 25×10^{10} kilowatt-hours of electricity each year.

Proliferation

John Collier, Director of Technical Studies at AERE Harwell, drew attention to an "environmental impact" of the nuclear fuel cycle not often considered in the context of a conference such as this: that of the proliferation of nuclear weapons, and concluded that all civil nuclear fuel cycles carried some risk of misuse, albeit small. His conclusion was coupled with the view that any country with the capability to build and operate a series of nuclear power facilities on a commercial scale would also have the capability to construct the rather less complex facilities needed to prepare fissile materials for nuclear weapons. In this situation the only real barrier to proliferation was the commitment of the government of that country to the principles of non-proliferation.

"Proliferation is a political and not primarily a technical problem," said Mr Collier. "Civil fuel cycles are not attractive routes to nuclear weapons, but if they do exist in a country they can be misused. All civil fuel cycles carry some risk; none is inherently better than any other, given their present state of development. Technical fixes are not effective on their own, although they can make a contribution; existing institutions like the IAEA and the NPT have been successful to date and are the preferred foundation on which to build for the future."

Mr Collier was asked in the discussion which followed his paper "What about terrorists?" "When we talk about proliferation we are talking about proliferation by governments," he replied. "If we are talking about the activities of terrorist organisations I refer to that as theft. Governments can do many things terrorist organisations cannot: in respect of theft or terrorist activity there is no doubt that technical fixes of the type I mentioned will be exceptionally effective. The question is to what extent should those be applied when they have disadvantages from the civil nuclear fuel cycle point of view—costs, operator dose and so on—just to combat that particular threat."

Mr F.J.L. Bindon, a CEGB shift manager, urged that "the UK should not embark upon any unilateral disarmament programme, neither should the western alliance embark on any multilateral disarmament programme; because only by remaining very, very strong in nuclear weaponry are we going to be able to make sure our civilisation will stretch forward into the 21st century." Mr Collier refused comment: but he reminded the conference that the NPT did require nuclear weapon states to cease the arms race, and ultimately to disarm. "That is what we have signed."

Waste management

The last two papers of the conference were on the management of radioactive waste, the first by Dr Alan Duncan of the Department of the Environment and the second by P.A.H. Saunders, of the Nuclear Environment Branch at AERE Harwell.

Drums of low-active waste being loaded for sea disposal

Dr Duncan recalled that the Royal Commission on Environmental Pollution had recommended in its sixth report (September 1976) that the responsibility for developing the strategy to deal with radioactive wastes should lie with the Government department concerned with the protection of the environment, rather than with that responsible for developing and promoting nuclear power. The Government had accepted that an overall long-term strategy was needed, and that the Secretary of State for the Environment together with the Secretaries of State for Scotland and for Wales, should be responsible for radioactive waste management policy. The main elements of this responsibility were:

- to ensure that creation of wastes from nuclear activity was minimised;
- to ensure that waste management problems were dealt with before any large nuclear programme was undertaken;
- to ensure that the handling and treatment of waste was carried out with due regard to environmental considerations;
- to secure the programmed disposal of waste accumulated at nuclear sites;
- to ensure that there is adequate research and development on methods of disposal; and
- to secure the disposal of waste in appropriate ways, at appropriate times and in appropriate places.

The Department of the Environment had concentrated initially on four major components: the preparation of a detailed inventory of UK waste accumulations and arisings projected to the year 2000; the identification of options for the management of all wastes with preliminary analysis of the technical feasibility, radiological detriment and costs; the identification of roles and responsibilities in respect of the development and implementation of the technical system; and the specification of a programme of activities and decisions leading to the establishment of the necessary range of disposal routes.

The first two components were currently being carried out with the assistance of waste producers, contractors, the Nuclear Installations Inspectorate and the NRPB; and the third and fourth had been undertaken by the Department of the Environment, said Dr Duncan.

A number of decisions had to be made, in respect of the disposal of low level wastes, other non-heat generating wastes, and heat generating wastes – the highly active liquid wastes arising from spent fuel reprocessing. The disposal routes for this waste were currently being researched – emplacement in a deep geological formation, or emplacement on or under the bed of the deep ocean.

In the UK, the timescale for the disposal of these heat generating wastes was long, and the more pressing problems were those associated with providing disposal facilities for the non-heat generating wastes, including low level wastes. Major decisions concerning the design and construction of facilities for such wastes would have to be taken within the next ten years, with the first in about two years' time.

Peter Saunders, in his paper, made the principal point that waste disposal need no longer be thought of as the Achilles Heel of the industry – as Mr Lamont had said in his opening address.

The nuclear debate

The conference reported here was opened by Mr Norman Lamont, Under-Secretary of State for Energy, who noted that the range of subjects to be dealt with covered every conceivable topic of interest in the nuclear debate.

"It is very important that the nuclear industry should continue to win that debate," he said. "I say 'continue to win' because I believe that so far the nuclear industry has been winning the debate; but the argument is going to continue and intensify, and the public are going to demand more and more efforts to explain why nuclear power is environmentally acceptable, and that it is economic, safe and under good, competent management.

"This Government, as I hope you will agree, has made quite clear its strong commitment to nuclear power, and I can assure you it will continue to do that. But, as I have learned, Ministerial statements and Government information are only a very small factor in maintaining public acceptability. The key and most important factor is in the hands of the industry, and that has a good track record on safety.

"Another important factor in the debate is education, education in the facts of nuclear power. The degree of ignorance in this country about nuclear power is disturbing. There is a lot of mis-information that is being disseminated, and I am sorry to say, believed. I know the industry is working hard to counter this, and I should particularly like to mention that a large number of people in the industry give up their time in talks . . . I know that is making a very considerable impact.

"There are two particular aspects of the presentation of the debate that do bother me. The first is the problem of providing a quick response when sometimes wild allegations are made, sometimes of a pseudo-scientific kind. Members of the public are always impressed by articles by people with lots of initials or people who say they studied physics or were at MIT; and sometimes the most scandalous allegations are made under a cloak of pseudo-respectability.

"I know it is very difficult in these instances to get a quick response out, but I would like to emphasise I know how quickly, on the basis of one article in a quarterly magazine a bowdlerised version of it can circulate and enter the mythology quickly. So one needs a quick response.

"We have to put the arguments in a way in which the public understand them. There is a further way in which both the Government and the industry can increase public confidence in nuclear power, and that is by openness in reporting incidents and decision-making. I know that sometimes the Government's determination to hold to that principle – and we do intend to hold to it – causes some resentment in the industry. I have heard people say that in nuclear sites they are compelled to report to the Government the equivalent of knocking over a can of oil by a workman. I know people feel the burden is onerous and sometimes unnecessary; but I believe this is an important factor in maintaining public confidence. It is good that there has been such openness; the publication of all reported incidents by the Health and Safety Executive every quarter does I believe expose the industry to publicity which no doubt they would rather be without, but it does show how safe nuclear power is. The track record speaks for itself.

"The holding of public inquiries as we are going to do on the PWR is another aspect of our determination that there should be an open debate in this country. I am convinced that this combined effort by Government and the industry to win public acceptability has been one of the reasons why opposition to nuclear power in this country has been largely non-violent, and has been on a much smaller scale than in other countries. Other countries have not been nearly so fortunate; there has been violence, even terrorism, in the anti-nuclear campaign in France, Germany and Spain. It is no coincidence that in this

The need to consider now the options for the ultimate disposal of high level wastes had arisen because of the perception of the long-term nature of the residual hazard this waste presented, and the worry that proper supervision of the waste could not be guaranteed for a sufficient length of time, he said; but it was ironic that such worries should be expressed in the case of high level radioactive waste, and seldom so strongly when thinking about wastes such as those containing arsenic and the like.

The choice between the various disposal options could only be made when current national and international research programmes were complete, and when detailed safety assessments of the various options had been carried out, said Mr Saunders. Even when the information on which a choice could be made was available, a choice need not be made immediately: it had been shown that storage was safe, and the longer the wastes were held in store the easier it became to design a safe repository as their heat production decayed. "One can readily envisage a period of at least 50 to 100 years before any final disposal is carried out, if indeed future generations decide that such an action is necessary.

"The stages of high level waste management preceding final disposal—high level liquid storage, vitrification and storage of the vitrified blocks—can be carried out safely and with no significant impact on the environment or on public health. There appear to be no major technical problems in carrying out these stages. While much detailed work on the disposal option remains to be done, the remaining uncertainties are not such as to affect the conclusion that disposal can be carried out without undue risk to man or to the environment."

Professor J.H. Fremlin, emeritus professor in the Department of Physics at the University of Birmingham, suggested that the industry might make more use in its public statements of the experimental evidence afforded by the "natural reactor" at Oklo, in Gabon: fission products had stayed where they had been created. "I think there is a danger that if you talk about the rates at which activity might [return to man's environment] people think you believe this, against the experimental observations that it won't," he said.

O. Ilari, deputy head of Radiation Protection and Waste Management at the OECD, Paris, remembered participating in many discussions in which opponents of the industry had thrown about statements such as "one gramme of plutonium could kill a million people." He continued: "I would like to suggest we need to use the same type of concept to demonstrate that certain things are not dangerous: to say in other words that a million cubic metres of granite or whatever contains so much radioactivity that it could kill so many people . . . The point in both cases is that one should not forget concepts such as the biological availability of things. The fact that certain things are here or there is not meaningful if you do not attach to it other factors so that you can arrive at a real risk to man." Mr Saunders agreed that parallels with natural activity or naturally toxic substances should be used to put the radioactive waste management problem into perspective, and to counter misleading statements. Certainly, pathway analyses and analyses of biological consequences of any escape of activity would have to be undertaken before any decisions were taken on disposal routes. □

country the threshold of violence has not been crossed, and we must do everything possible to keep it that way."

When we considered the environmental impact of nuclear power we should not under-estimate the problems, said Mr Lamont, but we should keep them in perspective. Standards of environmental acceptability had risen steadily over the years, and would continue to rise. We no longer regarded massive pollution from coal acceptable; it was inevitable that nuclear power should meet very exacting standards, but they must also strike a balance between environmental demands and other costs to society. They must above all keep in perspective the risks from nuclear installations and those resulting from the operation of other plants. "It is no part of the case for nuclear power of course to knock other industries, but the nuclear industry does have the right to be judged by the same standards of risk as other industrial hazards; and that is precisely where the difficulty begins, because although the risks from nuclear energy are very low the consequences in some circumstances could be very serious. Hence, the paramount importance of safety in operation and total management of radioactive wastes."

The degree of regulation to which the nuclear industry was subject was higher than in any other industry, but regulation and inspection was not at the end of the day what nuclear safety depended on. The responsibility for safety and for effective waste management lay on the operator. The interaction between operators and the regulatory bodies led to high standards of design of nuclear plant, and in its operation. The same principle applied equally to radioactive waste management.

"It is often alleged that waste management is the Achilles heel of the nuclear industry," said Mr Lamont. "There may have been a time when that was true, but I don't believe that it is true any longer. In fact, I think we have taken very considerable steps to solve the technical problems of waste management. What we have not done of course is to make the political decision, precisely where waste should be stored on a long-term basis. But the importance of this step is recognised by all the nuclear countries. A tremendous amount of research and development is being done both by Government and by the nuclear industries."

There had been some criticism of the dumping of low-level and some intermediate level waste at sea. "I regard this criticism as quite unjustified," said Mr Lamont. "I know that great care is taken both as regards the characteristics of the waste and the selection of sites. The practice is wholly in accordance with international regulations under the London Dumping Convention. I am confident that the results of international research that is currently being done will support the position of the UK's policy, and we will certainly in Government endeavour to see that this disposal route remains open."

Mr Lamont had "one slight criticism" of the agenda of the conference: there was nothing about the benefits of nuclear power. "Yet the benefits of nuclear power are real; nuclear power is indeed a friend of the earth," he said. "I wonder whether you might not have turned the theme of the conference the other way round and talked about the impact of environmentalism on nuclear power. This is a subject which has not always in all countries had beneficial results. Nuclear power has the right to be judged by common standards with the rest of industry. But opponents of nuclear power single it out. Sometimes I wonder whether it is because they think nuclear power epitomises the industrial society they so dislike. The benefits are ignored, and the environmental impact is much misrepresented.

"The debate on nuclear power is going to go on. It must be based on scientific evidence; it must be based on facts; it must be a debate which takes place with the industry vigorously putting forward its case in public. It is as a contribution to that vital role that the industry has that I particularly welcome this conference."

WHAT FUTURE FOR THE 'BREEDER'?

People do seem to want to have energy; and while the conservation of energy is rapidly becoming a distinct science and one that will greatly moderate energy demand, nevertheless the ambitions of most peoples will result in a total increase in consumption and therefore a need for fission as a major resource. If this is agreed then the breeder is the way to provide the bulk of that fission energy.

By James Daglish

Sir Samuel Curran, FRS, former principal and vice-Chancellor at the University of Strathclyde, reached this conclusion in his overview of a two-day symposium on fast breeder reactors organised by Scientific and Technical Studies (Oyez IBC Ltd) and held at the CEGB conference centre in London in May. Sir Samuel said it was sometimes assumed that the material standard of living was more than adequately high in the advanced countries, and that it was only most of the developing countries which needed to raise their standard of living – though, as other speakers had pointed out, the word "only" here glossed over the fact that the majority of the world's population does live in such countries. Be that as it may, Sir Samuel noted that it was difficult to persuade many in the developed countries that they should decrease their energy consumption markedly. A great deal of progress had been made in eliminating the more obvious methods of wasting energy, and in that sense conservation had already played and would no doubt continue to play an important part.

"We have to remember however that while there have been examples of waste that can be eliminated easily, the major part of the energy consumption in the advanced countries will not be readily reduced. In countries such as the UK and indeed most European countries, for example, space heating is very important for comfortable living and possibly even for health and well-being," Sir Samuel wrote. ". . . There is in fact a relationship between the average consumption *per caput* of energy and life expectation. Admittedly this must vary a good deal between different countries but it does show the broad average required consumption, for a life expectation of between 60 and 70 years, is 2 kilowatts *per caput*. Many peoples in the world are well below this level and while some of them may be able to increase their life expectancy without much consumption, it is more likely that they will need even more than 2 kW each."

Future demand

The conference had opened with a presentation by Jack Moore, formerly Director, Fast Reactor Systems, of the UKAEA at Risley and now Chief Expert of Motor-Columbus Consulting Engineers Inc., Switzerland.* He noted that some perspective of future need could be obtained simply by examining the rate of growth of world populations and the current rates of energy usage in different countries. It was estimated that the total world population would increase by 50 per cent by the year 2000 and by a factor of two – doubling – by the year 2025. Figure 1 here showed that there was a difference of more than a factor of ten in energy usage rates expressed as tonnes of oil equivalent (toe) *per caput* between "the least and the most fortunate nations", and less than a third of the world's population consumed two-thirds of the world's energy.

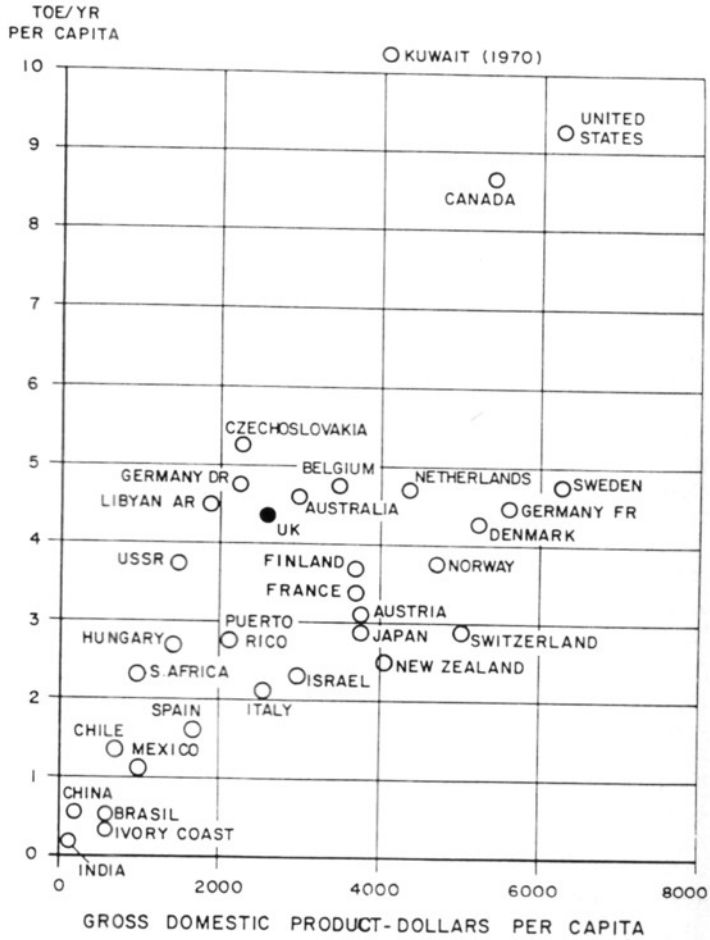


Figure 1 Gross domestic product v. energy consumption, *per caput*

"The underdeveloped countries have the right to aspire to higher standards of living that will increase *per caput* demand for energy," he said. "Allowing for population growth and some levelling of differences in *per caput* energy supplies in different countries a factor of three increase in energy demand by the year 2025 is estimated. On this timescale it is unrealistic to assume oil and gas can still be making a major and increasing contribution and it is clear that other major sources of power additional to coal will be required. The only known and proven 'new' major source is nuclear power, and that will require fast reactors.

"It would be foolish to plan on the assumption that a total solution to the problem could be achieved by a combination of controlling population growth, adoption of energy conservation measures and equitable sharing of available energy

*As Mr Moore said in the introduction to his presentation, "in dealing with a controversial subject like the fast reactor it is clearly of value to obtain an impartial and unbiassed opinion from an uncommitted country like Switzerland."

resources between nations. These measures would require a degree of international collaboration and goodwill and acceptance of constraints by populations that is unrealistic to assume. It would be wrong to deliberately force nations toward a low energy economy by unnecessarily constraining energy supplies. Current international friction stemming from oil supplies in the Middle East should serve as a clear warning that enforced and naturally developing energy shortages can cause friction that could escalate to conflict.

"The problem in the future appears to be one of avoiding such situations by a combination of alternative energy supplies and social pressures to reduce energy demand and population growth rates. The scale of the problem is such that substantial resources should continue to be devoted to development of alternative energy supply and conservation methods as well as continuing with nuclear power in the expectation that developed methods will take their share of the market depending on their economic viability and environmental acceptability.

"A long-term role for nuclear power with fast reactors is quite clear and is only likely to change at some time in the future if some new source, like fusion, is proven to be economically viable, environmentally acceptable and capable of wide-scale exploitation in many countries."

In the succeeding paper Frederic Romig, of the UN Economic Commission for Europe, explored the potential of conservation in 17 countries of the ECE region – the EEC member States, the United States and the USSR, and six other countries of the Comecon group. His paper was a foretaste of the publication of "The Role of Energy Conservation in the Economy", in *The Energy Economy of Europe and North America: Prospects for 1990* [to be published in the Economic Bulletin for Europe, Vol. 33, No. 2, Pergamon Press for the United Nations, Oxford, June 1981]. This study, he said, showed that the most common policy priority in all these countries was energy conservation: to hold down domestic energy demand so that they could export more oil, to raise living standards without using more energy, to reduce high energy consumption by cutting out waste. On the economic side, national forecasts prepared by governments called for high economic growth; but when such forecasts were studied together they appeared "most unrealistic".

"Labour productivity and energy supplies emerged as the main constraints to further long-term economic growth," said Mr Romig. "In particular, without drastic energy saving policies the balance of payments for most countries would rapidly become untenable,"

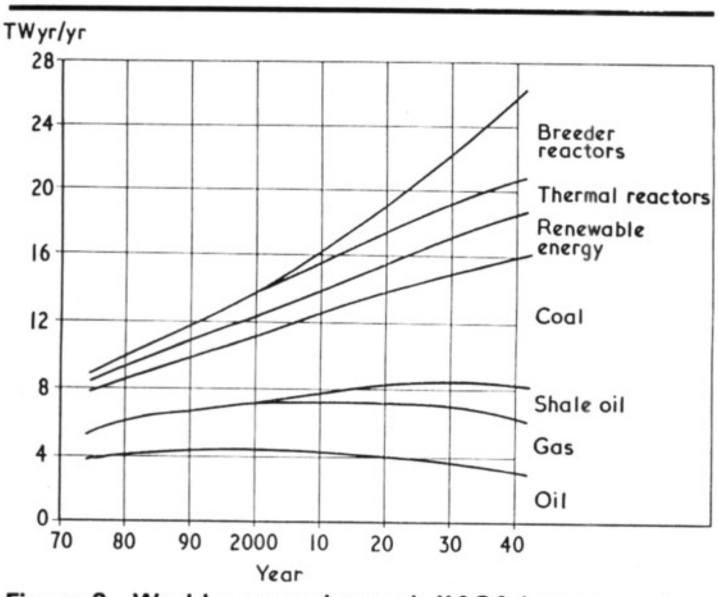


Figure 2 World energy demand, IIASA low scenario

Accelerated economic growth would require a 3 per cent increase from oil exporters each year; oil exporting countries were hardly likely to go along with this. Rapid growth would also cause labour shortages after 1985 because of population trends already in motion, which showed the labour force not growing very much and the growth of the productivity of the labour force slowing down.

To solve these problems, the ECE "consistent" economic forecast pointed to a programme of large investments linked to strong energy saving measures. Despite rising material standards, the "energy conservation forecasts" made by the ECE were about 10 per cent lower than government forecasts by 1990, and by 2000 conservation forecasts were about 20 per cent lower than government forecasts.

Would conservation remove the need for nuclear power, and in particular for the fast reactor? R.W. Orson, of the Electricity Council, acknowledged in the next paper that in essential respects the UK's energy situation was no different from that of other industrialised countries. Although North Sea oil and gas should give the UK considerable benefits while they last, in terms of the country's use of energy the UK would be affected by much the same pressures as the rest of the world. In the medium and long-term two factors were common to both the developing and the developed world's energy situation: first, the need to find replacements for oil and natural gas as main sources of energy, and secondly the increasing cost of energy. These two factors were cited as reasons for nuclear energy providing typically 10 to 15 per cent of world primary fuel supply in 2000. It was very unlikely that either all or a majority of developed and developing countries would choose to forego the use of nuclear energy. If this were to happen, it would have to be by one or two routes or more probably by a combination of both: by containing or reducing demand, or by finding alternative supplies of energy.

"The first of these, to use less energy, is an ideal supported by many people and indeed, up to a point, we can all support the objective of rational energy conservation," Mr Orson wrote. "But this only extends available energy resources: it does not in itself constitute a source of energy."

R.D. Vaughan, of the National Nuclear Corporation Ltd, explored economic factors in the introduction of fast reactors, taking as his starting point the fact that the energy potential of the world's uranium-238, which can only be exploited in fast reactors, is many times greater than the energy to be obtained from all the other fuels we are now using.

The recently-published study by the International Institute for Applied Systems Analysis [*Energy in a Finite World – Paths to a Sustainable Future,* IIASA 1981] put forward two self-consistent scenarios for primary energy production over the next half century. One of these was a high growth scenario constrained only by the ability of fuel suppliers to extract more energy from dwindling resources. The other was a low growth scenario in which the rate of increase in demand for energy was restricted to little more than the growth rate of world population.

In this low growth scenario (shown in Fig. 2) primary energy demand rose at 2 per cent a year to the year 2000, then continued to grow at 1·7 per cent a year. There were two significant changes to the pattern of energy production in about the year 2000. First, solid fuels began to be used for conversion to fluid fuels to make up for the shortfall in oil supplies expected about that time. Secondly, fast breeder reactors began to be installed for electricity production in place of fossil fuels being diverted to other uses. The scenario envisaged worldwide an increase in the primary energy production of breeder reactors from 0·02 terawatts-yr/yr to 3·28 TW yr/yr over the period 2000 to 2030, overtaking the energy supply from thermal reactors.

"In the context of very modest growth in energy demand

and increased contributions from all the other fuels this requirement for fast reactors does not appear out of place," said Mr Vaughan. "But it does, in fact, represent 1 900 gigawatts of reactors installed round the world over a period of 30 years, to produce a quantity of primary energy which is equal to that obtained today from coal. IIASA may have under-estimated the potential growth rate of extraction of coal or the expansion of solar-based energy sources, but by current standards even half this capacity of breeder reactors over 30 years would be a massive installation programme.

"If there is to be any prospect of installing fast breeders at this rate from the year 2000 they must be seen as commercially attractive to utilities (and their governments) in the timescale of the next 20 years' work. The breeder will be expected to generate electricity over the larger part of its working lifetime at a cost as low as that of thermal reactors which, by then, will be the main alternative source of electricity."

The plutonium economy

Prof. F.R. Farmer, FRS, consultant on safety to the UKAEA, presented a synoptic assessment of the safety of fast reactors in terms familiar to ATOM readers. Next, Prof. J.H. Fremlin (University of Birmingham) presented a paper on "the plutonium economy" – quarrelling in his first words with the title of the paper. "The amount of plutonium outside reactors is already much larger than it would be if breeders formed our main nuclear source," he pointed out.

After the complexities of the economic discussion earlier this paper was a delight. Prof. Fremlin looked in turn at sundry hazards arising in a "plutonium economy", from terrorism to proliferation of nuclear weapons.

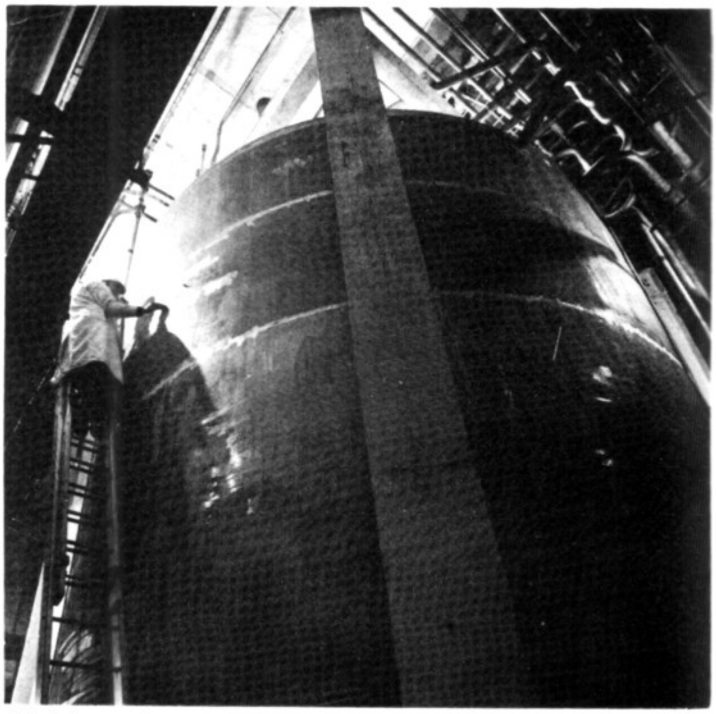
Terrorism, he noted, is the most difficult of all hazards to predict. All he could do was to discuss the probable actual consequences of terrorist behaviour directed against nuclear installations.

"Terrorists do not seem to want to kill very many people at a time," Prof. Fremlin wrote. "This can be reliably deduced from the fact that they very rarely kill even a dozen together. . . . Terrorists want to draw attention to their cause and their real or fancied grievances, and they may want to get rid of particular opponents, but they don't want a whole population to be searching with blood in its collective eye for anyone connected with their cause and demanding that the government should give them some *real* grievances to worry about.

"It would not, therefore, be *sensible* for terrorists to plan a nuclear disaster. Nevertheless we cannot know just how stupid they might be and they *might* try to do so or, more probably, threaten to do so, so it is worth discussing what they could or couldn't do."

It was unlikely but not impossible that terrorists could eliminate power station site and building guards quickly enough and silently enough to reach the control room without warning and shoot the operators before they could "scram" the reactor. Their problems would arise after that. To produce a large-scale release from a power reactor, in the weather conditions required to prevent the hot radioactive gases from going uselessly high and blowing out to sea, might not be absolutely impossible. It was however so obviously likely to kill a lot of terrorists without killing an appreciable number of the public "that one could almost wish they would try."

A more serious possibility was a similar attack on the Windscale plant, with the object of blowing up the water-cooled highly active waste storage tanks. After blowing a hole in such a tank a further bomb might be introduced, though it was not certain that anyone could approach the hole closely enough without disabling his central nervous system by radiation before this was achieved. If it could be achieved a large part of the site would be lethally contaminated, but such an explosion would liberate only a tiny proportion of the contained activity as airborne particles which could travel any great distance from the site and be retained efficiently in the lungs. If the weather were right many people living near the plant might be killed; but fewer than would be killed by an attack on a chlorine store.



Highly-active waste storage tanks are massive

Another possible target for attacks was spent fuel or plutonium nitrate in transit. It would not be difficult to steal a road carrier vehicle, but it would be difficult to avoid subsequent capture; the carrier was incapable of a speed over about 15 mph and was necessarily confined to the road. (Railway wagons are confined to the railway.) A field gun firing a solid steel missile might punch a hole in the 14-inch steel flask and release cooling water or plutonium nitrate solution, but neither of these was volatile and hot spent fuel would take several hours to warm up enough to evaporate any serious amount of activity. Terrorists could not be absolutely certain of failure; but they could be sufficiently sure to look elsewhere for a target.

Spiriting plutonium nitrate away to an undetected destination equipped with major chemical, metallurgical and engineering facilities was at the limits of possibility. "I could continue to detail the difficulty the terrorists would face in building the highly sophisticated structure required to make an effective bomb, out of reactor-grade plutonium of unknown isotopic proportions, without destroying the bomb and themselves in test assemblies. This is unimportant. Britain has a large stock of actual bombs. All we have to do is to use the same transport and escort system for plutonium shipments as we do for finished bombs. No terrorist will face the long delays and uncertain outcome of fresh construction if all this could be avoided and no greater difficulties faced by stealing an actual bomb."

Turning to the risk of proliferation, Prof. Fremlin noted that a country with the necessary chemical and engineering resources could not be prevented from building a plutonium-239 or uranium-235 bomb except by military occupation. A considerable number of countries had already, or soon would have, the required resources. None of the "bomb countries" found any difficulty in obtaining uranium, and we could not count on other countries finding it impossible. The decision whether to build bombs or not was therefore a political one.

"I regard the proliferation of Soviet and American bombs as more dangerous than the spread of bomb capability to new countries, but I accept that we should try not to make this spread more likely," he said. "The question of relevance to this conference is whether this spread, which is what is normally meant by the term proliferation, will be made more or less likely by the building of nuclear power stations for electricity production."

Given all the arguments, there did remain a risk of proliferation. But there was a risk in *not* carrying out the positive part of the Non-Proliferation Treaty, which committed countries such as the UK to supplying non-bomb nations who needed them with nuclear power plants. "If we refuse to do this, and continue ourselves not to disarm – also promised in the Treaty – we are creating a fair excuse and a strong incentive to the other signatories of the NPT to denounce it.

"Recent manoeuvrings round the Middle East by the USA and USSR underline the strains that may develop in the next two decades as the oil runs short. Shortage of world energy supplies could lead to greater dangers than proliferation – especially for us."

The state of the art

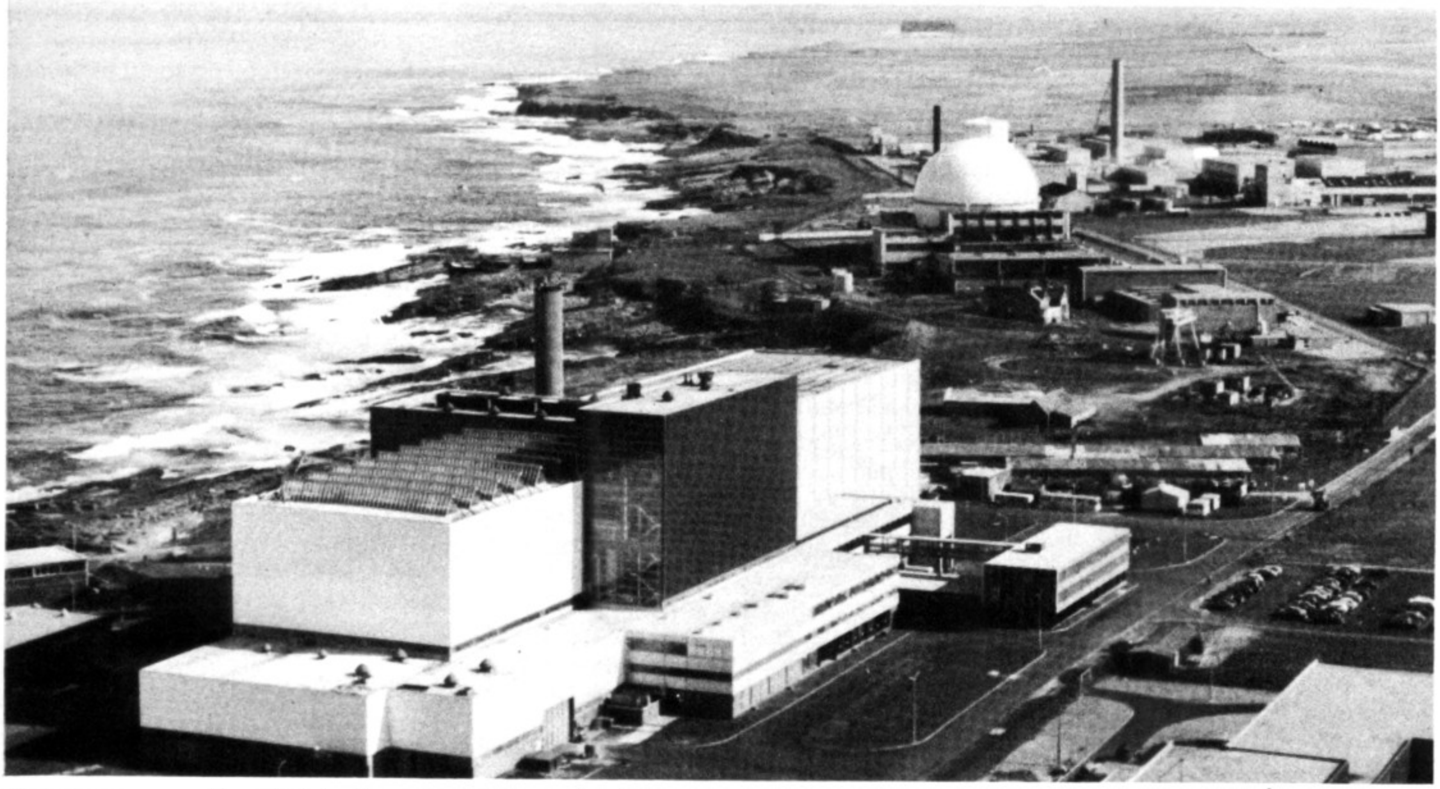
The second day of the conference was given over to reviews of national programmes, world uranium supply and plutonium supply and demand. Clifford Blumfield, Director of the Dounreay Nuclear Power Development Establishment, reminded delegates that the British fast reactor programme originated in far-sighted energy assessments in the late 1940s, which indicated that Britain as an industrial nation would run into difficulties in energy supply by the end of this century. This assessment related not only to conventional energy sources but also to uranium supplies for thermal reactors: the probability that fast reactors could multiply the useful energy from uranium by about a factor of sixty was the reason for looking at the system in detail. It had the promise of providing a major energy source for centuries.

The situation now was that Britain had the technological base for the next stage – the Commercial Demonstration Fast Reactor. The original theoretical concept had been developed in the late 1940s to 1953; the original low-power physics experiments had been made using the Zeus and Zephyr zero energy reactors from 1953 onward and early coolant evaluation and experiments had been done in 1947 to 1955. The Dounreay Fast Reactor (DFR), of 60 megawatts thermal (15 MWe) had been operational from 1959 to 1977, and the Prototype Fast Reactor (PFR), of 600 MWth (250 MWe) had become operational in 1975. The stages from DFR onward, including work on fast reactor fuel fabrication and reprocessing, were vital to the UK's industrial knowledge of fast reactor design.

The PFR design resulted from a conceptual design of a 1 000 MWe fast reactor, the objective being to determine the important factors which needed to be reproduced in the prototype. The major decisions taken from this were that the fuel assemblies should be full size, operate at the conditions of the large reactor and have the correct plutonium/uranium oxide mixture and treatment; and the sodium to water steam generators should be fabricated commercially to give specialised experience to British industry as well as confronting the very high heat transfer technology.

PFR experience had shown that the fuel was excellent, said Mr Blumfield. None of the production fuel had failed; in fact only two failures had occurred, and these had been minor ones in advanced experimental fuel. On the steam generator side, experience on PFR had shown the decision to produce the steam generators commercially to be correct. There had been no large leaks but there had been numerous small ones: all had been at the weld between the steam generator tubes and the massive tube plates. They had been a significant contributor to the electrical output from PFR being about 10 per cent of that anticipated. This should be compared with the operation of the reactor, which had been for 80 per cent of the time since 1975.

Various treatments were being tested to eliminate the problems which had occurred with welds on PFR; the CDFR design avoided the issue by avoiding welds with water on one side and sodium on the other, "I have somewhat laboured this point because this part of the technology had to be faced," Mr Blumfield wrote. "Although it has given us a



The Dounreay site: PFR to the left, DFR to the right

series of major headaches the results are of major benefit to the CDFR design. It certainly could not be achieved by a paper study and to do so by laboratory experiments would be a difficult if not impossible task. We know this from the problem of reproducing in the laboratory each situation after it had occurred on the steam generators."

PFR had been used for experiments designed to test its inherent safety. Fuel had been run with the sodium coolant at boiling point for periods of up to 24 hours without damaging effects – some of this with a blockage across 70 per cent of the flow area. Fuel with deliberately failed cladding had been operated to an additional 1½ per cent burnup without adverse effect.

The PFR had shown that fission product heat could be dissipated by natural convection: it did not need standby systems which had been provided, nor did it have to dissipate the heat to the water heat sink required by other reactors. Experiments indicated that the negative temperature and power coefficients are sufficient to shut down the reactor completely from full power by the time the mean sodium coolant temperature was 600°C. Calculations from the experimental data showed that the reactor would not overheat dangerously even if all sodium coolant pumps failed and the reactor remained at power. The effect of natural circulation of the sodium coolant within a fuel assembly which was blocked had also been calculated. This would dissipate the fission product heat without sodium boiling occurring even with a complete inlet blockage; with a blockage at the outlet the thermal syphon mechanism gave the prospect of removing fission product heat without sodium boiling.

Inside the PFR steam generator cell

Fuel processing for recovery of plutonium and uranium for refabrication was critical for the fast reactor to achieve its promise. Reprocessing of PFR fuel had commenced, and dissolution and separation of residual plutonium and uranium had been very successful. Over a period of time a range of conditions would be covered so that the system could be optimised technically and economically.

"I am certain that fast reactor technology is now far in advance of where thermal reactors were when they were first exploited commercially," said Mr Blumfield. "This is due to the progressive evolution of the programme since the late 1940s. The CDFR design has advanced in concert with the knowledge gained from the PFR. Subject to the public inquiry, which the Government has stated will be set up, the British fast reactor programme could now take a further progressive step by a commitment to build the CDFR. This would provide an insurance against future energy shortage,"

The commonality of thinking between countries with fast reactor programmes was demonstrated in the next paper, presented by J.F. Petit of the French Commissariat à l'Energie Atomique. The French energy situation, he said, in terms of resources and dependence on foreign supplies as well as from the point of view of political uncertainty and financial cost, was such that an extensive programme of electricity generation from nuclear power was a vital need.

The current programme was begun five years ago, and there were now about 18 000 MWe installed and in operation (20 plants), 30 000 MWe under construction and 15 000 MWe ordered. These plants were mainly PWRs; their building should lead in 1990 to a situation in which 70 per cent of electricity in France would come from nuclear power, corresponding roughly to 30 per cent of total energy need. French dependence on foreign supplies would be reduced from 75 per cent (now) to 50 per cent.*

However, in the French context a nuclear strategy based only on thermal reactors such as PWRs was not acceptable: first and mainly because the corresponding uranium needs (1 000 te a year between 1995 and 2000) would exceed French national and foreign resources as early as 1995; and secondly because the large plutonium production would lead rapidly to a difficult problem, either in terms of use if the fuel was reprocessed or in terms of waste if it was not. Fast reactors allowed first the well-known much better use of the energy potential of natural uranium, which could be almost completely burned through plutonium transformation; and the very large amounts of depleted uranium coming from the French enrichment plants could also be used. The problem of resources was thus completely solved. The French strategy was in consequence based on an important development of fast breeder plants, which could produce up to 10 to 15 per cent of nuclear electricity at the end of the century.

As in Britain, the French ambition was supported by a "coherent but cautious" development programme initiated in 1950, and culminating for the present in the 1 200 MWe Super Phénix plant being built at Creys-Malville. Commissioning of this reactor was expected to be at the end of 1983; it would produce electricity at a price comparable to that from a modern conventional plant burning imported coal in French conditions. The Super Phénix design would be used as a reference to be simplified and optimised for Super Phénix II.

At the R&D and at the industrial levels, France and Italy first, then France and the Fed. Rep. of Germany, Belgium and Holland, had signed agreements as a result of which they were engaged in a common venture to develop, realise in their own countries and propose to other countries fast reactors on common designs. A larger involvement with other countries in the future would, in M. Petit's opinion, be of great benefit to all parties.

"If a country like France has obviously no other choice to survive in energy supply during the uncertain 30 or 40 years ahead at least, than developing nuclear energy from thermal and fast reactors in the way that has been indicated, if we scientists and engineers take the technical responsibilities to succeed in realising the equipment programme, it remains that the corresponding short and long term political decisions imply political, financial, technological and public assistance

*The conference took place before the recent French elections.

possibilities to take them and maintain them efficiently during a long period of time," he said. "At the present time we are lucky in France to be in such a favourable situation. Some other friendly democratic countries are not. I do deeply hope their situation will change as soon as possible, because one cannot go alone in the nuclear venture today on a purely single national basis. It is world energy supply and hence the immediate future of the world which is in question."

Dr P.N. Cooper, of the Department of Physics at the University of Aston in Birmingham, noted that like Britain and France the USSR, the Fed. Rep. of Germany, Japan and the USA had had fast reactor programmes for many years. The USSR now had two large-scale prototype reactors in operation, and West Germany and the USA each had one under construction and Japan one in an advanced stage of design, awaiting permission to begin construction. All the prototypes showed marked similarities in core design, with the main differences being in the degree of containment and the design of cooling loops and steam generators. Most rapid progress had been in the USSR, which now had the largest prototype, of 600 MWe, in operation. All the other projects had suffered delays due to political considerations rather than design and constructional problems.

Support for the resource argument for fast reactors came from S.H.U. Bowie, FRS, geological consultant, who noted that it was not always recognised that it was the availability of uranium on an annual basis that mattered—not reserves or resources in the ground. On the evidence, it was unlikely that much more than 100 000 tonnes of uranium could be produced annually from known reserves. To add substantial tonnages to reserves would mean active prospecting, but this was already on the wane as a result of the fall in the spot market price of uranium from $115/kg U in 1979 to $66/kg U in 1981. A lead time of 10 to 15 years was necessary to prospect for, prove and bring a major deposit into production; considerable foresight and continuity of effort was necessary to avoid any future uranium shortage.

The historic rate of discovery of uranium since 1945 had been about 65 000 te U a year. Nearly five times that amount would need to be added to reserves annually to support middle-of-the-field requirement predictions for the years 2000 to 2025. Many of the uranium ore bodies with surface indications had already been discovered in accessible parts of the earth, and only a greatly increased search could be expected to increase the discovery rate to 100 000 te U/yr. It was doubtful if this could be maintained for long.

"It would seem prudent in the circumstances to give urgent consideration to the early introduction of fast reactors and at the same time to maintain or increase prospecting effort," he said. "In addition, there is a need for more R&D into new exploration methods, particularly those capable of detecting hidden ore bodies, and into methods of recognising uranium provinces in which new deposits are likely to occur. The need to utilise presently estimated resources efficiently would appear to be more apposite than to consider resorting to lower and lower grade uranium sources with all the problems that would entail."

Professor S.E. Hunt, of the University of Aston in Birmingham, argued in the following paper that there was an incentive in the long-term interest of the global nuclear power programme to commit plutonium reserves to fast breeders as soon as this could be done. However, the fuel doubling time of the liquid-metal cooled fast reactor was disappointingly long, between 25 and 30 years on current designs. In a system consisting entirely of fast breeders this would limit the rate of growth of the system, and there was therefore a need to supplement the plutonium inventory by auxiliary supplies which could come from a continued thermal programme—preferably based on reactors having a high uranium to plutonium conversion ratio, such as CANDU or Magnox. Professor A.A. Harms, of McMaster University, Hamilton, Canada, discussed further the alternative of incorporating non-fission processes such as the accelerator breeder and the fusion breeder to supplement plutonium supplies.

The Phénix reactor at Marcoule

Overview

In his concluding paper Sir Samuel Curran noted that the physicist, following the simple logic of the science of energy release from the nucleus, would adopt the breeder if there were no substantial arguments against this choice. "Simple scientific logic is however in no way enough these days, because while it might seem sensible to have 50 or 60 times as much energy from each ton of uranium that is mined, if the environmental, safety and various other factors are less satisfactory in a breeding system than in a thermal one then it is unlikely that breeding will be accepted," he acknowledged.

"... It is clearly good housekeeping, in the proper sense of that word, to mine the minimum amount of radioactive ore. Clearly it is likewise sound sense to consume it as completely as possible and maybe even more important to continue to consume one of the major by-products, namely plutonium-239. The breeder can be regarded as a consumer of plutonium, an excellent fuel which is also a by-product. The breeder machine can be used as the means of keeping the amount of plutonium available in the various countries with notable nuclear programmes at a near constant level. The breeder could of course reduce the amount of plutonium to any desired level. In a completely thermal reactor programme the amount of plutonium continues to increase in accordance with the scale of energy production.

"In spite of what has been said, it has been stated that the breeder is an integral part of what is called 'the plutonium era'. It is almost implied that the plutonium era is something to be greatly avoided and refusal to use the breeder can prevent the plutonium era. In fact, as I have stressed, the thermal reactor is the plutonium maker and already thermal reactors have been the main instruments used to produce tons of plutonium for huge stockpiles of nuclear weapons. One would hope that in due course plutonium would be readily burned in breeder reactors and so contribute to the peaceful use of fission energy." □

Monopolies report "fair and constructive" — CEGB

The Monopolies and Mergers Commission report on the Central Electricity Generating Board's efficiency and costs was "fair and constructive," the CEGB said in a statement issued on the day of publication — 20 May.

"The report is thorough, fair and constructive and the Board is giving detailed consideration to its comments and criticisms," the statement said. "This independent management audit acknowledges that the Board is well organised, operates the electricity system efficiently, and keeps its costs under effective control. It confirms that there are no easy or obvious ways of holding down electricity prices.

"The Commission has generally endorsed the Board's measures for improving performance in the construction of power stations and has made constructive suggestions for further improvements. The Commission has also endorsed the Board's approach to its relations with the National Nuclear Corporation.

"The Commission is critical of the Board's contribution to the electricity supply industry's forecasts of electricity demand, but notes that techniques have already been improved. There is substantial criticism of some of the assumptions used in the Board's investment appraisals of new power stations and the way the results are presented. These involve difficult areas of judgment. The Board takes this criticism very seriously and is seeking outside advice on possible improvements.

"The Commission seems to be laying more emphasis on the need for appraisals to reflect past performance than on the possibilities for doing better in the future. There is, however, a risk that if too pessimistic a view is taken of the time and cost of constructing new plant and of its operating performance, this will become self-fulfilling.

"The Commission also suggests that the Board is proposing a large nuclear programme on the basis of its investment appraisals, and that this would be against the public interest. However, in December 1979 the Secretary of State for Energy made it clear that the current commitment is to one AGR and one PWR power station only, and that the precise level of future orders would depend upon the development of electricity demand and the performance of the nuclear construction industry. Every additional station would be subject to the specific approval of the Board and the Secretary of State for Energy at the appropriate time."

The statement noted that the Commission's comments would assist in the review which the Electricity Council with the CEGB was already undertaking with respect to bulk supply tariffs; a report on this would be made to the Secretary of State. The Commission had also raised important issues about the extent to which it was right for the CEGB to continue to support British suppliers of fuel and plant, but that it recognised that there were limitations to what the Board could do. The CEGB hoped that the discussions that would no doubt follow with Government on these matters would take full account of the need to protect electricity consumers' interests, now and in the future.

Mr David Howell, Secretary of State for Energy, welcomed the Commission's report; it was, he said, "a helpful study of the Board's performance." The Commission had made a number of recommendations for action by the CEGB on which he was seeking the Board's early comments.

Mr Howell continued: "The Commission criticises the Board's investment appraisals, with particular reference to nuclear power station projects. As I made clear in my statement on nuclear power policy on 18 December 1979, while the orders to which I referred offered a reasonable prospect against which the nuclear and power plant industries could plan, the precise level of ordering would depend on the development of electricity demand and the performance of the industry. Within this general framework the Board will appraise each project case by case. I shall expect the Board to take full account in

The recommendations

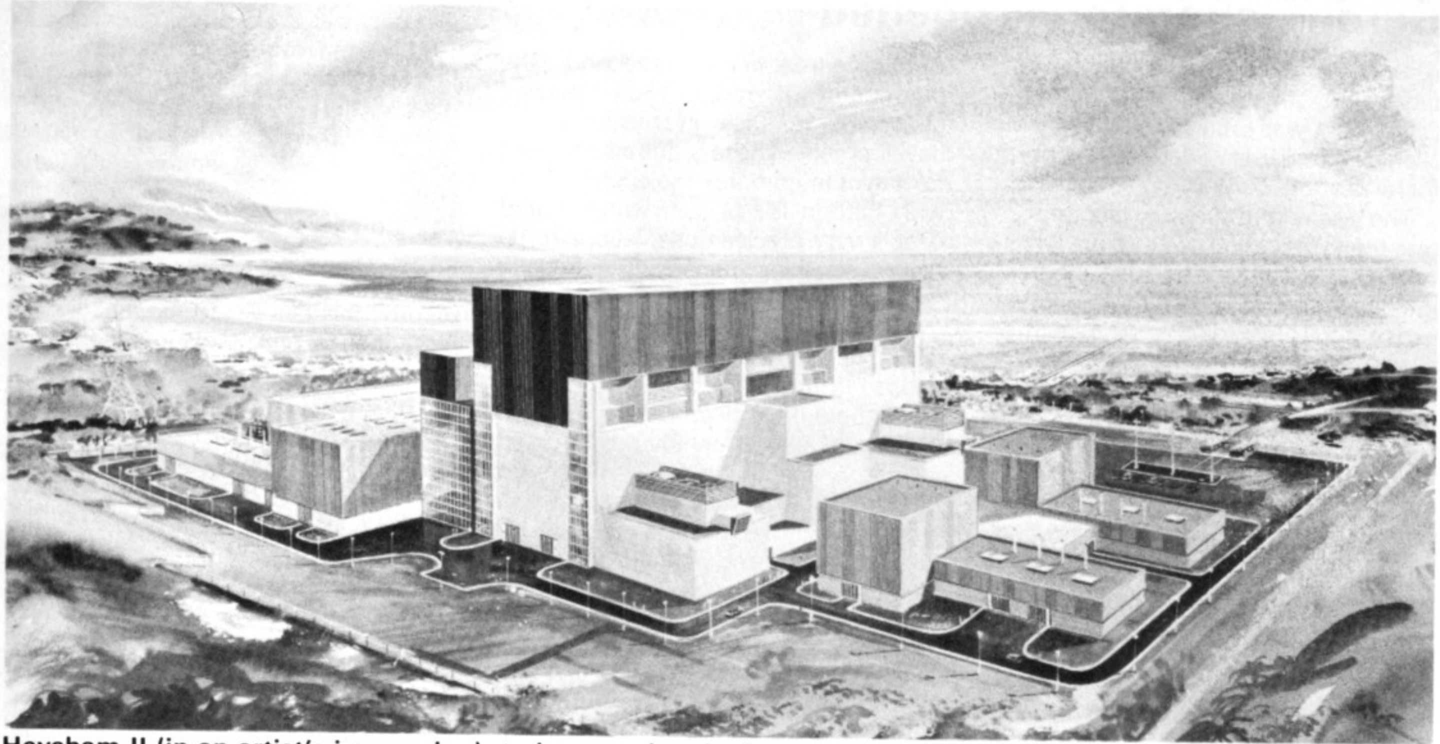
The Monopolies and Mergers Commission were required under their terms of reference to investigate and report on the question whether, in operating the bulk generation and supply system, the CEGB could without reducing the standard of service provided improve its efficiency so as to be able to reduce its costs or to mitigate the effect of any increases in its costs; and whether the Board was pursuing a course of conduct which operated against the public interest.

In its conclusions the Commission noted that coal has always been the CEGB's principal fuel. "It is natural that the Board should seek alternative fuels," the Commission said. "In the past this consideration has prompted the CEGB to build oil-fired stations; and now that the price of oil has risen above that of coal, the CEGB wishes to embark on a programme of nuclear power stations, as much for the sake of diversification of fuel supply as in the belief that early stations in the programme will generate power more cheaply than coal-fired stations. However, it is necessary to guard against the danger that the present coal price policy may make nuclear power appear to offer an economic advantage which it might not have if coal were priced at long-run marginal cost . . .

". . . In respect of its purchasing policies we feel bound to conclude that the Board could have had lower costs in recent years if it had been free to pursue the objective of cost reduction by every means available. First, the Board has not imported as much coal as it could have done at prices lower than it was paying for NCB coal; and it has not entered into long-term contracts for coal imports. At times the Board has been prevented from importing coal; and the knowledge that such restrictions might be imposed again has naturally affected its approach to planning for imports.

"The Board has also pursued a 'Buy British' policy in its procurement of plant. With only small exceptions it has placed its orders with the home industry, in the belief that it was in its own long-term interest to do so. If the Board is to build a number of stations with pressurised water reactors, it may be another matter, since specialised facilities for the building of components of the 'nuclear island' of a PWR station already exist in other countries. The investment necessary for establishment of such facilities in the UK would be likely to make British components more expensive than imported components. If it is to be Government policy that a British capability for building such components be established, it does not follow that this should be done at the expense of the electricity supply industry and its customers.

"Another reason why the Board's costs are not now, and are unlikely to be in the future, as low as they could be is that twice in the past decade, at the Government's request, the Board has ordered a power station 'in advance of need', namely Ince B and Drax completion. The facts show that a power station ordered in such circumstances is unusually expensive. Ince B was estimated to cost £110 per kilowatt, substantially more than Grain (£70) before and Littlebrook D (£91) after it; and tenders for Drax completion, at £342 per kilowatt, were substantially higher than had been expected. In each case the Government agreed to pay com-



Heysham II (in an artist's impression): to be completed advance of need?

their appraisals of the improvements recommended by the Commission.

"I remain convinced that in an uncertain world it is right to seek to secure this country's future energy supplies, and that continuing nuclear power station orders are required for this purpose."

Mr Howell noted the Commission's recommendations in connection with the calculation of demand charges in the CEGB Bulk Supply Tariff, and the Commission's suggestion that the industry's financial target, if it were to be achieved in present circumstances, would result in prices somewhat higher than those contemplated in the industry's current plans. Since the target had been agreed in January 1980 circumstances had changed, including reductions in electricity demand. The implication of these changes were already under discussion with the Electricity Council. Mr Howell said he was glad to note that the report commended a number of aspects of the Board's operations, and that the Commission paid tribute to the ability and dedication of many of those whom they met in the course of their investigation, and to their consciousness of the need to supply electricity at the lowest cost attainable with the present system. □

pensation to the Board for incurring capital charges earlier than necessary. It is already clear that the compensation for Drax completion, which is limited to £50 million, will fall far short of the additional costs which arise from bringing forward by several years a capital expenditure of at least £886 million. These additional costs are and will be reflected in the Bulk Supply Tariff, raising the cost to electricity users. We note that the same concern for keeping plant suppliers in work with a view to a future programme is a factor in ordering Heysham II 'in advance of need'.

"It is not for us to express any view about the justification of the policies mentioned . . . and we must not be understood to be doing so. We simply conclude from the foregoing that the Board's procurement costs could have been lower. This arises not from lack of efficiency in use of its existing resources, but from concern on its own or the Government's part for the interests of major suppliers. In these cirumstances we do not conclude that in these respects the Board has been pursuing a course of conduct which operates against the public interest."

The Commission said they had been called upon particularly to examine the planning and appraisal of new investment, and the Board's ability to carry out its proposals for such investment within the cost and time estimated. "Under the first part of this heading, while we find that the Board's demand forecasting has improved, we consider that there are serious weaknesses in its investment appraisal. In particular a large programme of investment in nuclear power stations, which would greatly increase the capital employed for a given level of output, is proposed on the basis of investment appraisals which are seriously defective and liable to mislead. We conclude that the Board's course of conduct in this regard operates against the public interest . . .

"Although in reaching our overall finding we have been critical of the Board in certain respects, we wish also to record that in the course of our investigation we were impressed with the evident ability and dedication to their work of many of those whom we met. They take a justifiable pride in the technical efficiency and security of the Board's system; and they are fully concious of the need to supply electricity at the lowest cost obtainable with the existing system. We hope that our recommendations represent a constructive attempt to assist the Board in its task, and that a programme for their implementation will be devised as a matter of urgency.

"However, we have to stress that, even if our recommendations are fully implemented, they offer no early prospect of comfort to the CEGB's customers by way of real price reductions, especially while all fuels are becoming dearer. In this connection, we note that even on the basis of its own latest forecasts, which we believe in some respects to be optimistic, the Board expects the cost of production of electricity to rise in real terms over the next 15 years by 0·77 p/kWh (28 per cent). The proposed investment in nuclear power is not expected to halt the rise in real costs until the late 90s. Since a substantial element of the increased costs up to that time relate to the capital charges of the investment programme itself, this serves to underline the overwhelming importance of the need for the Board to improve its investment appraisal."

The full report—in which there are many other recommendations and conclusions—is available as House of Commons paper 315 from HMSO, price £9·30. ISBN 0 10 231581 7. □

Cardiff laboratories opened

Amersham International's new 30-acre factory site at Cardiff, costing nearly £20 million, was officially opened by Mr Nicholas Edwards, Secretary of State for Wales, on 27 May.

The opening of the new laboratories was the culmination of a project which began in 1973 when it became apparent that the growth of what was then known as The Radiochemical Centre, based at Amersham, would outstrip the resources available on and around the original site. The search for a second site ended in 1974 at Forest Farm, Cardiff, 150 miles away from Amersham on the northern outskirts of Cardiff proper and adjacent to an interchange with the M4 motorway giving good communications with the parent site and with London Heathrow airport—from which company products are flown out nightly to customers all over the world.

It had been decided early on that the new site would accommodate two important technical functions of the company on an integrated complex having its own engineering, personnel, finance and administration services. The bias was to be toward scientific operation, to the highest standards of safety and engineering appropriate to the coming decade. Design work to a careful brief provided by the company began immediately, and a planning application for 210 000 square feet of buildings, which would double the technical space available to the company, was made to the Cardiff City Council in 1974. A public inquiry into the application was held in July 1975, and the Secretary of State's decision to approve the development was announced early in 1976.

Development of the site was planned and carried out in two phases: the first included the engineering services building, the power house and security lodge, and the second, larger phase included the two-storey laboratories housing development, production and quality control, and the offices. The first phase commenced building in August 1976 and was completed in November 1977, and the building of the laboratories and offices was completed toward the end of 1980. The total capital cost was £19·5 million, offset in part by £3·5 million of development grants.

Two important technical operations are carried out at the new laboratories. The first is the production of radioimmunoassay kits—clinical reagents used in hospitals and clinics to assist in the diagnosis of illness, to monitor the health of mother and child during pregnancy, or to measure the efficiency of drug treatment. The second is the production of radioactively labelled chemicals for use in research and development. These products are used to 'tag' the complex molecules of life with carbon-14, or with tritium, and enable very precise observations to be made of their behaviour in living systems.

Recruitment of staff to handle the work of the new laboratories was phased from 1977 onwards: more than 300 people have been employed from the Cardiff area, supplementing trained laboratory staff who transferred from Amersham to begin the radioactive work. Locally recruited staff were introduced to the company's work in a comprehensive training scheme which involved, in some instances, training at the Amersham site for long periods. Amersham International are confident that the expansion of the Cardiff site to its full potential of four laboratories and a staff of 1 000 will be readily achievable.

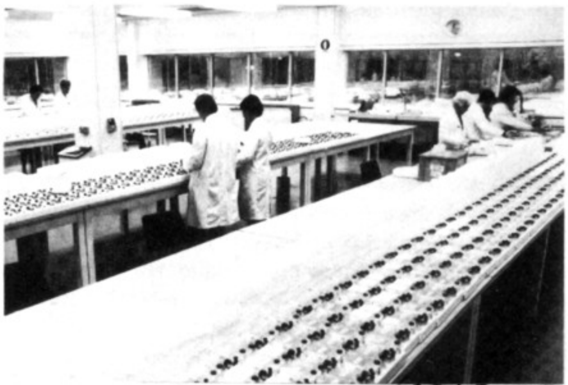
Dr J. Stuart Burgess, managing director of Amersham International, expects that the company's existing production capacity should double by the end of the decade. "Despatching and packaging thousands of labelled compounds and diagnostic aids to all over the world requires meticulous organisation, and it is often complicated by the presence of short-lived radioisotopes with an activity of only hours or a few days," he said. "Currently the company employs some 2 000 people—1 500 in the UK and 500 overseas. We hold a major share of the radioisotope market in the UK, as well as over 50 per cent of the market in western Europe, Africa and Asia including Japan, as well as 30 per cent of the North American market. Since we became a separate company in 1971 we have been consistently profitable: our turnover for the year to March 1981 is expected to reach around £50 million, as against £41·5 million for 1979-80, and sales are expected to double by the mid-80s.

"About 8 per cent of Amersham International's total income will continue to be spent on R&D. In the last 12 months this has led to the addition of more than 50 new items to the existing catalogue of more than 2 000.

"New products in the medical research fields include a new Amerlex kit for the radioimmunoassay of thyroid conditions and a range of high specific activity phosphorus-32 labelled nucleotides used in molecular biology and cancer research. On the industrial side, our activities have ranged from the development of low-energy neutron and gamma sources for oil-well 'logging', for which we have recently received an £85 000 order from China, to a new static eliminator for the paper printing and packaging industries."

Further information may be obtained from Alan Youd, Secretary, Amersham International Ltd, Amersham, Bucks HP7 9LL. Tel. Little Chalfont (02404) 4444.

Pictured: **The new Cardiff laboratories and (inset) the assembly of clinical assay kits.**



BOOKBRIEFS

Problems of nuclear science and technology

By A.M. Petrosyants. *Pergamon Press, December 1980; 400 pp; £23. ISBN 0 08 025462 4.*

Petrosyants is the Chairman of the USSR State Commission for the Utilisation of Atomic Energy; this is the fourth edition but only the second in English that the reviewer is aware of of his standard work. (The first in English appeared as 'From scientific search to atomic industry' in 1975, under the imprint of the American Interstate publishing company.) It deserves a wide circulation for the insight it gives into the Russian civil nuclear programme; it is especially interesting to see his treatment of radioactive waste disposal:

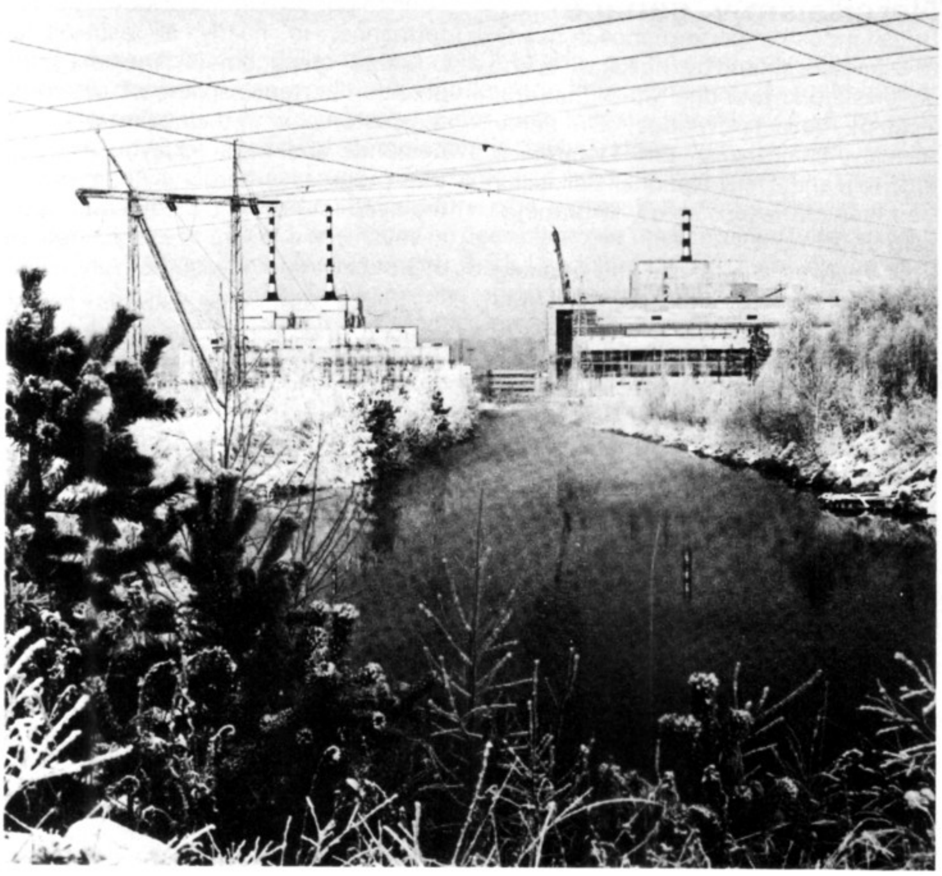
> "The problems of radioactive waste disposal, treatment and burial disturb many people, especially those not very well acquainted with the whole complex of technological processes of this type of production . . . A great deal of work has been undertaken in the Soviet Union and in other countries to investigate methods of burial, including deep underground burial of medium- and low-activity wastes, and quite a number of reliable, safe and economic methods of burying low and medium radioactive waste have been found.

However,

> ". . . it is not so easy to find regions which meet all the requirements for the reliable burial of highly-active wastes."

The Soviet Union is planning a considerable expansion of nuclear electricity generation, including the use of fast reactors. Here, though Petrosyants assures the reader that the USSR and its allies are in no way dependent on the West for uranium, "the problem of the rational utilisation of uranium is becoming very important, and the future development of nuclear power generation is changing into the very big problem of providing nuclear fuel for the nuclear power stations under construction." At some stage in the development of nuclear power generation, "fast neutron reactors in proportion to the assimilation and accumulation in sufficient quantity of plutonium will replace thermal neutron reactors." Petrosyants adds that higher breeding ratios than those achieved in the West will be required. "Without the accelerated development and assimilation of fast neutron reactors the intensive development of nuclear power generation will be impossible to achieve."

All in all, this book is essential reading for all those interested in what is happening on the other side of the fence. *JD*



BN-600, the 600 MWe fast reactor station at Beloyarsk which came into operation in 1980. The two units to the left are early graphite-water reactors at the Urals site

Nuclear Reactor Engineering

Van Nostrand Reinhold, February 1981; 805 pp; £29·65 (cloth). ISBN 0 442 20057 9.

Previous editions of this work by Samuel Glasstone, now in its third incarnation (with Alexander Sesonke), have served as an invaluable ready reference for almost literally generations of students, as well as hard-pressed engineers. His *Sourcebook on Atomic Energy*, first published in 1950, was a pioneering venture; Dr Glasstone was awarded the Worcester Reed Warner medal of the American Society of Mechanical Engineers in 1959 for his "outstanding contribution to permanent engineering literature in . . . writings on atomic energy". "Glasstone" is still a standard. In this edition, the scope is widened beyond the familiar treatment of reactor theory to include discussion of reactor safety, and of the environmental effects of nuclear power. Regrettably, the emphasis throughout remains on light-water reactors; but given the imminence of the public inquiry into the CEGB's proposed PWR at Sizewell this may be no bad thing. *JD*

Radioisotope Laboratory Techniques

By R.A. Faires and G.G.J. Boswell. *Butterworths, January 1981; 360 pp; £15. ISBN 0 408 70940 5.*

The fourth edition of this practical text contains "all a radioisotope worker needs to know about the design of experiments, safe handling, preparation for counting and measurement of radioisotopes, and current safety legislation", according to the blurb. The book is indeed a straightforward guide to modern radioisotope laboratory techniques, in four main sections: the basic physics of radioactivity; health physics, safety and legislation; the measurement of radioisotopes; and laboratory and industrial applications. The authors — retired leader of the Isotope Group at AERE Harwell, and senior lecturer in radiochemistry at the University of Salford, respectively — have an impeccable pedigree. □

Narcissism v. service

British industrial performance in nearly all aspects is limited by the failure to apply existing knowledge rather than the lack of new knowledge, Dr Percy Allaway, chairman of EMI Electronics Ltd, told the Third National Reliability Conference, *Reliability '81*, in Birmingham on 29 April.

Dr Allaway was giving the opening address at the conference, which was organised and sponsored by the UKAEA National Centre of Systems Reliability and the Institute of Quality Assurance. He said there was a risk that reliability practitioners could become narcissistic from the admiration of their own expertise. Those with expertise and insight into quality assurance principles should not be set aside as a service to line management, but should be part of it.

He told the 310 delegates from all over the world that in early attempts to maintain product standards inspectorates had deliberately been made independent of other corporate functions such as design, development and production. It was believed that this would favour the objectivity and integrity of the inspectorate. In due course the superior concept of QA took pride of place but in many organisations it retained the same independence and the same isolation.

Was this isolation "progressive" or did practitioners increasingly get satisfaction from the admiration of their own expertise, asked Dr Allaway. The conference alone would add some 60 learned papers to the record; but what relevance had it to the real cut and thrust of business? If QA experts were doing their jobs properly the conference would be crowded with managing directors, general managers, finance managers, production managers and sales managers. There was a great deal of education to be imparted.

Dr Allaway recalled that during his apprenticeship in the 1930s British was best and Japanese was rubbish. What a transformation has taken place.

"As a matter of deliberate national policy the Japanese have taken themselves from the bottom of the quality league to the top," he said. "Their trading performance and standard of living has been similarly transformed.

"Japan provides the living proof that a nation can, if it so desires, transform the quality standards of its manufacturing industry and that the transformation is primarily a management transformation, requiring management at all levels to become knowledgeable about and committed to the necessary disciplines. If you examine the limitations to our own national industrial performance, in nearly all aspects of business management, including the oh so important aspects of providing the customer with the quality which he demands and pays for, you will find that progress is hardly ever limited by the need for new knowledge but nearly always by the failure to make effective use of existing knowledge."

Quality assurance experts should change their practices and monitor regularly and systematically their own progress in bringing about the on-line application of existing knowledge. If they did not attend to this matter, who would? "Why not start by testing the material which will be presented at this conference from the 'can we use it on-line?' viewpoint," he concluded.

The opening address was followed by two invited papers: *Warships—the drive for availability*, written by Rear-Admiral J.C. Warsop but given by Commodore H.L. Thompson, and *The Targets for Safety—the CEGB policy*, by Roy Matthews, CEGB Director of Health and Safety.

The conference takes place every two years and attracts papers and delegates from all over the world. Papers were arranged in three parallel sessions over three days and included two special tutorial sessions on hazard assessment and Bayesian methods. Dr N.L. Franklin, Managing Director of the National Nuclear Corporation, was the speaker at the conference dinner, and spoke of British experience in the field of uranium enrichment.

A.J. Bourne, chairman of the organising committee and Reliability Technology Manager at the National Centre of Systems Reliability, said after the conference: "From a technical point of view the conference was an outstanding success with a very high standard of papers and discussion. Many delegates, including those from overseas who attend conferences such as *Reliability '81* all over the world, made a point of telling us that they thought it was the best they had ever attended.

"We were also very pleased to be able to attract well over 300 delegates to a three-day conference at a time when registrations are suffering badly as a result of the economic climate. It shows what importance companies are now attaching to reliability and it is great encouragement as we begin to think about *Reliability '83*."

The proceedings of the conference have been published and are available in two volumes from the Institute of Quality Assurance, 54 Princes Gate, Exhibition Road, London SW7, price £35.

PC

SGHWR beats own reliability record

The Steam Generating Heavy Water Reactor (SGHWR) at Winfrith, Dorset, was shut down for its annual overhaul on 8 May following the most productive winter operating programme of its 13-year history. Since it resumed generation in August last year after the 1980 overhaul it had operated with an average load factor of over 98 per cent.

"It's running better than ever, and its performance must rate among the best in the country," said Mr Bert Negus, operations manager. "It has been generating electricity almost continuously for 6 000 hours. This speaks volumes about the reliability of the engineering: if you tried to run a car for that long at just 30 mph it would travel 180 000 miles and probably need a new engine."

During the two-month summer shut down the plant was to be refuelled and given a complete inspection and overhaul. SGHWR is the only electricity generating water reactor in the UK. Producing 100 megawatts of electricity—enough for a town about the size of Salisbury or Gloucester—it is comparatively small by power station standards, having been built as a development prototype in the early 60s. It exports electricity to the national grid regularly during the high demand winter months and makes a substantial financial contribution toward the running costs of the Winfrith Atomic Energy Establishment.

Members of the public should be able to visit the power station in operation during the forthcoming Winfrith Reactor open days planned for 19, 20, 26 and 27 September. Similar open days last year attracted more than 3 000 people. ☐

Landfill gas

Most of the 40 million tonnes of domestic and commercial refuse generated in Britain each year goes to landfill disposal sites. There, the organic fraction of the refuse decomposes to a leachate of fatty acids—soluble compounds which can subsequently pollute water supplies. The fatty acids can however further decompose to carbon dioxide and methane; and the methane is potentially a very valuable energy resource. Theoretically, 40 million tonnes of rubbish could yield 8 000 million cubic metres of methane, the equivalent of 8·6 million tonnes of coal which at 25p per therm costs £710 million.

The Environmental Safety Group at Harwell has been concerned for some years with the disposal of a wide range of waste (non-radioactive) materials, and has included in its work an extensive programme aimed at controlling the fermentation of refuse to form methane and carbon dioxide. At present most landfill sites have a very polluting leachate and produce methane slowly. However, the tendency is for these sites to be very large (about 10 million m^3), and there is obvious scope for gas production and use. The main aims of the work of the Environmental Safety Group are to accelerate the reaction, possibly to completion in less than ten years, and in so doing to stimulate the production of methane rather than the fatty acids.

There are many important implications. Faster and more predictable rates of gas production would favour collection and use, which in turn would minimise the environmental problems associated with the migration of gas away from landfills, for example into adjacent houses; collection of the gas would reduce odour; an improvement in leachate quality would minimise water pollution; the acceleration of the process, to completion in years rather than decades, would enable early reclamation of land for building or agriculture; and the temperature of a bioreactive landfill rises to about 45°C, and it may be possible to use the contained heat directly.

In May, London Brick Landfill, a subsidiary of the London Brick Company, started up the first plant in the country to run on gas from domestic wastes. LBC digs out local clay deposits at Stewartby, Bedfordshire, to supply its brick kilns and fills the resulting large holes with domestic refuse from London boroughs—some 1 100 tonnes a day are compacted in the holes—with the eventual aim of restoring the land. The important difference between this and other landfill operations is that here pipes have been inserted into what amounts to a gas reservoir, and the gas is drawn off by suction; a network of pipes laid over the landfill channels gas from anywhere on the site to burners inside the kiln. The gas, which contains more than 50 per cent methane by volume, is burned untreated, replacing some of the coal which would otherwise be used.

The cost of the project has been shared by London Brick Landfill and the Department of Energy's Technology Support Unit (ETSU) and the work has been carried out in collaboration with the Environmental Safety Group. The hope is that the plant will save the cost of hundreds of thousands of tonnes of low-grade coal by contributing about 20 per cent of the company's needs at Stewartby. *Lynne Garne*

The politics of health and safety

Decision-making on health and safety issues should not be taken by the 'experts' alone. In one way or another the people involved in the operation, those who bear the risks and share the benefits, must also be involved, said Mr John Locke, Director of the Health and Safety Executive (HSE) in London on 15 May.

Such a process is more complex, less certain in its results and more protracted, but simple reliance on expert authority—however prestigious—is less and less certain to carry acceptance, he said.

Mr Locke was delivering the Alexander Redgrave Memorial Lecture at the Royal Institution on the theme 'The Politics of Health and Safety'. He said that decision-making based solely upon the judgement of a group of experts or on a quasi-judicial process is to assume that there is a single right answer: that any differences of opinion as to what should be done arise from ignorance or misunderstanding or a failure correctly to interpret the facts, and will be resolved by the logic of the expert.

The real situation, he maintained, is quite different. Decision-taking in health and safety should be a two-stage operation: firstly, by making an analysis of the nature and scale of the potential hazard and the means and cost of reducing the chances of anyone being hurt and reducing the number of people at risk—a task for the experts, and secondly, deciding whether the risk is one to be taken, or whether resources should be used to reduce the hazard or whether, in extreme cases, the operation should be abandoned altogether.

"Unless the experts have concluded that, to a high degree of certainty, there is no risk at all involved, then this second stage must be gone through. These decisions too can be left to the experts—and often are. The experts may well have a special contribution to make because of their understanding of the nature of the hazard. But, in my view, they should not take such decisions alone.

"One way or another the people involved in the operation, those who bear the risks, and those who share the benefits, must also be involved. The differences in 'interest' must be identified, acknowledged and reconciled. That process is the real politics of health and safety".

Mr Locke explained that the Health and Safety Commission (HSC) was composed of representatives of the main interests concerned with health and safety and welfare issues, and its structure reflected a particular view of how to handle the politics of health and safety. Employers and trade unions represented obvious interests. Local authorities were included not because they are large employers not affiliated to the CBI, nor because they were enforcement authorities for substantial parts of the legislation, but because, better than anyone else, they represented the general interests of society, particularly where work activities impinge on the general public.

Mr Locke said the Health and Safety Executive acted as the expert adviser of the Health and Safety Commission, assessing the scale of any problem such as appraisals of toxic chemicals or hazardous installations. "It forms part of the system of expert appraisal which is the pre-condition of sensible decision taking."

In addition, the health and safety inspectorates, which form part of the HSE, and who are "traditionally the defender of those too weak to defend themselves", must ensure that proper regard is paid, were necessary, to the interests of workers, members of the general public and firms.

"If today our role is less of a crusade and more of a negotiation with other interests—then that points perhaps to the current state of the politics of health and safety".

Elsewhere in his lecture, Mr Locke examined the role in health and safety of the overtly political institutions—the parties, Parliament, Ministers, concluding that party politics do not "as a rule" cut deeply into health and safety issues.

Mr Locke also spoke of the efforts being made to achieve common EEC standards on a number of health and safety issues. "Personally I believe in common EEC standards. But they must be common standards of enforcement as well as statements of objectives", he said. □

Microwave energy in nuclear processing

Work at AERE Harwell on the application of microwave energy in the nuclear fuel cycle was exhibited at the Conversazione held by the Royal Society in London on 7 May.

The use of microwave energy could be particularly advantageous in nuclear processing, where operations are conducted in hostile environments and where there is a premium on reducing servicing and maintenance to a minimum. One of the applications under investigation at Harwell is intended to simplify the handling of materials containing plutonium during the preparation of fast reactor fuel; another uses microwave energy in the direct conversion of highly active fission product wastes to glass.

Harwell and British Nuclear Fuels Ltd have developed a technique for the preparation of fast reactor fuel in the form of small spheres of uranium and plutonium dioxides. An organic gelling agent is added to a mixed metal nitrate solution and when droplets of the mixture are contacted with ammonia the hydrous oxides are precipitated and the droplets converted to robust insoluble spheres. After washing and drying, the final conversion to pure oxide is achieved through heat treatment where the gelling agent is removed by mild oxidation at about 800°C, followed by sintering.

The heat treatment can be accomplished by passing the spheres through a fluidised bed, heated by microwave energy delivered from outside the radioactive area via wave guides. In this operation the decomposition products are carried away in the fluidising gas and the mobile spheres then flow on to the next stage of the process. The technique uses equipment which is simple and lightweight in construction and which has no mechanical moving parts.

The second application relates to highly active fission product solutions which remain after the recovery of uranium and plutonium from spent reactor fuel and may be converted into leach resistant glasses. The vitrification process involves evaporating the waste solution, calcining the resultant solids, fusing with glass-forming additives and melting to glass. The resultant vapours and gases must be meticulously cleansed of entrained radioactive solids and volatile fission products.

The new microwave technique may allow the process to be carried out as a simpler, thermally efficient operation using glass fibre plugs, which are heated by microwave energy, and into which the waste solution is introduced. The glass fibre plugs act like a sponge for the evaporating waste solution and also serve as a filter for the solids entrained in the vapours. The plugs carry the calcined waste forward to a vessel where they are heated, again by microwave energy, to produce glass blocks of the correct composition. This work is funded by the Department of the Environment, which has overall responsibility for the UK's radioactive waste management research programmes.

The investigation of microwave techniques in nuclear processing is part of a more general approach to simplify the design features of chemical plants handling radioactive materials, with the object of facilitating remote control, reducing maintenance and minimising the exposure of personnel to radiation.

Further details on the development of these techniques can be obtained from Mr Bill Hardwick, Chemical Technology Division, Building 351, AERE Harwell. Telephone Abingdon (0235) 24141, extension 4848. □

Dounreay exhibition refurbished

Visitors to the public exhibition at the Dounreay Nuclear Power Development Establishment—ten miles west of Thurso—this year will find some new attractions, designed to give them a clearer insight into nuclear power.

The exhibition attracts about 20 000 visitors a year. Among new features on display this year are a cloud chamber, in which radiation from part of a wristwatch dial is made visible, and the original core from the experimental Dounreay Fast Reactor, which was installed in the reactor in 1959. Visitors will be able to try their hands at using a manipulator normally used in the remote handling of irradiated fuel elements [see pp. 152-155, ATOM No. 296, June 1981], or face a quiz on nuclear energy presented on a small computer terminal. Other exhibits include a laser hologram which can be used to display a three-dimensional image of the interior of a reactor core, and animated models.

The Dounreay exhibition is open seven days a week from May to September. Conducted tours of the Prototype Fast Reactor are conducted each afternoon from Monday to Friday, operational conditions permitting. It is expected that the total number of visitors to have seen the exhibition since its opening 21 years ago will this year top 300 000.

Further information about the tours may be obtained by ringing Thurso (0847) 2121, ext. 656. □

Name change

GEC Reactor Equipment Ltd will in future be known as GEC Energy Systems Ltd, in recognition of "the importance of all forms of energy and its conservation," the company said in a statement.

The statement said that while the company would continue its nuclear work, "the name change reflects a widening of its activities into energy projects such as hydro-electric and wind generation, energy storage, combined heat and power and small conventional generation systems."

As a unit of GEC Power Engineering group, GEC-ESL would be responsible for developing alternative energy systems and pursuing novel applications in the supply and conversion of energy, the statement said. □

STATUS franchise extended

Harwell has concluded two new franchise agreements to extend the marketing of STATUS—its free text information storage and retrieval software package.

Under these arrangements, Scicon Computer Services Ltd, one of the UK's largest and longest established Service bureaux, will make STATUS available throughout the EEC on its Univac based bureau; Computer Sciences of Australia Pty, the country's largest information services company, will offer STATUS in Australia and New Zealand through its Univac based 'Infonet' bureau.

Since the first version of STATUS was launched in 1976, the package has been adopted by nearly 50 organisations in the UK, Europe and Australia. It has now been implemented on over fifteen different mainframe and mini-computers.

In recognition of its commercial success, STATUS has recently been presented with the software industry's 'Million Dollar Award'. This mark of achievement is accorded by the US publishing company International Computer Programs Inc to those proprietary software products which have achieved gross sales of more than $1M. On behalf of Harwell and its franchise holders, the award was accepted by Derek Matkin (STATUS' commercial manager), at a presentation held at the Savoy Hotel in London on 12 May.

STATUS continues to be enhanced with improved performance and extended features. These are made available to users via franchise holders.

Further information can be obtained from Derek Matkin, Marketing and Sales Department, Building 329, AERE Harwell, Oxon. OX11 0RA. Tel. Abingdon (0235) 24141 ext. 2704. □

IBM network efficiency

SNAPI, a new diagnostic software tool for evaluating the performance of a network of IBM 3270 computer terminals, has been developed by Harwell and Data Processing Support Services Ltd (DPSS).

SNAPI—an acronym from Systems Network Architecture Performance Indicator—is designed to help central computer managers to choose the most cost effective configuration of 3270 type terminals and teleprocessing lines to meet their network performance objectives. It can be used in determining the optimum number of terminals to be attached to each 3270 control unit, the number of control units to be attached to each teleprocessing (TP) line, variations in network performance and the effect TP tuning has on response time.

The SNAPI programme runs on the central computer, giving an analysis of network response times that can be produced at both the central site and at the monitored terminal. It requires no additional hardware and operates without modification to existing software. Response time data is collected by SNAPI using sampling messages which specify that positive terminal responses are required. No terminal operator action is required.

SNAPI is now available to other 3270 users through DPSS and Harwell at the single charge of £860 plus VAT. DPSS will provide maintenance support to customers on request. Further information may be obtained from Kevin Gell, Data Processing Support Services Ltd., AERE Harwell, Didcot, Oxon. OX11 0RA. Tel. 0235 24141, ext. 3140. □

CEGB appoint Director of Nuclear Operations Support Group

Dr Bryan Edmondson has been appointed Director of the CEGB's newly-formed Nuclear Operations Support Group. He relinquished his former post of Director of Berkeley Nuclear Laboratories to take up his new appointment on 18 May 1981.

The Nuclear Operations Support Group, introduced as one of a number of recent organisational changes within the Board, is to ensure the provision of support for the operation of all the Board's nuclear plant in order that output from nuclear power stations may be maximised, consistent with sound safety policy.

The Group, which will be responsible to Board Member Mr G.A.W. Blackman, is concerned with the technical needs of operation, maintenance, integrity assessment and the preparation of safety case material.

Dr Edmondson joined the Board in 1959 as a metallurgist at Berkeley Nuclear Laboratories, became Head of Materials Division at the Central Electricity Research Laboratories at Leatherhead in 1970 and Director of Berkeley Nuclear Laboratories in 1973.

Energy for rural and island communities

The second international conference on *Energy for rural and Island communities* is to be held from 1 to 4 September this year at Eden Court, Inverness.

The conference is being arranged from the Energy Studies Unit at the University of Strathclyde, with the sponsorship of the UK Department of Energy, the British Council and the Scottish Solar Energy Group. The aim is to consolidate the role of small-scale energy systems in the planning, development and strengthening of rural and island communities in the UK and overseas; to emphasise the efficient use of energy and the opportunities for renewable energy supplies; to provide a forum for the needs of real communities to be matched with present-day commercial systems; and to demonstrate links between UK and overseas developments. The energy sources to be considered include solar, wind, hydro, biomass, wave and tidal; the systems covered range from electricity through control systems, combined heat and power, transport, agriculture, forestry and economics.

The conference fee of £85 includes a conference guide, published proceedings, and refreshments. Further information may be obtained from Dr John Twidell, Energy Studies Unit, University of Strathclyde, John Anderson Building, 107 Rottenrow, Glasgow G4 0NG; Tel. 041-552 4400, exts. 3307/3371. □

Courses in nuclear sciences

The Suffolk College of Higher and Further Education offers a wide variety of courses in radiation protection. It has a well-equipped nuclear laboratory suite, and works closely with other establishments and professional bodies; programmes of study are planned to align with the requirements of course members. Courses offered in 1981-82 include radiation safety practice (for nuclear establishments); preliminary and advanced courses for radiation safety officers in X-ray and radiotherapy departments of hospitals, and the handling and control of radionuclides in hospital pathology departments; industrial radiological protection, for radiation protection supervisors and for senior ambulance, fire and police officers; and, for schools, ionising radiation (for teachers) and nuclear science (for sixth forms).

Further information about course durations and timings may be obtained from the Department of Science, The Suffolk College of Higher and Further Education, Rope Walk, Ipswich, Suffolk IP4 1LT. Tel. Ipswich (0473) 55 885.

"Modular masters" degree courses

The University of Salford is offering part-time post-graduate course modules in nuclear subjects which can be taken by anyone with suitable experience attending the university one day a week for ten weeks. The modules form part of a larger scheme leading to a degree of M.Sc. by the "modular master's method": graduates registered on this scheme need to take six modules and submit a dissertation which may be on either an academic subject, or an applied topic of interest to industry.

The modules available (with their commencing dates in parenthesis) are: nuclear techniques in surface microanalysis (1 October 1981); radioisotope techniques in research (5 October 1981); radioisotope measurement (14 January 1982); introduction to the chemical effects of ionising radiation (11 January 1982); radioisotope applications in science, technology and the nuclear power industry (27 April 1982); and the utilisation of ionising radiations in chemistry (29 April 1982).

Other modules are available in chemistry, physics, mathematics, computing, biology, biochemistry and the arts. The scheme is described fully in the modular course calendar obtainable from The Postgraduate Office, Registrar's Department, University of Salford, Salford M5 4WT, or Tel. 061-736 5843, ext. 7060. □

IN PARLIAMENT

BY OUR PARLIAMENTARY CORRESPONDENT

The PWR option

30 April 1981

Even a part-completed PWR would provide some experience on which a decision about reactor choice could be made, Mr Norman Lamont, Under-Secretary of State for Energy, said in an adjournment debate.

Mr Mike Thomas had initiated a debate on the power plant industry, saying that he shared the Government's view that a reconstruction of the National Nuclear Corporation was essential if they were to carry through a major nuclear programme successfully—and he also agreed with the Government about the need for that.

He suggested that they could only evaluate the difficulties, cost and success in operation of a British PWR when one was running. That could not now be before the 1990s and any assumptions made about the PWR in the interim, other than on whether the CEGB could get planning and safety clearances in face of the legitimate concerns of local people and the environmentalists which the Sizewell inquiry would presumably resolve, would be just as likely to be proved wrong as had been assumptions about the first AGRs or the Isle of Grain oil-fired power station. Yet the Government allowed to grow abroad the feeling that they would, come what might, order a series of PWRs. That was not the position of the CEGB, nor the formal position of the Government, who until now had insisted that the mix would be open to decision in the future.

The Government did not know what it was doing, and the industry would stagger on, with no clear direction, no real support from the Government, and no steady ordering programme.

Mr Lamont replied that he dissented from what Mr Thomas had said about the CEGB not wanting to explore the PWR option. It wished to proceed with that option, subject to safety and other clearances. The Government proposal to allow the CEGB to proceed should help with employment prospects in that industry. Some components would have to be imported but the Government would seek to ensure the maximum contribution from the UK industry. The Government attached importance to the steady build-up of the NNC into a strong and independent design and construction company, fully able to supply nuclear power stations at home and abroad.

Reactor choice was a momentous and important decision. Decisions would depend first on demand for electricity at the time and on the experience with AGR stations being constructed and with PWRs, worldwide and in the UK. That did not mean that the PWRs would have to be completed.

Considerable experience would be obtained from the design and preliminary work. Decisions could be taken at that point as well.

No decisions had been taken by the Government. The Government would take the decision later in the light of experience gained.

Renewable energy sources

29 April 1981

Mr Dalyell asked the Secretary of State for Energy what international groups concerned with renewable energy sources he used in order to maximise the benefit to developing renewable energy sources in the UK, and if he would give any conveniently available figures, indicating *pro rata* Government expenditure on renewable energy sources in the UK and in other countries of the European Economic Community and the International Energy Agency.

Mr John Moore: The UK is involved in a number of international programmes concerned with the development of renewable energies. The programmes of the Commission of the European Communities and the International Energy Agency are of particular importance. An important aim of collaboration in these programmes is to supplement national programmes and to keep the UK abreast of developments in other countries.

The IEA has published figures in *Energy Research Development and Demonstration in IEA Countries – 1979 Review of national programmes* for the estimated Government expenditure by member States on renewable energy sources and for the larger member countries. These are as follows:

	Expenditure 1979 £ million (est.)
Belgium	2·1
Canada	8·7
Denmark	4·0
Fed.Rep. of Germany	21·8
Italy	6·3
Japan	18·1
Netherlands	4·7
Spain	4·3
Sweden	15·0
United States	301·9
United Kingdom	9·1

The figures have been converted from dollars at the rate of $2·127 to £1. The UK figures do not include the expenditure of the nationalised industries.

Northumberland National Park

5 May 1981

Dr David Clark asked the Secretary of State for the Environment when he expected to take a decision on the inspector's report of the inquiry into the dumping of nuclear waste in the Northumberland National Park.

Mr Giles Shaw: The inspector is still preparing his report of the inquiry which followed a refusal of planning permission to carry out geological test drilling in the Northumberland National Park. A decision cannot be expected for some time yet.

Electricity consumption

7 May 1981

Mr Hooley asked the Secretary of State for Energy what percentage of the UK's end-use needs required energy in the form of electricity.

Mr Lamont: Figures published in the April issue of my Department's statistical bulletin *Energy Trends* show that in 1980 electricity accounted for 13·5 per cent of consumption of all fuels by final users of energy.

Energy conservation

7 May 1981

Mr Hooley asked the Secretary of State for Energy what study had been made by his Department of the cost of saving energy by a programme of loft insulation of one half of all private dwellings in the UK as compared with the cost of building power stations to produce the equivalent of the energy thus saved.

Mr John Moore: My Department carries out a continuing analysis of the relative costs and benefits of investments in energy conservation and energy supply.

Nuclear Installations Inspectorate

7 May 1981

Mr Hooley asked the Secretary of State for Employment what was the approved establishment by grade of the Nuclear Installations Inspectorate as at 31 March 1981; and how many posts were unfilled at that date in each grade.

Mr Waddington: At 31 March 1981 attempts were being made to recruit inspectors to bring the strength of the NII up to at least 102 made up of:

Chief inspector	1
Senior deputy chief inspector	1
Deputy chief inspector	3
Superintending inspector	14
Principal inspector	67
Inspector	16
Total	102

On 31 March 1981 the following posts were unfilled:

Principal inspector	8
Inspector	2

The Health and Safety Commission hopes that the next phase of the continuous recruitment programme will enable the strength of the NII to be raised to 106.

● Mr Hooley also asked what were the current salary scales in each grade for the NII.

Mr Waddington: The current national salary scales in each grade for the NII are as follows:

Chief inspector	£20 500
Senior deputy chief inspector	£20 170
Deputy chief inspector	£19 500
Superintending inspector	£15 750 to £17 500
Principal inspector	£11 300 to £13 200
Inspector	£8 600 to £10 200

Most of these inspectors also receive inner London weighting allowance of £1 016.

● Mr Hooley also asked the numbers of serving members in each grade of the NII whose principal qualifications were in physics and/or mathematics, chemistry, metallurgy or one of the main branches of engineering.

Mr Waddington: At 31 March 1981 the numbers of serving members in each grade of the NII whose principal qualifications are physics and/or mathematics, chemistry, metallurgy or one of the main branches of engineering respectively were as follows:

Chief inspector (NI) (1) Engineering (1)

Senior deputy chief inspector (NI) (1) Physics (1)

Deputy chief inspector (NI) (3) Physics (1) Engineering (2)

Superintending inspector (NI) (14) Physics (2) Physics/Maths (2) Chemistry (1) Engineering (7) Other sciences (1)

Principal inspector (NI) (59) Physics (15) Physics/Maths (5) Chemistry (3) Metallurgy (2) Engineering (29) Other sciences (6)

Inspector (NI) (14) Physics (3) Chemistry (3) Metallurgy (1) Engineering (6) Other sciences (1)

The number of staff in each grade is shown in brackets. Each member of the inspectorate has one of the qualifications listed.

● Lastly, Mr Hooley asked what was the median length of service in each grade of the present serving members of the NII.

Mr Waddington: The median length of service in each grade of the present serving members of the NII is as follows:

Chief inspector	7 years 9 months
Senior deputy chief inspector	6 years 4 months
Deputy chief inspector	8 years
Superintending insp	6 years 1 month
Principal inspector	6 years 7 months
Inspector	1 year 9 months

Plutonium exports

14 May 1981

Mr Robin F. Cook asked the Secretary of State for Energy to list the amount of plutonium which had been exported, the countries to which it had been exported, and the purpose for which those countries imported it.

Mr Lamont: Since 1971, 1 280 kilogrammes of plutonium produced in the UK have been exported for civil purposes. The countries to which plutonium has been exported, in consignments larger than gramme quantities, are as follows: Belgium, France, Fed.Rep. of Germany, Switzerland, Japan and the USA. In addition, 1 930 kilogrammes of plutonium has since 1971 been exported and returned to BNFL's overseas customers, or to a country nominated by an overseas customer. This plutonium was derived from irradiated fuel imported and reprocessed by BNFL under contract. Ownership of this material at no time passed to BNFL. The countries to which such plutonium has been exported, in consignments larger than gramme quantities, are as follows: Belgium, Canada, France, Fed.Rep. of Germany, Italy, Japan and the USA.

All the above material was exported for civil use, principally for research and development on fast reactor programmes or on the recycle of plutonium in thermal reactors. All the countries listed (with the exception of France, a nuclear weapon state) are signatories of the Non-Proliferation Treaty. All nuclear material in non-nuclear weapon states party to the Treaty is subject to IAEA safeguards.

Nuclear waste disposal

13 May 1981

Mr Gordon Wilson asked the Secretary of State for Scotland if he would discontinue the programme of test boring in Scotland, and if he would give an undertaking that no nuclear waste would be dumped there for 100 years.

Mr Rifkind: The Government must ensure the continuation of a responsible long-term research programme in the UK into possible methods of disposing of high-level radioactive waste, of which geological disposal may be one. Meanwhile, there is no proposal to dispose of such waste in Scotland or elsewhere in the UK.

Strategic material transfers

14 May 1981

Mr Gerald Kaufman asked the Secretary of State for Trade to state the quantities of strategic nuclear material transferred between the UK and other countries in the past 10 years.

Mr Lamont: Strategic nuclear material is not a defined term, but is taken to mean separated plutonium and highly enriched uranium (HEU), that is, uranium enriched to 40 per cent or more in the isotope uranium-235. From 1971 transfers of these materials in consignments larger than gramme quantities for civil purposes have been made in gross terms:

Exports of plutonium	3 210 kg
Imports of plutonium	560 kg
Exports of HEU	660 kg
Imports of HEU	640 kg

All the above exports have been for use in materials testing reactors or in research, and have been subject to the application of relevant bilateral or multilateral safeguards agreements.

Generating capacity

14 May 1981

Mr Hooley asked the Secretary of State for Energy what planning margin of electrical generating capacity was used by the CEGB in 1980; and what were the comparable percentages in each of the European Economic Community Countries and the USA.

Mr Lamont: It was 28 per cent. Comparisons with other countries are difficult, and I will ask the chairman of the CEGB to write to Mr Hooley.

● Mr Hooley also asked what saving in the forward capital programme of the CEGB over the next 10 years could be achieved on the basis of a planning margin of capacity of 15 per cent.

Mr Lamont: I am advised by the CEGB that a reduction to 15 per cent would produce an unacceptable risk of failure to meet winter peak demand. I am asking the chairman to write to Mr Hooley.

Fusion research

15 May 1981

Mr Skeet asked the Secretary of State for Energy if he would make a study of the recent steps taken by the US to reduce expenditure on coal gasification and liquefaction in favour of expenditure on nuclear fusion projects; and whether he would consider the relevance of these decisions to the situation in the UK.

Mr Moore: UK development needs in coal conversion are strongly governed by our continental shelf reserves of oil and gas, and the US Administration's proposal to reduce its funding has little effect on our position.

Energy strategy

15 May 1981

Mr Skeet asked the Secretary of State for Energy if he would make a study of the relevance to the UK situation of reductions made by the US into research on alternative strategies and the concentration of resources on conventional energy and nuclear strategies.

Mr Moore: In many respects the pattern of development of alternative energies is peculiar to individual countries by reason of, for example, differing climatic conditions and energy supply situations. The UK's alternative energy resource programme is now well established and is appropriate to our needs. The reductions proposed by the US Administration on Government funded research into some forms of alternative energy will have little or no direct effect on the UK situation.

Departmental expenditure

15 May 1981

Mr Grylls asked the Secretary of State for Energy how much his Department spent on R&D in the year 1980-81, and how much it intended to spend in 1981-82.

Mr Moore: Estimate provision on my Department's industrial support Vote—Class IV Vote 5—for expenditure on non-nuclear R&D in 1981-82 is £45 million compared with a forecast out-turn in 1980-81 of £33 million.

In addition, Estimate provision for expenditure by the UKAEA on the scientific and technological assistance: nuclear energy Vote—Class IV Vote 7—in 1981-82 is £223 million net compared with a forecast out-turn in 1980-81 of £186 million net.

AGRs

15 May 1981

Mr Sheerman asked the Secretary of State for Energy when he expected that all the advanced gas-cooled reactor power stations of the first programme would be working to full capacity, and if he would give full details of what the current position is.

Mr Lamont: I am informed by the CEGB that it is intended to commence loading of fuel into these reactors by mid-1981 and output from the first generator on each station is expected during the current financial year. All reactors are expected to be fully commissioned by 1983. Progress towards full capacity will be assessed during the course of commissioning.

Cost comparisons

15 May 1981

Mr Wigley asked the Secretary of State for Energy what conversion factors were used by his Department in order to express the energy supplied by (a) nuclear power stations and (b) hydro-electric power stations in terms of an equivalent weight of coal.

Mr Lamont: In energy statistics published by my Department the following factors are used for converting 1 GWh of electricity supplied to tonnes of coal equivalent:

408·2 for public supply nuclear power stations,

457·7 for nuclear power stations operated by the UKAEA and BNFL,

520·8 for natural flow hydro-electric stations.

Generation share

15 May 1981

Mr Sheerman asked the Secretary of State for Energy what percentage of generated electricity was produced by nuclear power, and what had been the percentages over the last 20 years.

Mr Lamont: The information is given in the following table.

Nuclear electricity generated as a percentage of total electricity generated by public supply power stations: UK.

	Percentage
1961	-
1962	0·7
1963	2·2
1964	3·2
1965	7·2
1966	9·7
1967	11·1
1968	11·8
1969	11·6
1970	9·6
1971	9·8
1972	10·4
1973	9·1
1974	11·7
1975	10·6
1976	12·7
1977	13·9
1978	12·5
1979	12·4
1980	12·6