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ATOM

THE ASSESSMENT OF THE RISKS OF ENERGY

FAST REACTOR FUEL CYCLES

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ATOM contents

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Front cover: Care is taken at every stage to minimise the risks of electricity production from whatever source. In this issue, John Dunster discusses the assessment of risks; and Peter Jones reviews a report on coal and the environment.
Here: AGR fuel pins are inspected on arrival at the Hunterston B nuclear power station operated by the SSEB

AN ICONOCLASTIC VIEW

THE ASSESSMENT OF THE RISKS OF ENERGY

Collaboration between industry and regulatory authorities in the UK has reduced the levels of risk from all current energy sources to a reasonably low level. "The real question is not 'is an energy source too dangerous to use' but rather 'are the costs of making it safe enough so high that it becomes uneconomic'? Technology is now sufficiently developed that any process can be made safe enough if the necessary resources can be brought to bear."

This was the peroration to the 49th Melchett Lecture of the Institute of Energy* given in London on 26 November by H.J. Dunster, CB, current Deputy Director General of the Health and Safety Executive and Director of the Nuclear Installations Inspectorate and Director-designate of the National Radiological Protection Board. He concluded that while phrases such as "safety considerations are paramount" could be seen as useful slogans, they were a totally inadequate basis for making decisions.

Mr Dunster

Definitions

Risk assessment was a process that was as old as man himself, said Mr Dunster; but we had recently tended to elevate it to a science or, at least, to an art form. "Our society has become self-conscious about risks. They no longer appear to us as part of our natural environment," he said. "Most risks are now thought of as an artificial feature of our lives and, what is more, a feature which ought to be brought under control.

"Risk assessment has become the deliberate process of examining human activities, or the situations in which man finds himself, with the aim of identifying the various deleterious outcomes and estimating as quantitatively as possible the probability of their occurrence. . . . Having established and quantified our risks we now have to decide to do something with then. Clearly our decisions on what to do will be affected by our attitude towards the risks, and our desire to hang labels on things has produced the concept of 'the perception of risk'. All this means in fact is that people are more frightened of some things than they are of others, even when logic would suggest that the two outcomes are similarly undesirable."

Mr Dunster set out to take an iconoclastic view of risk assessment. "If we take the perception of risk seriously, and it is hard to see how we can avoid doing so if we are to use the assessment of risk in making practical decisions, we have to recognise not only that each individual fears some things more than others but also that individuals differ amongst themselves," he said. "The weighting factor for one risk against another may be much greater than unity for one individual and much less than unity for another. Finally, to make life even more difficult, these weighting factors, even if they can be defined and determined, are often volatile functions of time. Risks may suddenly spring into prominence in people's minds, not only to the extent to which they have been given additional information, but also because the way that the information is presented, and the extent to which it is repeated, sharply influences their response to the information.

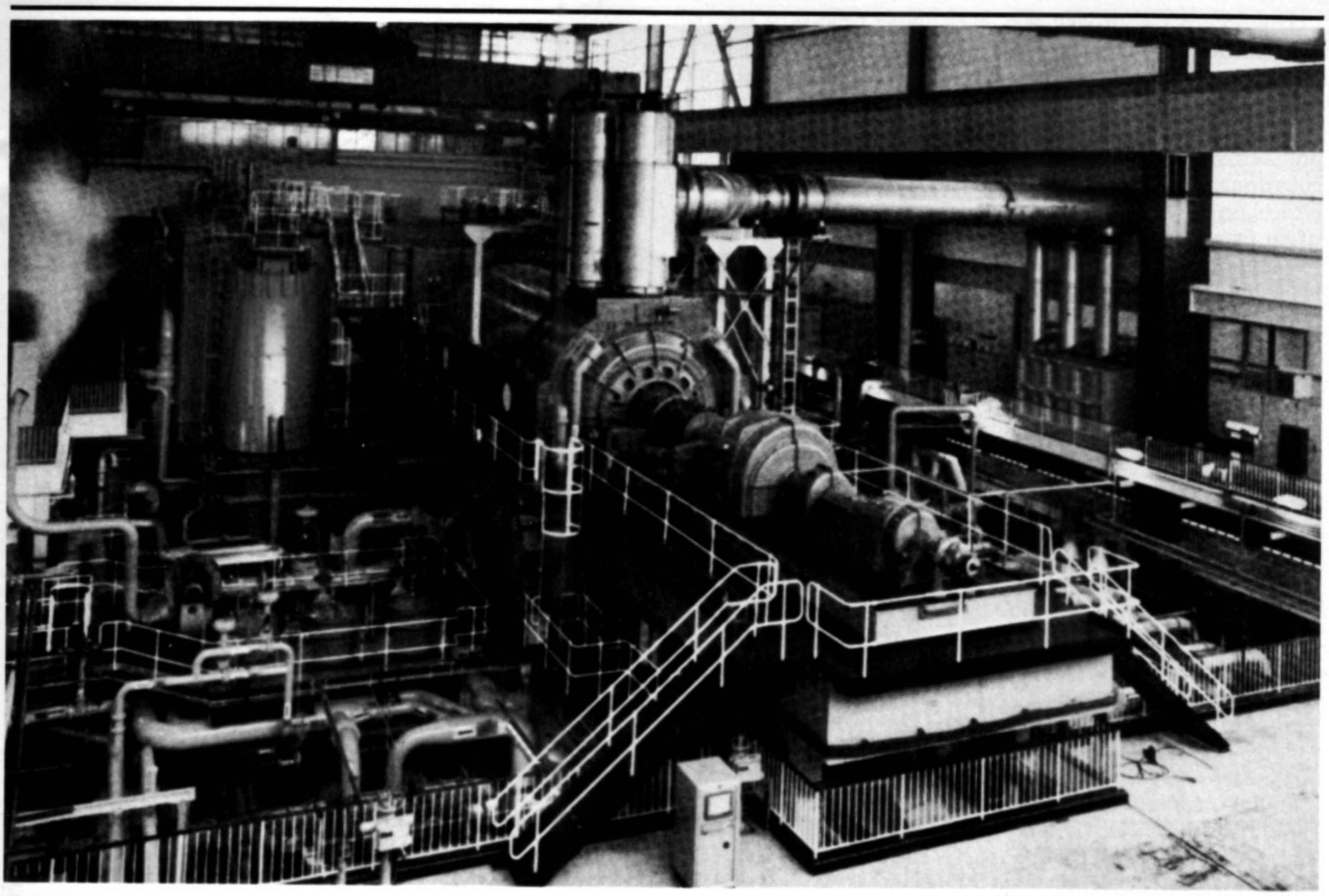
"None of this is new to industrialists (particularly if they are selling to the public) or to Government officials and politicians. It appears to have been more surprising to those who sit in less robust environments and produce reports on risk assessment. It is a natural progression from discussions of risk assessment, to considerations of the perceptions of risk, on to the idea of the acceptability of risks. This is altogether a different proposition. Risks are accepted by individuals on behalf of themselves or their families, by manufacturers on behalf of their customers, by officials such as inspectors on behalf of the people they are aiming to protect, and by governments on behalf of the people as a whole. Individuals often have to accept risks which they regard as undesirable, and the word unacceptable is sometimes used of such risks. However, if this word is used in its strict sense a risk which is genuinely unacceptable has to be modified regardless of cost, even to the extent of abandoning the process giving rise to the risk.

"In less extreme situations, a risk becomes acceptable when it is seen to be associated with adequate off-setting benefits and when it cannot be further reduced by reasonably sensible means. Acceptability is essentially a concept of cost-benefit analysis. The risks can with some difficulty be incorporated into the costs of a product or operation, but there then has to be a balancing against benefits. The assessment of risk and its evaluation in terms of perception cannot by themselves lead to decisions about acceptability."

Risk management was a useful general term to describe the process of identifying risks, establishing their nature, quality and magnitude; taking action to eliminate or reduce the identified risks where this could be reasonably achieved; and finally establishing whether the remaining risks were acceptable to those at risk, or at least to those who made decisions on their behalf.

"There has been no shortage of work on the risks of

The full text of Mr Dunster's lecture and of the discussion which followed it will be published in a forthcoming issue of *Energy World*, the journal of the Institute of Energy.



Turbine plant—here, that at the Hunterston B AGR station operated by the South of Scotland Electricity Board—does not mind what fuel is used to raise steam to drive it. Does the choice of fuel have an impact on society?

various forms of energy production over the past decades or even centuries," said Mr Dunster. "What is apparently new, and what has certainly become a growth industry in the last few years, is the attempt to make quantitative comparisons between the risks of various sources of energy. The idea of such comparisons goes back some time, and I can remember more than 20 years ago discussions in the atomic energy industry about the advisability of attempting to establish estimates of risks from other sources of energy as a form of defence against the already apparent fear of nuclear energy. Those original discussions led to nothing primarily, I believe, because of the belief widely held at that time in the advertising business that it did no good in the long run to 'knock the competition'."

The first reports of comparisons of energy sources, specifically sources of energy for electricity generation, began to appear in the middle of the 1970s, but the turning point came with the publication of the first report by Herbert Inhaber, then with the Atomic Energy Control Board in Canada, in 1978 [Report AECB 1119, March 1978; ATOM **262,** August 1978, p. 223]. This report was the first to create any widespread interest in the topic, partly because it explored a much wider range of possible energy sources than had previously been brought together in one comparison, partly because its results were fairly dramatic and unexpected, and partly because its scale of ambition made it easy to criticise. Several improved versions had resulted from the private and public criticism which that report attracted. These, and many other subsequent publications, had demonstrated that the comparisons were far from straightforward conceptually and exceedingly difficult to make in quantitative terms which were consistent across the whole range of possible energy sources.

The first objective of all this work was almost certainly the original qualitative one—to demonstrate that nuclear power was not alone in presenting risks to members of the public and, further, that these risks were, in real quantitative terms, smaller than those associated with most other energy sources, said Mr Dunster. Subsequently, however, quite substantial resources had been devoted to attempts to improve the comparability of the figures and to improve their precision. Decisions had to be made about the starting and end points of the operation—should one consider, for example, the risks associated with the production of the raw materials to be used in the construction of a power station? The next move was to decide what risk to take into account. Data were fairly readily available on accidental deaths and rather less reliably on serious injuries to workers. Accidents causing minor injuries, involving short absences from work, were widely reported but the reported frequency depended heavily on the quality of the reporting procedures and on local social situations, which influenced the length of time off work which a particular injury caused. Uncertainties in these accident rates by a factor of two or three were commonplace.

Health effects were notoriously difficult to assess. The formal records were often incomplete because occupationally-induced illnesses were not always easily distinguished from similar conditions with other causes. Indirect methods were sometimes used to forecast low frequencies of health effects due to current exposures from a knowledge of higher present frequencies resulting from earlier higher exposures: for example, the incidence of lung cancer in asbestos workers currently exposed was the subject of direct and continuing epidemiological studies. Meanwhile, however, the best estimates of the future incidence was that obtained by downward extrapolation from earlier epidemiological work.

This indirect approach was even more necessary for the assessment of the frequency of health effects in the general public resulting from industrial air pollution. Direct epidemiology could detect differences between population groups but could rarely attribute these differences to specific pollutants. Downward extrapolation from, for example, occupational studies could indicate the possible magnitude of effects on the public, although the basis of extrapolation was often extremely tenuous. The resulting estimates were correspondingly uncertain and gave rise to substantial and sometimes bitter disagreement. In the nuclear industry, detailed environmental and metabolic models were set up to estimate the radiation doses to workers and members of the public, and the studies were extended downward, to levels of dose which were minute compared with the natural levels of radiation background, and forward, into the future for thousands and sometimes millions of years. A simplistic linear relationship was then used to convert these calculated doses into health effects, usually deaths from cancer. More conventional pollutants were usually dealt with very differently. If the energy source was only a minor contributor to the total exposure to a particular pollutant that minor contribution was ignored. Other pollutants, such as sulphur dioxide and oxides of nitrogen, were usually assumed to have some threshold below which there was no significant effect on human health, although there might still be damage to the environment.

"My personal view is that the proper treatment lies somewhere between these extremes," said Mr Dunster. "Radiation doses below some fraction of natural background should, in my view, be ignored for the comparison studies and, with even greater emphasis, in the making of decisions which involve the deployment of resources. By contrast, I suspect that we may be paying too little attention to some of the potentially carcinogenic materials emitted in the combustion of fossil fuels, with their possible return to man through deposition and recycling by environmental processes. For these materials, the linear extrapolation may be as valid as it is conventionally taken to be for ionising radiation.

"All these problems apply in the apparently simple comparison of the risks associated with whole systems of energy production as they currently exist or as they can be predicted to exist at some point in the future. But even if these problems can be adequately overcome and fair comparisons made, these comparisons are no basis for deciding such questions as 'should the next electricity generating station be fossil-fuelled, nuclear, or based on some renewable resource?' To provide the risk input to such decisions we need to know the effect on the risks of existing systems of making marginal changes and the effects of the initial introduction of stations of a new type. The risks per unit of electricity sent out from these marginal changes may be very different from those of the system as a whole."

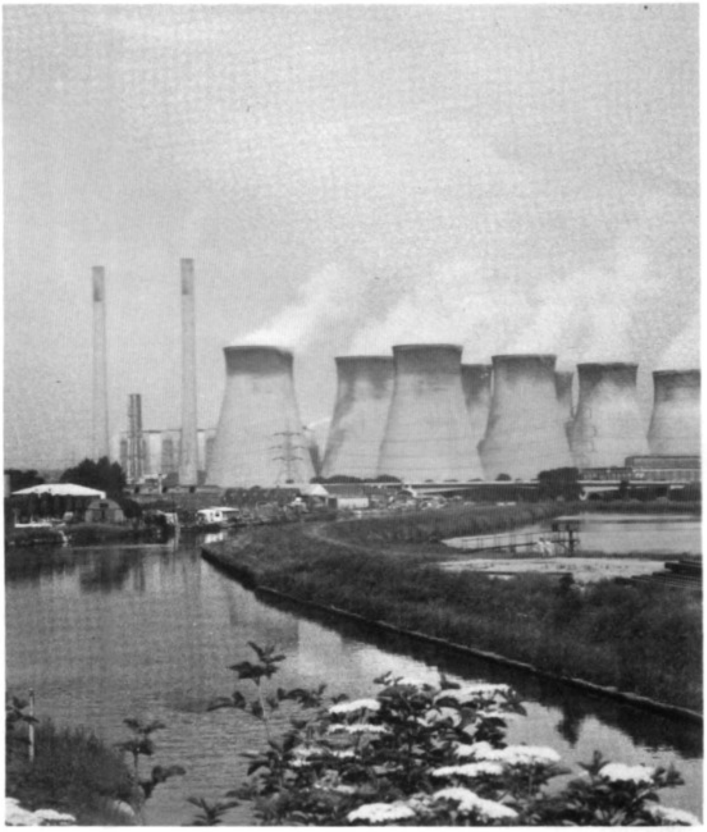
An index of woe

Given all the difficulties it was hardly surprising that the published estimates of the levels of risk per unit of electricity sent out varied widely, said Mr Dunster. In 1980 Cohen and Pritchard of the Health and Safety Executive completed a review of major publications in the field [ATOM **292,** February 1981, p. 51]. They did not add together all the various possible effects in order to arrive at some unified "index of woe"; with less restraint, and to give some idea of the overall range of values, Mr Dunster did make some attempt to add together all the estimated deaths other than those occurring in major disasters. (In fact, such disasters made very little contribution to the total death rate, though they played of course a major part in the public's reaction to different sorts of industrial situation.)

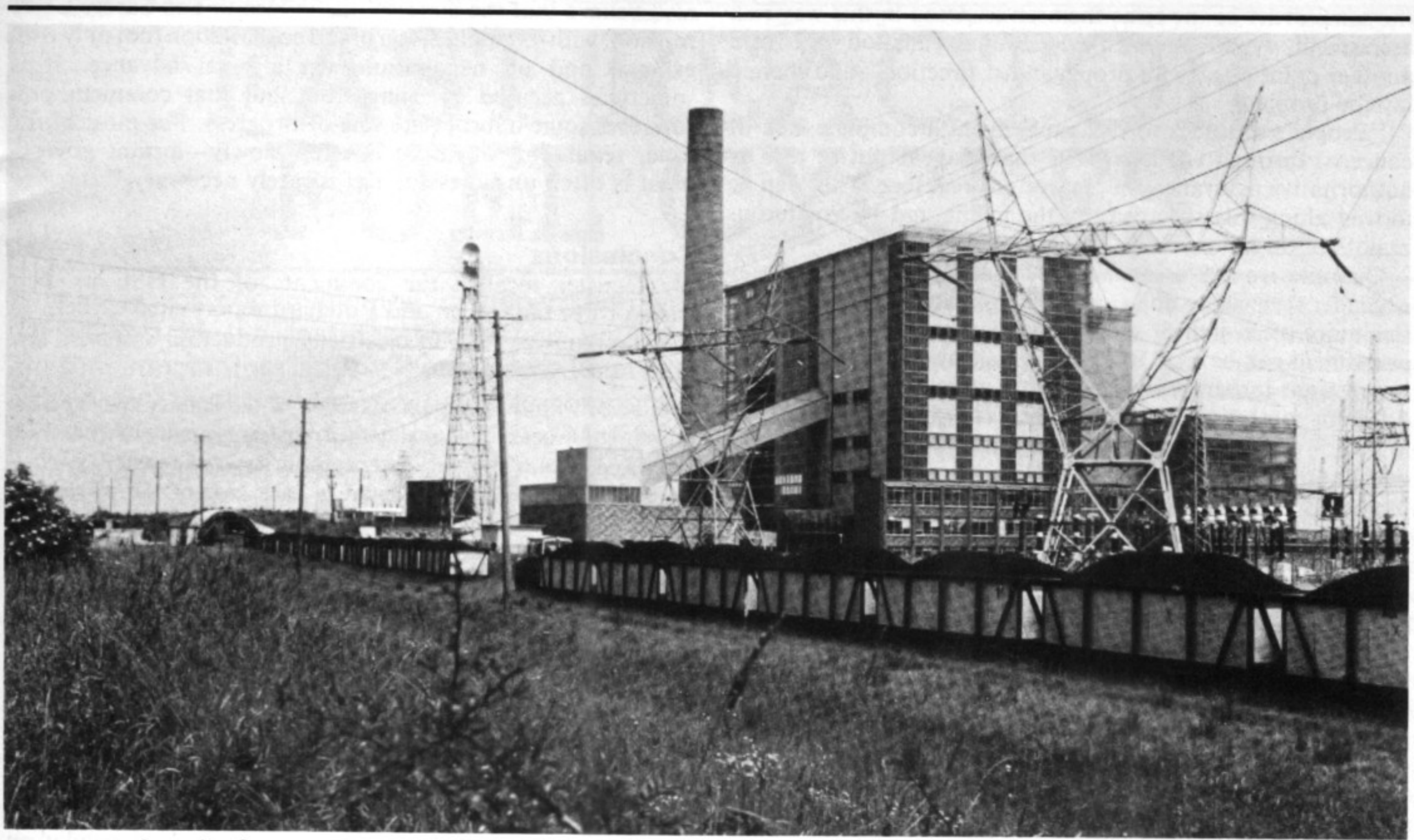
The results, he said, could be best summarised in terms of the expected number of deaths resulting from the operation of a 1 000 megawatt generating station, taking an average station over the whole of the generating system. The figures had been standardised to a load factor of 0·75, although their accuracy did not justify this sort of adjustment. The results for ten major studies showed coal at 0·6-10 deaths per station year; oil at 0·1-1·5 deaths per station year; and nuclear at 0·1-1 deaths per station year. If certain American views on the lethal effects of exposure to low concentrations of sulphur dioxide were taken at their face value, the upper limits for both coal and oil amounted to about 100 deaths per station year.

"Figures such as these may well have had some effect on the decisions in the United States on the removal of sulphur from power station off-gases and on the use of low sulphur fuel, but their validity is very widely questioned," said Mr Dunster. "If these very high values are ignored, the logarithmic means of the various estimates—and I should emphasise that these means have very little real significance—come out as coal, 2·5 deaths per station year; oil, 0·38 deaths per station year; and nuclear, 0·3 deaths per station year.

"Beyond suggesting that coal is a rather more dangerous fuel than oil or nuclear material, these numbers by themselves have little significance. Since a generating station of this size serves rather less than one million people and the associated industrial infrastructure, the number of deaths directly caused by the station is very small compared with those occurring naturally in the population served. There will be about 14 000 deaths a year in a population of one million. While this fact makes it clear that the deaths directly associated with the generating station make no real difference to the overall mortality of the area in which the station is placed, the pre-existing deaths provide absolutely no justification for any additional deaths. The numbers do, however, suggest that, if the objective is to reduce the number of premature deaths in the population as a whole, there may be better ways of doing it than by paying attention to the deaths concerned with the generation of electricity."



Which rank higher: risks from coal (left)



. . . or peat burning? *Bord na Mona, Dublin*

The risks of using energy v. the benefits

If there was any merit in comparing the risks of *producing* energy from different sources, there should also be some merit in comparing the risks of *using* different forms of energy. Thus, the use of electricity in the home gave rise to some deaths from electrocution and the use of natural gas caused some deaths from explosions. The use of petrol and diesel fuel in vehicles produced a very substantial risk for those who use the roads; and it might also give rise to health effects either from combustion products or because of the addition of lead compounds to petrol.

The benefits of using energy, similarly, was too wide a subject to explore in any detail. Many, however, considered that we used energy wastefully and for unnecessary purposes. "I do not doubt that we waste it, but avoiding that waste by so-called energy conservation programmes is a lot more difficult than is sometimes pretended," said Mr Dunster. "Improving the insulation of houses undoubtedly saves energy if the internal temperatures remain the same. But in practice many people take advantage of the insulation to improve their standard of comfort. Many of the allegedly unnecessary uses of energy are regarded by the users as ways of improving their quality of life. While such improvements may not be essential, they certainly have my whole-hearted support.

"I mention these points merely to emphasise that the emphasis on risk tends to give an unbalanced picture. If we are wishing to make a judgment about the merits of being an energy-consuming society we must consider not only the risks of generation and use but also the benefits. Perhaps, more importantly, we must take into account the risks of providing too little energy, or energy at too high a price."

Consideration of risks ought not to play a decisive part, and perhaps not even a significant part, in the decisions we made about the production and use of energy: but did risk estimates play a part in the decisions in practice? "I do not really know, but on the whole I doubt it," said Mr Dunster. "Certainly it is thought that the risks play a major part in decisions about nuclear power, but in this case it seems likely that it is the perception of risk—a sense of fear—which is important, not the risk itself. The fear would probably be overcome if the need for nuclear energy were much more imminent and the lead times much shorter."

It was clearly necessary to ask whether all these assessments of risk were a waste of time. Fortunately, the answer was no; the assessment of risk has at least three different functions:

- to contribute to major strategies and choices—for example, the choice of the appropriate mixture of energy sources;
- to identify cost effective ways of reducing risks in the projects resulting from these major decisions and to help decide when further reduction in risk was not justified;
- and to improve the understanding of the risk-producing mechanisms and thus to identify safer options in design and operating methods.

These three functions were not fully distinct; and a fourth was sometimes suggested. "Because of the influence that is attributed to the perception of risk, it is important to know whether this influence is benign from the point of view of society. In practice, governments, officials and industrialists all have, on occasion, to make decisions which they know not to reflect the popular view. They do this because they see it as being in some way the right thing to do—in other words, because they see the popular perception as not being in the best interests of society, or of that part of society which they judge to be important in the context. There is, however, a limit to the extent and frequency of such unpopular decisions. One of the arts of good government and good management is to identify this limit in advance. Seeing it by hindsight is only too easy."

Decisions of this kind were particularly difficult to take rationally where risks were involved, because of the enormous range of human reaction to risks which seemed in objective terms to be comparable. There was a very natural temptation to treat this range of reaction as fundamentally irrational and to imagine that well-presented accounts of the true risks would encourage people to react in a way which, if not proportional to the risk, at least ranked their concern in broadly the same order as the risks themselves. Used in this way risk assessment would have an educational function or, from another point of view, a propagandist function—and therein lay the problem.

"People's attitudes to risk range from a complete lack of concern, through vague worries that may be put at rest by authoritative assurances of 'safety', to real fear. They can be moved along this spectrum by the media and by vociferous zealots of all kinds.

Quantitative risk assessment may seem neutral, but it may engender fear where none existed before and it probably does this more often than it soothes worried breasts. Indeed, risk assessment can be used in a deliberate way to create a desired impression. It then produces counter attacks from those with different objectives, and the 'experts' become polarised. Whether this is a good or a bad thing is now an academic question. Risk assessors are already polarised and the position of those who use risk assessment as a neutral tool has become very difficult."

The difficulty was illustrated by the position of the Health and Safety Executive. Where the issues were emotive—and most health and safety issues fell into this category—a central position won the executive few friends. "There is no single impartial position. The atomic energy industry sees clearly the need to discuss risks openly and usually without deliberate distortion. But it naturally likes to take an optimistic view where it reasonably can. Much of the rest of industry is still unwilling to make any contribution to the public debate on risks and when it does it usually emphasises the 'expert' nature of the problem. Equally naturally, pressure groups wish to emphasise the dangers of the projects which they are opposing and sometimes adopt extreme views." In such situations the position of the Health and Safety Executive was extremely difficult. "In reality, our instinct is to be protective, perhaps even a little over-protective, but our views are tempered by the recognition that a risk-free society is not an available option and that most people are willing to accept some risk if their creature comforts are enhanced. Unfortunately, the trade-off is rarely a direct one—often the risks come from one source and the creature comforts from another. The trade-off then has to be viewed broadly across the whole economy."

There was a great need to clarify the position and the limitations of the expert, said Mr Dunster. "Unfortunately, there is a substantial vested interest in avoiding this clarification. Governments like to say that they have accepted the advice of expert committees—if they are right they appear enlightened, if they are wrong it was the fault of the experts. Professional bodies find the title 'expert' gives them status and influence and they ride the word as far as it will take them. Individuals claim an almost *ex cathedra* standing for views which are often far beyond the true limits of their expertise. And representative bodies, such as trade unions, local authorities, and local public interest groups and, for that matter, industrial managements, all of whom should know better, often find it more effective to field an expert on their behalf rather than to clarify the issues and to treat their representatives for what they really are—negotiators. . . .

"Energy production is increasingly dependent on complex technology. No longer can we say of coal 'great stuff—all you have to do is to burn it'. No one would choose to tackle the technical problems of nuclear power and its fuel cycle if there were easier alternatives. In such situations, when industry is both large scale and technically complex, it matters a great deal that the experts and the decision makers should achieve the proper relationship. Technically wrong decisions can be desperately expensive. Technically sound but insensitive decisions can severely damage, perhaps even destroy, a substantial block of industry.

"I believe that we are evolving a fair approximation to this proper relationship in much of the health and safety field. I also believe that the concept of the Health and Safety Commission, with its emphasis on broad consultation (not only with experts) and on negotiation was a great advance. It is sometimes accused of being slow, but that comment presupposes some appropriate rate of progress. For most of the time, regulation ought to develop slowly—instant government is often unsuccessful and is rarely necessary."

Conclusions

Mr Dunster recalled the comments of the HSE in their foreword to the Cohen and Pritchard report cited earlier, on the comparative risks of electricity production systems. The HSE said:

We agree with the general conclusion of the authors that suitably sited, constructed and maintained nuclear systems of the types reviewed involve no more, and probably less, risk than oil- or coal-burning systems, taking account in each case of the whole fuel cycle. We doubt if further comparative studies would greatly refine this conclusion. These views do not lessen the importance of health and safety considerations for whatever system is chosen. Rather, they emphasise the need, in determining a suitable mixture of energy sources, to see these risks in perspective. Such a perspective should take account of the risks associated with everyday life; of the fact that there is no such thing as a totally risk-free society; and of the economic, social, and health risks of a failure to provide adequate supplies of energy."

This conclusion, he said, was at variance with some widely published views, but it did nothing more than recognise the fact that the collaboration between industry and regulatory authorities in the UK had reduced the levels of risk from all the current energy sources to a reasonably low level. It was to be expected that any new unconventional source would be subjected to the same sorts of process and its risks would be brought broadly into line with the present level. "The real question is not 'is an energy source too dangerous to use?' but rather 'are the costs of making it safe enough so high that it becomes uneconomic?'," he said. "Technology is now sufficiently developed that any process can be made safe enough if the necessary resources can be brought to bear. In this context, phrases such as 'safety considerations are paramount' can be seen as useful slogans but as a totally inadequate basis for making decisions. That is why we must all recognise and accept that these are not and should not be matters for the 'expert' alone. But the solution is not to exclude the expert from the fields beyond his expertise but rather to persuade him to extend his range of activity and to recognise that he has a contribution to make beyond his expertise, but in a clearly identified capacity."

Mr Dunster concluded: "I believe that risks should be reduced whenever and wherever that can reasonably be done, but I think we agonise about man-made risks more than is good for us. Energy policy is not, or at least should not be, significantly affected by the risks of producing and distributing energy. It may be influenced by people's fear of those risks and that is a real factor, not to be dismissed as irrational. Some people play on those fears, others are blandly reassuring. Both groups need to examine their consciences and to remember the material used to surface and no doubt repeatedly to resurface the road to hell.

"The role of the expert is often misunderstood—as often by the expert as by the politician. Scientists and engineers have a major role to play in our present energy-dependent society, and this role goes far beyond that of the expert. In that extension, a university chair should be no more, and no less, influential than a soapbox in Hyde Park.

"We must have energy; we shall always have risks. I believe that the machinery which we have in this country for getting the balance right is broadly satisfactory. I wish I could be as certain about the arrangements elsewhere." □

FAST REACTOR FUEL CYCLES

The case for continuing the demonstration and installation of the fast reactor system with the present momentum and without discontinuity remains very strong and a very valuable component of world energy strategy, Dr T.N. Marsham, managing director of the Northern Division of the UKAEA and a member of the Authority Board, urged at the opening of an international conference on fast reactor fuel cycles in London in early November.*

Dr Marsham recalled the remark of the American author Mark Twain—that the trouble with the weather was that everybody talked about it and nobody did anything about it. "For many years and in many of the world's fast reactor programmes I felt that this was true about fast reactor fuel reprocessing also," he said. "The papers to this conference show that the position is changing.

"While I do not share the more pessimistic views that one sometimes hears about the relative capital costs of fast and thermal reactors—indeed, we shall not be clear about this for some time, and certainly not until the requirements for the degree of protection against remote accidents by engineered safeguards in comparison with the benefit of the unique intrinsic safety characteristics of the liquid metal cooled fast reactor have finally stabilised—nevertheless I am sure we must all accept that the fast reactor system offers us not a cheap power plant, but a cheap and inexhaustible supply of fuel. It is high time that we convincingly demonstrated this in practical terms to supplement the elegant theoretical assessments that have been such a permanent features of fast reactor conferences for nearly 30 years."

*The proceedings of the conference will be published by the British Nuclear Energy Society.

Dr Marsham said the basic potential of fast reactor systems to improve by more than 50-fold the utilisation of uranium resources and so transform them from a moderate to a major source of energy had been established increasingly firmly during those 30 years. This property of fast reactors had been so robust that it had stood the test of all the changes in the energy scene and all the assessments to which it had been subjected.

"In this country our very first Government policy statement on nuclear power in 1955 laid down the principle of embarking on nuclear power with thermal reactors, reprocessing their fuel and conserving the plutonium and depleted uranium for use in fast reactors," Dr Marsham said. "It also initiated a parallel development and demonstration of that system phased so that it would be available for large-scale use in time to stabilise power costs and uranium needs within available resources. We are fortunate that this has been a consistent policy ever since, with the result that the technology is now very highly developed indeed. If presently known technology is deployed on an industrial scale there need be no shortage of fuel for electricity generation, or any significant increase in its cost for the foreseeable future. Similar views have prevailed in all countries developing nuclear power. The recent International Nuclear Fuel Cycle Evaluation came to the same view.

"It was stated in that exercise that the timing and need will vary from country to country. For many industrialised countries, in my view, the timing uncertainties are small compared to the uncertainty in forecasting the total time needed to launch a fast reactor programme to the point where it is making a significant contribution to the nation's electricity supply and fuel requirements. Even in present circumstances there seems little time to waste in making this option available."

Economics

A paper by French authors highlighted the likelihood that fast reactors would generate electricity more cheaply than thermal systems within about 20 years; but Terence Price, Secretary-General of the Uranium Institute, argued that thermal reactors should be able to compete with fast reactors for substantially longer than might have been thought from considerations of resources and production of and demand for uranium. "Unless the fast reactor is an early and outright winner on economic grounds many other factors will contribute to the speed at which it is phased in: the economics of fast reactor fuel reprocessing; the technical possibilities of improved thermal reactor design; the availability of funds for promoting such improvements; uranium exploration and mine development; environmental considerations; and national views of how much extra it is worth paying for energy self-sufficiency. Although our crystal ball is therefore cloudy almost to the point of obscurity, it is at least possible to see that the future of the nuclear industry is not necessarily a sudden collapse of thermal reactors and uranium mining in the early years of next century."

Mr Price quoted "a leading figure in the European electrical industry" as saying that:

> 'The fast reactor is still only just passing the stage of prototype development. It would be surprising if it rapidly overtook the economics of the thermal reactor. So long as we can see about 30 years of uranium supply ahead at a price which makes it worth ordering fresh thermal reactors we shall continue to do so; once we are worried on that score then we shall turn to the breeder.'

This watershed might not be reached as soon as some had tended to assume, said Mr Price—possibly not until after the end of the first quarter of the next century. "The lesson I draw is that while fast reactor development should proceed with some urgency as an essential insurance policy, commitments to an extended power programme will in practice depend sensitively on the balance of all the influences" he had adumbrated.

Dr Marsham—terming this "a useful antidote to any complacency"—agreed that timing of need could not be forecast; but it could certainly be brought forward if perfectly feasible improvements in the efficiency both of processes and of arrangements for industrial exploitation were realised.

In several countries operation of prototypes and test reactors had proved clearly that we were technically ready to take the final development step of introducing full-sized demonstration plants with confidence, said Dr Marsham. France and Russia were already embarked on such plants. In

The need for standardisation

Teams developing fast reactors in various countries must put themselves in the position where they can absorb rapidly the best ideas, and the best engineering designs and take every opportunity for standardisation. They should also assume that there will be closer and more effective industrial links than exist today.

Sir John Hill, FRS, chairman of British Nuclear Fuels Ltd, acknowledged when he opened the BNES conference that in spite of all that had been achieved fast reactors were not being built anywhere on a commercial basis; it was unlikely that they would be for at least ten and maybe 20 years.

"Progress from a technical and engineering standpoint has been all that could have been expected and in the field of stability and safety probably better", he said. "Fast reactors are now operating in the US, Russia, Germany, France, Japan and the UK and electricity generation at prototype scale has been achieved in France, Russia and the UK.

"We now know how to design, build and operate sodium-cooled, plutonium-fuelled fast reactors. We have demonstrated that they are remarkably stable in operation. They are reliable. Extensive tests have shown that they are safe and that they obey the predictions of the nuclear physicists. We know that they can be designed to breed more plutonium than they consume and can therefore use depleted (waste) uranium as fuel. We have learnt how to make plutonium fuel of the highest integrity. We know the fuel will withstand very high irradiation levels and even gross maloperation of the reactor. We know how to reprocess this fuel and to recycle the plutonium. We now have at our disposal all the basic information needed to bring to fruition the vision and hopes of the fast reactor scientists of thirty years ago."

How then had the delay in fast reactor programme come about, and how should they respond?

"The problem we face is that the world's nuclear programmes have been slowed dramatically in recent years, and the projections of the past are no longer realistic," said Sir John. "Instead of facing a uranium shortage we have a glut. The difficulty is not finding uranium to fuel the reactors that are being built but building reactors to use the uranium that has been found. Whether we like it or not the timescale of commercial introduction has been put back by quite a long time.

"But the fast reactor is not the only project that has run into delays in commercial exploitation. In the synthetic fuel industry immense technical advances have been made and new highly sophisticated energy efficient processes developed for converting coal into liquid fuels. The new processes for hydrogenation of coal are very much more efficient than the old way involving the use of synthesis gas which was the process used during the war in Europe and used today in South Africa. Liquefaction of coal has however so far been prevented from being adopted commercially by the new 'times two' rule: this states no matter how much is learnt or whatever progress is made, oil from coal will be economic at twice the price of crude oil current at the time.

"In fusion we see an even more extreme case. Programmes of work aimed at achieving controlled fusion were under way 25 years ago. In 1958 the US built an impressive exhibition of fusion research at the Geneva Conference for Atoms for Peace. It was widely believed that controlled fusion would quickly be demonstrated and that it would become an alternative to fission without the problems of plutonium and fission products. Since that date great progress has been made and fusion pulses can be produced at will in the latest experiments. But fusion has been caught by the '25-year' rule. This states that no matter how much is learnt or whatever progress is made, the commercial demonstration of fusion power will always be 25 years away in the future.

"I am being facetious, of course, but there are dozens of examples where new and exciting technologies are almost the UK we had developed a design for a demonstration plant which, from an operational viewpoint, would have outstanding safety and performance characteristics, and was very soundly based on prototype experience and technology. However, the development of the essential fuel cycle plants had in varying degrees lagged behind demonstration of the reactor technology. Fortunately, papers presented at the conference showed that the balance was being redressed, particularly in the fields of fuel fabrication and reprocessing [and see the accompanying box].

"It has not in the past been sufficiently appreciated, perhaps because of institutional boundaries, that there is significant interdependence in the fast reactor system between the way fuel is designed and manufactured, the performance and endurance demanded of it in the reactor, and the way it has to be dismantled, reprocessed and refabricated," said Dr Marsham. "These cannot be optimised separately."

Technical status

Dr Marsham said all recent experience reported on the closure of the fast reactor fuel cycle gave cause for considerable satisfaction and encouragement. Even as recently as the inquiry into British Nuclear Fuels' proposals for a thermal oxide reprocessing plant at the Sellafield (formerly Windscale) plant, some pessimists were claiming that oxide fuel reprocessing would be extremely difficult, if not impossible. "However, our experience at Dounreay with the reprocessing of PFR fuel is that fast reactor mixed uranium/plutonium oxide fuel reprocessing is actually easier than we had dared to hope," he said. French experience was similar. There was steady progress toward higher burnups and shorter cooling times, and they could claim justly that the process technology was now well understood and proven.

Design and development work must now be concentrated on improvements to the plant engineering of commercially-sized units. For the fast reactor system, the total cost of the fuel cycle was a significant fraction of the total system cost and there was incentive to improve every aspect—capital cost, production costs and plutonium utilisation—to the limit. "While it seems to me that the evolutionary improvement of present plant concepts could meet all our requirements, nevertheless we should not ignore the possibility of more revolutionary improvements," Dr Marsham suggested.

Analysis of experience to date suggested to him that certain practical steps could improve both plants and the prospects for the earlier introduction of fast reactors:

- development and demonstration programmes now needed to concentrate on mechanical equipment and its reliability rather than on marginal improvements in flowsheet and process features;
- to reduce costs, the potential plant lifetimes should be maximised by designs which allowed the replacement or refurbishing of key components in particularly hostile environments—for example, the dissolver of a reprocessing plant;
- there must be close liaison between the designers of each stage of the fuel cycle and the reactor to ensure the best compromise between the often conflicting requirements for

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ready for exploitation but where the economic environment is not yet ready to receive them on a commercial scale.

"I believe that the analysis of 30 years ago which led to the fast reactor programmes being started is as valid now as then. I believe that we should sustain an energetic fast reactor development programme. I have been criticised by anti-nuclear groups for predicting that in the future our electricity requirements will be met from large fast reactors pumping electricity into the grid network of our industrialised society and that the fast reactor will ensure that we have for all time the electricity we require. I do not in any way retract that prediction.

"But what is more difficult to predict is the time scale on which it will come about and, because the timing is uncertain, the way in which fast reactors will be introduced. The problem to which we must all address ourselves is how to get from where we are today, where we have nearly all the technology we need at our disposal, to the widespread commercial use we all envisage in the future. Again, I suggest we should look at other industries with similar problems to our own to see if there are any lessons to be learnt."

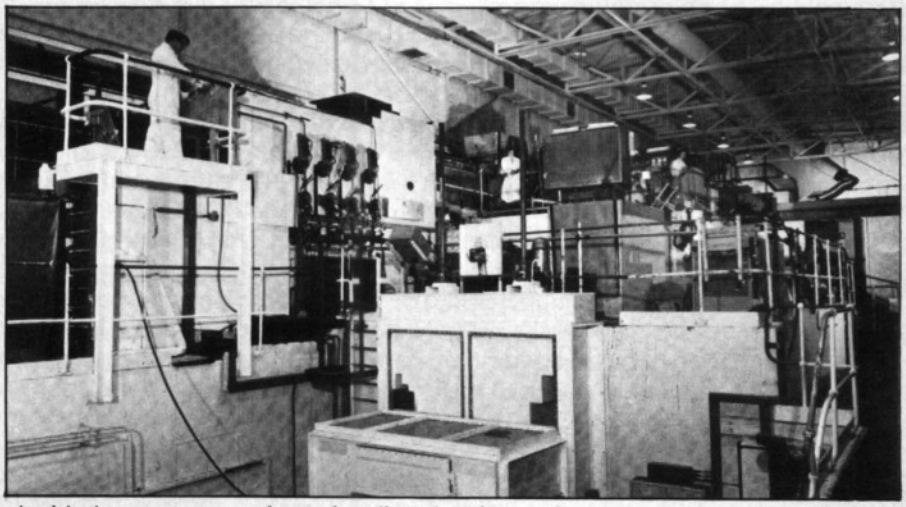
Sir John noted that the aircraft industry—started some 40 years earlier than the nuclear industry—had made immense contributions to man's freedom of movement and understanding of the world; its achievements were breathtaking. "No one should under-estimate the achievement of building a cinema to seat 500 people, lifting it high in the air, flying it at 600 miles per hour half way round the world and landing it again with pin-point accuracy. But this success has not been achieved without pain as well as exhilaration, setbacks as well as advances and disasters as well as successes. . . . Not everything is relevant, or a parallel, but there is no need for the nuclear industry to make again all the mistakes that have been made in the aircraft industry. It was not only in Britain where we were slow to appreciate the damage that was done to our aircraft industry by its fragmented industrial structure. But it should not have taken us nearly 20 years to recognise that the fragmented nuclear industry that was set up in 1955 to replace the efficient centralised one we had at the time was not the way to build nuclear power stations."

We should recognise that a high degree of standardisation would almost certainly come about and that the manner in which commercial fast reactors are built in 20 years' time will probably include many of the characteristics of the way large aircraft are built today, Sir John suggested.

"It is going to take longer than we at one time thought to launch the fast reactor commercially," he said. "Because of this time scale and the fact that the technology and engineering of alternative reactor systems will also have improved further, the commercial fast reactor will have to meet more exacting criteria. We should not assume that the best way to carry the fast reactor through this final stage is necessarily the way thermal reactors were introduced commercially 25 years ago. Much has changed in the meantime. We should develop them in a way that is consistent with our best guess as to what the industrial structure of the nuclear industry will be in 20 years' time. In my view this will resemble more the European airbus than the Caravelle, or the Comet—although it should be remembered that the Caravelle and the Comet had identical nose sections.

"Crystal balls are out of fashion these days and I would be the last to predict how things will evolve over this time scale. What I am sure of is that the various teams developing fast reactors must put themselves in the position where they can rapidly absorb the best ideas, the best engineering designs, and take every opportunity for standardisation. We should also assume that there will be closer and more effective industrial links than we have today. Twenty years ago there was a good international exchange of scientific information but little industrial cooperation. Today there is a substantial but by no means complete commercial and industrial cooperation. I believe economic pressures will force a tighter industrial integration in the future, particularly in the medium-sized countries of Europe, of which the UK is one." □

PFR reprocessing success



A full assessment of the results of the first round of reprocessing irradiated fuel from the Prototype Fast Reactor at Dounreay has confirmed the success of the project and demonstrated the technical viability of the fast reactor fuel cycle, delegates to the BNES conference heard.

Details of the campaign were contained in a paper presented by Owen Pugh, Assistant Director (Fuels) at Dounreay, with co-authors R.H. Allardice, Director, Process Technical and Safety Directorate, Risley; T.R. Barrett, Fast Reactor Reprocessing Manager, Dounreay; Dr W. Batey, Separation Chemistry Manager, Dounreay; A.L. Mills, Separation Processes Group, AERE Harwell; and J. Reekie, Assistant Chief Engineer, BNFL Risley.

The decommissioning and rebuilding of the reprocessing plant at Dounreay was described in a paper in ATOM **272**, June 1979, pp. 142-145 (available as a reprint). The modified dissolver cell and solvent extraction plant were recommissioned late in 1979 and reprocessed 0·7 tonnes of ex-DFR irradiated uranium fuel to complete the DFR programme. The new fuel disassembly and waste facilities were commissioned in 1980, and the first PFR irradiated plutonium fuel reprocessing campaign took place in the autumn of that year.

Fourteen fuel sub-assemblies were selected for the first reprocessing campaign with an average burnup of 4·06 per cent and a maximum burnup of 6·4 per cent heavy atoms. In addition, two unirradiated sub-assemblies used during reactor commissioning were available, and it was decided to reprocess the unirradiated fuel as part of the run up to active operation. Plutonium active operations began in early September 1980 and the 1·5 tonne PFR fuel campaign was completed in December of that year. The irradiated fuel sub-assembly cooling times following discharge from the reactor were greater than 2·5 years in all cases, and the maximum decay heat output handled during the campaign was about 1 kilowatt. The fuel had not in fact achieved its design burnup, as there had been problems with the conventional steam generating plant of PFR, which had limited high power operation; the irradiation history of the discharged fuel was not therefore typical of high power operation.

The recommissioned reprocessing plant easily achieved its design throughput, the only restriction being imposed on occasion by the system for the removal of solid waste from the fuel disassembly cave. Particularly important was the demonstration of very high separation efficiency, restricting losses to plant waste streams and to the environment and ensuring that fast reactors should be able to achieve the enormous gain in the utilisation of uranium that they promised.

New items incorporated in the plant, notably a centrifuge for removal of fission product insolubles and fluidic pumping devices, proved reliable and efficient in highly active operation. The campaign proceeded without any significant radiological incident, the total operator dose recorded over the four months of the campaign being 7 rem: an average man-dose of 100 millirem. Personal air samplers were issued to all operators and no air activity release was recorded, proving that the emphasis placed on plant containment during plant design and construction had been correct. Plant operation was subject to Euratom and IAEA safeguards inspection throughout the campaign. □

easy manufacture and reprocessing and in-reactor performance;

- modular concepts which allowed new plant stages to be added progressively as demand arose were to be preferred, to maintain high load factors as the reactor programme expands;
- there must be close liaison between those responsible for plutonium safeguards and accountancy standards, and the plant designers and operators, to ensure that standards and inspection procedures were effective without unnecessarily complicating plant operation;
- particularly during the launching phase, we must endeavour to identify areas for international collaboration, so that we not only shared the burden of development costs but we reduced the unit production costs of the early process plants by combining plant requirements with, perhaps, some degree of national specialisation. This implied a need for international standardisation and the adoption of common features so that transport flasks, for example, could be used universally; and
- for the longer term we must also encourage new ideas which could lead to major reductions in cost, efficiency or plutonium economy.

"The nuclear industry must not be complacent about its future or feel that it is in any way already determined," Dr Marsham cautioned. "The rate at which it increases its share of the energy market depends on the way it retains its cost competitiveness with other forms of electricity generation, on its safety performance and on our ability to convince the public at large of its acceptability—and this also is affected by relative economies. The search for greater efficiency and lower costs without compromising our excellent safety record applies particularly to the fast reactor and its fuel cycle.

"There is a danger of swinging from earlier complacency to demoralisation about the prospects for economic fuel reprocessing and the introduction of fast reactors. I would emphasise that the future is not in any way already determined. I am convinced that if we take a more enterprising approach to development, design and industrialisation, particularly in the fuel cycle area, in spite of certain adverse factors in the present energy scene, the case for continuing the demonstration and installation of the fast reactor system with the present momentum and without discontinuity remains very strong and a very valuable component of world energy strategy." □

Coal and the environment

Report of the Commission on Energy and the Environment; HMSO 1981. ISBN 0 11 751585 X. £23.

This long-awaited report will be seen by many as a companion volume to the sixth report of the Royal Commission on Environmental Pollution, which dealt with nuclear power and the environment.* It provides a clear and well-written account of the present state and future prospects of the technology of the coal industry and coal utilisation; it reviews the state of knowledge on environmental impacts, including those on health, crops, property and world climate, and apart from one or two mild reservations the authors conclude that the present situation is generally satisfactory.

As a basis for their quantitative conclusions the Commission have taken a Department of Energy low growth case (1 per cent p.a. growth in GDP to 2000) which leads them to a coal demand of 125 million tonnes in 2000, assuming 22 gigawatts (electrical) of nuclear capacity at that time. Against this background they review the prospects for UK and world coal supplies and comment on trends in production costs and prices.

The text discusses the occupational hazards of mining and points to the considerable improvements that have taken place over the years in both accident levels and pneumoconiosis (figs. 1 and 2).

The general impacts of mining operations on the environment are summarised, including the effects of spoil tips, of drainage and washing operations, of noise and of subsidence. On the latter the Commission recommend that additional compensation should be payable allowing for loss of property value as well as the currently covered costs of repair (Table 1). Both this problem and spoil tipping are matters giving rise to considerable local concern and the Commission examines ways of improving on the present situation. Unfortunately some techniques such as backstowing of spoil are not well matched to modern mining techniques.

The problems arising from mine closure might be considered to parallel the decommissioning of nuclear facilities. Environmental restoration would now be expected and is practiced, although the coal industry has a legacy of past activity that is still being worked upon with the assistance of grants under the local Employment and Local Government Acts.

The section of the report dealing with coal use points to the present dominance of coal in electricity generation and of electricity generation as a use for coal. The Commission reports that the expectation that coal will quadruple its share of industrial markets by 2000 is not generally recognised by local authorities.

Following a brief discussion of coal transport and its impacts and of synthetic natural gas production, the report looks at current and future combustion technology in power stations, industry and the home. The quantities of pollutants, mainly smoke and sulphur dioxide, are reviewed and likely future levels discussed.

The greatest interest outside the industry is likely to focus on the effects of pollutants on people and the general environment. The situation is complex because of the difficulty of allowing for the much greater effects of cigarette smoking, the long lags involved before chronic impacts are seen, and the understanding of the specific role of individual pollutants and their interactions. Figure 3 presents the acute effects as a function of smoke and

*The Commission on Energy and the Environment, like the RCEP at the time of its sixth report, was chaired by Lord Flowers, FRS.

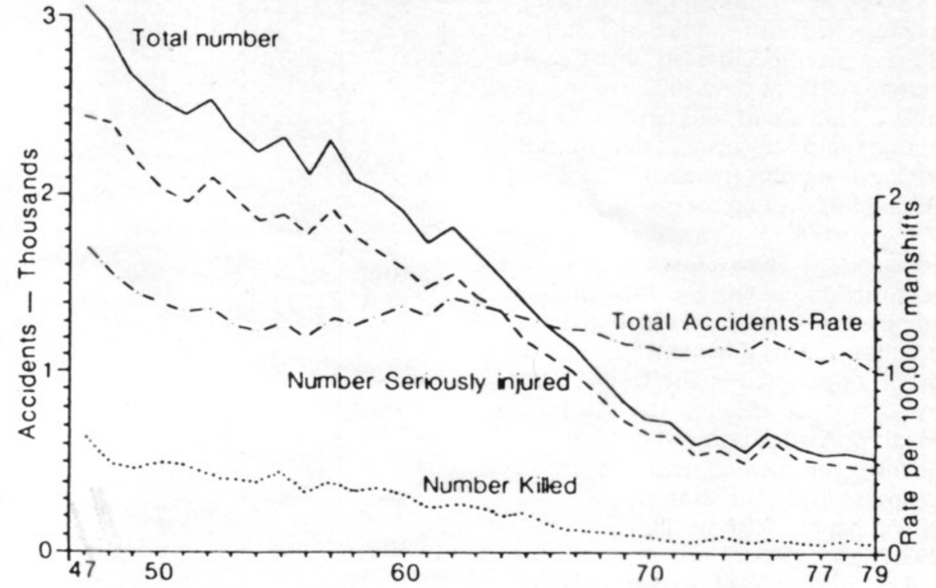


Fig. 1 (Fig. 5.2 in the report): Coal mines: accidents from all causes and total rate per 100 000 manshifts 1974-79

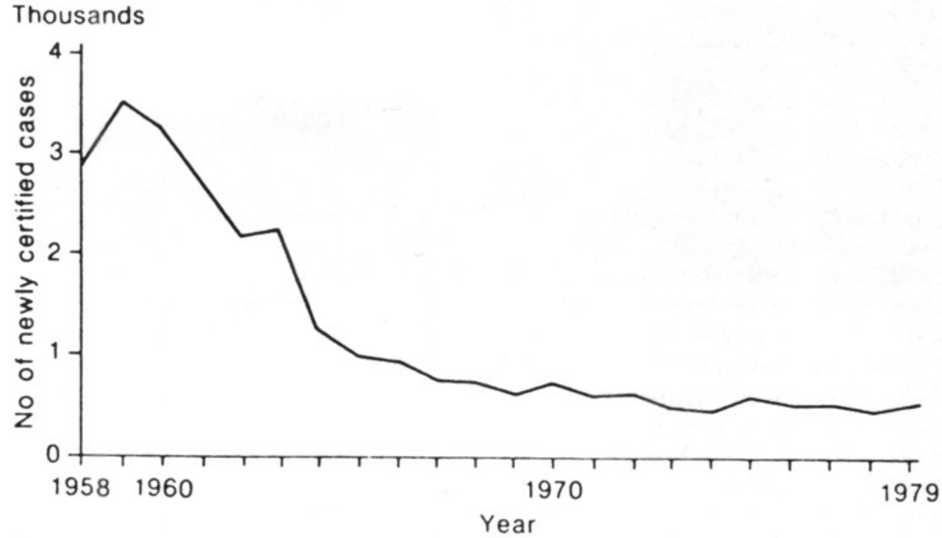


Fig. 2 (Fig. 5.5 in the report): Trend of pneumoconiosis cases (new) 1958-1979

sulphur dioxide concentration (para. 18.12 of the report). Current winter average levels of smoke and sulphur dioxide in the cities in the UK are perhaps 40 $\mu g\ m^{-3}$ and 100 $\mu g\ m^{-3}$ respectively. Not all of this is due to coal burning and only a small part of it due to power stations (paras. 17.12, 17.41). Because of the complexity of the problem (para. 18.15) no attempt is made to estimate the extra numbers of deaths resulting from chronic bronchitis or emphysema that can be attributed to air pollutants. This is in contrast to the approaches adopted in the United States by, amongst others, the American Medical Association, who attempt to quantify the consequences of chronic exposure (see, for example, Sir John Hill's paper, *Risk v. Benefit,* ATOM **293,** March 1981).

The question of excess deaths is examined for lung cancer, however, and here from correlation with benzo[a]pyrene levels it is concluded that the present contribution from coal combustion is unlikely to account for more than 100-200 cases a year (paras. 18.25, 18.32).

For the purpose of comparison, ATOM readers will know that the nuclear industry in the UK adds about 0·3 millirem per year to the average population radiation dose, which is less than 0·2 per cent of the natural background level averaging in the UK about 186 mrem per year. These natural levels are a thousand times less than those at which large doses of radiation delivered over a short period have been observed to cause early deaths. If linear dose response relationships are assumed, it can be calculated that the activity of the nuclear industry might lead to one fatal cancer per year in the UK, and this may be an over-estimate. This would appear to be comparable to the figure for enhanced cancer incidence due to coal burning in UK power stations, relative to energy output.

The radioactive emissions from coal-fired power stations are discussed in the report, which concludes that in terms of resultant radiation dose to the public these are comparable with the very small amounts arising from the normal operation of present nuclear power stations, including emissions from the nuclear fuel reprocessing cycle: in both cases, the average dose equivalent received by members of the public is far less than the natural variations in the annual dose received from all natural sources (paras 17.36, 18.31).

The effects of pollution on crops and property are generally considered by the Commission to be less serious. Crop damage costs of £23 million a year in the UK are cited for the worst conditions, and £130 million of corrosion damage (metalwork only considered) might be avoided by a reduction of 40 per cent in sulphur dioxide concentrations (paras. 18.40, 18.53). The costs of greater sulphur dioxide emission control would be considerable, and would for example add some 10 per cent to coal-fired electricity generation costs (paras. 17.70-17.73). Total costs in the UK might rise to £195-330 million per year and a recent figure for the EEC as a whole has been set at £5 000 million per year (para. 18.44). Such moves might affect acid rain and reduce crop damage and corrosion, though whether the benefits would exceed the costs is not explored in the report.

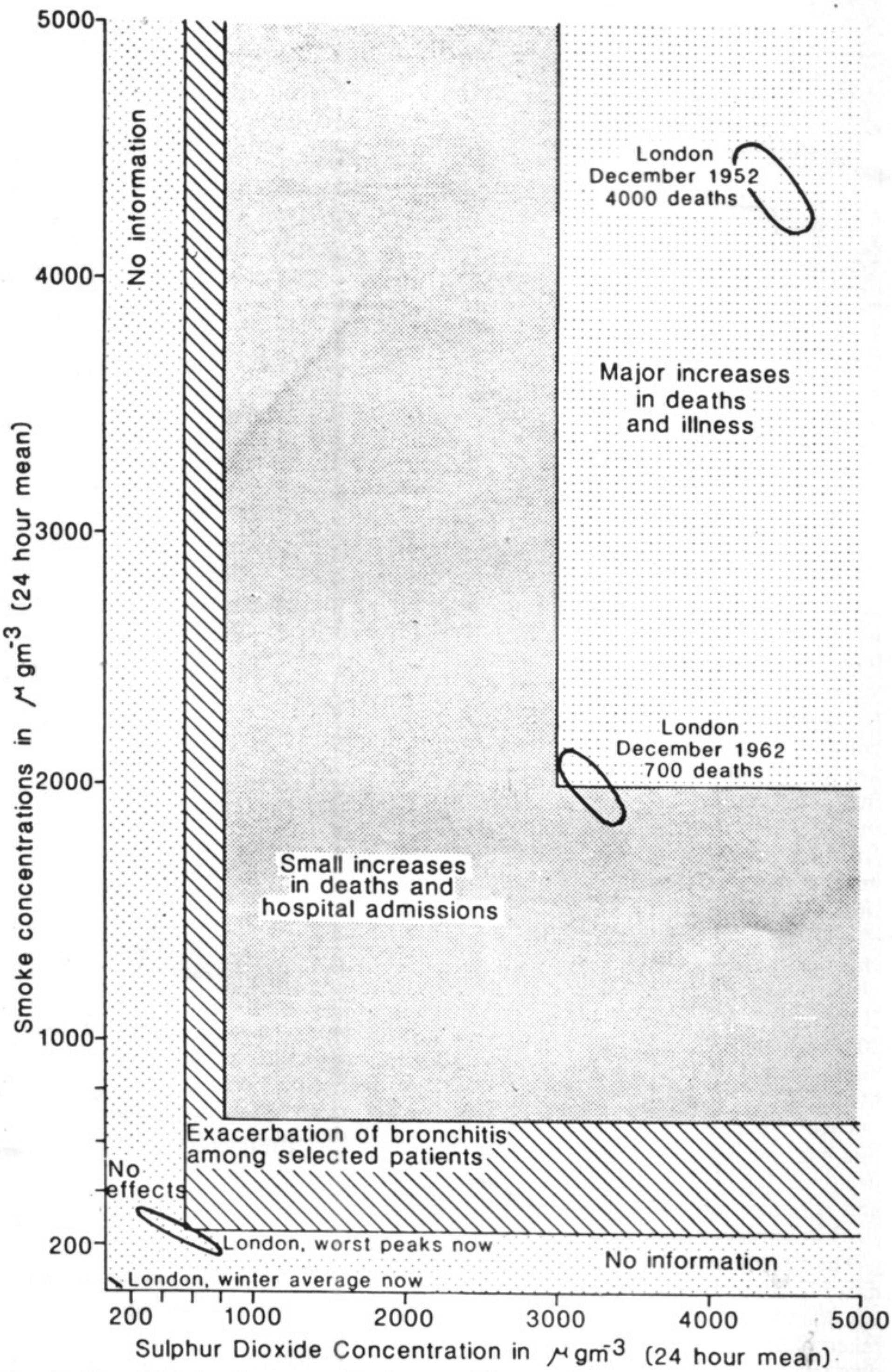


Fig. 3 (Fig. 18.1 in the report): Acute effects of exposure to smoke and sulphur dioxide pollution

Not surprisingly the question of carbon dioxide production and the greenhouse effect is discussed. The views of Sir John Mason are quoted, as supporting a 2°-3° rise in average global temperature over the next 50 years or so, and a 5-7 per cent increase in precipitation (para. 18.55). The economic and social effects of such changes are difficult to predict, although one cited source refers to carbon dioxide as "one of the most important contemporary environmental problems which threatens the stability of climates world-wide and therefore

Coal and radioactivity

A note on radioactive emissions from coal-fired power stations issued by the CEGB as a newsletter concludes that controls in operation at such power stations limit radiological exposure of the public to very low levels, and that there is no special cause for concern over public health.

The authors, A. Robson and P.T. Manning of the Generation Studies Branch at CEGB headquarters, and J.O. Corbett of the CEGB Berkeley Nuclear Laboratories, note that coal does contain trace amounts of radioactive substances so that when coal is burned small amounts of radioactivity are released into the atmosphere. Radiological assessments of coal-fired power stations have been reported from a number of countries: these cannot be assumed to apply automatically to the UK, the authors say, since they are likely to refer to power plants or to types of coal which have different characteristics to those prevailing in the UK. However, the data can be modified to take account of UK conditions, and there have been a number of evaluations leading to a general conclusion that the radiological impact of both coal-fired and nuclear plant is small in absolute terms. □

the stability of all nations''. The Commission concludes that ''it would be premature to do more than note the potential importance of the issue and that research is being carried out to clarify the problems'' (para. 18.58).

Overall, the Commission feel that the environmental and social costs of energy provision to an industrial society are far outweighed by the rising standards of living and reduced mortality from other causes (para. 22.6). Their initial expectation that their study of coal and environment ''would throw up a picture highlighting deleterious effects had, in the event, provided a reassuring and more promising picture'' (para. 22.3).

In their final chapter the Commission explore the problems of reconciling divergent interests through the planning process. An energy infrastructure is seen as ''vital to national prosperity'' and ways must be found to enable developments to proceed and to do so in a timely manner'' (para. 21.10). To assist in this, the Commission call for the Government to encourage greater debate on the energy options, and they make specific proposals which they believe would ease the planning process, achieve greater consensus and speed local planning inquiries. Some of these proposals could prove helpful to all interested parties. It is particularly interesting to note that they have come out against two-stage inquiries dealing with national and local issues separately (para. 21.60) and that they favour continuation of the present flexible UK approach to environmental impact assessment over the more formal mandatory requirements called for in the United States.

Dr P.M.S. Jones
Head, Economics and Energy Studies

Table 1 (Table 8·2 in the report) Subsidence costs at current and constant prices.

	NCB Payments—current prices	NCB Payments—Constant prices (1)
	£million	*£million*
1969/70	5·1	9·2
1970/71	5·4	8·7
1971/72	6·3	9·1
1972/73	6·2	8·2
1973/74	7·9	9·6
1974/75	10·1	10·1
1975/76	14·4	11·6
1976/77	17·0	12·1
1977/78	26·0	16·6
1978/79	30·9	17·8
1979/80	42·6	21·3
1980/81	54·7	23·3

Notes (1) At 1974/75 prices
GDP Deflator June 1981 Economic Trends

Source (for Current Price Figures): *NCB.*

The pursuit of the ideal

Twenty years ago there were four nuclear weapon states; in 1964 they were joined by a fifth. Since then this number has remained unchanged, but the danger of proliferation remains—in the long term, second only to the danger of a nuclear war. Whether or not proliferation is discouraged effectively will depend chiefly on the actions and policies of the most powerful nations, the ideal being the full and universal application of the non-proliferation regime in spirit as well as in letter, by either universal acceptance of the NPT, full-scope safeguards or the full application of regional agreements such as the Tlatelolco Treaty.

Dr Eklund

Dr Sigvard Eklund, retiring Director General of the International Atomic Energy Agency, struck this sombre note when he addressed the General Assembly of the United Nations in November. But he was as well able to conclude that international efforts to limit the proliferation of nuclear weapon states had so far been remarkably effective considering that during the past 20 years some 20 or more countries had increased their industrial nuclear potential considerably.

Dr Eklund recalled that the Agency's responsibility in the safeguards sphere derived from both its own Statute and the Treaty on the Non-Proliferation of Nuclear Weapons. A few years ago it had seemed that the number of parties to the NPT had reached a ceiling; but there had recently been some encouraging additions—notably Sri Lanka, Bangladesh, Indonesia, Turkey and Egypt. "As several of these countries are in regions of tension their willingness to accept the NPT is of considerable significance," said Dr Eklund. "It is of the utmost importance that NPT or full-scope safeguards be universally accepted by all nations of the world.

"More than 95 per cent of all nuclear material outside the nuclear weapon States is now under IAEA safeguards. In addition, three nuclear weapon states, the UK, the United States and France have also, under their voluntary offer, placed some selected civilian nuclear facilities under IAEA safeguards.

"For the past five years the Agency has been making a detailed statistical analysis and evaluation of the effectiveness of its safeguards operation and in no case has the Agency detected any discrepancy which would indicate the diversion of a significant amount of safeguarded material. It has thus concluded that all such material has remained in peaceful nuclear activities or has been otherwise adequately accounted for."

Dr Eklund cautioned however that with regard to nuclear power reactors which were refuelled on load the Agency would not, in a few cases, be in a position to give the requisite assurances of independent verification until certain necessary technical measures had been implemented. Further, there were a few countries which had not yet acceded to the NPT which were engaged in significant nuclear activities with the existing or the potential capability of producing nuclear explosive material. These activities were not subject to IAEA safeguards, and were a cause of serious concern.

Dr Eklund recalled that the second NPT review conference in Geneva had not agreed a final declaration. This was regrettable; but there had been general support and appreciation for the Agency's safeguards activities. Nevertheless, the NPT and by extension the Agency's safeguards regime had suffered a blow in June 1981 when a non-NPT country, Israel, had carried out a military attack against a research reactor in Iraq, a party to the NPT and thus subject to IAEA safeguards on all its nuclear activities. Dr Eklund had expressed his "deep concern" over this development in the UN Security Council as well as in the Board of Governors and the General Conference of the Agency.

"To the extent that the Agency has been successful in meeting challenges it has faced during the last 20 years, this has been due in part to the fact that it has focused attention essentially on the pursuit of the objectives enshrined in its Statute, particularly the technical aspects of its programmes," he said.

"The Agency has been relatively free so far from excessive involvement in some of the deeply divisive political and economic issues which, though of undoubted international concern, have little direct bearing on the Agency's sphere of competence and responsibilities. I hope very much that the Agency can continue on this path.

"The greatest challenges that we have to face in the nuclear field in the years ahead lie in three directions.

- "First, there is the future of nuclear energy itself. If the present trends persist, a time may come when the overwhelming relevance of nuclear energy in some countries may be only in terms of military uses. I trust this will not happen. As I stated at the Agency's General Conference last September, as a member of the scientific community I believe that in the long-term logic and reason must prevail. Those who are truly concerned about protecting the environment and safeguarding our health and safety will perceive that among the energy options available to us today the nuclear path is the one likely to be least damaging to the environment and the only one that does not carry the risk of long-term climatic change.

- "This question is also crucial for the second main challenge, that of bringing nuclear technology within the reach of more developing countries and helping those that have already introduced it in their national programmes. Their problems are essentially those of finance, infra-structure and trained manpower rather than those of coping with environmentalist opposition. Our success in meeting this challenge will depend to a large extent on whether or not there is a healthy nuclear industry in the industrial countries and foresight to share new technological developments with the developing countries.

- "The third main challenge is the support and extension of a viable non-proliferation regime. Of all the services that the IAEA can render to the international community this, in my view, is the most important. Let us not forget the dangers of proliferation. In the long-term, they would be second only to the danger of a nuclear war. Whether or not proliferation is effectively discouraged will depend chiefly on the actions and policies of the most powerful nations. The ideal would be the full and universal application of the non-proliferation regime in spirit as well as in letter, either by universal acceptance of the NPT, full-scope safeguards or full application of regional agreements like the Tlatelolco Treaty."

Dr Eklund acknowledged that the nuclear policies of the countries that were today operating unsafeguarded facilities capable of producing weapons material were imbedded in acute political tensions in their regions. The arms control and disarmament measures foreseen in the NPT were unrealised and, in particular, we seemed to be no nearer to the crucial step of a comprehensive test ban which because of its non-discriminatory feature would attract wider adherence and thereby strengthen the non-proliferation regime.

Recently there had also been disturbing reports on the possible use of new technology for transforming plutonium produced by civil reactors into weapons grade material. It would greatly hamper the Agency's task of safeguarding most power reactors and would tend to undermine international confidence in the NPT regime if reprocessed plutonium from such reactors were to be refined for use in nuclear weapons. "I profoundly hope that this technological option, in direct conflict with the objectives of the NPT, will not be taken up," he said. "I am relieved to learn now that there are already second thoughts about taking this course."

They had also to bear in mind that the day might come when one or more non-nuclear weapon state might feel inclined, for whatever reason, to test nuclear explosives. It was to be hoped that countries that were or might soon be producing unsafeguarded nuclear explosive material understood that such a course would detract from instead of adding to their national security: in other words, one must hope that wisdom and restraint would prevail.

The brink of the abyss

Dr Eklund reminded delegates that they had to be realistic: they could not close their eyes to the possibility of some unwelcome eventualities in connection with the nuclear industry. Even with all available precautions, the possibility of a significant nuclear accident could not be ruled out. There could be armed conflict involving civilian nuclear installations: radiological warfare could, in effect, be initiated by the use of conventional weapons. "One shudders to think of the consequences of military attacks on any of the existing 260 nuclear power reactors, or on the 300 research reactors," he said.

"Over long years much has been said on the subject of nuclear arms control but little has been done in reality. The task is no doubt formidable, but there is none before us that deserves a higher priority. The Secretary-General, Dr Waldheim, has pointed out in his annual report to this General Assembly that 'Disarmament, in a nuclear age, is a matter of survival'.

"The world today stands on the brink of an abyss. Never before has mankind been in such grave peril. A nuclear war would mean the end of civilisation and could lead to the extinction of the human race. It is thus self-evident that the highest priority of international diplomacy should be to ensure that we do not, through our own folly, go over the edge.

"Our future, our civilisation, our lives are at stake. If we had a Bertrand Russell or Albert Einstein today they would certainly have felt compelled to issue a new Manifesto, a new appeal to the conscience of the world. in far sterner terms. I am pleased to note that there are many institutions in the world today seized with this problem, and their activities should be supported. The fact is that there must be an end to the madness of the nuclear arms race, a halt to the slippery slope of annihilation. This is my deepest conviction, and I should like to conclude my last address in this Assembly with an earnest appeal to you and to the Governments you represent, in their own interest, to subordinate all other aims to that of bringing the nuclear arms race under control before it is too late." □

THE NUCLEAR POWER EXHIBITION

Atoms for energy

Not blind technological optimism, but deeply-considered economic pessimism underlies the argument for nuclear power: a fear that the world in the coming century could be gravely short of energy and as a result short of everything else.

Sir Alan Cottrell, FRS, Master of Jesus College, Cambridge, came to this conclusion when he opened the 'Atoms for Energy' exhibition at its last showing in Birmingham in November.

Sir Alan recalled that two years ago the Government had announced a new programme for civil nuclear development in Britain, aimed at ordering about one more nuclear power station each year and so building up to an additional 15 000 megawatts of nuclear electricity by the early 1990s—subject to demand and to the performance of the industry. "This was good news, partly because the successful implementation of this programme will bring new energy on stream just when we shall need it, as the supplies of North Sea oil and gas begin to run down in the 1990s; and partly because it represented a continuation, realisation and extension of the previous Government's embryonic policy for civil nuclear power, so that there is not much difference between the present Government and the previous administration on this most important aspect of national policy," he said.

"It should never be forgotten that energy is the one and only fundamental physical resource. With energy, all material things are possible. Without it, none are. Here in Birmingham at the centre of a great industrial area huge amounts of iron, aluminium, glass, copper and other materials are worked up daily into all kinds of manufactured goods. What happens in these processes? The atoms themselves are not changed. Just as many iron, aluminium, copper and other atoms come out of a factory as go in. All that we do is move them about, mix them up and sort them out into various patterns and shapes. And the one thing that is absolutely essential for doing all this, and which is used up in the process, is the high quality energy that comes out of electricity lines, gas pipes, and coal and oil bunkers.

"Given enough energy, as well as the time and scientific and industrial skills to use it effectively, we can extract all our required minerals and turn them into metals and manufactured goods; we can turn oil and gas into plastics, purify water, recycle scrap metals, and even turn carbon compounds into protein foods. High quality energy is truly the lifeblood of industry and modern society.

"Energy is bottled force. Kept under control, it can perform wonders for us. But also, like the genie in the bottle, it can break out, uncontrollably, and wreak havoc in accidents. Fuel stores can catch fire and explode, hydro-electric dams break, boilers burst and flywheels tear themselves apart. Nuclear energy brings with it a new kind of hazard in the form of radio-activity, and it is not surprising that the general public is particularly fearful of this. That is why exhibitions such as this have such an important part to play in explaining the immense care that is taken to make nuclear power the most safe of all major energy sources. In fact, the safety record of civil nuclear power is almost perfect, but nevertheless there is still an enormous task to be done in giving the public a true and good understanding of the facts of nuclear safety."

Energy needs

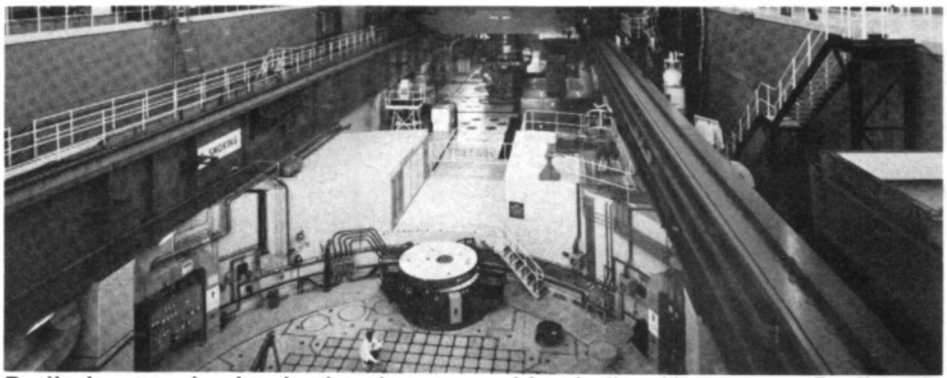
Sir Alan continued: "If the world, and this country, are to get out of economic depression then more energy must become available: at the very least to compensate for the run-down in the more accessible oil and gas fields. Some amelioration of the effects of shortages can be obtained by conserving the use of energy more rigorously than we do at present. This is very important, but nevertheless energy conservation can only take us about a third of the way toward closing the gap between future supply and demand. For the other two-thirds we must look to additional energy sources, of which the only important ones in the foreseeable future are coal and nuclear power.

"The world's requirements and supplies of energy over the next few decades have now been most thoroughly studied by several international groups of independent experts, who all more or less agree that the world's economic growth will be limited by energy constraints to not more than about three per cent a year. Presumably the developing countries, with their fast-expanding populations and their well-recognised needs for economic improvement, will claim the largest share of the world's future economic growth. As regards energy, the need for this in 40 years' time will almost certainly be four times the present level; and for electricity it will be six times.

"These are terrifyingly large figures but the consequences of falling badly short of them would be most serious. There would be worldwide recessions, much worse than today's and probably ending up in social disintegration, revolutions and general war.

"The electricity needs could not possibly be met unless at least half comes from nuclear power. Since the Third World countries will generally not by then have developed their economies to the level at which large centralised nuclear power stations would often make sense for them—and since it would be morally right for the industrialised countries to reduce their demands for fossil fuels, so as to leave more for the Third World countries—then the industrialised countries must look almost wholly to nuclear power to meet their future electricity needs. This conclusion is surely inescapable.

"That is why we need nuclear power. It is not blind technological optimism that leads to the argument for nuclear power, but deeply-considered economic pessimism; a fear that the world in the coming century will, unless special steps are taken, starting now, be gravely short of energy and, as a result, short of everything else—food, employment, goods—but not short of lots of hungry, cold and very angry people. The use of atoms for energy provides one of the best ways we know of trying to avoid this unhappy prospect."



Radiation monitoring in the charge machine hall at Hunterston B, directly above one of the reactors

CEGB view

Sir Alan, a former chief scientific adviser to the Government, was introduced by Mr Dennis Lomer, a member of the Board of the CEGB.

Mr Lomer stressed that the CEGB has the duty to provide an efficient, secure and economic supply of electricity. The board had to plan well ahead, and the fact that the lead times for consent, order, manufacture and erection for a new station could be about ten years from start to finish underlined one of the major difficulties of planning for future electricity supplies. Decisions made today would not bear full fruit until the 1990s, and the fuel chosen must produce economic electricity for the life of the station—25 years for nuclear, and 40 years for coal.

"The planning process is further complicated by the rapidly changing state of world energy supplies and in the price of, and demand for, those supplies," he said. "The economic recession has reduced demand for most fuels. Electricity has been no exception, and its usage is likely to grow only slowly in the 80s.

"But even with relatively slow growth and energy conservation measures which we fully support, new power stations will still be needed. They will be needed to provide a greater degree of flexibility in responding to the availability of primary fuels, to improve the economy of supply and to replace old stations which have reached the end of their technical and economic life. We cannot mortgage the nation's electricity supplies to antique units of production. They must be renewed—in much the same way as the car owner eventually has to replace his vehicle.

"The question we face is how best we can meet the future demand for electricity. We firmly believe that together with coal nuclear power is the only established technology capable of meeting the country's future electricity needs reliably and economically."

Mr Lomer noted that in the past year coal had accounted for nearly 82 per cent of the CEGB's total fuel requirement. While it would continue to play a vital role, such heavy reliance on a single fuel did not offer a sufficient basis for the security of electricity supplies into the future. It was not at present possible to place any substantial reliance on renewable energy resources for the large-scale and economic production of electricity, and the CEGB believed that they would make only a limited contribution to public electricity supply over the next 20 years. Nuclear energy represented not only an additional primary fuel in the UK, but also enabled electricity to be produced at lower cost than by other means. The CEGB had built up nearly 20 years of operational experience with nuclear power, and had shown it to be safe as well as economical.

Beyond the CEGB's proposals for a PWR station at Sizewell, the board had made no commitment to the construction of any further nuclear stations, said Mr Lomer. "Nevertheless, it believes that the continued development of nuclear power is the right policy for new plant, and it aims to build further nuclear capacity to gain the advantages of economy and flexibility in fuel supplies. Our planning strategy, therefore is to approach the future step by step. Decisions on future power stations will be taken as and when the need arises." □

Materials Unaccounted For—1981

The UKAEA and BNFL published on 27 November the inventory differences—known as 'material unaccounted for', or MUF—arising from the use of uranium and plutonium in their civil nuclear programmes during 1980-81. Publication of the data follows the practice introduced in 1977 and repeated annually since then [see, e.g. ATOM **292,** February 1981, p. 54].

The figures show no adverse trends. They conform to the pattern in previous years and give rise to no concern over either the safety or the security of the operation of UKAEA and BNFL plant.

Accounts of the movements and stocks of nuclear material are maintained at all UKAEA and BNFL sites and comparisons are made regularly, within defined accounting areas, between (i) the quantity of material determined at each stocktake and (ii) the quantity recorded in the book inventory: this latter takes account of receipts and dispatches, etc. since the previous stocktake. The difference between (i) and (ii) constitutes MUF.

Although nuclear materials accounting procedures are well developed, the chemical and physical form of many of the items to be measured and the nature of the measurements involved are such that absolutely accurate material balances are not possible. Thus, a negative figure in the statements of MUF does not necessarily mean that the nuclear material has been lost or that it has been stolen or otherwise removed: a much more likely explanation is that the difference arises from uncertainties in the measurements on which the material balance has been based. Because it is most improbable that nuclear material is ever brought surreptitiously into a plant, a positive MUF is a clear indication of the uncertainty of measurements.

Site or Works	Plutonium kg[1]	HEU kg U235[2]	LEU kg U[3]	Natural U te U[3]	Depleted U te U[3]
AEA					
Dounreay	−2·7	−3·5	−4·7	−0·008	+0·051
Harwell	+0·2	−0·1	*	−0·015	−0·003
Springfields	N/A	+0·1	+9·5	−0·150	−0·004
Windscale	+0·6	−0·1	+1·8	+0·036	+0·002
Winfrith	+0·4	−0·2	−23·9	−0·003	NIL
BNFL					
Springfields	N/A	N/A	+115	−6·4	+10·4
Sellafield[4]	−9·9	+0·5	+3·1	−0·1	+3
Capenhurst	N/A	N/A		+2·5teU	

+ apparent gain; − apparent loss; * negligible; N/A not applicable.

Notes

1. The figures for plutonium cover all plutonium isotopes.
2. The figures for Highly Enriched Uranium (HEU) are for the uranium-235 content of uranium enriched to above 20 per cent of that isotope.
3. For completeness, the published figures include low enriched uranium (LEU), natural uranium, and depleted uranium, even though these grades of uranium cannot be used to make explosive or dispersal devices.
4. Sellafield is the new name for the BNFL site referred to previously as Windscale.

An important instance of uncertainty leading to MUF arises in accounting for plutonium contained in fuel elements transferred from civil power stations. This plutonium has to be estimated from information on the reactor operating conditions over the period for which the fuel elements have been in the reactor, because it cannot be measured directly until it has been separated from the uranium and fission products contained in spent fuel. These irradiated fuel elements are highly radioactive and can only be handled safely remotely, from behind heavy shielding. Their illicit removal and subsequent extraction of the plutonium they contain are consequently virtually impossible.

Nuclear material accounts are not the only check on the location of nuclear materials. The transfer of nuclear material within sites, into waste streams of between sites, is closely controlled to enable any unauthorised movements, or accidental discharges, of uranium and plutonium to be detected. Additionally, there are various separate physical security measures in force giving added assurance that the material has not been stolen. Procedures are kept under regular review and improved in the light of experience and with the benefit of new and improved equipment and methods. □

PWR appointment

The Board of the National Nuclear Corporation have appointed Mr C.E. Pugh a director of NNC responsible for the UK pressurised water reactor project.

The appointment was made in agreement with the Board of the CEGB, who also agreed that the detailed design for the PWR should be prepared by a joint team comprising staff from NNC, CEGB and specialists from Bechtel and Westinghouse, and reporting to NNC. Subject to clearance of the necessary safety case and all consents, this team will later be responsible for the construction of a PWR at Sizewell with the CEGB as client.

Mr Pugh, who is 59, has been Director of Projects in the CEGB Generation Development and Construction Division at Barnwood, and for many years had a close association with NNC in nuclear design and construction.

Mr B.V. George remains the CEGB's Director of PWR responsible for the discharge of all the client's responsibilities as related to the PWR.

Inverness '82

More than 170 abstracts—two-thirds from outside the UK—have been offered for the Third International Symposium of the Society for Radiological Protection, on advances in theory and practice in radiation protection. The symposium is to be held in Inverness, Scotland from 6 to 11 June.

Copies of a final announcement of the symposium, giving details of the provisional programme for scientific delegates, are now available from the SRP International Symposium Organiser, c/o National Radiological Protection Board, Chilton, Didcot, Oxon OX11 0RQ.

Application forms for exhibition space and facilities for a trade exhibition to be staged adjacent to the symposium are available from Mr M. Wright, Conference Manager, Eden Court, Bishops Road, Inverness IV3 5SA; tel. Inverness 41140. □

Premature despatch resulted in Sellafield release

The Central Electricity Generating Board advised the Secretary of State for Energy in early November of the conclusions of a report by a Board of Inquiry set up following an abnormal release of activity from the Sellafield works of British Nuclear Fuels Ltd [ATOM **302,** p. 324]. The incident caused no hazard to public health.

A statement from the CEGB noted that the nature of the activity indicated that the release had been caused by the reprocessing of fuel elements which had been stored for a shorter period than normal in cooling ponds after their removal from a reactor. BNFL's initial investigations indicated that the fuel could have originated from the Oldbury-on-Severn nuclear station operated by the CEGB, which then established a Board of Inquiry to investigate this possibility.

The Board's investigations established that on 7 September 1981 seven fuel elements had been taken in error from a skip containing newly-discharged fuel and sent to Sellafield with other fuel identified as adequately cooled after removal from the reactor. On 4 October, 27 days after discharge from the reactor, six of the seven fuel elements were reprocessed at Sellafield. Shortly after the reprocessing started higher than normal quantities of iodine-131 were detected by a monitoring instrument on an exhaust stack at the works, and reprocessing was halted. The seventh element from the same batch was not reprocessed.

Irradiated fuel is stored for a period in cooling ponds after discharge from a reactor in order to dissipate residual heat and to allow some of the shorter-lived radioisotopes to decay to acceptably low levels. At Oldbury the required storage period is 90 days, although in practice this is normally much longer.

The irradiated fuel is placed in skips in the cooling pond for storage; each skip is identified by a unique number, and detailed records are kept identifying the contents of each skip. Shortly before despatch from the station the outer sections of the Magnox-clad fuel elements are removed to reduce the volume of stored material before transport to Sellafield. This process—known as 'desplittering'—takes place in an area of the cooling pond alongside the point where fuel newly discharged from the reactor is received.

The CEGB statement said the Board of Inquiry had examined the procedures for the handling and storage of irradiated fuel elements at Oldbury and had concluded that they provided "adequate" control when properly implemented. "The incident showed, however, that within the procedures the possibility of error was present and the station manager at Oldbury has now modified working arrangements to ensure that fuel cannot be despatched prematurely in the future," the statement concluded. □

PWRs and the UK

A seminar is to be held at the University of Birmingham on 24 and 25 March to provide information on the pressurised water reactor prior to the public inquiry on the adoption of this type of reactor for the proposed Sizewell B power station. The seminar is intended to bring participants up to date on experience with PWRs abroad and the safety arguments surrounding the introduction of this technology to the UK; in addition, detailed information relevant to the design of the Sizewell station will be presented by a panel of speakers who will include members of Dr Walter Marshall's PWR Task Force.

There will be ample time for discussion, and an introductory evening class will be given on 23 March for those less familiar with advanced reactor technology. Residential accommodation will be available.

Further details may be obtained from Professor J. Walker, Birmingham Radiation Centre, University of Birmingham, P.O. Box 363, Birmingham B15 2TT; tel. 021-472 1301, ext. 2094.

International waste management conference

A major international nuclear waste management conference is to be held in Winnipeg, Manitoba in September.

Sponsored by the Canadian Nuclear Society (CNS) the conference will bring together speakers from Canada and other countries to discuss scientific, technological, social and other aspects of nuclear fuel and reactor wastes. It will cover as well uranium mine tailings and other active waste materials.

The conference, the first major specialised conference to be organised by the newly-formed Canadian Nuclear Society, will take place from 12 to 15 September, at the Winnipeg International Conference Centre. Further information may be obtained from the CNS at 111 Elizabeth St, Toronto, Ontario, Canada M5G 1P7.

AEA courses

The following courses are to be held at AERE Harwell:

Process instrumentation
19 to 23 April 1982
The instrumentation of process plant, nuclear reactors and scientific apparatus; suitable for graduates entering the field, junior design staff or engineers of other background wishing to acquire an overview of measurement and control.
Fee: £350 + VAT.

Digital computer fundamentals
26 April 1982
An elementary one-day course covering the organisation and architecture of small computers. Topics to be covered include the structure of a computer; number systems; hardware and input/output devices; software—programming; simple logic and Boolean algebra; and an outline of micro-computers.
Fee: £70 + VAT.

Introduction to the use of small computers
27 to 29 April 1982
This is a course of lectures for present and potential users of mini and micro-computer systems. The course emphasises the range of small computer applications with illustrations from business, industrial, communications and laboratory systems. It also discusses the basic principles of hardware and software organisations. Students participate in an exercise to gain experience in planning and operating a computer installation, and have an opportunity to use a number of small computer installations.

Lectures are given mainly by specialist staff from Harwell who draw upon considerable practical experience gained from many years of using computing systems in exacting laboratory and industrial environments. Their discussion of topics is supported by lecturers from industry and commerce.
Fee: £210 + VAT.

Enquiries should be addressed to the Education and Training Centre, AERE Harwell, Oxon. OX11 0QJ; tel. 0235 24141, ext 3116 or 2140. □

Senior appointments

Dr P. Iredale has been appointed Director, Engineering at Harwell following the retirement of Mr J.P. Byrne.

Dr R.H. Flowers has been appointed Authority Programme Director, Fuel Processing, in succession to Mr K.D.B. Johnson, who has retired. Dr Flowers is also based at Harwell. □

First winners of EC essay prize

Two undergraduates from Christ's College, Cambridge, and two graduates from Aston University were named in November first winners of an Essay Award prize introduced by the Electricity Council to encourage engineering undergraduates to increase their understanding of the ways in which electrical techniques can benefit manufacturing industry.

The winners were Andrew Bud and Richard Davies, the Cambridge undergraduates who founded *Energy Matters*, the college magazine; and David Pavely and Clive Poole, who have completed their engineering technology courses at Aston and are now working for the CEGB. Richard Davies wrote on 'Combined Heat and Power', and Andrew Bud on 'The Feasibility of Fusion Power'; Bud has the additional distinction of having won The Times' National Engineering essay competition earlier in the year. David Pavely wrote on 'An Improved Electromagnetic Separator' and Clive Poole on 'The Switchable Separator'.

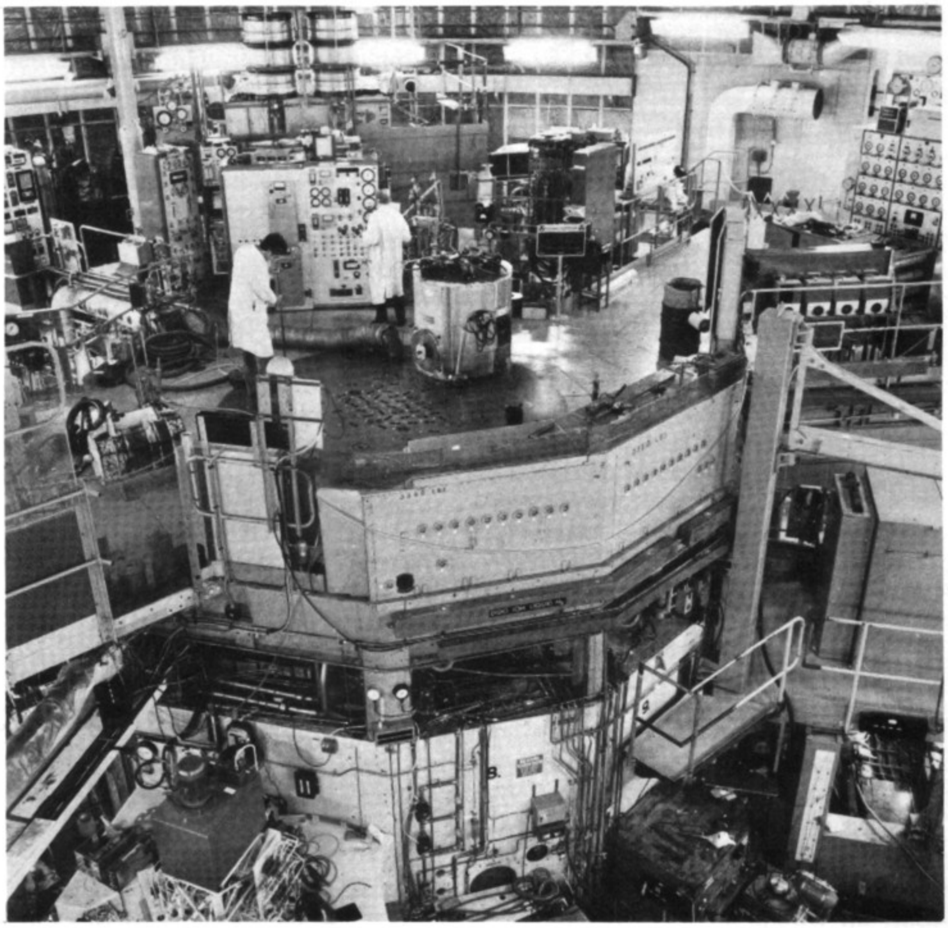
Each winner was presented with a silver medal incorporating the Electricity Council's armorial ensigns by Mr Alan Plumpton, deputy chairman of the Electricity Council. □

Vacuum science award

The British Vacuum Council invites entries for its annual 'C.R. Burch' prize of £150 for the best submitted paper on vacuum studies, surface science, thin films or any related topic in which vacuum science or engineering plays an important role.

Entrants must be under 27 years of age on the closing date for the submission of entries; and the paper must be based on R&D carried out in a laboratory in the UK. Papers which have previously been published are not eligible for entry, and authors must consent to the publication of their paper in *Vacuum*. All papers entered for the competition will be considered for publication in *Vacuum* subject to refereeing. Papers should be about 3 000 words long: guidance on presentation may be obtained from the editor of *Vacuum*. The closing date for entries is 31 December 1982, and the result of the competition will be announced in January next year.

Further information may be obtained from, and entries should be submitted to, the editor of *Vacuum*, Dr J.S. Colligon, Department of Electrical Engineering, University of Salford, Salford M5 4WT. □



Silver DIDO

DIDO, the first of the Materials Testing Reactors at AERE Harwell, celebrated its silver jubilee on 7 November.

Since it was commissioned in 1956 DIDO—with its sister reactor, PLUTO, commissioned in 1957—has played a key role in testing under reactor conditions the materials and components for the UK's Magnox, AGR and fast reactor systems. It has as well facilities for reproducing the conditions which obtain in PWRs.

DIDO is a major producer of radioisotopes for use in medical research, diagnosis and treatment; and of gamma-ray sources which are used to sterilise medical equipment and pharmaceuticals. Other isotopes are produced for industrial applications and environmental research. All these products are sold throughout the world by Amersham International Ltd.

More recently, a major commercial application of the MTRs at Harwell has been the irradiation of silicon crystals used in the manufacture of semiconductors: during irradiation a small fraction of the silicon is transmuted into phosphorus, conferring desired semiconducting properties. Harwell is now providing a silicon 'doping' service for many of the major semiconductor manufacturers in Europe and the Far East.

DIDO and PLUTO are the principal source of neutrons in the UK for basic research into the properties of materials. These facilities are used for Harwell's own fundamental research programmes in the materials sciences and in collaboration with universities and the Science and Engineering Research Council. Two areas of increasing industrial interest are in the use of neutrons for the study of catalysts in chemicals production and in the development of neutron radiography. In this latter application the near transparency of steel to neutrons allows neutron radiographs to be taken through 2 inches (~5 cm) of steel; as neutron beams are strongly attenuated by hydrogen atoms it is possible to investigate oil flows in motor vehicle and aircraft engines, for example, while they are operating.

Over the years continuous programmes of reactor fuel development, safety analysis and control systems have enabled the operating power of DIDO to be increased in stages from 10 megawatts in 1959 to 25 MW today. Its cumulative load factor—the fraction of its life during which is has operated at its full permitted power—is 80 per cent.

Further information on DIDO may be obtained from Des Taylor, Research Reactors Division, Building 443, AERE Harwell. Tel. Abingdon (0235) 24141, ext. 5262. □

AEA REPORTS

The titles below are a selection of reports published recently and available through HMSO.

AERE-M 3223 *Ultrasonic verification of weld signatures.* By K.D. Boness. October, 1981. 13pp. HMSO £2·00. ISBN 0 70 5800834 3

AERE-R 9780 *An organic scintillator neutron spectrometer suitable for in-phantom studies.* By K.G. Harrison. July, 1981. 41pp. HMSO £3·00. ISBN 0 70 580604 9

AERE-R 10079 *MA32—a package for solving sparse unsymmetric systems using the frontal method.* By I.S. Duff, March, 1981. 51pp. HMSO £3·00. ISBN 0 70 580853 X

AERE-R 10024 *The application of high resolution gamma spectrometry to the in-line determination of uranium and plutonium concentrations in solution.* By D. Scargill. August, 1981. 26pp. HMSO £2·00. ISBN 0 70 580744 4

AERE-R 10095 *Calculations of the reflection and transmission of ultrasound by rough sodium-filled defects in steel.* By J.A.G. Temple. July, 1981. 52pp. HMSO £3·00. ISBN 0 70 580624 3

AERE-R 10102 *The calculation of methane profiles in AGR graphite structures. Part 2 Two dimensional problems.* By R.L. Faircloth and A. Harper. July, 1981. 28pp. HMSO £2·00. ISBN 0 70 580704 5

AERE-R 10141 *Measurement of gamma dose rates in a cluster of pressure vessels in the Harwell spent fuel pond.* By W.S. Walters and W.R. Marsh. September, 1981. 31pp. HMSO £3·00. ISBN 0 70 580784 3

AERE-R 10209 *Preliminary small angle neutron scattering studies of pore size in oil shales.* By P.L. Hall. June, 1981. 34pp. HMSO £3·00. ISBN 0 70 580564 6

AERE-R 10184 *Comparison of the measured and calculated neutron output from a mixed oxide fuel pin.* By E.W. Lees and D. West. August, 1981. 12pp. HMSO £2·00. ISBN 0 70 580754 1

AERE-R 10219 *Application of digital techniques to the restoration of out-of-focus photographs.* By S.F. Burch. July, 1981. 17pp. HMSO £2·00. ISBN 0 70 580634 0

AERE-R 10251 *A facsimile code for calculating void swelling and creep, with vacancy loops present: Version VS4.* By M.E. Windsor, R. Bullough and M.H. Wood. October, 1981. 42pp. HMSO £3·00. ISBN 0 70 580844 0

AERE-R 10257 *Applications of SPECK to the design of digital hardware systems.* By M.H. Gilbert, W.J. Quirk, R.P.J. Winsborrow and A. Langsford. July, 1981. 20pp. HMSO £2·00. ISBN 0 70 580694 4

AERE-R 10298 *A temperature controller in the 6000 series.* By C.E. Cox and M.A. Reid. September, 1981. 14pp. HMSO £2·00. ISBN 0 70 580804 1 ☐

ATOM BINDERS

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IN PARLIAMENT

BY OUR PARLIAMENTARY CORRESPONDENT

Nuclear financing

16 November 1981

The Nuclear Industry (Finance) Bill, which increases the financial limit imposed on British Nuclear Fuels Ltd, was given an unopposed second reading in the House of Commons.

Moving the second reading, Mr David Mellor, Under-Secretary of State for Energy, explained that it had been decided in 1976 that BNFL could borrow in the market but that a Government guarantee would be necessary. The 1977 Nuclear Industry (Finance) Act established a limit of £300 million with the power to raise this sum to £500 million. In March 1981 an order increasing the limit to £500 million had been approved by Parliament and BNFL expected to reach that limit by the middle of 1982.

The Bill proposed to set a new limit of £1 000 million with power to raise that to £1 500 million by order.

It was the future investment programme of BNFL which lay at the heart of the Bill, the minister told MPs. It planned to invest about £3·5 billion (at 1981 prices) over the next ten years. Actual investment would depend on the rate of inflation. On the company's inflation projections, the actual outlay could be about £6 billion.

Individual requirements within that total would arise principally from reprocessing—the largest investment amounting to perhaps £3 billion in plant for the reprocessing of irradiated fuel from Magnox and AGR reactors. It was estimated that the additional cost of the Magnox reprocessing investment could be about £1 billion and the construction of a Thermal Oxide Reprocessing Plant (THORP) to serve existing AGR stations as well as some light water reactor fuel from abroad could be about £1·6 billion.

On enrichment, about £800 million was likely to be invested in the centrifuge project. On the fuel division, about £400 million might be invested in fuel fabrication and related activities. Up to £800 million had been set aside for unspecified projects. Much of this would be concerned with the management and reprocessing of nuclear waste, but that specific projects that were likely to be required by the end of the decade could not be more fully identified at this stage.

About £220 million was likely to be required for a plant for the vitrification of highly active liquid wastes. It could be estimated that about 25 per cent of the total investment programme would be concerned with improving and expanding storage and handling facilities for all types of nuclear waste.

This was an ambitious but sound programme. The company was confident that about 86 per cent of the investment contained in the current programme was covered by secure contracts which provided at least for the recovery of all its costs. The other 14 per cent was largely investment in the centrifuge project, where BNFL was collaborating with both the Dutch and the Germans and the kind of guarantees which were at present in the bulk of the company's business were not possible in this project.

Mr Mellor pointed out that the investment programme for domestic customers was mainly to provide services for the existing UK nuclear power programme. It was not significantly dependent upon future nuclear expansion.

The Bill gave the Government the power to guarantee the borrowing necessary to finance the investment. BNFL would be able to finance from internal sources about 70 per cent of planned investment over the next decade. The company had a small equity base—only about £32·7 million. The Government did not intend to increase that base nor did it intend to lend money to the company.

It was intended that BNFL should borrow on the market. This meant it would have to borrow £1·5 billion over the next ten years, and a Government guarantee was necessary. The limit of £1 billion would be reached between 1984 and 1986.

Mr Edward Rowlands, for the Opposition, said MPs should maintain a close scrutiny of BNFL's operation and expenditure because it was a 100 per cent Government concern. Above all they should seek assurances that there was no plan or intention to alter fundamentally what had been a remarkable success story.

Although wholly Government owned, BNFL had been remarkably successful in its commercial dealings and its safety record. Its expanding capital programme was important, and the Opposition would not wish to oppose it.

Spending on alternatives

23 November 1981

There are no plans for any substantial change in Government spending on research into alternative forms of energy, having regard to the fact that expenditure on R&D into renewable energy sources will be about £15·4 million in 1981-82 compared with £3·7 million in 1978-79, Mr David Mellor, Under-Secretary of State for Energy, told the Commons at question time.

Mr Penhaligon asked the Minister to reflect on the comparison between the cost of building a single PWR station and that of R&D into the renewables, "and say why he believes the Government have got the balance of expenditure correct."

Mr Mellor: Mr Penhaligon, in his usual enthusiasm to denigrate the nuclear industry, is making false comparisons. The cost of a nuclear power station is the cost of implementing previous research. Mr Penhaligon's question deals only with research. If some of those projects were put into production the cost would, in many cases, exceed the cost of a nuclear power station.

Sir David Price suggested that the biggest immediately identifiable need was not goodwill toward alternative strategies but the need for a common fund of knowledge. Could the Department of Energy act as a central point to bring together all the experts and the many people who were doing a lot of work on alternative energy sources?

Mr Mellor: Much of that goes on already. Our Energy Technology Support Unit at Harwell does a great deal, both in collecting together expertise and results and in disseminating that. . . . We work on the basis that any reasonable project which should go ahead in the national interest is being funded.

It was important that they should not be deluded into thinking that development of the renewables would in any way reduce the need for new power stations, whether coal-fired or nuclear, Mr Mellor added.

Support for fusion

23 November 1981

The Government is fully committed to support for the European fusion programme, the total budget for which is running at £130 million in the current year, Mr John Moore told the Commons.

Mr Alex Eadie said there were reports that the Government were about to contract out of nuclear fusion research. Would it not be wise for the Government to make a statement clarifying the Government's attitude.

Mr Moore: I do not see that I could express much more clearly the fact that the Government are participating fully in the programme. We are fully committed as a host to the programme and expect to spend around £30 million this year on the programme.

Plutonium

29 October 1981

Mr Cook asked the Secretary of State for Energy what was the proportion of plutonium-239 normally contained in the plutonium extracted from Magnox spent fuel.

Mr John Moore, Parliamentary Under-Secretary of State: The average proportion of plutonium-239 in the plutonium currently extracted from Magnox spent fuel is of the order of 70 to 75 per cent.

• Mr Cook also asked how much Magnox spent fuel was currently awaiting reprocessing; and approximately how much plutonium was due to be extracted from it.

Mr Moore: The current unreprocessed irradiated civil Magnox fuel stock in the UK is approximately 2 million kilograms U which contains approximately 4 500 kilograms of plutonium—all isotopes.

• Mr Cook asked the Secretary of State for Energy what discussions had taken place on the possibility of the UK supplying the United States of America with plutonium for its fast reactor programme; what was the amount of plutonium for civil purposes previously exported to the US; what were the amounts currently being discussed; and whether any assurances were being sought to ensure that any plutonium exported would not be used for military purposes.

Mr Moore: I refer to the answer I gave to Mr Mudd on 19 October and to the answer I gave to Mr Allaun on 26 October [ATOM **302,** p. 325]. The quantity of UK origin civil material exported to the US since 1971 totals approximately 50 kg of plutonium. This material was subject to the relevant bilateral safeguards agreements.

• Mr Cook asked whether figures for the yield of plutonium in tonnes per year from various types of nuclear power station given in an answer on 3 March 1980 [ATOM **283,** p. 150] related to gross or net electrical capacity.

Mr Moore: The figures given in the previous answer were based on an annual average availability of between 74 and 75 per cent for a station with an installed capacity of 1 000 MW gross.

• Mr Cook asked whether any Magnox station had been altered or programmed for military purposes for reasons other than to increase plutonium production; and, if so, which.

Mr Moore: The reactors at Chapelcross are used to produce tritium for military purposes.

Subsidies

29 October 1981

Mr Cook asked the Secretary of State for Energy what was the total Government subsidy given to date to all forms of non-conventional renewable energy sources.

Mr David Mellor, Parliamentary Under-Secretary of State: My Department does not give subsidies for renewable energy sources. It has, however, since 1975 been undertaking research and development to investigate the potential contribution which new and renewable sources of energy might make to UK energy supplies. Expenditure to March 1981 totals £19 million.

Capenhurst

29 October 1981

Mr Cook asked the Secretary of State for Energy what was the initial capital cost of the modified gaseous diffusion enrichment plant opened at Capenhurst in 1968; what was the value of the subsidy provided by the Ministry of Defence in terms of the original defence diffusion plant; what was the nature of the modification carried out; and what was the expected and achieved throughput of the plant.

Mr Moore: The modifications to the Capenhurst gaseous diffusion plant which opened in 1968 cost about £15 million. The modifications involved changes in design of the low enrichment stages in the plant to increase their capacity. The cost of the original stages involved in the modified plant had been fully recovered by the operator—at that time the UKAEA—before its start-up. The plant will have generated some 4 000 tonnes of separative work prior to its closure in 1982, well in line with design expectations.

Windscale

29 October 1981

Mr Cook asked whether the expansion of Windscale referred to in a Parliamentary answer on 16 February 1981 [ATOM **294,** p. 117] was for civil or military purposes.

Mr Moore: The expansion at Sellafield—Windscale—is primarily intended for civil purposes, but some residues arising from Ministry of Defence operations may also need to be treated in the complex.

Defence exchanges

29 October 1981

Mr Cook asked the Secretary of State for Defence to what extent the UK had been exporting plutonium to the United States of America for use in their weapons programme in exchange for importing highly enriched uranium; under what agreements of what duration such exchanges had taken place; over what duration the exchanges had actually taken place; whether they were currently taking place and what were the plans for the future; what quantities of plutonium and highly enriched uranium had been and were involved; for what purposes the UK had used, was using and was intending to use the highly enriched uranium; and what was the source of the plutonium involved, whether from Calder Hall and Chapelcross stations or other Magnox stations.

Mr Pattie: The 1958 agreement between the UK and the US on cooperation on the uses of atomic energy for mutual defence purposes provides for transfers of special nuclear materials between the two countries, but it has been the normal practice of successive Governments not to reveal details of such exchanges.

Military fuel

29 October 1981

Mr Cook asked the Secretary of State for Defence how much spent fuel from nuclear submarines was currently stored at Windscale.

Mr Pattie: I refer Mr Cook to the answer given to him on 16 July 1981 in response to his general question on nuclear waste arising from military reactors [ATOM **299,** September, p. 253]. It would not be in the national interest to provide information on the amount of spent fuel from nuclear submarines which is in storage.

Depleted uranium

11 November 1981

Mr Skeet asked the Secretary of State for Energy how much depleted uranium suitable for eventual use in fast reactors remained in store in the UK.

Mr Mellor: Approximately 20 000 tonnes of depleted uranium is stored in the UK and available for eventual use in fast reactors.

Plutonium shipments

11 November 1981

Mr Donald Stewart asked the Secretary of State for Energy how many shipments of plutonium waste had been made to date from Dounreay to Windscale.

Mr Moore: I am advised by the UKAEA that there have been no shipments of plutonium waste between Dounreay and Sellafield (formerly Windscale). There have, however, to date been two shipments of reprocessed plutonium fuel (plutonium nitrate) by sea between the sites in question.

Waste spending

12 November 1981

Mrs Renée Short asked the Secretary of State for the Environment how much had been spent in £ sterling by the Commission of the European Communities on R&D into radioactive waste management for each of the last ten years at current prices, and how much was being budgeted for 1982-83.

Mr Giles Shaw: Since 1975 the Community has supported radioactive waste management research in member States by its indirect action programme. The actual expenditure in each year for which information is available is as shown in the table.

In addition, the Community supports research at its own joint research establishment at Ispra in Italy. This work forms part of the nuclear safety programme and figures are not separately available for the limited amount of work there on radioactive waste management.

	*European units	*Sterling equivalent £ million
1975	1·314M u.a.	0·548
1976	3·797M u.a.	1·582
1977	4·635M u.a.	1·931
1978	1·030M u.a.	0·684
1979	5·353M EUA	3·372
1980	5·010M EUA	3·382
For subsequent years, only budget figures are available		
1981	6·231M ECU	3·922
†1982	6·864M ECU	3·590

Notes:

* (i) the u.a. (unit of account) had a fixed rate of 2·4 to £1.

(ii) the EUA/ECU (European Unit of Account/European Currency Unit) have been converted using the usual budget factors as follows:

1979 = 1·5875 to £1
1980 = 1·4813 to £1
1981 = 1·5889 to £1
1982 = 1·9118 to £1

†Not yet approved by the European Parliament.

Waste R&D

12 November 1981

Mrs Renée Short asked the Secretary of State for the Environment what work and projects had been carried out by the Commission of the European Communities into the management of radioactive waste since 1970.

Mr Giles Shaw: The Community's joint research centre at Ispra in Italy has carried out work on risk evaluation, protective barriers, actinide separation and actinide monitoring. In addition, the Commission of the European Communities has supported, by its indirect action programme, research by member States on a large number of individual projects. The current five-year programme for 1980-84 includes work on eight areas:

i. immobilisation of low- and medium-level waste, process development and pilot-plant operation;
ii. conditioning of highly active solid waste, fuel cladding and dissolution residues;
iii. treatment of medium-level liquid wastes;
iv. treatment of alpha-emitting wastes;
v. testing and evaluation of solidified high level waste;
vi. shallow land burial;
vii. storage and disposal in geological formations;
viii. immobilisation and storage of gaseous wastes.

Similar work was carried out in the previous five-year programme for 1975 to 1979.

PWR design

11 November 1981

Mr Michael O'Halloran asked the Secretary of State for Energy what bearing the relative changes of the new design submitted by the National Nuclear Corporation for the first Pressurised Water Reactor to be built in the UK at Sizewell in Suffolk would have on the necessary

Electricity generation

12 November 1981

Mrs Renée Short asked the Secretary of State for Energy:

- what percentage of electricity generation had come from (a) coal, (b) oil and (c) nuclear power for each year since 1970, and what were the projected percentages for 1990; and
- what plans he had to increase the use of nuclear power stations in order to reduce the amount of electricity generated by oil by 1990.

Mr Mellor: For the years since 1970 the information is given in the [accompanying] table. The percentages of electricity that are likely to be generated from the various fuels in 1990 are uncertain and will depend on a number of factors, including the evolution of electricity demand, plant availability and performance, and the price and availability of fuels.

With the completion of the nuclear stations presently under construction, nuclear capacity in the public supply system is expected to increase from its current level of 5·8 gigawatts to about 11 GW. This capacity will make an important contribution to keeping oil burn at low level in 1990.

Electricity generated by public supply power stations by type of fuel—United Kingdom

						(Per cent.)					
	1970	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*
Coal (*)	70·8	65·6	57·1	65·1	56·2	64·5	67·4	66·7	67·9	70·1	75·7
Oil (†)	17·1	22·0	28·6	23·2	26·6	19·9	15·7	16·0	17·0	15·2	9·8
Nuclear	9·6	9·9	10·4	9·1	11·7	10·6	12·7	13·9	12·5	12·4	12·6
Other	2·5	2·5	3·9	2·6	5·5	4·2	5·0	3·4	2·6	2·3	1·9

Notes:
(*) Includes generation from Coke and estimates of generation from coal at mixed and dual fired stations.
(†) Includes estimates of generation from oil at mixed and dual fired stations.

extra safety requirements that were said to be the reason for the high cost of the former design.

Mr Moore: It would be inappropriate for me to comment at this stage on the detailed features or relative merits of the NNC's Reference Design; nor can I anticipate the outcome of the assessment of this design by the Nuclear Installations Inspectorate of the Health and Safety Executive.

Conservation

16 November 1981

Mr McCrindle asked the Secretary of State for Energy what relative level of importance he gave in his policy on energy conservation to (a) the price mechanism and (b) taking positive steps to reduce usage.

Mr Mellor: The single most effective instrument of energy conservation policy is the economic pricing of energy, but the policy also requires a range of positive measures to promote more efficient energy use.

Microwave radiation

16 November 1981

Mr Skinner asked the Secretary of State for Employment what was the current acceptable safety level at work of microwave radiation, and how this compared with the safety levels of other European Economic Community countries.

Mr Waddington: Within the frequency 30-30 000 MHz, the currently recommended limits in the UK are:

For continuous exposure: $10 mW cm^{-2}$
For discontinuous or intermittent exposure: $1 mW hr^{-1} cm^{-2}$ during any period of 0·1 hr.

So far as I am aware, the only other Member State of the European Community which has yet fixed any comparable limits is Denmark, which is understood to have adopted a significantly more stringent Swedish standard.

● Mr Skinner also asked the Secretary of State for Social Services if his Department would commission research into the illnesses and ailments associated with exposure to microwave radiation.

Mr Geoffrey Finsberg: Research which has been undertaken in the United States and in this country over a number of years has not indicated a need for further research. The Medical Research Council and the National Radiological Protection Board are, however, keeping the position under review. The Board is currently discussing with the Health and Safety Executive's employment medical advisory service the feasibility of a study of people exposed to microwave radiation in industry.

European research

17 November 1981

Mr Gordon Wilson asked the Lord Privy Seal to list the locations in the UK of all EEC research projects which were being undertaken at present, and to specify the work being done and the numbers employed.

Mr Luce: The main Community research project in the UK is the Joint European Torus—JET—which is researching the production of energy from fusion, and which is established in Oxfordshire as a joint undertaking under the Euratom treaty. It is the largest single research project under the Community, and will represent £35 million, or roughly 15 per cent of the Community estimated payments from the research budget in 1981. It currently has a staff of 270.

The European Commission is also responsible for implementing the research programmes agreed by member States, and for placing contracts with research establishments, universities and industry. There are a very large number of these, many of which are quite small. There is no comprehensive list available, while the details of some are also regarded as commercially confidential. We know that a large number are placed in the UK.

Welsh electricity

19 November 1981

Mr Best asked the Secretary of State for Energy what was the total amount of electricity produced in Wales and the contribution of each source to the total electricity produced for the year 1980-81.

Mr Mellor: Information on the amount of electricity generated by type of plant for 1980, the latest period for which figures are available, is given in the following table:

Electricity generated by public supply power stations—Wales

	GWh	*Per cent*
Nuclear	8 590	37
Conventional steam	14 233	61
Gas turbines	2	—
Water power*	556	2
	23 381	100

*Includes units generated at pumped storage station.

Nuclear irradiation and embrittlement

19 November 1981

Mr Skeet asked the Secretary of State for Energy to what extent irradiation caused embrittlement of steel, and how the problem was dealt with in nuclear power plant construction.

Mr Moore: I am advised that irradiation can cause embrittlement of steel when impurities such as copper, phosphorus and sulphur are present above certain levels.

The nuclear industry worldwide is aware of this problem and preventive measures have now been adopted including stricter controls of the level of impurities, and improved welding procedures.

Advisory bodies

19 November 1981

Mr Philip Holland asked the Secretary of State for Social Services when he last carried out an overall review of the need for retaining unchanged both the Administration of Radioactive Substances Advisory Committee and the Committee on Radiation from Radioactive Medical Products; whether in each case he considered alternative sources of advice; and what conclusions he reached.

Dr Vaughan: The committees were reviewed in September. They have a largely common membership, but meet separate statutory requirements which other sources of advice could not meet. We are considering whether they can be reduced in size.

Encouragement for conservation

23 November 1981

Mr Geoffrey Johnson Smith asked the Secretary for Energy what measures his Department was taking to encourage domestic conservation of energy.

Mr Mellor: Our information campaign explains both the benefits of energy conservation and the methods, two of which, loft and tank insulation, attract partial grants from local authorities funded by Department of the Environment. Other measures include our work toward greater heating efficiency under the ECA 1981 and support for voluntary organisations' conservation initiatives.

● Mr Watson asked the Secretary of State for Energy whether he was satisfied with current measures to promote energy conservation.

Mr Mellor: Yes.

Progress of nuclear power

23 November 1981

Mr Teddy Taylor asked the Secretary of State for Energy to make a further statement on the progress of the nuclear power programme.

Mr John Moore: Construction of the two latest AGR power stations is now under way. Progress on the three AGRs nearing completion is continuing and output from the first unit of each station is expected in the first half of 1982.