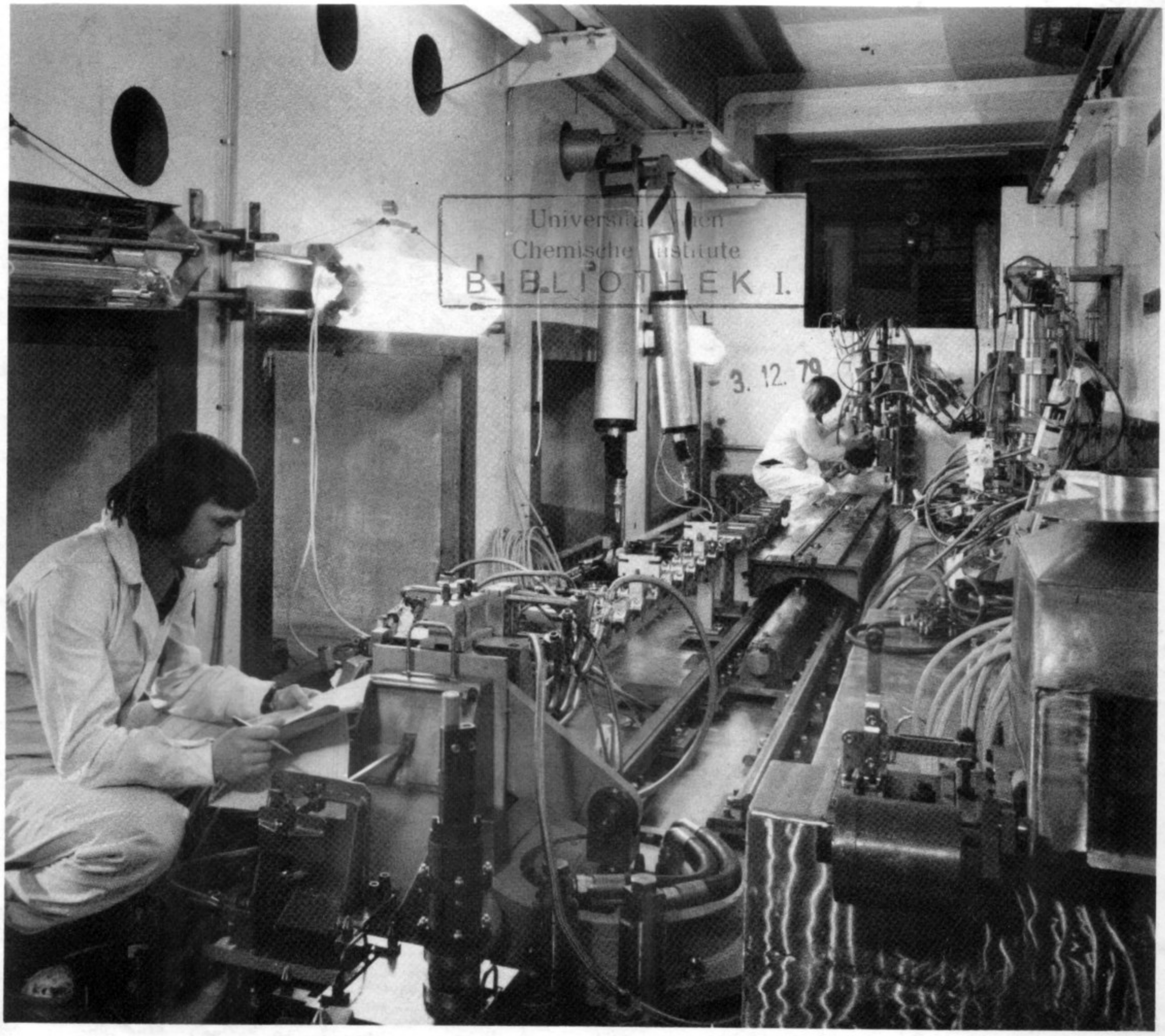
NOVEMBER 1979 NUMBER 277

ATOM

UKAEA REPORT ON PROGRESS
THE FAST REACTOR AND ENERGY SUPPLY
WORLD CHURCHES AND NUCLEAR POWER
LESSONS FROM CRISES
THE NUCLEAR POWER EXHIBITION
NUCLEAR POWER IN SWITZERLAND



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ATOM contents

THE MONTHLY INFORMATION BULLETIN OF
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Front cover: A general view of the PFR Fuel Dismemberment Cave during plant commissioning earlier this year. At the far end is the laser cutting head used to expose individual pins; a hydraulic pin cropping machine is in the foreground. The rebuilt plant was started up by the Prime Minister, Mrs Thatcher, on 6 September.

REPORT ON PROGRESS

The 25th annual report of the UKAEA — published on 20 September — was introduced at a press conference that day given by the Chairman of the Authority, Sir John Hill, supported by other Authority members and senior staff.

Sir John began by referring to the world scene. "Energy analysts have for a long time been forecasting an impending energy shortage or, to be more accurate, an end of the cheap energy era to which we have all become accustomed", he said. "The oil shortage of 1973 was in a way artificial because it was caused by a deliberate reduction of supplies as a political weapon and was not the result of a shortage of reserves or of equipment. But the margins between supply capability and demand have been getting progressively smaller and the events in Iran earlier this year demonstrated dramatically just how narrow is now the balance between supply and demand. With a world population still rising rapidly and the poorer countries of the world making every effort to raise their standard of living, we must expect recurrences of energy shortages and rising energy costs.

"This was well recognised at the European summit meeting in Strasbourg and the World summit meeting in Tokyo in the unqualified acceptance of the need for nuclear power and the declaration by Heads of States to limit oil imports in an attempt to control demand. Statements of policy by the British Government have made clear their full understanding of the situation and their recognition of the need to develop our nuclear programme and, further, to ensure this is carried out efficiently, to establish a regular pattern of ordering of nuclear plant.

"I have at more than one of these press conferences emphasised the need for continuity in our nuclear programme. I am confident that there is now the understanding and the intent to proceed in this way. If we do we will be more efficient in the future than we have been in the past. We have now as an industry, a great deal of work in hand for projects that have been authorised over the last two years — two twin reactor AGR stations at Heysham and Torness, preparations to build a PWR and a large fast reactor which will, of course, involve a public inquiry, the rebuilding and expansion of the Windscale reprocessing site and the expansion of the centrifuge project. The speed at which we can progress is determined by the resources available in the industry and, after a long period of uncertainty and lack of orders, it takes time to build up again.

"The degree of proof and demonstration that is required before approval can be obtained for any new project — whether by public inquiry or by the normal regulatory processes — is very much greater than in earlier years and the resources and time needed to take any large project to the approval stage is correspondingly increased. This is a real limitation on the rate at which progress can be made, but I should add, that our procedures, although by no means perfect, are very much better than those in many other countries.

"Turning now to the work of the Authority, I must emphasise that we are busy and our resources are fully stretched. All frills have been cut out to make resources available for high priority work. We have a major programme to assist BNFL — particularly in relation to reprocessing, waste management and the expansion of Windscale. We have major programmes on behalf of the CEGB and NPC. We have work for Government Departments and we have our non-nuclear activities. In fact nearly 40 per cent of our income is derived from work carried out on behalf of other organisations and paid for by them.

"Of the work paid for by Government grant to the Authority there is first our fast reactor programme, and we are making sound progress. The reprocessing plant is now in operation and we were delighted that the Prime Minister was able to perform the opening ceremony when she visited Dounreay earlier this month. The final closure of the fast reactor fuel cycle is not now far away. We were also most encouraged by the Prime Minister's support for the programme and to hear her view that a single specific inquiry for the next fast reactor might be the preferred method of advance even though the preparations may take longer initially. Mrs. Thatcher expressed her view that a decision on the fast reactor could be taken within two years. In preparation for the inquiry we are now having discussions with other countries to determine to what extent international collaboration would benefit this programme.

"The fusion programme continues to make good progress in collaboration with other countries. The field is so wide that we have to be carefully selective in what we, in this country, undertake. Construction work on JET — the Joint European Torus — started at Culham earlier this year with the foundation stone being laid by the EEC Commissioner for Energy, Dr. Guido Brunner.

Public understanding

"The re-activation of the UK nuclear construction programme will necessitate increased effort to explain to the public what we are doing and why it is necessary and desirable. The Three Mile Island accident caused great public concern at the time, though less, I think, in this country, with our long experience of industrial nuclear power, than elsewhere. It was certainly a serious accident which should not have happened. We shall, of course, have to wait until the full report of the inquiry is published before passing judgment, but preliminary analysis shows that the accident was a very long way from the fantasies of the "China Syndrome" and that the exposure of the public was even less than the low levels indicated from earlier assessments.

"INFCE — the International Fuel Cycle Evaluation — which is being carried out on a worldwide basis will also be completed later this year and discussed publicly next year. The view as of today is that it has to all intents and purposes confirmed the policies being pursued in the UK. We find this most reassuring.

"On the other side, however, there is still a great deal of public misunderstanding and concern about the hazards of low level radiation and about waste disposal. I do earnestly ask you to be strictly objective in what you write on these emotive subjects. But I have spoken so often on these matters that I will not go over the ground again here. Let me instead speak of a major experimental programme related to safety that we are carrying out on the fast reactor at Dounreay.

Fast reactor safety

"As you know, there is a need for core cooling during shutdown, and emergency power supplies are required to ensure that the circulating pumps are kept running even in the event of a major power failure. We believe that the fast reactor of the pool type such as we have at Dounreay has characteristics which have outstanding safety advantages in the event of such a power failure.

"You will recall a series of experiments carried out some three years ago just before the first small Dounreay fast reactor was shut down which demonstrated the robustness of fast reactor fuel to extreme operating conditions: in particular, that it was unharmed even when operating in boiling sodium. The core of a fast reactor is, as you know, immersed in a very large tank of sodium, the majority of which is at the cool, inlet, temperature. We have now demonstrated that even with the pumps switched off natural circulation of the sodium will remove the shutdown heat from the core without the fuel element temperature rising appreciably above their normal operating temperature. Two types of experiment have been carried out to demonstrate this effect. The first has been to operate the reactor at a steady power of up to 20 MW (heat) corresponding approximately to maximum fission product heating and then to shut down the coolant pumps while keeping the reactor running. The second series of experiments have been to trip the reactor and the pumps simultaneously from progressively higher operating powers, thus simulating a total power failure. These experiments have been entirely successful to date, and have demonstrated a steady transition from pumped flow to natural circulation flow. The whole programme of demonstration is of necessity a long one because of the need to do a full safety analysis (as is necessary for any non-standard operation) between each experiment.

"Even with no cooling at all it would take many hours before the sodium was raised to the boiling point (well over 24 hours for PFR) and a natural circulation emergency cooling circuit rejecting heat to the air as installed on PFR could extend this time very substantially — and could in fact extend it indefinitely. No other power reactor has this ability to cool itself for this period without operator intervention or electricity. So our already great confidence in the safety of fast reactors is enhanced.

"We like people to come and see the prototype, and the fast reactor at Dounreay is open to members of the public every day, Monday to Friday, during the summer season — tickets are available from the Thurso tourist office, and already some 4600 visitors have been over the plant."

Sir John concluded by drawing attention to a Nuclear Power Exhibition [see elsewhere in this issue] opened by Sir Jack Rampton, Permanent Under Secretary of State at the Department of Energy; and an exhibition of scientific and industrial photographs taken by Authority photographers during the 25 years of the Authority's work—reviewed in the October issue of ATOM [No. 276, pp.284-285].

Strategy not in doubt

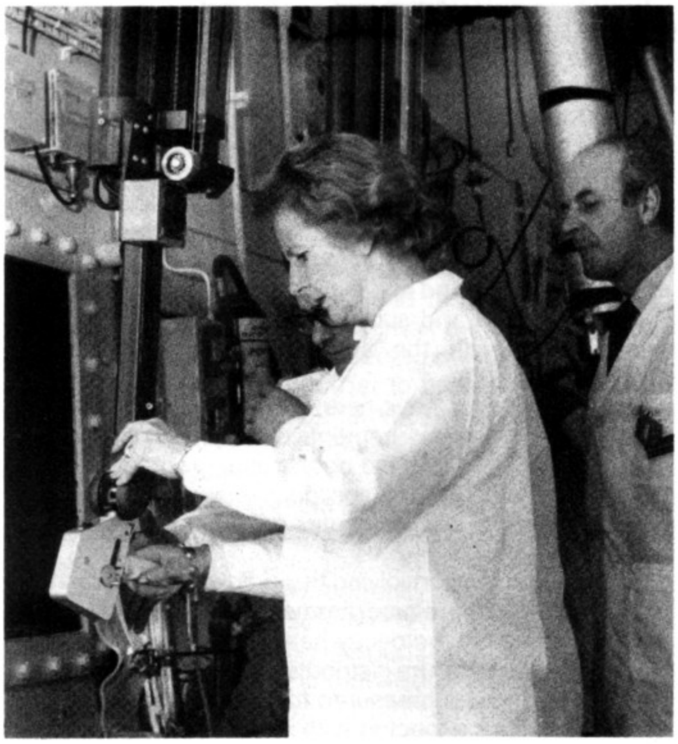
During her visit to Dounreay on 6 September the Prime Minister, Mrs Thatcher, pressed a switch to start up the newly rebuilt reprocessing plant, toured the Prototype Fast Reactor and met Dounreay staff.

At a press conference, Mrs Thatcher said that without prejudging the issue, she personally would like to see fast reactor development go ahead. "The major issue at Strasbourg and Tokyo was the energy needs of the world," she said. "For two decades, certainly, the world has depended on oil for the generation of a large part of its electricity and, of course, for petrol. There has been an increasing demand for electricity, and we shall be vulnerable to oil supplies unless we find an alternative supply. The obvious alternative supply that is continuous, which will not run out like fossil fuel, will be the fast breeder. We have the Magnox reactors, which have been operating for many years, and what we have to consider is the next stage in this country . . . The strategy is not in doubt. We want a source of electricity generation that by definition is not limited as is fossil fuel."

Mrs Thatcher said she did not share the fears that some people had of nuclear power. "Comparing nuclear with other methods of generating electricity I do not know of one person who has lost his life because of the generation of nuclear electricity. Think of the risks that are involved in one using coal, oil or gas — the risks involved there are enormous."

Recalling that she had that day started up the reprocessing plant at Dounreay, Mrs Thatcher said: "The best thing is to burn it — the safest thing is to burn it in a fast reactor. Oil, gas and coal will not last forever; some of these things should be conserved as a source material for chemicals. The chemical industry depends on coal, gas and oil. If you can find a different source of fuel you can put oil and gas to better uses in the future. I happen to be a conservationist of natural materials."

Mrs Thatcher was asked whether she would expect to make a decision fairly soon on the Commercial Demonstration Fast Reactor. "I have been told: do not just have an inquiry in principle, have it in relation to a specific project," she answered. "It may be that this would be a faster way of proceeding than having an inquiry in principle. My own personal view is that we should continue with fast reactors, but the Government has agreed and is therefore obliged to have an inquiry, and it is not up to me to prejudge the outcome." Dounreay would obviously have to be one of the sites to be considered for such a project.



Mrs Thatcher examines remote handling equipment during her tour of the Dounreay establishment.

The £3.4 million reprocessing plant at Dounreay will over the next few months handle uranium-based nuclear fuel from the Dounreay Fast Reactor which was shut down in 1977 after 17 years' successful operation; in 1980 the plant will switch to reprocessing plutonium-based fuel from the much larger PFR. The decommissioning and rebuilding of the plant was reviewed in the June issue of ATOM (No. 272, pp. 142-145). □

NATURAL CONVECTION COOLING OF PFR

An interruption of the main electrical supplies to the Dounreay Prototype Fast Reactor (PFR) causes the reactor and main coolant circulating pumps to trip. Multiple auxiliary electrical supplies ensure that the auxiliary coolant pump system continues to circulate the coolant under these circumstances to maintain the fuel at low temperatures. A multiple cooler system dissipates by natural circulation the decay heat resulting from fission products in the fuel.

From the early stages of design of PFR consideration has been given to the practicality of relying on natural circulation[1] of the reactor coolant to provide a very simple alternative to the multiple auxiliary pump system. Computer calculations could not adequately model the system and therefore fluid flow experiments were carried out in PFR in 1973, during the early days of commissioning, to provide basic system data for more detailed calculations. These did not provide assurance that natural circulation would be adequate. Laboratory experiments were also carried out at this stage but these could not sufficiently reproduce the reactor system conditions.

It was therefore decided to carry out a series of experiments in PFR, each stage of which was a progressive step towards gaining basic knowledge. Before any proposed experiment in the reactor is permitted, its safety is formally assessed; it has to be technically approved by the reactor management and vetted by an independent safety committee which includes representatives from the Authority's Safety and Reliability Directorate. If the Director accepts their advice, he authorises the work to be done.

In any series of experiments the information from each stage is fully analysed and then used for the safety assessment of the next and subsequent stages, each of which must comply with the authorising process described above.

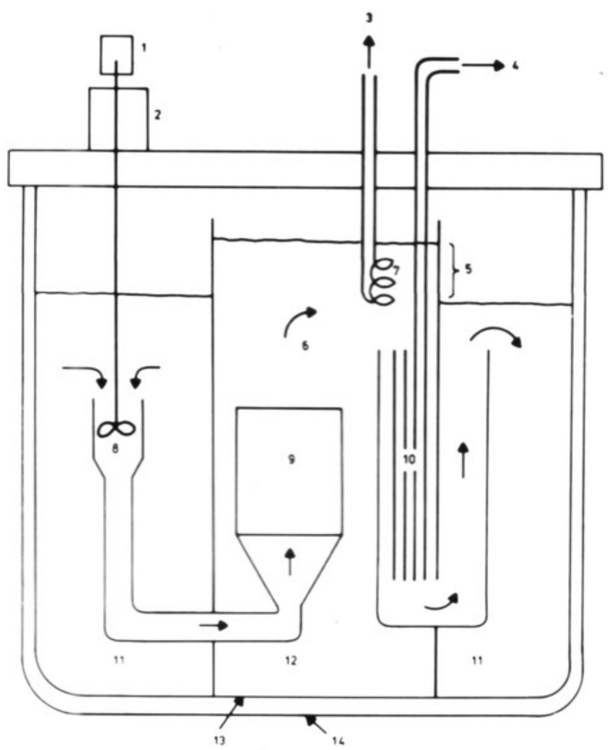
Since 1975 there have been 13 natural circulation tests and innumerable measurements of the physical characteristics in PFR fitted into the operational programme of the reactor. This step by step approach ensures that the basic data is available and computer codes can be produced which are realistic.

In detail, the tests involving the simulation of decay heat by fission power were programmed from 1.5 MW to 20 MW — i.e. up to nearly the decay heat after a reactor trip from full power. Temperature distribution of the coolant throughout the reactor was measured for periods up to one hour and behaved as expected with a smooth transition from pumped to natural circulation of coolant.

Further tests were carried out using decay heat after a trip at 50 MW thermal power and these also confirmed the rapid smooth flow transition during the period of zero to 350 seconds after which it had reached constant flow. It is now obvious that natural circulation in PFR will ensure that with the reactor tripping from full power and no pumped coolant, the fuel temperatures will not exceed normal operational temperatures.

The experiments have shown

- That in the event of a loss of all pumping power in the primary circuit, resulting from a loss of electrical supplies to site (causing the reactor to trip) combined with a highly unlikely failure of the auxiliary motors, the reactor is inherently protected by natural circulation of the primary coolant which dissipates the core decay heat, thereby ensuring that coolant and fuel temperatures do not exceed operating levels and



Key: 1, Ancillary pump motors; 2, main pump motors; 3, to natural circulation coolers; 4, to secondary circuits; 5, sodium level difference; 6, above-core plenum; 7, decay heat rejection coolers; 8, primary pumps; 9, core; 10, main heat removal systems; 11, outer sodium pool; 12, inner sodium pool; 13, primary vessel; 14, secondary vessel.

- The natural circulation of coolant combined with the effect of the power coefficient[2] of the reactor now gives considerable confidence that the PFR would be able to withstand the loss of pumped coolant and the unbelievable loss of reactor trips, i.e. the reactor continuing to run in spite of all the multiple safety systems.

Theoretical studies show that as the pumps run down the initial temperature rise is controlled by the power coefficient which automatically depresses the reactor power. Thereafter, core temperatures are determined by the equilibrium power level and the natural circulation flow. The results available from pessimistic calculations show that local coolant boiling at fuel sub-assemblies would not occur for an incident at the beginning of a reactor run and the reactor operating strategy can be modified to prevent such boiling during an incident later in a run if this should be necessary, bearing in mind that further experiments will be carried out during the next twelve months to eliminate the pessimism in the calculations; and that the local boiling would be safe as previously shown in the series of coolant boiling experiments in the Dounreay Fast Reactor over the period 1975 to 1977. □

Notes: 1. Natural circulation (or free convection) results from the variation of material density with temperature which causes hot fluid to rise relative to cold. This principle underlies — for example — the operation of many domestic hot water systems. 2. The power coefficient describes the relation between the power level and the temperature of the reactor, including factors such as the Doppler effect — increasing thermal agitation of the atoms of the fuel with increasing temperature causing a reduction in the efficiency of fission.

THE FAST REACTOR AND ENERGY SUPPLY

Although fast reactors have reached a comparatively advanced stage of development, a number of factors make it likely that their introduction for electricity generation will be a gradual process. Nevertheless, it is necessary to complete demonstration and development phases in good time.

These are principal conclusions of the following paper, by R.L.R. Nicholson* and A.A. Farmer†, which they presented to the recent annual Uranium Institute symposium. "The option will be the more valuable the more fully it has been demonstrated, and therefore the more quickly it can be exercised when the need comes," they write. "But lead times are long and, in the authors' view, the likelihood that fast reactor introduction will be a gradual process is no argument for delay in current development programmes." The paper is here slightly abridged; the full proceedings of the symposium will be published early next year by Mining Journal Books, Edenbridge, Kent.

Since the earliest days of the development of peaceful nuclear power, there has been interest in fast reactors. A fast reactor system was one of those initially chosen for study in the UK. A fast reactor in the United States was the first reactor of any sort to generate electrical power. When the possible future of nuclear power was reviewed in this country in 1950 it was recognised that it would probably be 25 to 30 years before power from fast reactors could be supplied on any appreciable scale. There have, of course, been many developments since those early days, not least the effect of the greatly increased size of power plants of all types. The availability of cheap oil and natural gas, which was not then foreseen, improvements in coal extraction and burning, possibly stimulated by the successful development of thermal nuclear reactors, have doubled that time and have allowed the work on fast reactors to proceed at a pace dictated more by technical evolution than by the pressure of demand. These improvements have also altered the targets for fast reactor performance, although as we will demonstrate these are not the only criteria for its early introduction. Nevertheless, fast reactors are now sufficiently well developed and understood to have large-scale prototypes operating or near completion in several countries, and commercial size plants under construction in two. The attraction of the fast reactor system as a means of utilising the energy in uranium to the full has been confirmed, and its potential as a means of minimising dependence on imported energy supplies is widely recognised.

Experience

It may be helpful to summarise the progress that has been made with fast reactor development. In this country the successful experience with the experimental Dounreay Fast Reactor which operated from 1959 to 1977 led to the construction of the 250 MWe Prototype Fast Reactor, pool-type, also at Dounreay, which has been in operation since 1974. Parallel with the reactor programme, the UK has had a major programme of supporting research and development, and has made particular progress with fuel cycle work. A plant to reprocess the spent fuel arising from PFR is currently being commissioned, and will be the first of its type in the world.

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Consideration is now being given to the next stage of UK fast reactor work, with the objective of ensuring a capability to construct a programme of fast reactors at the end of the century.

Work in continental Western Europe is now proceeding under a series of collaborative agreements between France, Germany, Italy, Holland and Belgium. Development is most advanced in France, where work on fast reactors started in the 1960s with the test fast reactor Rapsodie at Cadarache. A prototype power reactor, Phénix (250 MWe — pool-type) at Marcoule went critical in 1973 and the 1200 MWe Super Phénix at Creys-Malville in France was begun in 1977 and is due for completion in 1983. It is being built as a joint venture with Italy and Germany. In order to provide the necessary reprocessing facilities the Cogéma plant at Cap la Hague is to be expanded to cope with fuel from at least three Super Phénix-sized reactors.

Work on fast reactors in the Federal Republic of Germany has included participation in two collaborative projects, Super Phénix and a prototype 300 MWe, loop-type, fast reactor at Kalkar (SNR 300) currently under construction. It has also included the construction of the small experimental fast reactor KNK II (20 MWe). As part of the collaborative arrangements it was envisaged that a successor to SNR 300 to be called SNR 2 would be built in Germany. Work at the national level in Italy is taking place at the national nuclear research centre at Brasimone where a 188 MWt fast reactor for the testing of fuel elements is under construction. The Belgian nuclear industry's tentative plans for the introduction of fast reactors call for one station between the years 1995 and 2000 and two or three more between 2000 and 2025.

The major fast reactor programmes are under way in the US, the USSR, Japan and India. American interest in fast reactors dates back to the early 1940s and over the next 20 years they designed and built a number of facilities to test the feasibility of fast reactors and subsequently the development of liquid metal fast breeder reactor technology. In the early 1970s the US Administration placed high priority on the LMFBR programme and the proposed construction of the 350 MWe, loop-type, reactor at Clinch River (CRBR) Tennessee, which was intended to demonstrate the fast reactor concept by 1980. More recently, the present Administration have deferred the introduction of the use of plutonium by postponing reprocessing and the 'commercialisation' of fast reactors. The future shape of US fast reactor work is still being debated, but the US continues to undertake a very substantial fast reactor programme; the US Department of Energy's budget for 1980 shows $ 590 million (£300 m) for such work, and a large loop-type fast test reactor (fast flux test facility, FFTF) of 400 MWt is due to become operational during this year at Hanford, Washington.

The USSR have a strong commitment to fast reactors. Their first major experimental fast reactor, the BR 5 of 5 MWe, was built at Obninsk some 20 years ago and is still operational. This was followed by a larger reactor, BOR 60, and a prototype reactor, loop-type, BN 350, at Shevchenko on the Caspian Sea which came into operation in 1973. BN 350 is designed to purify 120 000 tons of water a day as well as to generate 150 MWe of electricity. The first commercial scale fast reactor to be built in the USSR, BN 600 (600 MWe, pool-type) is under construction at Beloyarsk and is expected to be in operation by 1980. There are plans for a 1600 MWe, pool-type, fast reactor for completion in 1989 (work would start in about 1982), also at Beloyarsk, and the Russians confidently expect the majority of their nuclear programmes after 1990 to consist of fast reactors.

In 1968 the Japanese Government announced a plan for the development of the fast reactor which would lead to the construction of a prototype reactor with the aim of reaching the commercial stage in the second half of the 1980s. This plan involved the construction of a 100 MWt experimental reactor (JOYO) for use as a fuel and materials testing facility and this went critical in April 1977. The next step is the design and construction of a 300 MWe, loop-type, prototype (MONJU) by 1986, and this is intended to demonstrate the feasibility and reliability of the system. Research and development work for the necessary fuel cycle activities for the demonstration fast reactor that will follow MONJU are already under way.

Fast reactor research and development work in India is undertaken at the Reactor Research Centre near Madras, where a 15-18 MWe fast breeder test reactor and other support facilities are being constructed as part of the long range objective of thorium utilisation. It is expected that the test reactor will be operating in 1981 as a test-bed for experiments in connection with a larger reactor. India's declared intention is to have fast reactors in operation by the beginning of next century.

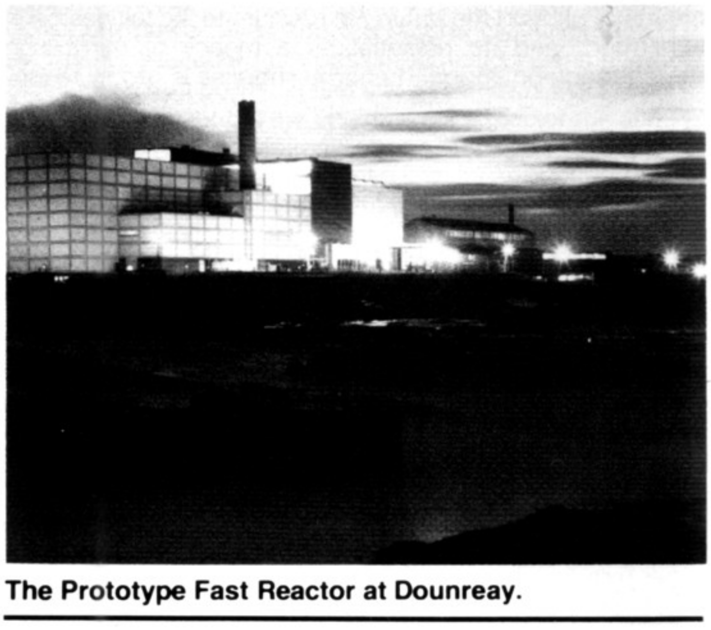
Targets for development

Most of these development programmes aim, then, to provide to the nation concerned an ability to instal fast reactor power stations at the end of this century or early in the next one. Until then, the relative economics of nuclear power and the pressure on oil and gas supplies will continue to provide incentive to build thermal reactor power stations. These will ease the supply position directly through the substitution of nuclear for hydrocarbons as a primary source for electricity generation. At the same time, the increase of the nuclear share of electricity reduces the influence of oil (and coal) prices on power costs, thus encouraging electricity to take a bigger share of the total energy market and thereby extending the scope for substitution for oil. At the same time, such an expanded programme of nuclear power, if based solely on thermal reactors, would put increasing pressure on uranium resources and production which in due course would be reflected in rising uranium prices; at some stage the prospective forward uranium prices over the lifetime of a new power station will make the fast reactor a competitive prospect. Views vary as to when this stage will arrive — the range is from the early 1990s to around 2025.

If depletion or restriction of oil and gas supplies does make nuclear power attractive, as seems likely, the uranium constraints on thermal reactor nuclear power expansion will only be eased, but not removed, by major increases to the currently identified reserves. Even if the more optimistic forecasts of speculative resources are borne out there will be acute pressure on the supplies of reasonably accessible moderate cost uranium by the end of the first quarter of the next century. If some of these forecasts of speculative resources prove too optimistic, or if production has been disrupted in any of the major producing areas, the strain could appear appreciably earlier, particularly for countries entirely reliant on imported supplies. Furthermore, the more pressing the need to find alternatives to oil and gas, the more pressing also will be the need to relieve pressure on uranium resources. As an example of the timescale of the pressures that could arise, it is pertinent to point out that the presently known reasonably assured resources and estimated additional resources up to an extraction cost of $ 130/kgU will be committed to the planned and operating thermal nuclear programmes by 1995-2000.

Thus, the attraction of fast reactors is likely to coincide with major incentives to increase the use of nuclear power (as well as of coal). In view of this demand, and of the large investment needed to introduce fast reactors on a major scale, it is important to reduce as far as possible the associated uncertainties, as indeed would be the case with the introduction of any new technology on a large scale. Designers, builders, plant operators and the general public, need a learning period. A crash programme is to be avoided. In fact there are, we will show, a number of factors which control both the rate and the mode of introduction of fast reactors and these factors will, it is thought, preclude a rapid and disorderly change.

Firstly, the timing of introduction of fast reactors onto national grids will be influenced by other factors beside comparative prospective generating costs. Constraints associated with the use of plutonium fuels and environmental factors may defer the dates. On the other hand, the security of long-term energy supply offered by the use of the fast breeder reactor is a strong incentive to those countries which are short of indigenous economic energy resources to invest in fast reactors. One may therefore expect a variety of timings across the nations, depending on each nation's perception of its prospects for secure energy at economic prices. This will be particularly the case where governments are able to control or influence investment into power stations. The most forward plans for fast reactors are those of France; although the exact programme is not yet firm, the construction of a number of full-scale stations, after Super Phénix, is expected to start in the mid-1980s and some 10-20 GW of fast reactor capacity could be on-line by 2000 AD.



The Prototype Fast Reactor at Dounreay.

Influencing factors

The importance of fast reactors as a potential independent source of energy of major significance lies in their ability to convert a high proportion of the energy latent in uranium through breeding. But they cannot do this in a single 'pass', for the fuel could not stand the burn-up required. The residual and bred plutonium must be recycled by reprocessing the irradiated fuel and incorporating the plutonium so extracted in new fuel elements. The plutonium clearly has value as a fuel, and the effectiveness of fast reactors depends among other things on the level of plutonium held up both inside and outside the reactor. It is necessary, therefore, to reprocess and recycle the fuel without undue delay. An electrical utility will need to provide for a continuous supply of new fuel and will need to have the services of a reprocessing plant available soon after the start-up of a reactor. On a national scale, the fuel cycle plants must be planned at the same time as the first power stations. The cycle cannot be left open for long, as has occurred in many countries for thermal reactors.

Because of the economies of scale, the fast reactor can be introduced most economically in planned programmes of probably 5-10 GW size (or more), complete with the plants to service them, and most likely therefore to be on a 'national' basis. The problems of viable industrial infrastructure are not confined to the fuel plants. Fast reactors will have to compete, subject to the qualifications we have already noted, with thermal reactors of 1300 MW size or more and will be of similar size. The development programme has therefore to achieve reliable performance with a new technology and to solve the problems of scaling up. This factor has already lengthened the lead-time and will further extend it. But also the nature of manufacture will limit the number of companies that the market will support in early years unless either there is rapid growth in a general world market, or there is something like series ordering of fast reactors within a few particular countries.

This problem of industrial capability poses the question of the best route to achieve early competitiveness in fast reactors — series ordering to reduce component cost, or step-wise improvements in design and performance through development, or some combination of both. It also argues the need for establishing viable fuel and manufacturing plants, for a high degree of international collaboration, and coordination of resources. Thus, at least two of the factors that go to make up fast reactor costs — their capital costs and the cost of fabrication and reprocessing of the fuel — depend themselves upon the extent and rate of introduction. By comparison with thermal reactors, the economics of fast reactors depend on:

- The relative capital costs, which are likely to be higher for fast reactors.
- The fuel cycle costs, which depend on fuel performance as well as the costs of fabrication, reprocessing and waste management. Although the costs per tonne of fast reactor fuel will be higher than those for thermal, the costs per unit of electricity should be lower because of the high rating and long burn-up to be achieved.
- The price of uranium (from which fast reactor power costs are virtually independent).

It would be convenient if we could express the target fast reactor capital cost to achieve break-even as a function of uranium price, but the other factor, the fuel cycle costs, is itself difficult to predict since, in particular, the reprocessing is subject to further developent. As an indication of the likely target, if uranium prices were in due course to rise to about four times their present level, then fast reactors would appear to compete if their capital costs were not more than about 40 per cent above those of a light water reactor at that time. But, as we noted earlier, because of their advantages in limiting dependence on imported fuel materials, it may not be necessary for them to show a definite cost advantage at the time of commissioning, and much will depend, not only on the weight given to this feature, but also on how uranium prices are expected to move (in real terms) in the 25 years or so of the reactor's life.

So far we have discussed the effect of industrial and technical factors on lead time. But for widespread introduction in democratic countries, fast reactors will also need to achieve a sufficient degree of public acceptability. A major source of concern particular to fast reactors relates to their use of plutonium as a substantial component of the fuel cycle, although as Dr Walter Marshall indicated at the Uranium Institute symposium last year this needs to be kept in perspective [see ATOM No. 263, September 1978: *Proliferation and the Recycling of Plutonium*]. Fast reactors have been said to pose problems for safety and for the proliferation of nuclear weapons, and it has been further suggested that solutions can only be found in ways that prejudice democratic rights and erode the economic advantages. These topics have been the subject of intensive discussion and research and many of them are at the heart of the massive International Nuclear Fuel Cycle Evaluation now proceeding. It is, of course, too early to know what the outcome of the evaluation will be. We would expect, however, there to be a general confirmation that there are a range of solutions to all these problems.

Two aspects of the use of plutonium fuel may affect the international use of fast reactors. The first is the management of plutonium across national boundaries. To some extent this is already with us, inasmuch as plutonium originating in the thermal reactor operations of one country is being separated from the depleted uranium and fission products in the reprocessing plants of another. The contracts covering these transactions provide for the return of the fission products to the country of origin, but the future of the extracted plutonium has been a matter for inter-governmental bilateral agreements. The number of these arrangements is still small, as is the number of reprocessing plants. As reprocessing activity expands, and plutonium bearing fuels assume greater importance in the future plans of countries using nuclear power, these existing arrangements will need to develop into an internationally accepted regime for the management of plutonium. This will undoubtedly develop from the existing safeguards machinery, involving material accounting, containment, and surveillance, and all these aspects will continue to be kept under review to ensure that they are effective as the nuclear programme expands.

For example, plutonium is now being produced in significant quantities during the operation of thermal reactors around the world, and an increasing proportion of this is likely to be separated during reprocessing from uranium and fission products in the spent fuel. For at least the next two decades the availability of plutonium from this source will exceed the amounts required for the initial stages of fast reactor installation or for recycle. The plutonium will therefore have to be stored. The IAEA have convened an expert group to consider in detail the possible scope for an international plutonium storage system. The overall IAEA responsibilities for safeguards throughout the fuel cycle ensure that they are in a strong position to assess how such a storage system should be organised and controlled.

The second issue is the status of plutonium as a commercial fuel. The present generation of nuclear power reactors rely on uranium, which is a naturally occurring mineral, mined and supplied under commercial arrangements. Its special status as a fissile material is reflected in the special measures taken by governments to oversee its movement and the uses to which it is put. For the majority of reactors the uranium requires enrichment, and here too governments have taken a direct interest. Nevertheless, the market for uranium remains primarily a commodity market, obeying the laws of supply and demand with its pricing and contract arrangements subject to those laws.

As plutonium becomes used on a more extensive scale, a different situation will obtain. Plutonium is not a naturally occurring element, requires special precautions in its handling and treatment, and is sensitive for proliferation purposes. At present the very limited use being made of plutonium for power generation makes it hard to arrive at a 'value' to place on it when it emerges as a product from thermal reactor operations. In the future, particularly if demand for inventory for new fast reactor power stations develops before breeding has alleviated the limitations on the total amount of plutonium available, the material will be of immense 'value' as a source of power.

Questions thus arise as to how an open plutonium market will operate. Where utilities are large enough and choose to operate a 'balanced' system of thermal and fast reactors, the problems of ownership and purchase are reduced. But such balanced situations may be rare and in any case take a long time to achieve. In nations where electricity generation is primarily by private rather than state or local government enterprises, under what conditions will governments agree to the utilisation of plutonium as a fuel on a significant scale? It is likely that governments will wish to take a prominent responsibility in the disposal and use of plutonium; commercial practices will have to be compatible with such responsibilities. Dialogues on these issues need to be initiated well in advance if later delays, with damaging effects on availability of energy, are to be avoided.

These questions related to plutonium as a commodity cannot be divorced from the corresponding general issues surrounding the projected use of fast reactors. Such matters as location policy, organisation and operational patterns for the fuel cycle to support reactor installations, the handling, treatment and disposal of wastes, security and safety — all will inter-relate with the treatment accorded to plutonium. These issues may seem, to some, to be matters for the middle or distant future. But if, as in the UK, the debate on the use of commercial scale fast reactors is to include at least one major public inquiry, then industries and governments organisations must have firm proposals to put forward in due time for an inquiry.

WORLD URANIUM REQUIREMENTS

Linear doubling time is proportional to total plutonium inventory (both in-pile and out-of-pile) and inversely proportional to excess plutonium production rate. Out-of-pile inventory, excess plutonium production and hence doubling time depend critically upon the performance of the fuel-processing plants. In Fig. 1 the bottom left-hand corner represents the doubling time that a typical early commercial mixed oxide-fuelled fast reactor would have if the plutonium held in process plant waste residues is 0.5 per cent of total throughput and the time taken to return pllutonium fuel to the reactor after discharge is 9 months. Under these circumstances the doubling time would be about 30 years and would support a growth rate of fast reactor capacity of around 3 per cent a year. The longer the time taken to return plutonium back to the reactor after discharge, the larger the out-of-pile inventory of plutonium in cooling ponds, reprocessing plants and fuel fabrication plants and so the longer the doubling time. In addition, as all the plutonium in irradiated fuel must be reprocessed before recycle, the excess plutonium production decreases significantly as the percentage of total throughput held in process plant residues increases, thereby further lengthening doubling time.

World uranium requirements will depend upon the reactor strategy adopted and the performance of processing plants. For an illustrative nuclear programme that is representative of WOCA programmes seen in recent documents published by WEC, OECD and others the top curve in Fig. 2 shows the ever-increasing annual uranium requirements if the world continues to install only thermal reactors. Here it is assumed that irradiated fuel is reprocessed to allow the recycle of uranium but plutonium is stored or disposed. If the plutonium were to be recycled also, uranium requirements would decrease by 15 to 20 per cent; if the once-through mode is adhered to, uranium requirements would increase by 15 to 20 per cent.

The next two curves show the effect if introducing fast reactors from around 1990, at first slowly but after 2025 to the extent of plutonium availability. However, the plutonium turn-around time is long and so, although annual requirements reach a peak around 2025 at 110 000 or so tonnes a year, there would still be a large commitment to further uranium supplies after the middle of the century.

The bottom two curves illustrate that countries with major fast reactor programmes could be independent of uranium supplies by the middle of the century providing plutonium recycle times are short and the amount held in waste residues is small.

What can be done to alleviate the situation if countries require large nuclear programmes and, at the same time,

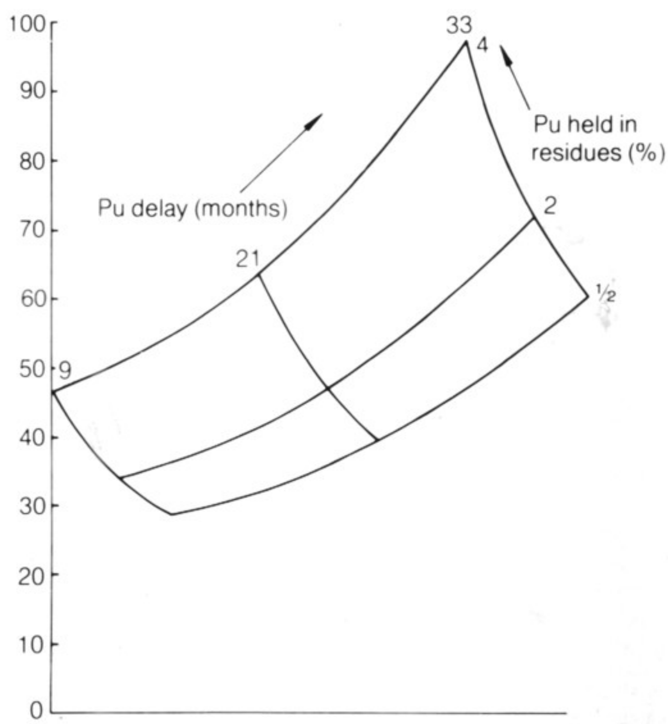


Fig.1: Effect of fuel cycle parameters on breeder linear doubling time.

In considering the overall lead time for the introduction of fast reactors, therefore, it is necessary to attach due weight to the question of public acceptability. In a democratic society, it is absolutely right that the role of any new technology on a major scale in that society should be subject to scrutiny and it raises the issue of the probable need to demonstrate the acceptability of that technology on the right scale. In a number of countries there is, we believe, need to build a demonstration commercial fast reactor in the fairly near future in order to avoid the overall lead time discussed above being adversely affected should, as seems likely, the need for fast reactors become urgent. In view of the importance of reprocessing, which we have already stressed, demonstration must include the back end of the fuel cycle as well as the reactor itself. It is not proposed to discuss this issue in detail in this paper, but we would like to emphasise that it is separate from the engineering development role which such a project would provide and that such demonstration of public acceptability could well comprise the major 'lead time' item in the application of fast reactors.

The picture then is that fast reactors are likely to be introduced on different timescales by individual countries who will aim to instal viable programmes of power fast reactors, in some cases with a preceding 'demonstration' station. Pressure on the uranium market will be reduced in discrete sectors rather than across the market as a whole. There will be plenty of advance warning. There are additional, basic, reasons why the expected eventual reduction in demand for uranium should be gradual and orderly. These stem from fast reactor logistics, and it is to this aspect we now turn.

Technical factors

In a fast reactor most of the energy is derived by splitting fissile atoms with high energy neutrons. Excess neutrons released during fission are captured by fertile atoms to produce more fissile atoms. Neutrons leaking from the core can also be captured in a blanket of fertile material placed round the core. The aim in fast reactors is to make the quantity of fresh fissile material produced or bred in both the core and blanket exceed the amount of primary fuel consumed. Of this fresh fissile fuel produced, an equal amount to the primary fuel destroyed is required after reprocessing for recycle into the reactor to maintain operation leaving an excess for use in new plants. Before allowing for reprocessing losses, this excess over unity is the 'breeding gain' and is dependent upon factors of fuel design such as rating, geometry and

wish to reduce uranium requirements to the minimum? One possibility is to introduce more advanced fuels such as carbide which should provide high breeding gain. But relatively little work has been done on proving carbide fuels in fast reactors, and even less on the difficult problems associated with reprocessing and fabrication, so the lead time is probably very long. A possible alternative is to use U-235 enrichment in fast reactors at times of plutonium shortage, instead of continuing or reintroducing thermal reactor programmes. The uppermost curve for thermal reactors in Fig. 3 is, of course, the same as shown in Fig. 2. But now we see that for the range of fuel process plant performance parameters considered, the annual uranium requirements of those countries with major fast reactor programmes could fall away to zero by 2040 to 2050.

Furthermore, although the maximum annual requirement is about the same, but needed perhaps some 5 to 10 years earlier, the total cumulative requirement is less because the total areas beneath the curves in Fig. 3 are less than for the corresponding curves in Fig. 2.

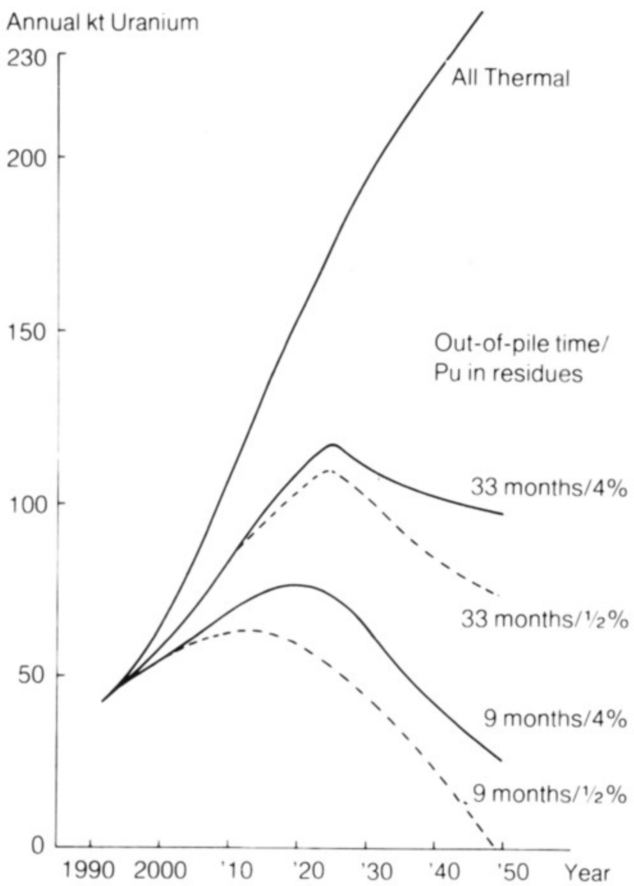


Fig.2: Uranium metal requirements: Pu FR only.

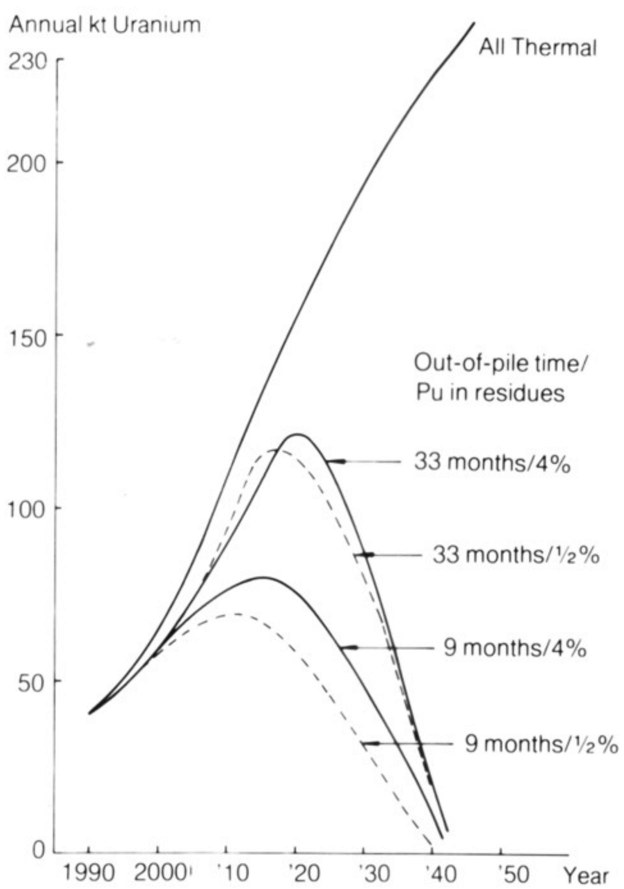


Fig.3: Uranium metal requirements: Pu and U-235 FRs.

burn-up, as well as the amount of neutron-absorbing materials in the reactor core. Following reprocessing, the important quantity is the net plutonium production over that required to maintain operation.

Another important consideration of fast reactor logistics is the amount of fissile material needed for a reactor to produce a given power output at a given load factor, i.e. its inventory. This inventory comprises two parts — fissile material present within the reactor itself, and fissile material outside the reactor in the fuel processing parts of the cycle. The former depends particularly upon the fuel rating and burn-up achieved. The latter amount is dependent upon the rate fuel passes through the reactor (i.e. upon burn-up and load factor) and also, in turn, upon the time taken to cool irradiated fuel to a level at which processing can be undertaken; upon the time to reprocess the fuel; and then to fabricate fresh fuel and transport it to the reactor.

Optimisation

The time taken for a fast reactor to produce enough plutonium to provide the total (in-pile and out-of-pile) inventory required by a new reactor is known as the linear doubling time. It is proportional to total plutonium inventory and inversely proportional to its net plutonium production, the latter, as indicated above, depending upon breeding gain and the amount of plutonium not recovered from process residues, together with the fast reactor load factor.

Both a decrease in specific inventory and an increase in breeding gain lead to a reduction in doubling time, and a small specific inventory and a low doubling time are desirable attributes. A small initial plutonium inventory is important at the beginning of a fast reactor programme since at a time when plutonium stocks are being drawn on the design with the smallest inventory will allow more fast reactors to be fuelled from the stock. This is of immediate importance to uranium requirements because over the lifetime of each 1 GWe of fast reactor capacity installed there will be a reduction of some 4000 tonnes of uranium compared with using a similar thermal reactor capacity. Subsequently, shorter doubling times will become increasingly important if thermal reactors are to be phased out of an expanding nuclear programme. But a short doubling time depends critically upon the performance of the fuel-processing plant. Fig. 1 shows the effect of increasing both the time to recycle plutonium and the amount of plutonium not recovered from process residues on the doubling time of a typical early 1250 MWe commercial reactor. The annual growth rate of a nuclear sector that an all-fast-reactor installation could just match is virtually equal to the inverse linear doubling time; it follows that thermal reactors can be completely phased out of a nuclear programme if the fast reactor doubling time is such that its inverse is larger than the growth rate of nuclear capacity. Such a situation leads to the eventual elimination of the need for new uranium. Conversely, if the fast reactor inverse doubling time is smaller than the nuclear system growth rate, there will be a continuing need to instal thermal reactors and for supplies of fresh uranium to fuel them. In these circumstances, the split in thermal/fast reactor installed capacity becomes a balance determined by the availability of plutonium. Although forecasts of future nuclear installation programmes have shown a tendency to decrease in recent years, they still indicate a growth rate for nuclear installations of between 5 and 10 per cent a year in the period from now to the first decade or so of the next century, decreasing to around 2 to 3 per cent toward the middle of the next century. It follows, therefore, that if fast reactors with core parameters such as those assumed for Fig. 1 are to limit total uranium requirements by eventually eliminating the need for further thermal reactors, fuel cycle plant performance must be developed to ensure that plutonium out-of-pile times and plutonium held in waste residues are restricted to a maximum of around 12 months and 2 per cent respectively. The importance of this is emphasised in Fig. 2, which indicates the effect of fast-reactor processing-plant performance on world uranium requirements for a nuclear programme that is representative of the WOCA programmes seen in recent documents published by WEC, OECD etc.

One of the disadvantages of the fast-reactor programmes considered so far [discussed in detail in the full paper presented to the UI symposium] is that the installation programme for fast reactors is not smooth, in that following the initial build-up, the rate of installation falls again when plutonium shortages first occur. The corollary of this is that the thermal installation programme is also not smooth as during times of plutonium sufficiency no thermal reactors need be installed, whereas later when plutonium becomes short thermal reactors must be re-introduced. Obviously both these effects can be smoothed out by restricting fast reactor installations at times of plutonium surplus, and studies have shown that such a procedure would have little effect on the ultimate reactor mix and total uranium and separative work (enrichment) requirements. However, a possible alternative is that instead of re-introducing thermal reactor installations at times of plutonium shortage, fast reactors with uranium-235 enrichment in their fuel charges should be introduced: the effect on world uranium requirements is illustrated in Fig. 3. Comparison of Fig. 3 with Fig. 2 shows that such a procedure tends to reduce cumulative uranium and separative work requirements and that the saving is larger the more that plutonium is held up out-of-pile. It appears that uranium enrichment need only be applied to fast reactors during a relatively short period of time — say, up to around 2030, since their high net plutonium production would bring forward the time when plutonium-fuelled fast reactors fully penetrate the nuclear generation systems; consequently, annual uranium requirements would rise to a peak earlier than otherwise, in our example in the period 2015 to 2025, and in countries with major fast reactor programmes could fall away to zero by 2040 to 2050. In due course, this potential use of enriched uranium, by reducing long-term demand, may have implications for the quality of low-grade deposit that will merit extraction.

Conclusion

Notwithstanding the comparatively advanced stage of development of fast reactors, there are, as we have indicated in this paper, a number of factors which make it likely that the introduction of fast reactors for electricity generation will be a gradual process, concentrated initially in a few uranium-importing countries. Likewise, the effect on uranium demand, and thus on the market, will be gradual and well-signalled.

In those countries with fast reactor power programmes, there could arise plutonium shortage and continuing requirements for new thermal reactors well into the next century. The use of enriched-uranium fuel in fast reactors to reduce the "secondary" long-term demand for uranium in further thermal reactors is a possible alternative. The full exercise of the fast reactor option will take some time because of the learning processes and the investment involved. When it is exercised, pressure on energy resources may be great. If the fast reactor is to be most effective in meeting energy demands it is necessary to complete the demonstration and development phases in good time. The option will be the more valuable the more fully it has been demonstrated and therefore the more quickly it can be exercised when the need comes. But lead-times are long and, in the authors' view, the likelihood that fast reactor introduction will be a gradual process is no argument for delay in current development programmes. □

WORLD CHURCHES AND NUCLEAR POWER

In July this year several hundred scientists, engineers, theologians and pastors met at the Massachusetts Institute of Technology as delegates from the mainstream Christian churches of the world to discuss "Faith, Science and the Future". Among them as an accredited visitor was Eric Jenkins, Vicar of St Stephen's, Hightown, in the Diocese of Liverpool, a former member of the research staff at AERE Harwell and author of this article. Rev. Jenkins attended the very first World Council of Churches discussion on nuclear power, in Geneva in 1956, and has taken part in other WCC discussions on this theme: in London (1977), and in Geneva (1978).

Delegates from less-developed countries could have been influenced in their evident anti-nuclear stance by the general air of suspicion at the conference against the alleged misuses and injustices brought about by advanced technology in general, particularly in the Third World, Rev. Jenkins writes. But it must not be thought that the anti-nuclear mood of some delegates went unchallenged.

Both sides of the nuclear power controversy were well represented in Boston this year; and the nuclear issue aroused the greatest tension in the closing debates on the draft reports from working Sections of the Conference. At one stage it seemed likely that Section 6, on 'Energy for the Future', would gain Conference acceptance for its majority recommendations, which included:

- as point 7, a recommendation that existing nuclear power plants should be used only to the extent, for the purposes, and for the time that there is no better alternative;
- as point 8, a recommendation that a moratorium be imposed on the construction of all new nuclear power plants, worldwide, until the overall risks and costs of nuclear power are fully determined and justified;
- as point 9, a recommendation that spent nuclear fuel should not be reprocessed to extract fissile material such as plutonium — except for the separation of small quantities for research and medical applications — and that plutonium-fuelled reactors should not be built.

A minority report, signed by 12 members of Section 6, dissented from recommendation 8 (it did not mention recommendation 9) on five grounds, among them that:

- 'The production of nuclear generated electricity is to date the safest energy industry in the world';
- and 'An indefinite moratorium without a precise method of determining its conclusion is tantamount to a veto.'

The minority signatories included Prof. David Rose of the Department of Nuclear Engineering at MIT, Bishop Hugh Montefiore of Birmingham (who chaired the two-day public hearings on the fast reactor in London in 1977) and scientists from Sweden, Switzerland, Canada, and the United States, as well as a Baptist pastor from the Soviet Union.

The tradition of WCC conferences is unfavourable to minority reports; delegates prefer every effort to reach even a minimum consensus. In this case, a compromise amendment was moved successfully by Dr John Francis, a nuclear physicist and Scottish Office civil servant, who from 1970-74 was full-time leader of the Church of Scotland programme on 'Church, Science and Technology' and has supported nuclear power in previous WCC conferences from 1975. He is co-author with Paul Abrecht of the WCC book *Facing up to Nuclear Power* (St. Andrews Press, Edinburgh, 1976).

His amendment limited the moratorium to five years, and made it clear that its purpose would be "to enable and encourage a public debate on the risks, costs and benefits of nuclear power in all countries concerned". This was accepted by the Moderator of Section 6 (Dr Albert van den Heuvel, Secretary General of the Netherlands Reformed Church), and the substantive motion was carried by 129 votes to 45 with 21 abstentions.

Even after the inclusion of the compromise amendment, the Conference might be seen as taking a rather definite line against civil nuclear power. It is worth recording here the conclusions of previous WCC meetings. In 1975 at a WCC Consultation at Sigtuna in Sweden, the participants "would not feel justified in either entirely rejecting, nor in wholeheartedly recommending large-scale use of nuclear energy". Following the larger-scale WCC Consultation at Bossey, Switzerland, in 1978 the Central Committee of the WCC in January 1979 'received' a four-point statement on nuclear power. Summarised, it said:

- The nuclear debate cannot be addressed in an absolutist sense, but must be seen in the context of other energy options.
- Energy consumption and more radical utilisation deserve much more attention.
- Most of the nuclear debate is but symptomatic of much deeper societal debates: more versus less, centralised technologies v. decentralised, etc.
- Nuclear power can be neither rejected nor accepted categorically; it is a conditional good.

I think it fair to comment that as the 1979 Conference took place in the US, its thinking on nuclear power was influenced by two special factors: (i) the serious nuclear incident at Harrisburg, Pennsylvania, in March 1979; and (ii) the long drawn-out discussions amongst representatives of the mainstream US Christian churches, organised through the National Council of Christian Churches since 1974, had finally resulted in May 1979 in a policy statement by the Governing Board (carried by 120 to 26 with one abstention) which included the words: "We support a national energy policy which will not need to utilise nuclear fission" and "We support a continued ban on the commercial processing and use of plutonium as a fuel in the United States, and stringent efforts to reach world-wide agreement banning such use of plutonium." The reasons given recently by the NCCC for its anti-nuclear stance include (i) that the secure handling of nuclear wastes and the safe operation of nuclear plants "require that humans and their machines operate without endangering human beings or the environment. Human beings are not infallible; they will make mistakes"; (ii) that "commercial use of plutonium can result in proliferation of nuclear weapons. The potential misuse could result in pressure to curtail civil liberties". No doubt these well-worn arguments were repeated in the closed sessions of Section 6, also that delegates from the less-developed countries could have been influenced by the general air of suspicion at the Conference against the alleged misuses and injustices brought about by advanced technology in general, particularly in the Third World. At the same time, in many of their countries the local nuclear power option may seem to lie so far in the future that a five-year moratorium was neither here nor there? For one reason or another, 62 delegates from less-developed countries signed a petition to the Conference supporting a nuclear moratorium.

It must not be thought that the anti-nuclear mood of the US liberals and of some of the Third World went unchallenged. The plenary sessions included some powerful statements by well-informed churchmen in favour of nuclear power — notably a lecture by Prof. David Rose and a spirited intervention by him in the debate on the report from Section 6, when he particularly emphasised the danger of over-reliance on an expansion of coal mining and burning, and indeed of any burning of fossil fuels leading to an increase in atmospheric CO_2. To forgo nuclear power was also, in his view, to risk world political and even military conflict in a scramble for scarce oil.

Despite the (to me, rather disappointing) majority vote about a moratorium and a ban on plutonium fuel, it remains clear that the weight of world Christian opinion at WCC level is *not* overwhelmingly against civil nuclear power but *is* anxious not to commit ourselves irreversibly and too hastily to a technology which has its dangers (as have other branches of industry) — dangers which may sometimes be perceived by the public in a specially unfavourable light. Hence the quite reasonable WCC plea for continued and increasing public education, information and democratic participation in decision making. The churches in the UK as elsewhere should continue with other opinion-forming organs to play a part in this process, while cautious of the activities of purely obstructionist anti-nuclear groups. I welcome, for example, the continuing studies by the British Council of Churches Energy Advisory Group, the Shaftesbury Project nuclear study group at Abingdon-Harwell, and the willingness of my own diocese (Liverpool) to free me part-time from my other clerical duties to take part in discussions and to lecture on nuclear issues as they affect the public, in my role as Science Adviser to this diocese. I was personally encouraged at MIT to meet several US Christians with an informed and favourable attitude to civil nuclear power, including Dr David Elias (Clinch River Breeder Reactor project), Dr David Cope (Oak Ridge), Rev. Dr Stan Turner (Florida), and Rev. Dr William Pollard (Oak Ridge).

Quite properly — in my view — the conference also devoted a special session to the far more pressing dangers of nuclear war and the escalation of nuclear weapons. There were notable speeches from MIT staff (Prof. Phillip Morrison — 'Begin to wind this terrible danger down . . .') churchmen from the USSR (Archbishop Kirril, Rector of the Leningrad Theological Academy — 'Push your giant and our giant . . .') and the Third World (Prof. Mrs Maathai of Kenya — 'You are so mad you want me to die with you, leave me alone on the earth . . .'). Prof. Roger Shinn (Union Theological Seminary, New York) and also Bishop Hugh Montefiore (Birmingham) cautioned against the naivety of calling for *unilateral* nuclear disarmament; and the Conference set up a special working party, chaired by Bishop John Habgood (Durham), whose recommendations were later adopted unanimously, calling for support for WCC and United Nations programmes on disarmament, the full implementation of SALT II, work toward reduction of nuclear weapons through a SALT III, and the completion of a Comprehensive Test Ban. Conference recommended the formation of local study groups on the danger of nuclear war and on approaches to disarmament, and resolved "never again to allow science and technology to threaten the destruction of human life, and to accept the God-given task of using Science for Peace."

Literature was made available by members of Riverside Church, New York, about the possibilities for congregational and citizen participation in a popular campaign against nuclear war, epitomised in a memorable slogan voiced by Mrs Jimmy Woodward of that church — "Hearts full of love, heads full of facts, work to avert the nuclear arms race". My dim memory turns to an international slogan of the 1950s, "Atoms for Peace". It still makes sense to me.

Eric Jenkins

LESSONS FROM CRISES

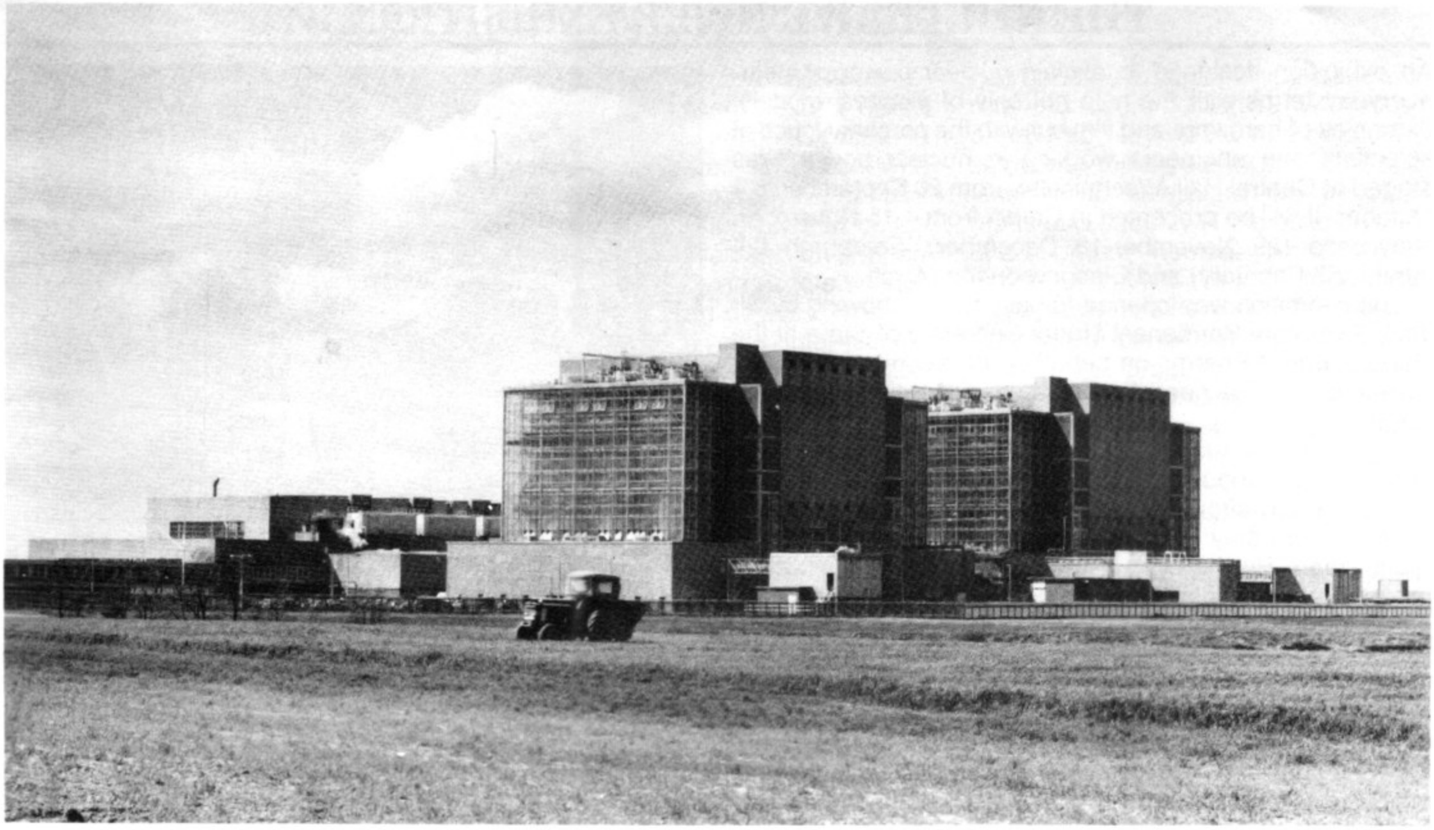
There could no longer be any doubt about the need for a nuclear contribution to energy supply, both nationally and world-wide, Mr Con Allday, Managing Director of British Nuclear Fuels Ltd, said in his Presidential Address to the Risley Nuclear Engineering Society on 11 September.

"We have to recognise that nuclear is not the total answer or panacea to the world's energy shortage, but it does at least offer a solution to its electricity demand — some 12 per cent of total energy, a figure which should and will increase if we can produce nuclear electricity efficiently," he said.

"I know it is argued that electricity as at present produced is an inefficient way of using primary energy, but this to a large extent misses the point. Yes, we should use primary energy more efficiently, and I believe the economic pressures of the price of fuel will drive electricity producers to use their waste heat. But far more important is the fact that uranium is otherwise a useless material. Far better to use it relatively inefficiently than burn oil or coal, which are valuable materials in their own right for chemical feedstocks. When one considers that the uranium remaining from such 'wasteful' use can in the future be put into fast reactors and produce prodigious amounts more energy, it serves to emphasise the point and the shallowness of the objections to nuclear electricity from overall primary energy utilisation considerations."

In the 1960s the papers were full of recurring 'economic crises', said Mr Allday. "The term has been dropped because it has ceased to be a crisis condition — it is chronic. This is what is likely to happen with energy. The crisis situation will become a fact of life and we shall have to learn to live with and adapt to it. Provided that things do not get so bad that either one or other of the powerful 'have' powers decide to take possession of scarce resources by force, or the 'have nots' revolt because of denial of their right to social evolution, then the relationship between supply and demand will prevail and all the inventiveness of man will be used to satisfy the demand with limited supply."

Thus, more efficient use of energy would become worthwhile. Recycling of materials — disgracefully squan-



The Bradwell Magnox nuclear station, on the Blackwater estuary — "giving yeoman service".

dered at present — would pay. More efficient power stations, the use of waste heat in combined heat and power systems, more efficient cars using less petrol per mile, and better insulation, heat pumps — all sorts of things would come. Providing the right climate for invention and technological advance was one of the major problems governments were going to have to face in future.

"Coming back to the nuclear industry in this country, it seems that the way ahead is becoming clear," he said. "The Government recognise the role to be played by nuclear and is in favour of an expanding programme. It is clearly determined to see the design and construction part of the industry put on to a viable basis and is publicly committed to such action within the very near future. We all hope that a sensible, workable organisation evolves in which our colleagues in the Nuclear Power Company can participate with enthusiasm and vigour".

It was important to remember, said Mr Allday, that the demand for further nuclear stations was not entirely dependent on growth in electricity demand. The Magnox stations had been giving yeoman service for a long time now — some were 17 years old. With ten-year lead times for the planning and building of new stations, it was none too early to be taking replacement capacity into account. For the UKAEA, the main policy decision was the timescale and programme for the development of the fast reactor. "With world economic growth slowing, uranium resources looking as though they will last well into the next century, North Sea oil providing an interim stopgap and the need to establish a viable but not monopolistic long-term coal industry in this country, the need for the fast reactor seems to be less urgent than it appeared to be a few years ago. Nevertheless it will be needed: it is only a question of when".

Public acceptance

Against all the convincing reasons why we should and could get on with nuclear power development there was the nagging question of public acceptance, said Mr Allday. "The attempt to organise public opinion against the concept of nuclear energy is a fascinating field for study," he said. "It is a luxury which only the comparatively affluent nations of the West can afford. Certainly in the Communist world there appears to be little sign of deep-felt anti-nuclear sentiment: nuclear power stations are seen as good things, like tractors and machine tools. We do not know whether there is anxiety on safety grounds, on anti-proliferation grounds, or anti-terrorist grounds, or any other grounds with which we are so familiar in the West. But if there is, the small minority involved do not appear to have much sway. Whether this is a good or bad thing for democracy or freedom of expression is, of course, a different matter".

Again, in the developing world there seemed "virtually no" opposition to the concept of nuclear power — no doubt because the population of the Third World, and their governments, faced more immediate problems. It was only in the West that anti-nuclear sentiment had had scope for development; and it had been seen at its most effective in the United States, where it had fed on the growing distrust of industrial corporations. Opponents of nuclear power had acted there as a very effective brake on nuclear expansion, as could be seen in the virtual drying up of orders.

"Here in Britain the public has been much less easily swayed", he said. "The Windscale Inquiry showed the paucity of evidence against us and the overwhelming good sense of the country in putting things into perspective. And by the beginning of this year the tide was beginning to turn in America. It was starting to become obvious that further delays to the ordering of new plant would soon have a serious effect on the electricity consumer. The arguments against nuclear power — indeed, against any new power plant — are obviously more persuasive when there is enough electricity to go round. But when a nation faces the prospect of brown-outs and blackouts, it is less tolerant toward those who stand in the way of new development, less uncritically receptive to arguments about safety and environmental impacts which seek higher standards of the nuclear industry than are felt reasonable in other fields of activity, or would be involved in some of the suggested alternatives." □

THE NUCLEAR POWER EXHIBITION

An exhibition designed to explain nuclear power in clear, everyday terms with the help not only of pictures, models, examples of hardware and film but with the personal touch of scientists and engineers working in nuclear power, was staged at Central Hall, Westminster, from 20 September to 4 October. It will be presented in Cardiff from 1-15 November, Newcastle (29 November-13 December), Edinburgh (24 January-7 February) and Glasgow during March.

The exhibition was opened for its London showing by Sir Jack Rampton, Permanent Under Secretary of State at the Department of Energy, on behalf of the Secretary of State, who stressed the need for informed discussion of nuclear issues.

"The need for such discussion is, I know, widely accepted in the nuclear industry, as this exhibition shows," he said. "Considerable effort has gone into explaining nuclear projects — what they involve and why they are needed — in recent years. But there is a lot more to be done. As our nuclear programme develops, it must be accompanied by broad public understanding and acceptance of what it involves. Attitudes toward nuclear power are of course influenced by many different factors: prejudices, preferences, personal values — they all enter into it. As in other areas of energy too, unless projects and policies are properly explained, misconceptions arise and needless anxieties are created. There is a major responsibility on all concerned with nuclear power to make information freely available and to do so in a fair and balanced way."

Sir Jack said he would emphasise three points. "First, there is the need for nuclear power. My Department's projections suggest that, even allowing for a substantial contribution from our reserves of North Sea oil and gas in the year 2000, and maximum production from our coal reserves, our indigenous energy supplies could fall significantly short of our energy demand. Without nuclear power this shortfall would be even larger, imposing an even greater burden on our balance of payments.

"To believe that we can do without a sizeable contribution from nuclear power is very high risk thinking. To abandon nuclear power could have incalculable consequences for our society. It could also have incalculable consequences for the less developed countries if the developed countries were to compete for increasingly scarce oil as a result. And it is very easy to show that if the energy supplied by nuclear power had now to be met from other sources, there is no credible answer.

"For these reasons the Government has made clear its intention to give the growth of nuclear power the priority it deserves. Similar considerations led to industrialised countries at the Tokyo Summit in June to recognise that without the expansion of nuclear generating capacity in the coming decades, economic growth and higher employment would be hard to achieve.

"A second area where public understanding is of great importance is nuclear safety. The safety record of our nuclear industry to date is excellent, and this deserves much wider recognition than it has so far received. There is also a real need for a perspective on the risks involved in nuclear power. I doubt, for instance, whether many people realise that natural radiation is far and away the principal source of radiation received in the UK today.

"At the same time, it must be made clear that there is no complacency on nuclear safety. The Government have emphasised the priority which they attach to safety matters and their determination to do all they can to promote it. Those concerned with nuclear projects must make every effort to ensure that high standards are maintained and, as necessary, improved."

Visitors to the exhibition inspect a model of a flask used for spent fuel transport.

Debate about nuclear power was likely to be with us for months and years ahead, Sir Jack said. Everything which contributed to making that debate well-informed and balanced was to be welcomed.

The exhibition is sponsored jointly by British Nuclear Fuels Ltd, the Central Electricity Generating Board, the Electricity Council, the North of Scotland Hydro-Electric Board, the Nuclear Power Company Ltd, the South of Scotland Electricity Board and the UKAEA.

The exhibition points to the link between Britain's economic prospects and the ready availability of energy at a price industry can afford: although conservation may reduce the consumption of fossil fuels considerably, it will not add to resources. To sustain even a modest growth rate of 3 per cent a year Britain's energy demands will increase by 50 per cent by the year 2000. Even with the contributions that may come from solar, wave, wind and tidal power, nuclear power is the only proven alternative to fossil fuels that can make a growing contribution to Britain's energy requirements. Nuclear generation already accounts for up to 14 per cent of all the electricity produced in the UK, and this figure will rise to 20 per cent when three new nuclear power stations come into production in the next year or two.

Exhibits draw attention to the need for nuclear power; its safety record; its major industrial application in the generation of electricity, and the manufacture and reprocessing of nuclear fuel; and the uses of nuclear energy in medicine, research and industry. Two major research projects shown at the exhibition are the fast reactor, and work on fusion power.

The exhibition also features research into the ultimate disposal of the comparatively small amounts of highly radioactive nuclear wastes arising from nuclear power, either deep underground in suitable geological formations or on or under the sea bed; and examines other alternatives to fossil fuels — wind and wave power, solar power, tidal power, and satellites which might be used to turn solar energy into microwave energy beamed down to collecting stations on earth. The wind and waves exhibit points out that at the present state of knowledge replacement of one large power station — coal, oil or nuclear — would require a mile-long string of wave energy converters, or 4000 windmills with blades 150 feet across. □

NUCLEAR POWER IN SWITZERLAND

BY THE OVERSEAS RELATIONS BRANCH, UKAEA

Switzerland has traditionally depended heavily on hydro power for the generation of electricity but by the early 1960s it was apparent that the possibilities for further exploitation were limited. In considering alternatives the electrical utilities and the Federal Government rejected, on environmental and security of supply grounds, a policy of constructing more fossil fuel power stations and, with substantial public support, turned to nuclear power to meet Switzerland's future requirements for electricity.

The first Swiss nuclear power station, Beznau 1, came into service in 1969 and was followed in 1972 by Beznau 2. Both these plants are 350 MWe pressurised water reactors. At Muhleburg a boiling water reactor, also of 350 MWe, came into operation in late 1972. A 920 MWe PWR at Goesgen commenced operation this year. These stations currently provide some 20 per cent of Switzerland's electricity. Construction is progressing well at a fourth site, Leibstadt, where a 940 MWe BWR is being built. Further plants are planned at Kaiseraugst (925 MWe BWR) and Graben (1100 MWe BWR). Details of the stations are given in the table. Swiss energy requirements are increasing despite measures for energy conservation. In 1978 overall energy consumption rose by 5 and electricity consumption by nearly 4 per cent.

A Federal Commission set up in 1974 to consider Swiss energy policy produced a report in January this year in which it was concluded that after completion of all the reactors under construction and planned an additional 1100 MWe of nuclear capacity would be required before the end of the century. The report also estimated that the share of total energy produced from nuclear power could rise to 17.4 per cent if use were to be made of process heat.

The Federal Institute for Reactor Research *(Eidgenossisches Institut für Reaktorforschung* or EIR) at Wurenlingen is Switzerland's principal nuclear research institute. EIR was founded in 1955 as a joint industry-government venture in the development of nuclear energy but since 1960 it has been owned and operated entirely by the Government.

EIR has three research reactor installations: DIORIT, a 30 MWt heavy water moderated and cooled materials testing reactor, SAPHIR, a 5 MWt swimming-pool reactor, and PROTEUS, a zero energy reactor with a mixed thermal-fast core which is used to study fast reactor physics. The Institute's programme lays emphasis on technology, especially that of advanced systems such as high temperature reactors, gas-cooled fast reactors and fusion devices. Many of EIR's activities involve international co-operation. Collaboration on gas-cooled fast reactors is undertaken with France and West Germany and the USA, and EIR also participates in the West German development programme for a high temperature reactor with a helium turbine (HHT). Arrangements have recently been concluded for Switzerland to join the Euratom fusion programme and to take part in the JET project.

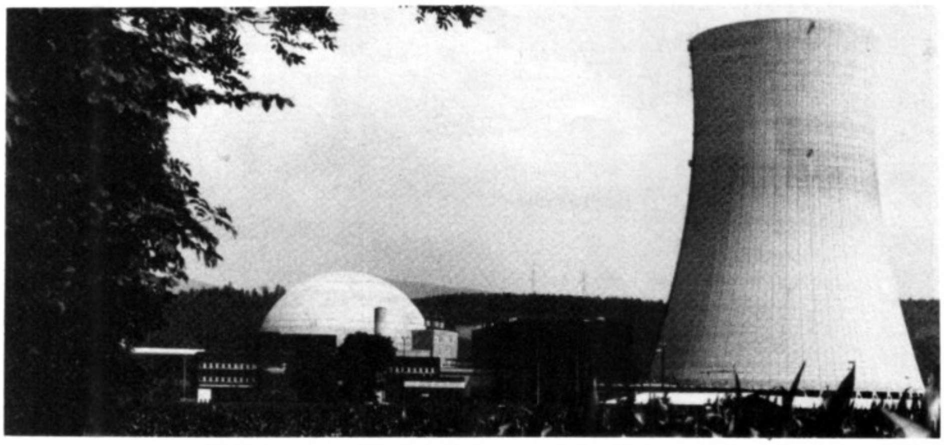
Although the introduction of nuclear power was generally approved by the public, Switzerland, in common with several other countries, has witnessed the growth of a strong anti-nuclear movement over the past few years. Opposition has stemmed from a variety of concerns, including environmental considerations, reactor safety and waste disposal. Legal interventions have delayed licensing procedures and reactor sites have been occupied in an attempt to halt construction. In an attempt to resolve what had become a major political issue two referenda were held in 1979. The first on 18 February was a vote on a constitutional initiative — "The People's Initiative to safeguard the people's rights and security in the building and operation of nuclear facilities" — which, if passed, would effectively have prevented the construction of further nuclear power stations. It called for a complex process of consultation with the local (Cantonal) governments and required that a proposed plant should have the approval of the majority of registered voters within a 30 km radius. The initiative was defeated by a narrow margin.

The second referendum was held on 20 May when nearly 70 per cent of Swiss voters approved the Swiss Government's proposals for revision to the 1959 Law on the use of nuclear energy. The changes which had already been approved by both Houses of Parliament placed the responsibility for the authorisation of new nuclear power plants on Parliament. The new Law requires that the essential need for new power plant has to be proved and the feasibility of safe and permanent storage of the resultant waste demonstrated. There must also be an approved plan for the safe dismantling of the station at the end of its working life. □

Nuclear Power Stations in Switzerland

Location	Type	Reactor Manufacturer	MWe	Date in Operation
Beznau 1	PWR	Westinghouse	350	1969
Beznau 2	PWR	Westinghouse	350	1972
Muhleburg	BWR	General Electric	350	1972
Goesgen	PWR	Kraftwerk Union	920	1979
Leibstadt	BWR	General Electric	940	Under Construction
Kaiseraugst	BWR	General Electric	925	Planned
Graben	BWR	General Electric	1140	Planned

MWe in operation	1970
MWe under construction	940
MWe planned	2065
Total	4975 MW



The 920 MWe Goesgen nuclear station *Kraftwerk Union*

ACTION TO AVOID AN ENERGY CRISIS

BY THE OVERSEAS RELATIONS BRANCH, UKAEA

In his foreword to the annual report of the Commissariat à l'Énergie Atomique for 1978 the Administrator General, M. Michel Pecqueur, reminds readers that swift action is necessary to avoid a grave energy crisis which could threaten the world's already shaky political stability. France, he feels, has reacted far more positively to the oil crisis of 1973 than have other nations, perhaps because of her greater vulnerability; she has undertaken one of the most ambitious energy saving programmes in the world and, alongside plans for the exploitation of coal and natural gas reserves, is developing a nuclear programme which will provide 20 per cent of the country's energy needs by 1985 and almost a third by the end of the century. This balanced policy is in his view the only way to meet France's future energy needs.

The year reviewed

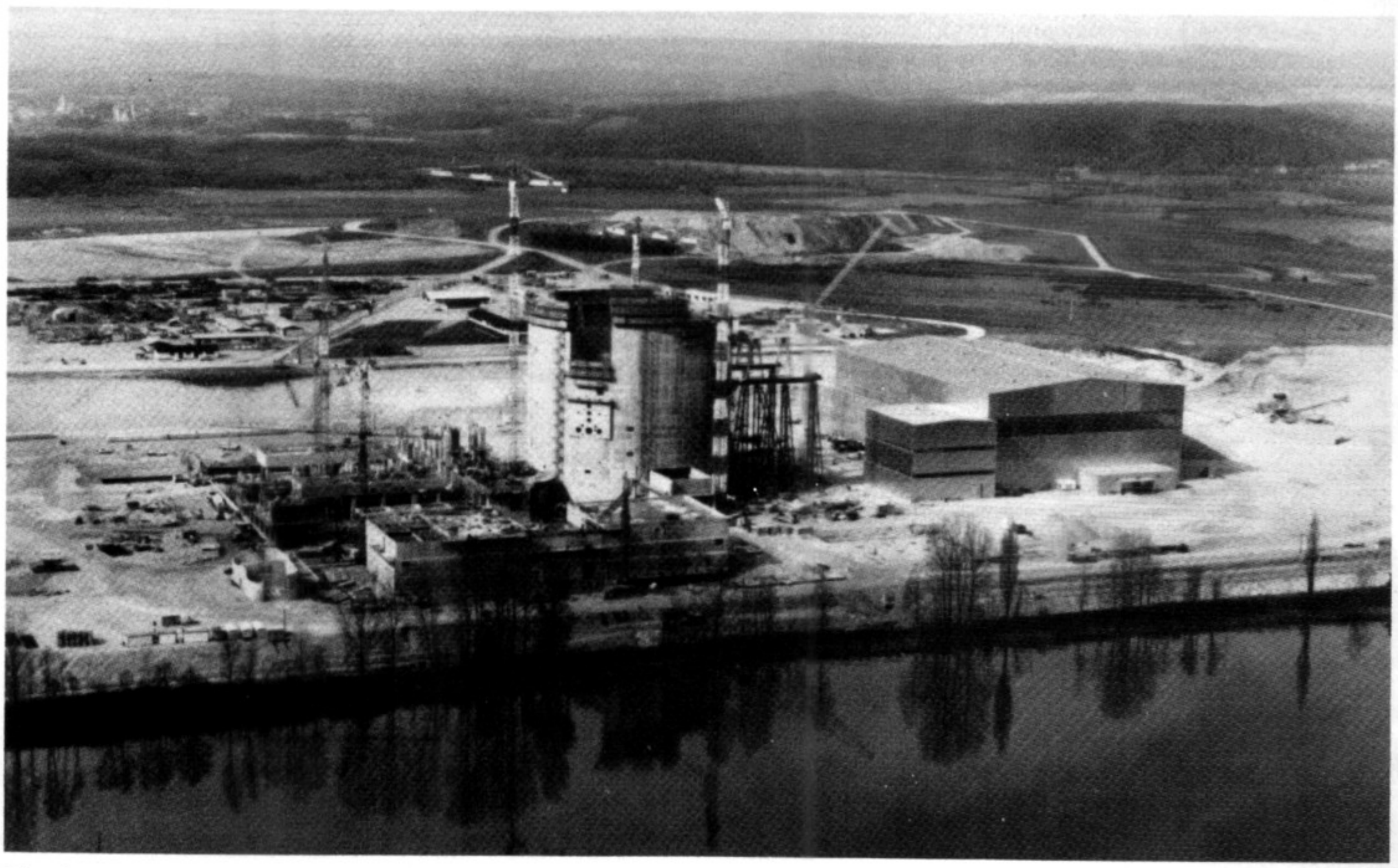
The fast reactor plays an important part in French plans for the nuclear programme, since it will relieve the programme from dependence on imported uranium supplies. Phénix, the 250 MWe prototype fast reactor, was brought back into service during the year after repair of all of its intermediate heat exchangers, and has since returned to full power output. By the end of 1978 it had produced more than 5 billion kWh of electricity since it came into operation; the successful repair of the heat exchangers demonstrated that it was possible to repair quickly and safely major components which have remained for long periods in the primary circuit of the reactor.

Work was well under way in 1978 on the Super Phénix demonstration fast reactor of 1200 MWe being built at Creys-Malville, and it is estimated that the reactor will be completed by about 1983. Super Phénix is still a prototype and so cannot be expected to compete in terms of cost with current commercial light water reactor designs. However, the cost of electricity per kWh produced by Super Phénix should be comparable to that of electricity from coal-fired stations. The French plan that several fast reactors very similar in design will follow Super Phénix. Electricité de France have also commissioned a design study of a 1500 MWe fast reactor based on Super Phénix technology.

The re-structuring of the commercial organisation in the fast reactor area which had been in progress since Novatome was created in April 1976 was largely completed in 1978. The last stage was the establishment of SYFRA (Société de Système Française pour les Reacteurs Avancés). The company is to take charge of collecting and collating all existing knowledge and expertise for the licensing documents which SERENA is to negotiate.

The CEA's review also reports significant progress in the fuel cycle area. The UP2 reprocessing complex at Cogéma's plant at La Hague has been extended and renovated. Its capacity for the reprocessing of light water reactor fuels will now reach 650 tonnes a year by 1984 and eventually 800 tonnes. In addition, Cogéma intends to build a new plant, to be known as UP3, at this site with an initial capacity of 800 tonnes a year.

The report says the vitrification plant at Marcoule (AVM–Atelier de Vitrification à Marcoule) was brought into



The Super Phénix reactor, under construction at Creys-Malville *NEI* service on 27 June 1978, and is functioning satisfactorily, demonstrating the viability of the CEA's process for the solidification of highly-active waste. Research is going ahead to adapt this process for the treatment of the waste produced by the reprocessing of more highly radioactive fuels and for the increased output of waste from larger plants, such as those at La Hague.

The pilot plant at Marcoule for the reprocessing of fast reactor fuel has already treated successfully the first half core (of enriched uranium) from Phénix, and the first reprocessng of mixed oxide fuel began in late 1978. It was decided in October 1978 to build a larger pilot plant (TOR — Traitement Oxydes Rapides) which is to be a further development of the existing Marcoule plant and which will make use of part of its existing facilities. TOR will reprocess all the fuel from Phénix and also treat small volumes of other fast reactor fuels. Construction work has already begun, and it is hoped that TOR will come into service in 1984. Design studies began in 1978 on a project known as PURR (Pilote d'Usine de Retraitement des combustibles Rapides), a demonstration plant for the reprocessing of fast reactor fuel, which is to be the next development in reprocessing and will provide facilities for the reprocessing of fuel from Super Phénix and the similar reactors which are to follow. It is hoped that the plant will be in service by the end of the next decade.

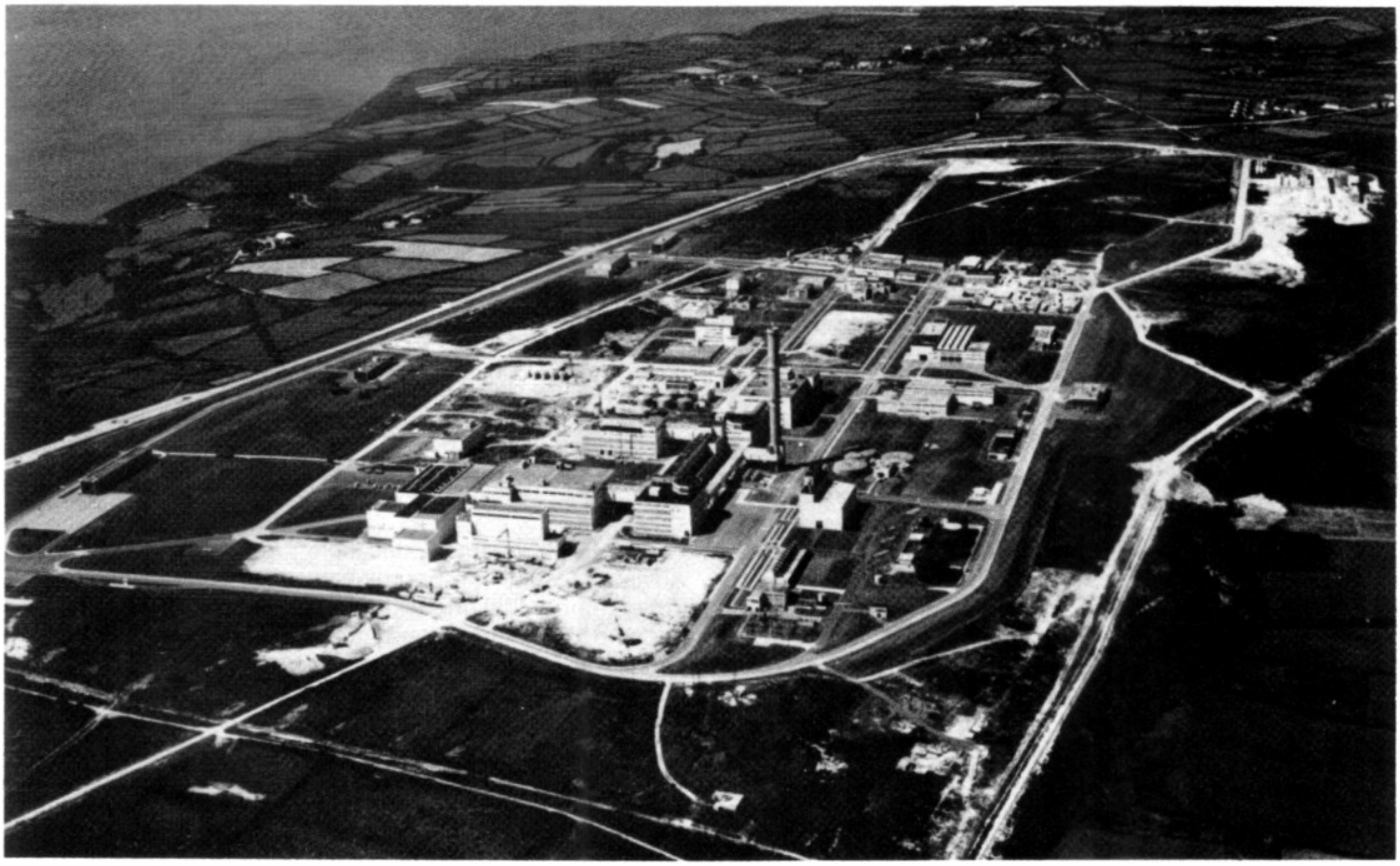
The first units of the Eurodif plant at Tricastin for the enrichment of uranium by the gaseous diffusion process went into operation in December 1978, and production began in early 1979. It is expected that the plant will reach its full output of 10.8 million SWU at the end of 1981.

The report also records that in 1978 the first uranium was produced at the mine owned by Cominak (La Compagnie Minière d'Akouta) in Niger, and converted into concentrate. The full capacity of the plant, 2000 tonnes of uranium a year, will be reached by 1980. The CEA holds shares in Cominak together with the Spanish group ENUSA, the Japanese OURD group and the Niger Government.

Safety

Effort on safety-related work in the CEA more than tripled between 1973 and 1978. The Institute for Radiological Protection and Nuclear Safety (IPSN) created within the CEA in 1976 to coordinate safety research undertook considerable research on both light-water reactor and fast reactor safety in 1978; work on LWRs concentrated on studies of accidental depressurisation of the primary circuit. Experiments were conducted in the Omega test loop at Grenoble and will continue in the new Phébus test reactor. The fast reactor safety programme covered two main aspects: first, the stability of fuels under loss-of-coolant conditions or variations in reactivity, and secondly sodium fires and means of controlling them. With respect to the first part of the programme, the first phase of work using the Scarabée test loop was completed and, although the results have not yet been published, the report says it is clear that transient boiling phenomena are less important than had been thought previously and that the fuel pins are remarkably robust. This programme is being carried out under an agreement for co-operation between the CEA, the UKAEA and the West German Karlsruhe Research Centre. These three bodies, together with the Japanese Power Reactor and Nuclear Fuel Development Corporation, also participate in a programme of research using the Cabri experimental reactor at Cadarache, designed to study the effects of large and fast increases in reactivity and power, which began in 1978.

The Esmeralda facility, designed to study the efficiency of smothering and extinguishing agents for use on sodium fires, was completed in 1978 and a programme of experiments began this year. □



The Cap la Hague reprocessing plant *NEI*

THE IMPORTANCE OF CONSERVATION

Energy conservation has gone from being viewed as a short term solution for dealing with temporary supply disruptions to being an important element in national energy programmes, the International Energy Agency says in a new review.

"Energy conservation became an element of energy policy in IEA countries at the time of the oil crisis of 1973-74," the Agency says in the introduction to its 1978 survey of national programmes, published on 28 September.* "The oil embargo led many industrial countries to introduce emergency measures, such as a ban on Sunday driving, which were intended to produce a drop in energy demand. The need for such measures was well understood by the man on the street and public perception of the benefit of conservation was sharpened by the spectacular rise in oil prices.

"By the end of 1975 the situation had changed. The rate of increase in oil demand had dropped significantly in most IEA countries, principally as a result of the economic recession which followed the events of 1973-74. Prior to the events in Iran in 1978, oil was in plentiful supply and in general the real price of oil was declining. Within national administrations, energy had ceased to be a matter for emergency action, and had taken its place alongside other concerns, such as stable economic growth, environmental protection and control of inflation . . .

"In October 1977 IEA Ministers set an objective for IEA countries to establish an oil imports ceiling by 1985 of 26 million barrels a day through energy policy measures including strong conservation and pricing policies. IEA findings since then indicate that there is a growing risk of a serious imbalance between energy supply and energy demand in the 1980s unless strong action is taken now. The recent events in the Middle East and the OPEC price increases underline how vulnerable IEA countries remain. Although energy conservation alone cannot solve the problem, alternative energy supplies other than imported oil cannot by themselves cancel out the energy imbalance which will impact significantly, not only on the IEA, but on the world economy as a whole. For this reason, as well as for economic, environmental and social reasons, energy conservation is an important and necessary element in the overall energy policy of Member countries of the IEA."

The report notes that many governments and individuals find energy conservation measures to be an effective method of dealing with the energy problem because it is economically attractive; it is consistent with environmental protection; it does not, in general, consume finite resources; and due to production and distribution losses, a unit of final energy consumption saved saves more than a unit of energy at the production end.

"Furthermore, there is a growing consensus that oil demand will exceed the capacity or the willingness of producers to supply oil during the 1980s," the report continues. "Fuel switching efforts have been developing slowly, e.g. there have been slippages in nuclear power programmes, wider use of coal is difficult and a large contribution from renewables is not likely in the near to mid-term. Therefore effective conservation actions seem to be the main preconditions for continued economic growth."

Constraints . . .

The report notes that there are many constraints to the conservation of energy, including lack of understanding of the

Conservation month

October was designated International Energy Conservation Month, when the 20 countries of the IEA including the UK combined to promote energy conservation throughout the month.

In the UK, nearly 100 events were planned to mark the Month; and more than 80 organisations announced their support for it. The UK programme was sponsored by HRH the Duke of Edinburgh. There were to be three major international conferences in the UK — an International Energy Management Conference organised by the Department of Energy, in Birmingham from October 9 to 11; a Brewing Industry Energy Conference in Burton-on-Trent from October 23 to 25; and a conference organised by the Royal Institution of British Architects on "Buildings: the Key to Energy Conservation" in London from October 25 to 27, under the patronage of the Duke of Edinburgh.

In a message to launch the Month Prince Philip said it would be worthwhile if it encouraged governments and both industrial and private consumers not to waste what limited supplies of energy were left and to face the inevitable consequences of the increasing cost of oil and gas as supplies began to run out. "One of Parkinson's Laws is that demand rises to meet supply, but he doesn't go on to say what happens when the supply starts to drop behind demand," he said. "Yet this is a problem which has confronted all the civilisations of history. In our case it has taken about 80 years for the world to take full advantage of natural oil and gas as the most convenient sources of energy the world has ever known. But the resources are limited, and it is only sensible to look ahead to the day when these fuels become hopelessly expensive, and to look around for alternatives."

The Publicity and Education Working Group of the Advisory Council on Energy Conservation recommended in September that energy and energy conservation should become an integral part of children's education; that special in-service training for teachers to teach energy conservation should be investigated; and that energy and energy conservation should be considered for inclusion in GCE and CSE examination syllabuses. The working group recognised "the extreme importance of imparting the energy conservation message to the younger generation. Those who are in school now will, as adults, have to face a much more difficult energy situation towards the end of the century." □

energy problem, of information on energy usage and of knowledge of what can be done to reduce energy use. Public funding for energy conservation activities is often inadequate, and the economic recession has limited industrial energy conservation investments. The most significant constraint to energy conservation in industry was probably the lack of information on conservation possibilities, as well as uncertainties over the cost effectiveness of such investments. In transportation, conservation was most severely constrained by a pattern of transportation and land use that resulted in a heavy reliance on the private automobile, the infrastructure having been developed during a time of cheap energy. In the residential/commercial sector there was again a lack of understanding of the energy situation, as well as uncertainties over measures that should be taken and their effectiveness.

. . . and potential

The report says that although in many countries much has already been done to encourage and promote energy conservation, and although the constraints are significant, there is still considerable potential for energy conservation. In industry, rapidly rising energy prices have created a big energy saving potential: a rough estimate of this potential by 1985 was about 10 to 15 per cent, based on 1977-78 energy prices and assuming no additional government conservation programmes. There was significant potential for savings in the transportation sector: automobile fuel economy could be improved considerably, especially in North America but also in Japan and in Europe. In building, too, the overall potential was great: the potential for economically justified energy savings had in some cases been estimated at 40 per cent in existing buildings, and very often more than 50 per cent in new buildings.

"During the period of cheap and plentiful oil many energy conservation activities were not economically attractive and energy conservation was not an element in most governments' energy policies," the report says. "Since 1973, however, energy conservation policies have undergone marked developments. Governments and many individuals have come to realise the economic attractiveness of many conservation measures. Despite these developments the constraints to the greater realisation of conservation and the potential benefits of energy conservation argue for a substantially greater government involvement in promoting the adoption of energy conservation measures than has occurred to date."

In a review of national programmes, the report says that although the importance of public information and education is generally recognised, except for six countries (Austria, Canada, Germany, the Netherlands, Sweden and the United Kingdom) which have expanded their programmes, information efforts in most IEA countries had been maintained at previous levels or had been reduced. In industry, the UK was one of 12 countries which offered grants or subsidies for industrial energy conservation; eight countries including the UK offered tax incentives; and in the UK alone the government had requested companies to state in their annual reports the expenditure incurred on fuel and the steps taken to save energy. The UK, too, had set up Industrial Energy Thrift and Audit Schemes which established accurate information on energy use and advised industry on effective conservation measures. Government energy conservation meetings or seminars had been arranged in many countries; in the UK, these seminars had been institutionalised by the formation of Energy Management Groups.

The report goes on to consider in detail the transportation sector and the potential for savings in the residential/commercial sector, the "limited" short term potential of renewable energy sources in contributing to the fulfilment of demand, and district heating and combined heat and power. Here, the report notes that in the UK 15 to 20 per cent of industrial electricity requirements are met from industries' own CHP plants. A variety of measures are available to promote district heating and CHP, the report says; a necessary first step is for governments to clarify the overall national interests and to decide on objectives and procedures.

The report says progress in implementing conservation programmes overall has been considerably less than had been expected a year ago in several member countries, and the success of some measures has been less than had been foreseen. The report's judgment is that — with Germany — the UK has made good progress since the last review in implementing incentive programmes in the residential and commercial sectors, but that programmes in other sectors, especially transport, need strengthening.

The full report is available through OECD sales agents including the HMSO. □

**Energy Conservation in the International Energy Agency: 1978 Review.* 52pp. ISBN 92-64-11969-8. £3.40.

NUCLEAR ENERGY: TIME TO TAKE STOCK

In the 21 years since the Nuclear Energy Agency of the OECD was created, nuclear energy has developed from a potential to a necessity, Mr I.G.K. Williams, Director General of the Agency, told the National Press Club of Japan on 10 September. "It is already providing between 10 and 30 per cent of electricity supply in several countries, and . . . it is the one major new prospect in a fragile world energy supply situation. Thus, nuclear energy is rightly a matter of major political significance." he said.

"At this time, we can identify four substantial questions of broad international concern. These are:

- Nuclear safety, for which the technology is largely international. As has been rightly stated, an accident anywhere is an accident everywhere.
- Radioactive waste management, for whichthe remaining questions are concerned essentially with long-term environmental protection. There is no justification for concern about the technology of waste management in the short and medium term.
- Security of energy supplies; and
- Measures to prevent the proliferation of nuclear weapons."

With respect to nuclear safety, "it is not possible to over-emphasise that 'absolute' safety is a myth," said Mr. Williams. "No technology will ever be accident-free: human errors, malfunctioning or equipment failures are bound to occur from time to time. What is important is that designers, operators and regulators are promptly informed of events elsewhere having a relevance to their work."

It was now clear that the Three Mile Island accident in March was very serious; but it was a long way from being a catastrophe in terms of human injury or of its impact on the surrounding population.

In radioactive waste management, it was clear that the utmost care was necessary to protect present and future generations, and that this required a cautious approach consistent with developing knowledge. Nevertheless, for all categories of waste, safe interim management arrangements existed already, and enough was known to be confident that the remaining problems would be solved. Research and development to this end must be intensified; "on this understanding, there is no reason to believe that nuclear power programmes should be postponed or delayed — the problems of radioactive waste management remaining are not of a nature to justify this."

The NEA's principal contribution in the question of security of energy supply was in technical and economic analysis, in collaboration with the International Atomic Energy Agency in Vienna, of the factors influencing supply and demand in all phases of the nuclear fuel cycle. The two agencies had for many years carried out surveys of world uranium resources, production and demand, and in 1976 they embarked on an international uranium resources evaluation project, aimed at assessing what further potential resources were likely to exist beyond those already identified. A first report, entitled "World Uranium Potential", had been published earlier this year [see ATOM, No. 272, June 1979, p. 158]. These first results indicated that additional world resources might lie within the range of 10 to 22 million tonnes of uranium, but it must be considered unlikely that the major part of these resources would be produced within the next 50 years — "in other words, they should be regarded as a qualitative measure of the state of geological knowledge rather than as a prospect which is a valid base for energy planning." The NEA was now initiating a follow-up phase in which a number of promising areas were to be studied more closely.

The next in the NEA/IAEA series of reports on uranium resources, production and demand would be published toward the end of this year, said Mr Williams. "While the data are not yet complete for this report, it seems likely that it will show an overall increase of about 15-20 per cent in the level of known uranium resources since the last report. This would bring the total of known and estimated resources to about 5 million tonnes of uranium. Much of the indicated increase will require further exploration to verify its existence (and the extent of the resources) before development and production could take place."

Projections of future uranium demand depended considerably on the choice of reactor type, the rate of growth of nuclear power and whether the breeder and reprocessing were to be adopted. The indications were that presently planned uranium production capacity would be adequate to meet demand only until the early 1990s and that, by the end of the century, production would depend increasingly on resources which had not yet been discovered. Since the lead time from initiation of exploration to production was about 15 years, the state of exploration today and over the next ten years (during which adequate supplies were expected to exist) would be of crucial importance to uranium supply from towards the end of the century.


Mr I.G.K. Williams

The nuclear contribution to security of energy supplies was linked inseparably with the problem of the potential proliferation of nuclear weapons, said Mr Williams. The main focus of discussion on this topic during the past two years had been the International Nuclear Fuel Cycle Evaluation. It seemed unlikely that major changes in the technological strategy for nuclear power would follow the conclusion of INFCE, "but there is no doubt that INFCE has contributed substantially to improved mutual understanding and has ensured that the search for a convergence of opinion will continue."

The basic problem was the potential for conflict between programmes based on economic considerations alone, and the achievement of non-proliferation objectives. "It must be clear that a constructive solution to this dilemma will have to depend on a reconciliation of non-proliferation and economic objectives," he said. "The search for a solution along these lines will require patient discussions at all levels and in both bilateral and multilateral exchanges. Practical progress is most likely to be achieved, in my view, by the development at international level of institutional mechanisms assuring access to services and materials for customer countries in exchange for acceptance of regulatory measures in the interest on non-proliferation. The emphasis for the acceptability of such a regime will have to be its multilateral character.

"The vital contribution of INFCE may well be that it has begun to prepare international opinion for reconciliation in this sense. It will be up to all of us concerned with international relations in the nuclear field to pursue these possibilities vigorously. I can certainly assure you that the experience and framework of the OECD Nuclear Energy Agency is well adapted to the development of institutional mechanisms of the type I have mentioned, and that we shall certainly be glad to contribute in this sense if this is the wish of a sufficient number of our member countries."

Mr Williams declared himself "cautiously optimistic" with respect to each of the four concerns he had listed earlier. "Although the development and introduction of nuclear energy continues to be a matter of lively public interest in many countries and must continue to engage the close attention of Governments," he said, "the responsible way in which the many problems involved are being tackled gives grounds for confidence that nuclear power will be enabled to fulfil its promise as one of the principle alternatives to imported oil and, consequently, as an important contribution to security of energy supplies." □

IEA awards solar contracts

The International Energy Agency has announced the award of contracts for the final design and construction of two 500 kWe solar electric power demonstration units which will be built and operated near Almeria, in southern Spain.

The project is a collaborative effort on the part of eight IEA countries — Austria, Belgium, Germany, Greece, Spain, Sweden, Switzerland and the United States. One of the contracts, worth 26 million Deutschmarks, is for a 'central receiver' type of plant, and the other, worth more than 22 million DM, is for a 'distributed collector' plant. The operating agent for the project on behalf of the participating countries is the Deutsche Forschungs-und-Versuchsanstalt für Luft- und Raumfahrt eV, Cologne, the German Air and Space Agency.

The solar power project is one of a number of collaborative projects being conducted under IEA auspices to develop alternative energy supplies in order to reduce dependence on oil. The two differing solar plants now to be built will be sited adjacent to each other to enable comparison of the relative merits of the two technologies involved; the unit size was chosen partly as it is of interest for possible application in developing countries. Construction and commissioning of the two units is expected to take about two years. □

REVIEWS

Ethics and Energy

Decision-makers Bookshelf, Vol. 5: **published by the Edison Electric Institute, 1111 19th St, Washington D.C., 20036 USA. 85pp; free.**

This booklet is one of a series put out by the Decision-makers Bookshelf which — according to the flyleaf — "seeks to provide to the public important discussions and reasoned viewpoints on national policy problems related to energy". It needs to be said, however, that the series is put out by the Edison Electric Institute, which was established in 1933 as the association of American investor-owned electric utility companies, with the role of exchanging information between people in the electric utilities and maintaining liaison between the industry and the Federal Government.

It could be argued, therefore, that the book is no more than an apologia by the electricity industry. It consists, however, of a series of essays by individuals, most of whom have no direct connection with the industry. The worst that could be said therefore is that the Edison Electric Institute may have been selective as regards authors. Be that as it may, all the essays tend to give the lie to the somewhat extravagant charges that have been made against electricity and the electricity industry by the zero-energy-growth movement, though only one of the nine authors is employed by an electric utility. The remaining eight all come from independent academic institutions of one sort or another — mainly universities.

Most of the essays were first published in other journals, though all within the last year or so. They all struck me as incorporating what I had previously noted as an attractive feature of many American academic papers — namely, the embedding of little nuggets of real wisdom in a largely unpretentious, sometimes almost homespun, discourse. I will quote some of the best of these as I discuss each author's essay.

Energy/GNP Trajectories: The Relationship between Economic Growth and Energy Consumption, **by Aden and Marjorie Meinel.**

Mr and Mrs Meinel are an interesting couple. They are mentioned in Alan Wyatt's book *The Nuclear Challenge* (reviewed in ATOM No. 267, January 1979 — an issue which is now, regrettably, out of print). He is Professor of Astronomy at the University of Arizona, and Mrs Meinel is a research associate at the same university. They were at one time keen proponents of solar energy as the solution to the world's energy shortage problems. As they came to learn more about the economics of energy use — or as they put it "the macro dynamics of energy" — they recognised some of the shortcomings of solar energy as a major contributor to world energy supplies and they switched their attention to more general studies of energy. The result has been some first class essays taking a highly enlightened view of the role of energy in human societies and a novel approach to its analysis.

In this essay they take a fresh look at the hoary old diagram plotting energy consumption *per caput* against gross national product *per caput* for the various countries of the world. This is the diagram that is used by our critics to show that we are much less efficient than the Swedes, the Swiss etc in our consumption of energy per unit of economic output. The Meinels argue that there are all sorts of reasons why one country might use more energy in total than another — climate, the make-up of the economy, the extent to which energy intensive goods are imported or home-produced, etc. A much more meaningful measure of efficiency in energy use, according to them, is the *incremental* energy consumption per incremental dollar's - worth of national product. On this criterion the UK emerges, along with Mexico, as the most efficient of the countries examined with Sweden no better than the USA and both of them somewhat less efficient than the average. The Meinels give their results in a simple, vivid way showing, with the aid of a distribution diagram, that energy efficiencies (in terms of incremental energy consumed per unit increment in GNP) for the period they studied (1960 to 1973) fell neatly upon the familiar hump-backed distribution curve. The average performance over the whole period, for each of the seven countries examined, was fairly close to the mean of this distribution. This, plus some other analysis, led the Meinels to doubt the claims that have been made by conservationists that further growth is possible without increasing energy consumption. They acknowledge that there have been steep increases in the efficiency of energy use in the past, but show that there is comparatively little more to be expected from this source, and they argue that future savings in energy would have to be through conservation and waste heat utilisation "at an added cost that may make the net results disappointingly small when viewed in a GNP/energy diagram". They see the "post industrialism", that some writers seem to welcome, as bringing decaying GNP *per caput* along with it. They say "no country has been able to produce an increase in income without the expenditure of an additional increment of energy". In periods of slump, energy consumption has often stayed constant whilst GNP has fallen. At best, they have simply retraced their steps.

The Meinels show their originality of approach in a discussion of the relationship between energy consumption and income inequalities. They note that the countries with the greatest inequality of income (defined as the ratio of income of the richest 20 per cent to the poorest 20 per cent) also have the lowest energy consumption per unit of output. They argue imaginatively (or fancifully, whichever you prefer) that there may be some analogy between thermodynamics and energy systems. Some degree of income inequality may be necessary to make the system work — just as temperature differences are necessary for a Carnot cycle heat engine to work.* The inefficient economies need large differences in incomes. Developed nations with a heavy reliance upon technology and energy use can operate at much smaller income differences.

A plot of income inequality against energy consumption *per caput* reveals the UK, once again, as a highly efficient performer — the removal of inequality has gone further than in other countries with similar levels of energy consumption. The Meinels note, however, that the UK economic performance has been poor and they wonder whether we have traded income equality against growth. They conclude that, whether we have or not, our energy consumption *per caput* must remain high or we shall lose our income equality as well as our growth.

They go on to use arguments dear to my own heart, that a high price for

*An economist would argue that capital and energy intensive industrial activity increases the marginal productivity of labour and hence the price it can command.

energy will restrict its use and produce poorer performance — either in terms of growth or inequality of income. "The poor will become poorer and the gap between the poor and the rich larger. Expensive energy will first hurt the poor . . .. We need inexpensive energy to protect that highly vulnerable and fragile thing called human welfare."

Energy, Economic Growth, and Human Welfare, **by Sam H. Schurr**

I already had a much valued copy of this paper, taken when it first appeared in the Journal of the American Electric Power Research Institute last year. Sam Schurr is a patriarch of the energy studies business and I regard this article as containing more wisdom to the square inch than any article of similar size that I have encountered.

Schurr examines two previously widely accepted propositions that have come to be challenged. The first is that there is a direct connection between economic growth and the growth in human welfare and the second that there is a strong link between energy growth and economic growth. He argues that the debate on the first proposition is likely to be endless because the holders of the opposing viewpoints base them on quite different value judgments. He suggests that it is more practical to ask not about human welfare but about the conditions of economic growth that are most compatible with minimising political and social conflict and goes on to argue that it is obviously far easier to provide more for everyone by distributing shares of an ever-growing economic pie than by re-apportioning the shares of an unchanging pie (another paper in this anthology makes a similar point). Many of the specific problems affecting the United States, unacceptably high levels of unemployment and price inflation for example, would yield to higher levels of economic growth. So would housing and urban rehabilitiation.

On a world scale he argues that, however much we in the developed countries may pontificate about the wisdom of the industrialisation of the undeveloped countries and the likelihood of their attaining their targets, there is no doubt that some progress toward those targets would considerably relieve international tensions.

It is tempting to give Schurr's analysis of the relationship between energy growth and economic growth in some detail. I will resist the temptation and draw attention only to the most important feature of his analysis. Schurr is one of the few writers on energy to give serious consideration to the direction of causality of the energy/GNP relationship. He is concerned about the tendency to view energy consumption as something that flows from exogenously projected economic growth — and therefore something that can be reduced by giving the right price signals. Schurr argues that the case is at least as good for saying that it is commercial energy that drives modern economic systems. Like the Meinels he is dubious about the argument that a greater proportion of non-industrial activity (services) in the more highly developed economies will reduce energy requirements. He points out that many services are highly energy intensive and that growing personal incomes result in demands for these highly energetic services. "It is not unusual" he says "for people to travel great distances by aeroplane or automobile for a skiing weekend or to engage in other types of leisure activity that require substantial travel". The growing trend toward second homes will also produce a demand for energy-consuming weekend travel.

He concludes that economic activity could well be absolutely constrained by the supply of commercial fuels at the right price. If this is so, he says, then the present tendency to view energy shortages and high prices as inevitable may be very damaging to our future. The emphasis should be on "the need for pursuing policies whose objective is to surmount [energy] supply and environmental constraints in an acceptable manner rather than to bow to their supposed inevitability".

The Energy/Environment Dichotomy, **by John C. Sawhill**

John Sawhill is now president of New York University. He was, at one time, Federal Energy Administrator. John Sawhill is an exceptionally lucid and articulate speaker and writer. He has the gift of saying rather outrageous things in an entirely acceptable way. In this paper he challenges the correctness of using the courts to adjudicate between the conflicting claims of energy planning and environmental protection. He instances two cases: "the Tellico Dam *versus* the Tennessee Snail Darter (a type of fish)" and "the Seabrook Power Plant *versus* New Hampshire Clam Larvae". The environmentalists won the first and the energy producers the second. Ninety per cent of the cost of the dam had been incurred and it would have provided indirectly almost 7000 new jobs and enough electricity to heat 20 000 homes but, on narrow legal grounds, the Court of last resort — the Federal Judiciary system — stopped it. On similarly narrow grounds the Court approved the completion of the Seabrook nuclear power plant although certain clam larvae were likely to be destroyed in the area affected by the plant's cooling system.

Sawhill points out that the real victory in each case remains in doubt because at no time was any attempt made to reconcile the conflicting aims of environmental protection and energy planning by objective evaluation of the costs and benefits on each side.

He regrets that the upswing of concern for the environment came when energy supplies were seen to be copious and cheap. Environmental protection therefore gained momentum which has not been much affected by the more recent concern over energy supplies. The result is that the Environmental Protection Agency and the Federal Energy Administration are both going full steam ahead with conflicting Congressional mandates. There are no fewer than 50 different regulatory bodies to be satisfied before a power station can be built. It now takes 14 years from start to finish to construct a nuclear power station in the United States, compared with about seven years in Japan. Environmentalists have come to believe that they have a constitutional right to achieve delay. It is urgent, says Sawhill, to resolve this problem by simplification and greater co-ordination or "regardless of which special interest groups may count themselves as winners or losers over the next decade" it will be the nation as a whole that will suffer.

Energy, Society and the Environment: Conflict or Compromise? **by Margaret N. Maxey**

Dr Maxey is Associate Professor of Bioethics at the University of Detroit; this is a first-rate paper. Margaret Maxey challenges three beliefs cherished by the environmentalists and advocates of "soft energy paths" — (1) that energy and high technology are major causes of environmental degradation; (2) that resource depletion is directly traceable to industrialisation and high technology; and (3) that centralised energy technologies are major causes of social injustice. She finds that the first of these views has a very long history — going back at least to Georgius Agricola writing in 1556 who argued, in effect, that mining was against nature: it was only those wares on the surface that we were intended to use. Here is perhaps the first recorded example of the view that nature in the raw is basically benign whereas, according to Dr Maxey and Dr J.R. Dunn, a geologist whom she quotes copiously, the untamed environment has done enormous damage to human society through the catastrophic effect of famines, plagues, floods, earthquakes and so forth. We are not, therefore, she says, in a situation of trying to "sustain a simplistic non-degradation of the environment. Rather, the problem is a complex one of devising appropriate means to protect both life-sustaining and aesthetic qualities of the biosphere, and at the same time develop technologies which provide basic human goods as a necessary condition for maintaining a preferred environmental quality." She clearly finds Dunn a kindred spirit. He points out that the greatest damage to the environment has occurred in poor non-industrial societies. They may have no choice but to plant crops or graze sheep on steep slopes which ought to have been left wooded. The twin pressures of demand for firewood and for food under primitive food production methods results in soil erosion. There is, says Dunn, more woodland in the United States today than there was 100 years ago. "In our present world, both renewable and non-renewable resources tend to increase with industrialisation and technology."

Dr Maxey quotes the paradoxical conclusion of a National Science Foundation report that "whilst we seem never to have completely exhausted a non-renewable natural resource, many renewable resources have been wiped out." From one third to one half of the world's forests have been stripped. In many hilly and mountainous regions of the world, over-tilling and over-grazing are causing the rapid loss of top soil in virtually all under-developed nations. Because vegetation and soil cover have been lost, ground water is not sinking into the ground and this is altering climates from semi-arid to arid in much of the world.

In the industrialised, technological societies on the other hand renewable resources are being held and even expanded. This is because farmers make the best use of remaining farm land by using machinery and crop rotation and returning nutrients to the soil. The fact is that burning so-called renewable wood from our forests would damage the environment — it is precisely what less-developed countries have been forced to do for thousands of years, to the great detriment of the environment.

Dr Maxey quotes the Meinels as having debunked solar energy. She argues that it is false to see nuclear power and the renewables as in opposition. They will both be needed. She rejects the artificial distinction between renewable and non-renewable resources, pointing out that there are no natural resources. Natural resources are simply raw materials transformed by man. Even agricultural land exists only where it has been transformed from wilderness and preserved by man. Our resources are human inventions transformed by our technology. Therefore, technology is the amplification of our natural resources, not the means of their depletion.

One of her quotations (from the Meinels) is topical, given the current spate of articles arguing that nuclear energy creates unemployment whilst the renewables create jobs. The Meinels point out that a soft energy path advocate says in the same breath that solar energy is cheaper and that it will create more jobs. If this is true, the Meinels say, then one must pay solar energy workers much less than is paid in the alternative industries. The fallacy lies in assuming that money is somehow equated with high technology systems and employment with low technology. The truth is that money goes to pay people wherever they work. "It is intellectually dishonest" she says "to claim that creating more jobs in one energy sector can and should be a trade-off . . . for abandoning high technology." The hazards to the rest of our socio-economic system are not even considered in such a claim.

She argues that the only known device that will stabilise population and domestic unrest throughout the world is the achievement of moderate levels of material well-being, health etc, for those deprived of it, and that reliable energy supplies are essential to that well-being. She assures us that we can expect a backlash from the poor of the world if we fail them, and says that they already resent environmental organisations in the richer societies when they demand a freeze on growth in energy supplies and then retire into "local bastions of privilege."

She even has something to say about nuclear weapons proliferation in this commendably broad survey. "Just as there is nothing that predestines sulphur, charcoal and saltpetre to be skilfully combined into gunpowder, there is nothing that predestines plutonium to be made into weaponry." "If we do not muster the political will to learn how to govern nuclear knowledge, then we cannot hope to govern all other potential sources of weaponry." She deplores the idea that such an important source of energy as plutonium should be rejected because of fear. She quotes Madame Curie: "Nothing in life is to be feared: it is to be understood."

The other papers in this anthology are also well worth reading. Dr Luther P. Gerlach, Professor of Anthropology at the University of Minnesota, analyses the anti-growth movement very effectively; Fred Abbate, Director of Public Affairs Research at Atlantic City Electric Company, demolishes the case against centralised electricity systems; and Reverend Father Olof Scott of St George Orthodox Church in Charleston, West Virginia (a former nuclear engineer) rejects the suggestion that there is any reason for the Church to adopt an anti-nuclear stance. He quotes Isaac Asimov in support of his argument that the world cannot reject the high technology basis of human survival. Its population is already too great to be sustained by any other means.

Altogether this little anthology represents as thoughtful a collection of commentaries on the wider issues in the energy debate as it would be possible to find in any single volume anywhere.

L.G. Brookes
Economic Adviser, UKAEA

Canadian proposals for waste management

The Science Council of Canada suggested in their report No. 23, *Canada's Energy Opportunities*, that Canada should have a national energy policy supported by a research and development programme designed to keep open all the major energy supply options. The Council have now published in report No. 30, *Roads to Energy Self-Reliance: The Necessary National Demonstrations**, proposals for a set of energy demonstration programmes in areas which would aid decision-making on those options. The programmes are in oil and gas, coal, nuclear energy, renewable energy and conversion technologies. The programme in the nuclear field summarised here deals with the demonstration of an acceptable irradiated fuel management and disposal system.

Some of the assumptions this programme makes on radioactive waste management are:

- If all the irradiated fuel accumulated in Canada by the year 2005 were to be placed on a regulation football field 100m long and 60m wide, the height of the storage would not exceed 2.5m — 8 feet.

- Large disposal facilities to accommodate this volume might not be needed, therefore, until the beginning of the next century.
- Most radioactive wastes will be stored in the interim in a way that will facilitate safe retrieval.
- The first phase of storage, as in the past, would constitute storage of irradiated fuel bundles in special containers at the nuclear reactor site for the first 5-10 years.
- Engineered surface storage facilities away from reactor sites will last 50-100 years: possibly they would be needed for only 20-30 years.
- Conceptual development and preliminary engineering work for disposal systems can be completed over a period of two decades.
- A sufficient time will be provided for the appraisal of the selected disposal system before it is used on a large scale.
- The problems of radioactive waste are as much sociological/environmental/economic/political as they are technical/scientific.

The programme would aim to identify types of geological formation suitable for the permanent disposal of long-life wastes. Several types of formation (e.g. igneous and metamorphic rocks, volcanic rocks, shales, clay, salt and ocean bed) might need to be considered; and consideration should also be given to whether the disposal procedures should leave the wastes totally irretrievable. The programme would also aim to carry out a careful study of the disposal systems selected for development; develop materials and processes which would enable the wastes to be incorporated into insoluble (glass or ceramic) materials before disposal; consider the present procedures for the interim storage which spent fuel, fission products and actinides require before they can be disposed of; develop and demonstrate methods of storing medium and low-level activity wastes; continue research into and development and demonstration of safe and efficient methods of handling and transporting nuclear wastes; consider the possibility of locating interim spent fuel storage, fuel reprocessing and ultimate disposal at the same site, thus improving safeguards, reducing costs and easing transport problems; and monitor and evaluate international developments in waste management.

The report gives the estimated costs of the demonstration programme, which include:

	$ Canadian
Capital cost of the construction of pilot facilities:	27.5 m
Exploration for underground storage, including drilling and evaluation testing at several sites:	10.5 m
The completion of a full-scale evaluation system:	367.75 m

The estimated timescale for what the report terms "a possible demonstration programme and follow-up" is:

1985 Selection of disposal sites finalised
1991 Depository completed
1997 Depository demonstrated
2005 Beginning of substantial reprocessing
2010 Plans for model repository finalised

Barry Carpenter
Authority Health
and Safety Secretariat

*Science Council of Canada Report No. 30, June 1979. 200pp; available from the Canadian Government Publishing Centre, Supply and Services Canada, Hull, Quebec, Canada K1A 0S9. ISBN 0-660-10259-5. $ Can. 5.40.

Nuclear has 5.8 per cent electricity share

Installed world nuclear generating capacity rose by 15 000 megawatts during 1978 to about 110 000 MWe, — 5.8 per cent of the world total electrical generating capacity, the International Atomic Energy Agency says in its annual report for 1978.

The IAEA says the 227 nuclear power stations now operating in 21 of the Agency's Member States have a total operating life of 1700 reactor years. To the end of 1978, there had been 20 years of commercial nuclear power generation without a single radiation-induced death or a serious radiation-induced injury at any nuclear power plant — a statement which remained true even after the Three Mile Island accident which occurred on 28 March this year.

The report notes that for the past five years the IAEA has been preparing a comprehensive set of internationally agreed recommendations for the safety of nuclear power plants, a series of some 50 codes of practice and safety guides for thermal nuclear stations under the Nuclear Safety Standards (NUSS) programme. Five codes of practice — on government organisation, siting, design, quality assurance and operation — were published in 1978, and 11 safety guides covering in more detail some aspects of corresponding codes of practice. The NUSS programme was reviewed by an IAEA Senior Advisory Group after the Three Mile Island accident, who emphasised the necessity for the Agency to give assistance to Member States in establishing their own national emergency plans. The IAEA's own emergency assistance plans were reviewed with respect especially to the qualified personnel who could be made available to Member States at short notice, and to the special functions of the IAEA in giving emergency assistance and the kind of equipment which the Agency could provide.

During 1978 the Agency's programme on the disposel of radioactive waste into geological formations was expanded to include underground disposal of radioactive waste. Although suitable processes for managing the present amounts of radioactive wastes and effluents exist, more needs to be done to demonstrate the technology and to harmonise the principles on which waste management policies should be based, the Agency says. The Agency is developing a series of technical documents covering regulatory activities, siting, waste acceptance criteria and repository design, construction, operation and shutdown.

The Agency says there are now 110 parties to the Treaty on the Non-proliferation of Nuclear Weapons — the NPT — which came into force in 1970 and is to be reviewed in Geneva in August 1980. In 1978, as in previous years, the Agency Secretariat did not detect any discrepancy which would indicate the diversion of a significant amount of safeguarded nuclear material for the manufacture of any nuclear weapon, or to further any other military purpose, or for the manufacture of any other nuclear explosive device. The nuclear material under Agency safeguards remained in peaceful nuclear activities, or was otherwise adequately accounted for.

"On one point, however, there was no progress since 1977," the Agency says. "The number of non-nuclear weapon States that were operating unsafeguarded nuclear facilities remained unchanged at five, and the number of those which had unsafeguarded facilities capable of making nuclear weapons material remained unchanged at three."

The report surveys as well the Agency's activities in technical assistance to Member States, the collaborative programme on the use of nuclear techniques in agriculture conducted with the Food and Agriculture Organisation of the UN, and other areas. Copies of the report may be obtained from the IAEA Public Information Division, Kärntnerring 11, A-1010 Vienna. □

Derived limits

The National Radiological Protection Board published on 27 September a technical report[1] describing the principles on which it will calculate Derived Limits (DLs) — necessary in practical radiological protection work to enable the comparison of measurements of such quantities as radioactive contamination of environmental materials, rates of release of radioactivity into the environment, radiation dose rate in a workplace and so on with the basic radiation dose limits.

Derived limits are set with the intention that compliance with a Derived Limit ensures virtual certainty of compliance with the basic dose limits. They will not involve any change in those limits. Failure to comply with a DL does not necessarily mean that dose limits have been exceeded, but rather that a more careful study of the circumstances is required.

The principle adopted has been to derive generalised DLs for use when the level of contamination, release rate, etc, is a small fraction of the DL. If the level approaches the generalised DL, then calculations which take into account local circumstances will probably need to be undertaken.

The new report is the first of a new series, the DL-series, which the NRPB has established; the reports will be sold through HMSO.

Derived Limits will be published in due course for a wide range of radionuclides and for circumstances relevant to the general environment and the workplace; the former will include Derived Limits in foodstuffs and associated environmental materials such as soil and grass, and for discharges from stacks.

The Board has stated (in ASP1[2]) that the system of dose limitation recommended by the International Commission on Radiological Protection provides a satisfactory basis for controlling the exposure of persons to ionising radiation. These recommendations may be summarised as follows:

Justification:
Every activity resulting in an exposure to ionising radiation must be justified by the production of a positive net benefit.

Optimisation:
All exposures shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.

Dose Equivalent Limits:
An annual upper limit of 50 mSv (5 rem) for a worker and 5 mSv (0.5 rem) for a maximally exposed group of the general public, which must not be exceeded.

The first two principles apply to all man-made exposures to radiation and include exposure of patients during the medical use of radiation. The ALARA principle is already a feature of the Health and Safety at Work etc. Act 1974, for all types of risk. The third principle does not apply to patients during medical examination and treatment or to exposure to natural background radiation. These principles are applied through the following framework of limits and levels:

Primary limits — the dose equivalent limits — are based on knowledge of radiobiology and assessment of risk.

Secondary limits — such as annual limits of intake by inhalation or ingestion of radioactive nuclides — which are directly related to primary limits through knowledge of the metabolic behaviour of radioactive materials; their purpose is to ensure that the safety of workers exposed to radiation is equally maintained whatever the manner of irradiation, whether of the whole body uniformly or of particular organs selectively.

Derived limits — these enable the primary and secondary limits to be complied with, eg, by means of practical measurements in the environment of contamination of food, soils, surfaces etc.

Authorised levels — levels often arrived at following the process of optimisation and which enable regulatory authorities to maintain effective control of radiation exposures; they are generally below the Derived Limits.

In ASP1 the Board also commented on the need for interpretation of ICRP's detailed recommendations and supporting argument and data and stated its intention to publish comments and views on these from time to time.

Further information is available from the Information Officer, National Radiological Protection Board, Harwell, Didcot, Oxon OX11 0RQ. Tel. Abingdon (0235) 831600, Ext. 410 □

1 NRPB-DL1 *The Estimation of Derived Limits*, by N.T. Harrison, P.M. Bryant, R.H. Clarke and P. Morley (HMSO, £1.00)

2 *Recommendations of the International Commission on Radiological Protection (ICRP Publication 26): Statement by NRPB on their acceptability for application in the UK*. Harwell, NRPB. ASP1 (1978). London, HMSO.

OBITUARIES

Dr G.W. Dolphin

The Authority regret to record the death of Dr Geoffrey Dolphin, Assistant Director (Research and Development) of the National Radiological Protection Board on 20 August. After graduating at Reading University Dr Dolphin served in the RAF from 1943 to 1946, then returned to Reading where he completed a Ph.D. in physics. He joined St. Bartholomew's Hospital Medical School as an assistant lecturer, later working as a research associate with the British Empire Cancer Campaign where he developed an interest in biological problems.

Before joining the Radiological Protection Division of the UKAEA Health and Safety Branch at Harwell in 1959, he spent a year in the Biophysics Department at Yale University. In the UKAEA he worked on the biological problems associated with radiological protection and, on the formation of the NRPB, he became Head of its Biology Department. He was appointed Assistant Director (Research and Development) in 1973; and he was awarded the degree of Doctor of Science by the University of Reading in 1975.

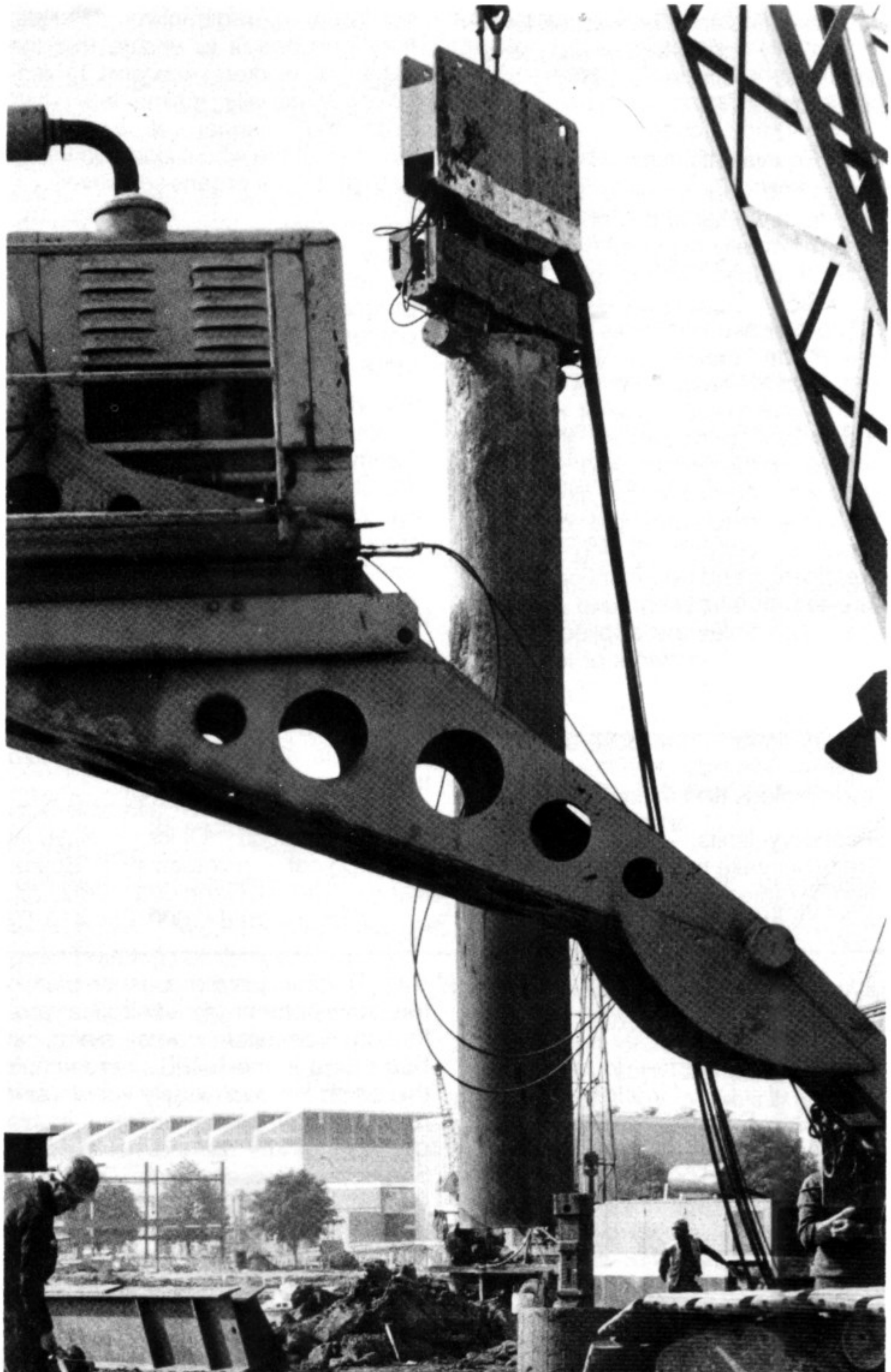
Dr Dolphin played a major part in the development of radiological protection concepts on a biological basis, and in the NRPB's research in this field. He was widely known and respected for his contributions in this country and abroad. He was Secretary of Committee 2 of the International Commission on Radiological Protection, and a member of the Advisory Committee on Programme Management "Biology — Health Protection" of Euratom.

Dr Dolphin published numerous papers on many aspects of radiological protection. He is survived by his wife and two daughters.

Miss Sarah Kronberger

The Authority have learned with regret of the death in an air crash in India of Miss Sarah Kronberger, daughter of Dr Hans Kronberger, a pioneer in the development of nuclear energy for electricity production in the UK.

Dr Kronberger's career in nuclear energy began in 1944, when he joined the war-time atomic energy project known as Tube Alloys. He gave distinguished service to the Authority from its inception and was Member for Reactor Development from 1969 until his death in September 1970. □



Construction work in progress on buildings to house the Joint European Torus (JET) project at the Culham Laboratory, near Abingdon. The project is a European cooperative venture on the part of the countries of the European Atomic Energy Community (Euratom), with Sweden and Switzerland; building work began in September.

Radioactive waste controls satisfactory

The basic objectives for radioactive waste management in the UK laid down in 1959 have worked well and have resulted in very low average radiation doses to members of the public, an Expert Group of the Radioactive Waste Management Committee conclude in a report published by the Department of the Environment on 25 September.

The report* is of a review of the 1959 White Paper *The Control of Radioactive Wastes* (Cmnd. 884). The group considered the control of radioactive waste through all stages of the nuclear fuel cycle, and examined the controls governing the accumulation and disposal of waste, in the first comprehensive review of radioactive waste management policies and practices since the entry into force of the Radioactive Substances Act in 1960. It concluded that the existing regulations governing the disposal of radioactive wastes were satisfactory, and that there was no need for any major change to the Radioactive Substances Act. However, it did suggest some changes in emphasis to reflect the developments of the past 20 years — particularly the recent recommendations of the International Commission on Radiological Protection.

The group felt that methods now used for the disposal of low- and intermediate-level solid wastes were based on satisfactory radiological principles, and did not give rise to any hazard to the public. The methods used in the disposal of low-level liquid waste were also generally satisfactory: in particular, the liquid discharges from Windscale had never exceeded the ICRP limits. [The level of activity released from Windscale will be further reduced by the refurbishment of a treatment plant at the works which will be completed in the early 1980s.]

The group was satisfied that waste for which there is no suitable disposal method at present can be safely stored for the present, but felt that R&D for all types of waste should be pursued. This research should include work on all the three options now being considered for the disposal of vitrified high-level waste — emplacement in deep geological formations under the land, or on or under

**A Review of Cmnd 884: A Report by an Expert Group made to the Radioactive Waste Management Committee.* Copies are available on request from the Department of the Environment, Rm. 418, Becket House, 1 Lambeth Palace Rd, London SE1, price £1.35 plus 40p postage and packing.

the deep sea bed. The group was confident that an acceptable disposal method for these wastes will be found.

The report has been discussed by the Radioactive Waste Management Advisory Committee (RWMAC) and any comments which the Committee have on the group's recommendations will be published in their report to the Secretaries of State for the Environment, Scotland and Wales, to be made at the turn of the year.

The RWMAC is an official body set up in 1977 to serve as a working party to consider radioactive waste management policy overall. The Expert Group which has now reported was set up in March 1976 by an earlier official coordinating committee.

The Department of the Environment points out that the group's recommendations represent the independent view of a group of experts and do not constitute a statement of Government policy: the Government will formulate its response later, taking into account both the views of the group and any comments the RWMAC may make in their first annual report, which is due to be presented to Ministers to lay before Parliament later.

The expert group's report will be discussed at greater length in a later issue of ATOM. □

NRPB annual R&D report

The metabolism of plutonium, biological studies relating to the thorium/uranium fuel cycle and studies of the mortality rate of American nuclear workers are among the subjects reviewed in the Annual Research and Development Report 1978, published by the National Radiological Protection Board on 6 September.*

The report shows that there has been continued progress in the investigation of the metabolism and effects of radioactive materials incorporated in the human body. Studies have confirmed that industrially-produced radioactive dusts do not necessarily behave as predicted from models devised by the International Commission on Radiological Protection (ICRP), which are based on investigations using pure, laboratory-produced materials. The behaviour of very small particles of plutonium dust, approximately 0.001 microns in diameter, is of particular interest. While larger particles of plutonium-239 dioxide are insoluble and tend to remain at the site of entry, these smaller particles move rapidly through the body. The results imply that the dose commitment to bone and liver may be greater than calculated from the lung model following inhalation of some forms of mixed oxides of plutonium.

The fate of ingested radioactive materials is of interest in considering environmental sources. Changes in physico-chemical form and in the mass ingested may influence gastro-intestinal absorption. Evidence so far suggests, however, that the current ICRP models are substantially correct in predicting the fractional absorption of actinides.

The report says there is growing interest in the thorium/uranium fuel cycle as an alternative to the uranium/plutonium fuel cycle. Preliminary work on some materials from the thorium cycle has established their metabolic behaviour, an important factor in considering consequences of the alternative fuel cycle.

The NRPB notes that an important part of its research in physics is to refine the calculation of radiation dose and risk, for instance, from the interpretation of chest monitoring results and estimations of plutonium body content. Among its epidemiology studies, the Board has obtained from the US Department of Energy the data used in the study of the mortality of workers at Hanford in Washington State and is carrying out its own analysis, the report says.

Investigations of new X-ray diagnostic techniques have shown that the radiation dose to the patient during computerised tomographic scanning with EMI brain and body scanners is no more than that associated with a few conventional X-radiographs of the same part of the body provided that the scanner is operated at its normal (i.e. fast) scan speed.

Further information is available from the Information Officer, National Radiological Protection Board, Harwell, Didcot, Oxon OX11 0RQ. Tel. Abingdon (0235) 831 600, ext.410. □

*Annual Research and Development Report, NRPB/R&D 3, June 1979. 249pp. HMSO. £6. ISBN 0 85951 103 0 □

Nuclear incidents

The Health and Safety Executive published its second quarterly statement on incidents at nuclear installations in Britain on 30 August. The statement — made in accordance with arrangements announced by the former Secretary of State for Energy in February 1977 — deals with incidents which occurred during the period 1 April to 30 June.

As in the first quarter of 1979, small spillages or leakages of activity were the main type of incident reported. The circumstances of a number of these incidents were still being investigated at the time the report was made; some were of cases or potential cases of radiation exposure of workers exceeding the permitted levels recommended by the International Commission on Radiological Protection. Three fires were reported during the period. None of the incidents involved a significant radiological hazard, and no member of the public was involved in any of them.

Details of the incidents are given in chronological order, together with the names of the establishments at which they occurred: the Windscale works of British Nuclear Fuels Ltd; the Hunterston nuclear power station operated by the South of Scotland Electricity Board; AEE Winfrith; the Trawsfynydd nuclear power station operated by the CEGB; and the Dungeness nuclear power station, also operated by the CEGB.

Copies of the statement are available free from the Enquiry Point, Health and Safety Executive, Baynards House, 1 Chepstow Place, London W2 4TF. Tel. 01-229 3456 ext.732. □

UKAEA courses

Two-phase flow and heat transfer

An intensive course covering fundamentals and applications of two-phase flow and heat transfer is to be held at the UKAEA establishment at Winfrith, Dorset, from 14 to 18 January 1980. The course, for which the fee is £275 plus VAT, is aimed at engineers and research workers in the process chemical, petrochemical, power generation and nuclear industries.

Active handling for designers and users

A course in the principles and practice of active handling is to be held from 17 to 21 March 1980 for those concerned with the design and use of active handling facilities, associated equipment and techniques. It is aimed to give an appraisal of the current principles and practice of active handling in the UK and overseas laboratories with a projected indication of possible future trends.

The course will include technical visits, where examples of some of the latest active handling equipment will be displayed and discussed. The course fee is £240 plus VAT.

Further information about both courses may be obtained from the Education and Training Centre, AERE Harwell, Oxon. OX11 0QJ. Tel. Abingdon (0235) 24141.

AEA REPORTS

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

AEEW-R 1251 *Current status of evaluated heavy element decay data for reactor calculations. Problems and anomalies, May, 1979.* By A.L. Nichols. July, 1979. 53pp. HMSO £1.50. ISBN 0 85182 048 4

AERE—M 3019 *Floating point packages for the PDP-8.* By M.D.J. Bright, J.W. Hall and C.R.T. Heard. March, 1979. 115pp. HMSO £2.50 ISBN 0 70 580940 4

AERE-R 9027 *A CARS system for the study of liquids and gases.* By D.R. Williams and I.A. Stenhouse. April, 1979. 15pp. HMSO £1.00. ISBN 0 70 580541 7

AERE-R 9199 (Suppl.) *Some recent literature describing liquid metal embrittlement.* By M.G. Nicholas. April, 1979. 12pp. HMSO £1.00 ISBN 0 70 580641 3

AERE-R 9360 *Using the AM9511 arithmetic processing unit with the motorola M6800 microprocessor.* By M.A. Reid and D.A. Newton. February, 1979. 75pp. HMSO £2.00. ISBN 0 70 580850 5

AERE-R 9416 *A design study for a fission product fixation plant and storage at Windscale.* By K.M. Hill, G. Ridley and D.G. Adler. 1961 (reprinted March, 1979). 99pp. HMSO £2.50. ISBN 0 70 580910 2

AERE-R 9452 *Resuspension of particulate matter from grass and soil.* By J.A. Garland. May, 1979. 30pp. HMSO £1.50. ISBN 0 70 580561 1

AERE-R 9473 *Solar power satellites: a study of the relative merits of different power conversion options.* By E.H. Cooke-Yarborough. May, 1979. 19pp. HMSO £1.00 ISBN 0 70 580621 9

AERE-R 9383 *Some applications of TSO command procedures.* By P.A. Shovlar. February, 1979. 40pp. HMSO £1.50. ISBN 0 70 580920 X

AERE-Bib 199 *List of unclassified documents by staff of metallurgy division, AERE, Harwell from August 1977 to December 1978.* Compiled by J.M. Wall. July, 1979. 18pp. HMSO £1.00. ISBN 0 70 580671 5

AERE-R 8301 *A measurement system for use in the selection of plutonium contaminated waste for disposal.* By J.W. Leake, K.P. Lambert and M.C. Warner. April, 1979. 11pp. HMSO £1.00. ISBN 0 70 580531 X

AERE-R 8730 (1979 Rev.) *MA28 — A set of Fortran subroutines for sparse unsymmetric linear equations.* By I.S. Duff. March, 1979. 89pp. HMSO £2.50. ISBN 0 70 580900 5

AERE-R 9079 *A reanalysis of neutron diffraction data from* UO_2. By M.J. Cooper and M. Sakarta. April, 1979. 24pp. HMSO £1.00. ISBN 0 70 580501 8

AERE-R 9213 *An investigation into pollution from a disused gasworks site near Ladybank, Fife.* By A. Parker and J.D. Mather. February, 1979. 24pp. HMSO £1.50. ISBN 0 70 580880 7

AERE-R 9359 *An investigation of ion beam irradiation techniques for the simulation of 14 MeV neutron irradiation of ceramics at high temperatures.* By G.P. Pells. March, 1979. 28pp. HMSO £1.50. ISBN 0 70 580950 1

AEEW-R 1242 *An analytical treatment for multi-layered reflector regions in neutron diffusion codes.* By A.N. Buckler. March, 1979. 56pp. HMSO £1.50. ISBN 0 85182 046 8

AERE-R 9390 *A search for the* $^{238}U(\gamma, \alpha)^{234}Th$ *and* $^{238}U(n, \alpha n^1)^{234}Th$ *reactions and measurements of the* $^{60}Ni(n, P)^{60}Co$ *and* $^{62}Ni(n, \alpha)^{59}Fe$ *cross-sections at 14.7 MeV neutron energy from associated monitor foils.* By E.W. Lees, B.H. Patrick and S. Lindley. March, 1979. 18pp. HMSO £1.00. ISBN 0 70 580970 6.

AERE-R 9444 *A finite element study of driven laminar flow in a square cavity.* By K.H. Winters and K.A. Cliffe. April, 1979. 62pp. HMSO £2.00. ISBN 0 70 580511 5

AERE-R 9426 *Formation of the polycyclic aromatic hydrocarbon benzo (A) pyrene during straw burning.* By D.H.F. Atkins, R.D. Wiffen, C. Healy and J.B. Tarrant. April, 1979. 12pp. HMSO £1.00. ISBN 0 70 580980 3

CLM-R 188 *Elastomer seal for a large toroidal vacuum chamber.* By S. Skellett, F. Casey and H. Blake. July, 1978. 9pp. HMSO £1.00. SBN 85311 070 0

AERE-R 9450 *Automatic data acquisition and processing with APEX goniometer, PDP11/03 and IBM 370 computer, with application to surface texture studies of magnox fuel cladding.* By M.O. Boles, B.A. Bellamy and G.A. Burras. June, 1979. 61pp. HMSO £2.00. ISBN 0 70 580651 0

CLM-R 181 *A Monte-Carlo computer program for analysis of backscattering and sputtering in practical vacuum systems.* By K.P. Brown. January, 1978. 38pp. HMSO £1.00. SBN 85311 066 2

CLM-R 189 *CUPID. A ray tracing program for continuously varying refracting media.* By M. Hubbard and A. Montes. July, 1978. 13pp. HMSO £1.00. SBN 85311 073 5

CLM-R 190 *Changing the profile of an annular beam by aperturing its diffraction pattern.* By A.C. Selden. August, 1978. 13pp. HMSO £1.00. SBN 85311 072 7

CLM-R 191 *Transport calculations for a high density ohmically heated D-T tokamak.* By J.J. Field and E. Minardi. November, 1978. 14pp. HMSO £1.00. SBN 85311 074 3

CLM-R 192 *Holographic interferometry of isolated deuterium plasmas produced by a* CO_2 *laser.* By P.V. Gatenby and A.C. Walker. October, 1978. 17pp. HMSO £1.00. SBN 85311 075 1

ND-R-285(R) *A glossary of terms for fast reactors.* Edited by R.C. Wheeler. April, 1979. 67pp. HMSO £2.00. ISBN 0 85 356121 4

Hazard control

A meeting on hazard control and planning in the working environment is to be held at the Middlesex Hospital, London, on 22 January 1980 under the auspices of the Society for Radiological Protection; and the Society is organising a second meeting, on emergency arrangements — planning and practice, at the hospital on 29 April 1980.

Enquiries should be addressed to the Programme Committee Secretary, Prof. J.H. Martin, Department of Medical Biophysics, Blackness Laboratory, University of Dundee, Dundee DD1 4HN. □