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ATOM

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WORLD ENERGY AND THE EEC

NUCLEAR R&D IN THE EUROPEAN COMMUNITY

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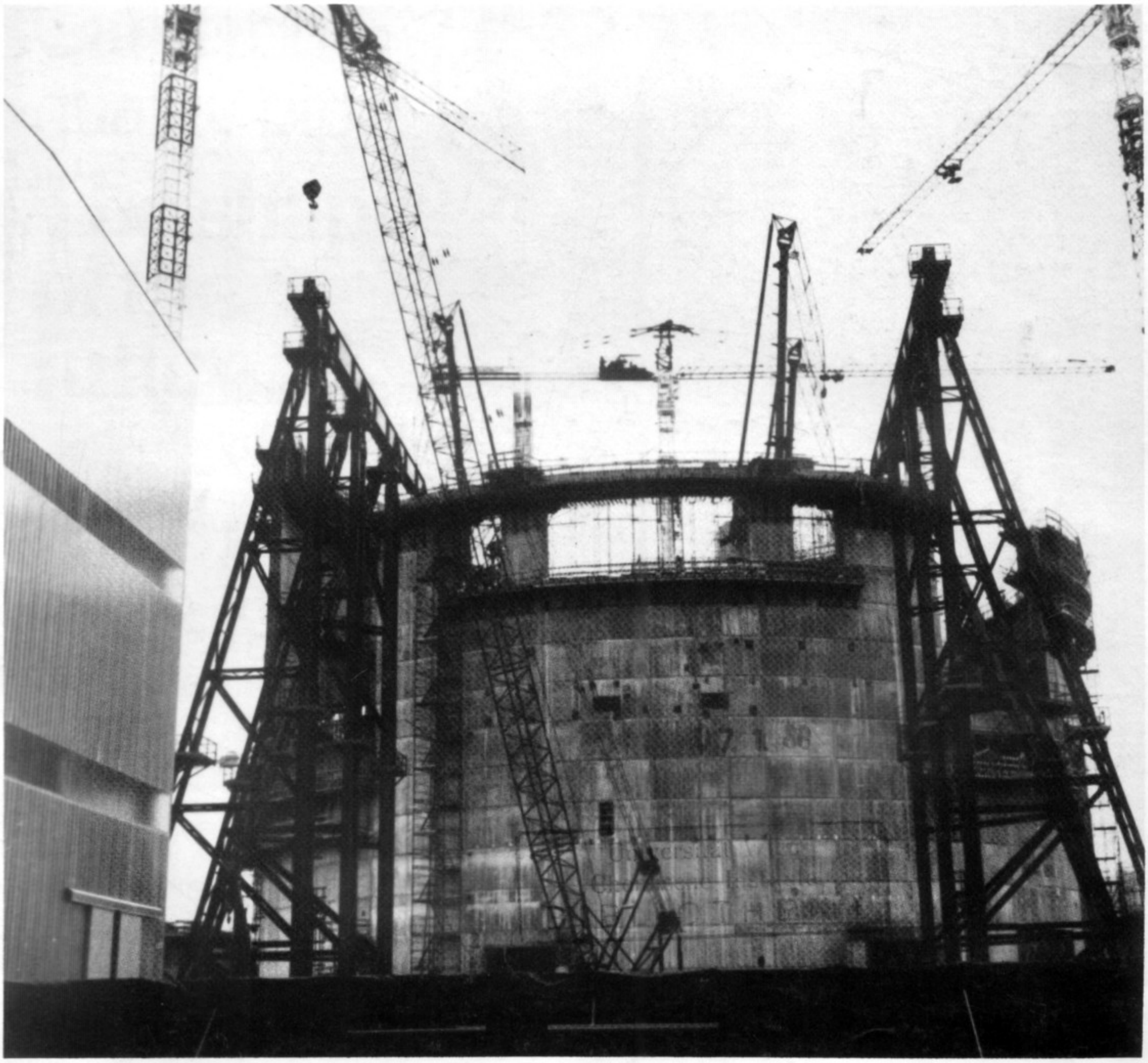

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ATOM contents

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Front cover: Work in progress on the construction of the containment building for the 1200 MWe Super Phénix fast reactor at Creys-Malville — the first "commercial" fast reactor power station in the West. In this issue, reviews of work on fast reactors in Europe, the world energy situation and the EEC, and nuclear R&D in the European Communities. *NEI*

THE BREEDER REACTOR AND EUROPE

If nuclear power is to play a major role in meeting world energy needs in the long term, thermal reactors must in time be complemented with more advanced reactor systems that conserve uranium resources — which are huge but not unlimited. This is not questioned; disagreement begins with discussion of the desirability of the breeder, and how fast and how far the introduction of such reactors should go.

This was the starting point taken by the Swiss Association for Atomic Energy (SVA) and the Association of European Atomic Forums (Foratom) for a conference on the breeder reactor and Europe held in Lucerne, Switzerland, from 14 to 17 October. The two organisations, as co-sponsors, hoped that participants would present the basic facts of fast reactor technology, discuss introduction strategies and commercial and safety aspects of fast reactor programmes, and review the breeder programmes of the countries active in this field; the 'target audience' were utilities, industries, engineering and consulting companies and authorities with a broad interest in the overall breeder programme.

The true value of the conference will become apparent only when the proceedings have been published and digested: this article can only touch on the highlights. James Daglish reports

The conference was sub-divided into four main sections, with a wide-ranging panel discussion at the end. Each main subject was reviewed in turn in oral presentations of papers which had been circulated to the 160-odd participants (from 19 countries) in advance, each being followed by a question and answer session. I spell out the mechanics of the conference in this way to give some idea of how it was that in only two and a half days the discussions could range from elementary nuclear physics of fast reactors, through assessments of the world energy supply and the need for fast reactors in the longer term, to questions of economics and safety, to reviews of the current status of the breeder programmes of Europe, the UK, the USSR, Japan and the United States — and at the end still leave time for a panel discussion in which the main themes of the conference were reviewed once more. In what one might call 'normal' circumstances each topic could — and usually does — occupy an equally distinguished group for a week, and still leave questions unanswered.

I do not mean to imply that any question was treated superficially. The papers went quickly to the key points for discussion; and they contained much that was novel — or at least brought together for the first time in a manageable way. Thus, we heard detail of the Russian fast reactor programme, for example, which had been known previously only to quite a specialist fraternity in the West.

Why breed?

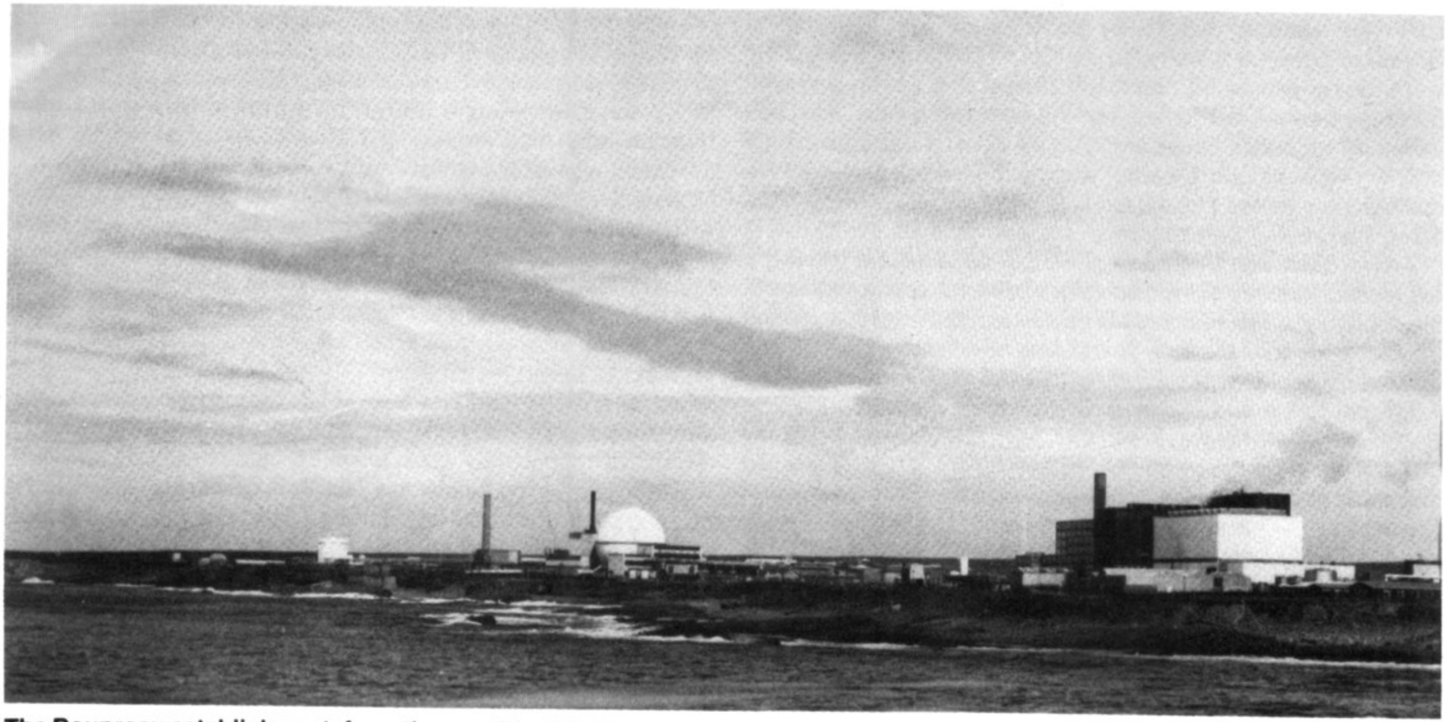
The first session — under this title — was opened by Dr N.L. Franklin, chairman of the Nuclear Power Co. Ltd, Risley. He reminded delegates that we had seen in the 70s a decade in which quarter-scale and fifth-scale demonstration reactors had been built and in some cases commissioned in Europe. Although the costs of such units and of associated development programmes were quite high they had been found acceptable to the larger countries. "The 80s are likely to be the decade of full-scale demonstration reactors and the associated demonstration of the fuel cycle," he said. "The actual costs and the risk costs for these operations will be very large — perhaps too large to be borne by single countries, although of course they can be sustained in the Soviet Union and the United States, if the Governments of those countries are minded to do so. Certainly, so far as Western Europe is concerned the time interval between the construction of full-scale demonstration units and the exploitation on a commercial basis of these units is likely to be sufficiently great that the investment cannot be recouped on a simple discount basis. This means that we are concerned with strategic questions: questions relating to the reliability of national supply rather than of the purely commercial investment by businesses. In turn, we are inevitably associated with investment by Governments in addition to that by the electrical utilities."

The prospective need for the fast reactor in the context of future world energy supply and demand was spelled out in the first paper, presented by Dr P. Graf (Motor-Columbus Consulting Engineers, Inc., Baden)*. Dr Graf recalled that world energy demand totalled at present between 6 and 7 billion tons of oil equivalent a year. Mineral oil accounted for about 48 per cent of total consumption; coal, about 30 per cent; and natural gas, 19 per cent. Hydro power accounted for about 2 per cent and nuclear electricity, about 1 per cent. Many projections of future energy demand had been made; an important element in all such projections was the expected economic development of Third World countries. "Even if one should succeed in reducing the forecasted increase of energy consumption by enforced energy savings or due to major price increases," he said, "there still remains compared with today a considerably higher energy demand to be met."

How, and under what conditions, could energy demand be met by the available resources? Studies made by the World Energy Conference — though already a little dated — showed that if all available resources were developed they could contribute considerably to the demand expected within various scenarios by the year 2020: coal production might be expanded to about four times its present level, nuclear energy might grow to account for 25 to 30 per cent of world energy production potential. But if the production of fossil fuels did not increase as much as expected — "which is not too unrealistic a possibility" — or should nuclear energy in general and correspondingly breeder technology not be used or developed as the WEC expected, then there would be quite serious energy supply difficulties.

Then again, the prospects for world energy supply could not be generalised. "The perspectives for western Europe are quite unfavourable," said Dr Graf. "With the exception of coal in the UK and the Fed. Rep. of Germany, there exist considerably less indigenous reserves of fossil fuels than the world average. The reserves of natural gas in the Netherlands seem at an end. The oil resources in the North Sea, compared with the overall oil demand of Europe, are rather modest. Also uranium deposits are very limited. As regards these primary energy sources western Europe will strongly depend on imports, which gives rise to security of supply problems. Only as far as coal is concerned does Europe have large reserves. The

*Co-author with Dr H. Baumberger and K.P. Gibbs.



The Dounreay establishment, from the sea. The 250 MWe Prototype Fast Reactor is to the right of the picture.

problem, however, is that in the indigenous form it can only partly satisfy the energy usage (e.g. the direct use of coal for process heat in industrial facilities or power plants). By means of coal liquefaction and gasification, however, coal can be transformed into a more useful form for energy utilisation. The efforts to solve the technical development problems of coal processing should be enhanced. Nuclear energy can participate in these coal processing schemes; however, the production costs envisaged for liquid or gaseous fuels extracted from coal are considerably higher than today's fuel prices. Thus, in the future strategic considerations may well override pure economic considerations."

A real oil shortage before the turn of the century was very probable; and the use of alternative energy souces would take considerable time and require major investments. The present considerable delays in the nuclear programmes of most European countries with the exception of France, however, led to apprehension that the required share of nuclear energy to satisfy the future energy supply spectrum could hardly be achieved. "Near the turn of the century, the energy supply situation could become really critical with shortages in mineral oil, natural gas and uranium. With the present light water reactor technology, having a relatively unfavourable uranium utilisation, it is to be feared that serious nuclear fuel supply problems will occur. The fast breeder technology, with considerably better nuclear fuel utilisation, could however start to ease the critical energy situation at the turn of the century which is expected to be particularly uncomfortable for western Europe, and perhaps even more for Japan."

The International Nuclear Fuel Cycle Evaluation and other working groups had studied the requirements for nuclear energy, uranium availability and the role of fast reactors very comprehensively, said Dr Graf. Although the final reports of the INFCE studies had not yet been published, tentative conclusions could be drawn. Over the next 40 to 50 years world demand for energy was expected to increase by at least a factor of three to four, on "most modest" assumptions, as already outlined. The role of nuclear energy would be to increase its share of the electricity component, substituting for the use of oil and gas and easing the supply situation.

Two projections had been made, one for high demand for the use of nuclear energy and one for low demand. Assuming that the world nuclear programme was "all LWR", known uranium resources of 4.65 million tons of uranium would be fully committed by the year 1992, and on the low demand case by 1998. With the implementation of a reasonably assured breeder programme this level of uranium resources could last well into the next century. [And see the paper on the fast reactor and energy supply, by Nicholson and Farmer, ATOM No. 277, November 1979, for a fuller treatment of this point.] Thereafter, by "breeding" fresh feedstock plutonium in otherwise unusable depleted uranium resulting from the thermal reactor programme, it could be an assured contributor to energy supply for some time to come.

As for the timing of the introduction of fast reactors on a large scale, "it is unlikely that over the course of the next couple of decades the breeder can be deployed on the basis of its economic, or near-economic, competitiveness with the thermal reactor," said Dr Graf in his paper. "Therefore, in reviewing strategic issues one must consider a less favourable situation. If a utility delays breeder deployment because of economic unattractiveness or uncertainties, then political considerations may become the overriding factor in breeder deployment decision-making. . . . If breeder deployment is made on strategic criteria rather than economic it will be because of the serious outlook regarding energy supply. In such cases government intervention will become very pronounced and it could bring about fundamental changes in the institutional arrangements of electricity supply in some countries."

Much had been said and written about the need for much greater international cooperation, especially among the leading OECD countries. The main motivation for such cooperation stems not only from economies in breeder development and demonstration but in areas, such as safety and licensing, commercial factors and non-proliferation — as well as strengthening political and economic relationships.

"The political problems facing the breeder are very severe," said Dr Graf. "The widespread reaction against our technology-based society has focussed quite illogically on nuclear power and has selected the fast reactor as the arch villain. This makes it unattractive for a political party in a democracy to give fast reactors the support they need, and can also make such support a subject for party politics, thus making the continuity of the support doubtful. The long time scale of fast reactor development and construction makes political uncertainty particularly damaging. As well as this emotional opposition to fast reactors there are many real political problems to overcome in the field of safeguarding nuclear materials and plants [against unauthorised diversion of nuclear materials — see p.322]. It is to be hoped that the present INFCE exercise and its successor proposed by Chancellor Schmidt may solve some of these.

"These political factors are of crucial importance because decisions concerning the deployment of the early breeders will be taken for strategic reasons by politicians. Public acceptability issues will continue to worry the politicians: on hearing some of the views being expressed one might believe that the present anti-nuclear views will last for eternity. We earnestly believe that such views will moderate considerably in the coming years as energy supply problems and a harder world economic climate begin to make people realise that the advantages of nuclear power — including the breeder — far outweigh its disadvantages."

I have dealt with this paper at length because the thinking it expressed underlay all the discussions of the remaining sessions of the conference: fast reactors will be needed, but not yet; and when they are needed in the early years of the next century it will be on a fairly large scale, especially in Europe. Dr A. Salmon (Manager, Technical Policy and Planning, BNFL Risley) presented the next paper, of which he was co-author with R.H. Allardice, Deputy Director of the Dounreay Nuclear Establishment. In it, they recalled that it was now almost exactly 33 years since the first fast reactor — Clementine — burning plutonium clad in stainless steel, commenced operation in the United States. In Europe, there was 25 years' experience of fabricating fuel containing plutonium. Thermal reactor fuel reprocessing had been in progress for over 25 years, mainly in the USA, the USSR, France and the UK. Several pilot plants for the reprocessing of fast reactor fuel had been operating for almost as long: the first reprocessing of fast reactor fuel in the UK took place at Dounreay in 1961, and the plant where that was done had now been modified so that the plutonium-containing fuel from the Dounreay Prototype Fast Reactor (PFR) could be reprocessed. [The decommissioning and rebuilding of this plant was reviewed in ATOM in June this year — No. 272] Two requirements were more important in fast than in thermal reactor fuel reprocessing: the need to maximise the amount of plutonium immediately available to the fuel cycle, and the need to minimise the out-of-reactor time of the fuel. Present work gave confidence that these requirements could be met.

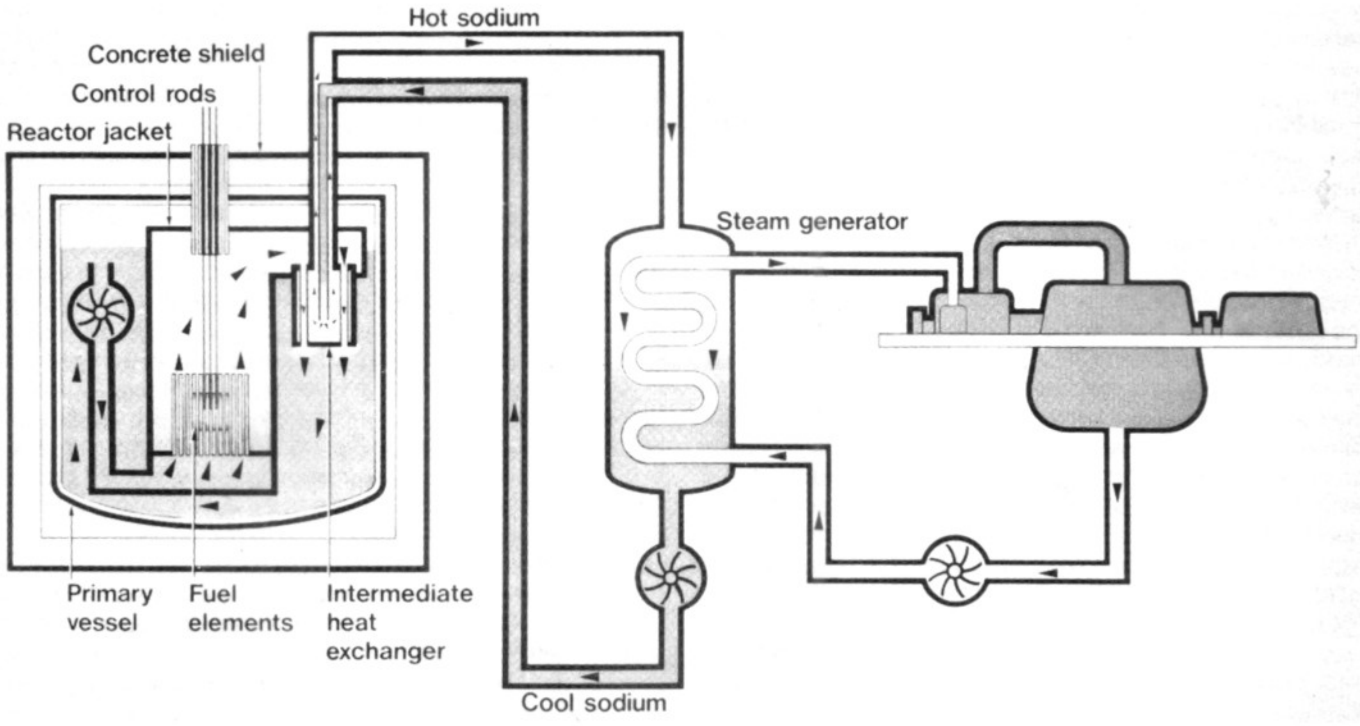
Waste arisings from fast reactor fuel reprocessing would have very similar decay patterns with time to those of thermal reactor reprocessing, and they would follow the same route. Highly-active waste liquors would be stored in stainless steel tanks at the reprocessing plant, and would later undergo vitrification in preparation for ultimate disposal. Fast reactor wastes would require a greater storage volume than those from thermal reprocessing, or would be

'Thermal' and 'fast' reactors

Similarities and differences between thermal reactors — such as those used in commercial nuclear programmes today — and fast reactors were discussed in the introduction to one of the papers, by Dr E.C. Cobb of NPC Risley and Dr R.D. Smith, of the UKAEA Risley, from which this explanation is taken.

In a thermal reactor a moderator is provided to slow the neutrons emitted in fission to low energies before they interact with other atoms in the fuel. In a fast reactor not only is the moderator omitted but the reactor is made from materials which slow the neutrons down as little as is practicable. Fast reactors can use either plutonium, uranium-235 or uranium-233 as fuel, but plutonium-239 is favoured because of its suitable neutron cross-sections — its ability to capture neutrons — and its production as a by-product from thermal nuclear reactors. In a fast reactor the fissile material must be more highly enriched than in thermal reactors: most practical power producing reactors use a mixed plutonium-uranium oxide fuel with enrichments in the range 15 to 30 per cent, whereas thermal reactor fuel enrichment may be only 2 or 3 per cent. The enrichment of fast reactor fuel is kept as low as possible by minimising ways in which neutrons can leak from the core, both by using a small space for coolant and by surrounding the core itself with a reflector or blanket. Uranium is usually used for the blanket, performing the dual role of reflector and breeder — neutrons absorbed in it forming fresh plutonium.

The relatively large investment in highly enriched material in a fast reactor makes it essential, at least for as long as plutonium is in short supply, to extract as much power as possible from a core of a given size. Given this requirement sodium is a near-ideal coolant, and has been adopted throughout the world for power-producing fast reactors. About the only other practicable coolant is high-pressure gas, which has some advantages; but gas-cooled fast reactors cannot achieve the same fuel ratings as liquid-metal cooled fast reactors. From the safety point of view, one of the most important features of sodium is that it can be used at low pressure — its boiling point at atmospheric pressure is 892°C. Sodium does react with air or water, and precautions have to be taken against sodium fires and the effects of leaks in the steam raising units; on the other hand, it is non-corrosive to the structural materials used in the reactor and to fuel cladding materials. □



A pool-type LMFBR in diagrammatic cross-section.

capable of being stored for a shorter time, as the degree of evaporation which could be achieved (as a means of reducing the volume requiring storage) was almost inversely proportional to the burn-up of the fuel if the resulting liquor was to remain stable and free from solid precipitates; nonetheless, there was more than 20 years' experience of storing highly-active liquors in tanks in Europe. The first large vitrification plant for thermal reactor waste began operation in France in 1978, and the UK was planning to have its vitrification production facilities operating in about 1990. These would be used for the vitrification of wastes from thermal reactors, but a proven design would thus be available, when required, for the vitrification of the highly-active wastes from fast reactors. In parallel with the UK work at Windscale, the vitrification plant at Dounreay — required to treat the highly-active liquors from DFR and PFR — could well be a flexible facility with the capability to allow new or improved plant items to be tried over a period. Such a plant could be operating in about 1990, vitrifying Dounreay's wastes and also giving development information for future plants.

Commercial aspects

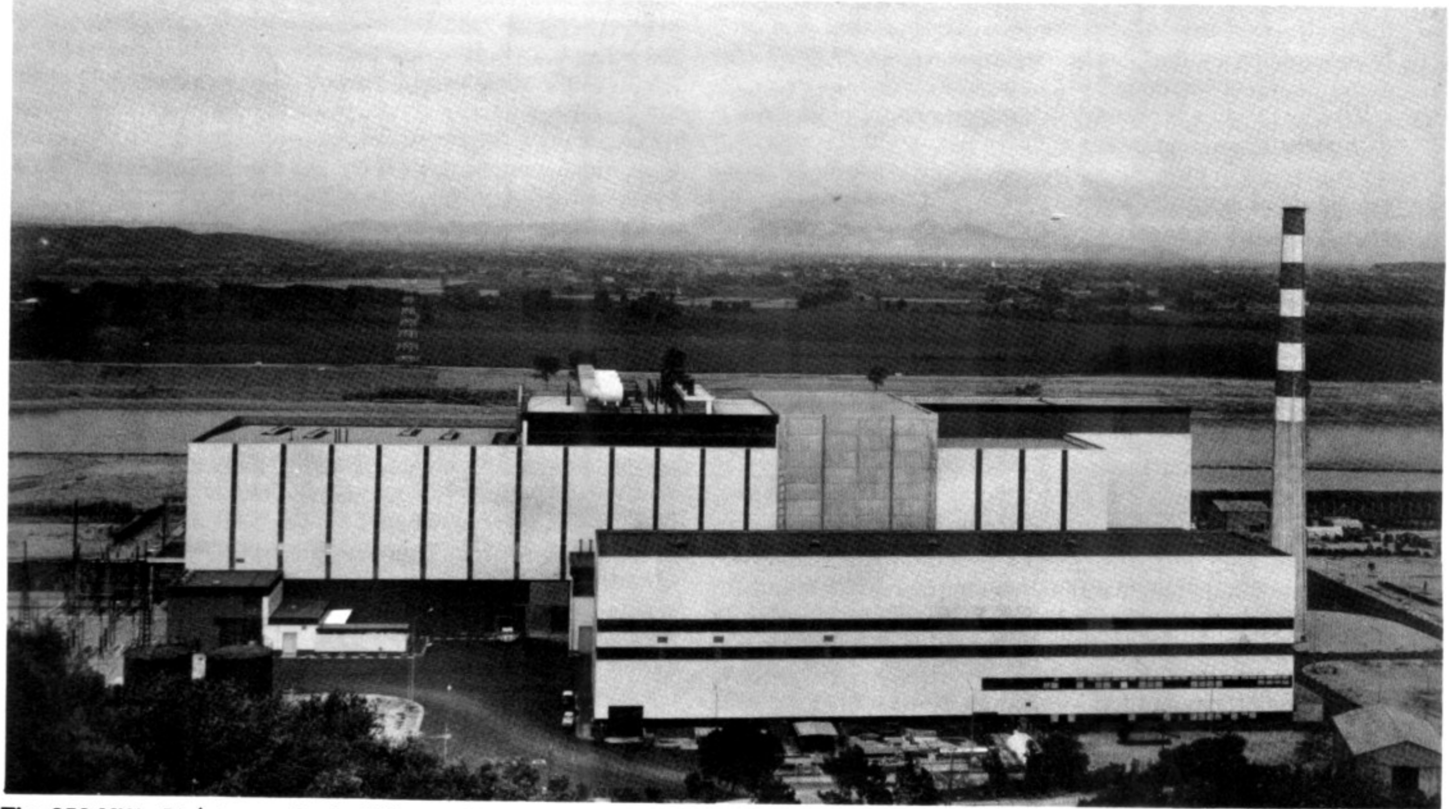
An eventual objective of the fuel cycle is to produce plutonium fuel fast enough for all the power reactors required, the authors noted in their paper. The only input to the fuel cycle would then be some uranium; the amount required, even over centuries, would be relatively small.

"A typical thermal reactor, using enriched uranium, during its lifetime requires sufficient natural uranium for about one hundred fast reactors, and the uranium for the FBR fuel cycle will arise from the thermal reactor fuel cycle," they wrote. "As a nation progresses to this stage of the fuel cycle it will be producing a greater proportion of its nuclear power from fast reactors, eventually reducing its requirements for uranium to near zero. This will relieve the pressure on the price of uranium, thus allowing other nations, particularly the developing nations, to make increased use of thermal reactor fuel cycles."

There was already considerable international collaboration on the fast reactor fuel cycle. Technical exchange agreements abounded, on R&D information covering all aspects of the cycle. Super Phenix I was particularly notable in that it involved collaboration in a construction project being built for an international consortium, NERSA, whose members were utilities from France, Italy, Germany, Belgium, Holland and the UK. "With regard to the timescale of the development of the fuel cycle markets, outside the centrally planned economies, so far as the authors are aware no contracts have been placed for the construction of any plants beyond those required for the 'demonstration' of the fuel cycle, and even these have only been placed by NERSA. However there is, and must be, an intent in several nations to expand beyond this stage. If [known] programmes are to be achieved then France will need a full-scale reprocessing plant, of say 300 tonnes a year design capacity, within the 1990s; Japan will need a similar plant about the year 2000 and the UK will need one in the early years of the next century. The expansion of the required capacity, after the turn of the century, will have to be rapid if this fuel cycle is to be expanded, as it should be, so that the world does not run short of uranium. If the latter happened the options then would be an even more rapid expansion of the fast reactor fuel cycle or an eventual halt to the production of nuclear power."

Alternatives to the LMFBR

Dr B. Pellaud and R.C. Dahlberg, of the General Atomic Co. (Zurich and San Diego) argued that it was prudent to develop concurrently more than one breeder system, and to develop advancer converter reactors along with breeders. On the first leg of their argument, they asserted that the gas-cooled fast reactor had a number of important features. The support of technological breadth had long been characteristic of the utility industry in both the US and Europe; in 1976 Helium Breeder Associates had been formed with the support of some 80 electric utility companies in the US and in Europe — among them many who were also members of the group supporting the Clinch River (liquid-metal cooled) Breeder Reactor Project (CRBR). The single-phase, inert nature of helium as a coolant led to reduced concern about corrosion, and had safety advantages; it enabled the use of a vented fuel element design which equalized the pressure between the inside and the outside of the fuel pin, thus reducing pressure stresses on the fuel cladding. This system was now undergoing successful testing in the BR-2 reactor at Mol, Belgium, under the direction of the Kernforschungsanlage (KFA), Jülich. A GCFR could use a pre-stressed concrete reactor vessel, and the non-radioactivity of the coolant and the lack of intermediate coolant



The 250 MWe Phénix reactor building, at Marcoule. *P. Jahan/NEI*

loops had led to a design which promised significant capital cost savings when compared to liquid-metal cooled breeders. There were compelling reasons for continuing to develop such reactors, in parallel with LMFBRs.

Secondly, the thorium cycle was of considerable potential. Its early introduction could ease the commercialisation of fast reactor technologies from an economic point of view. "A few breeders, operated as transmuters, can significantly increase the number of lower capital cost thermal spectrum reactors supportable by given U_3O_8 resources, provided U-233 is the bred fuel," they wrote. "This aspect of the strategy could be particularly attractive as annual U_3O_8 requirements push the capabilities of the uranium supply industry. Uranium supply could well be the resource problem of the foreseeable future, not the size of the uranium resource base. Advanced converters, a few breeders and the connective thorium cycle can greatly ameliorate this problem."

Dr Franklin wound up the short discussion which followed this paper by recalling some words written on a gravestone in the UK: "The epitaph of the gas-cooled fast reactor might be. . . 'He grew to old age as a man of great promise'.

How to build a fast reactor

J. Befre, Director of Novatome, Le Plessis Robinson presented what was perhaps one of the most interesting papers of the conference — on the experience of European industry of the building of the 1200 MWe Super Phénix plant at Creys-Malville, the first "commercial"-scale fast reactor in the West. Two and a half years after the placing of the first order, he said, Super Phénix was progressing reasonably on time — despite many problems due to its being "first of a kind". Its designers and builders were of course able to draw on their previous experience of the smaller Phénix plant, and its predecessors; the solid basis represented by Phénix together with the substantial backing afforded by six European partners united in their determination to take a decisive step in fast reactor development would result in the commissioning of a commercial plant in 1983.

"Super Phénix is in fact a prototype, and the Creys-Malville plant investment costs are relatively high, a little over 5000 million French Francs at 1977 prices, not including fuel and interim interest," said M. Befre. "This is by no means peculiar to the fast breeders; the same problems are encountered for any large scale 'first of its kind' undertaking involving a new technology. However, the Super Phénix kWh rate will doubtless be very close to that of a conventional plant complying with present pollution prevention requirements.

"Creys-Malville is to be followed by Super Phénix 2. The main objective of preliminary work on this project is to derive maximum benefit from the Creys-Malville design and construction data and lower plant investment costs while maintaining the same level of reliability and safety. Similar efforts are being made by a CEA group, with a view to reducing fuel cycle costs. The purpose of all these surveys is to get as close as possible to competitivity with light water reactors, which is particularly difficult in France, where LWR costs are relatively low because of the number of these reactors under construction."

Future decisions of Electricité de France on breeder deployment would depend on plant and fuel cycle costs, but would also be influenced by the need for France to decrease its energy dependence.

The next topic on the agenda was safety, introduced by a joint paper by Dr E.C. Cobb (Head, Safety Policy, Nuclear Power Co. Risley) and Dr R.D. Smith (Chief Technologist, UKAEA Risley). They noted that one of the biggest handicaps the fast reactor had to overcome was its name — too often, the fact that the word fast described the speed of the neutrons inducing fission in its fuel was not appreciated. Basically, the liquid-metal cooled fast reactor was an extremely safe system; nevertheless, over the past 30 years there had been many hundreds of papers discussing safety topics in which attention centred on the extreme accident — often referred to as the 'hypothetical core disruptive accident'.

"When fast reactors were first studied it was realised that if the core were to be compacted by moving fuel into the spaces normally occupied by the coolant there would be a rapid rise in reactivity. Alarmists suggested that the reactor might indeed explode like a nuclear weapon. It was soon shown that this was impossible, since the very special processes which are used in nuclear weapons are impossible in a reactor core. Nevertheless, if it is assumed that there

THE FAST REACTOR AND THE PROLIFERATION ISSUE

Prof. Dr H. Grümm, Deputy Director General of the IAEA, made the final presentation of the conference — on the possible impact of fast reactors and their fuel cycle on the non-proliferation regime when they were introduced on a large scale.

"The public has a completely distorted and in some ways, I would say, dangerous picture of the nuclear world," he said. "At the moment their main concern is nuclear power plants, whereas the existence of 40 000 nuclear warheads in the world seems to be of no interest to protestors. It is easily possible, for instance, to concentrate in some countries 50 000 opponents against nuclear power plants, but it is very difficult to concentrate maybe 5000 opponents against nuclear weapons. There has been no single attack in the world against a plant producing military plutonium, and there is no concern about military nuclear waste — which is of the same quality as civil nuclear waste, and the quantities are several hundred times greater. We have here some dangerous perversion of the human mind. . ."

It was a fact that none of the 40 000 warheads had been produced through the use of civil, commercial power plants and commercial plutonium. "On the other hand, we know already that it is possible that a country which could be characterised as a very poor, developing country, of a low technological standard, a country which is not able to build or develop a fast breeder — not even a light water reactor — that such a country is able to acquire nuclear technology such as centrifuges, to be able to produce enriched uranium. That is a fact."

Dr Grümm said this meant that as a matter of fact there were no *technical* defences against the proliferation of nuclear weapons: the main problem of proliferation was a political one. Safeguards could give technical support only to the non-proliferation regime.

Stockpiling of reactor-grade plutonium might create some danger — though as he had said already this route had not been taken by any of the nuclear powers. "The reason is well-known: the quality of reactor-grade plutonium does not satisfy the requirements of developing nuclear weapons technology. On the other hand, we should not forget that the possibility of misuse of this material exists — and that is not a question for the next century. There are already 66 tonnes of plutonium in non-nuclear-weapons States under safeguards — not counting plutonium in nuclear weapons States not under safeguards; 11 tonnes are in separated form and the remainder is contained in spent fuel elements. This number increases, like it or not, at about 10 to 12 tonnes a year. This plutonium obviously is of most concern to nuclear opponents.

"These 66 tonnes are well safeguarded at the moment, and I see no big difficulty in extending safeguards to larger amounts coming from the thermal reactor fuel cycle. But we have to be aware of the fact that the time has come to create new institutional arrangements, like internationally controlled plutonium storage, to absorb all the plutonium that is not immediately needed in the fuel cycle and to release this plutonium under certain strict criteria and full safeguards control, and so create a greater assurance for the nations of the world that this material is not being misused. Such internationalised controlled stores would be under the custody of safeguards inspectors; working groups are already discussing the principles of such a regime.

"The problem — if I may call it so — of the safeguardability of the fast reactor is not very different from safeguarding light water is a very large addition of reactivity and in addition all the normal means of shutdown fail, the core of a fast reactor would disrupt itself, conceivably violently, in order to terminate the power surge.

"The energy generated in such a surge is small, generally only a few full-power seconds, but if it were released on a very short time-scale, as is in the case in these postulated accidents, the pressure pulses generated would have the potential to cause considerable mechanical damage. Much of the safety work on fast reactors has been devoted to calculating the damage potential of these postulated accidents, and to determining the ability of the reactor and the containment structures to accommodate them. Since the combination of physical processes involved in these accidents is so unlikely it may well be thought that they receive an undue share of attention. They are certainly attractive to theoreticians since the calculations are difficult yet not entirely intractable. In fact, even the initiation of these accidents involves such extreme assumptions, such as the failure of all reactor trips, that the probability of their occurrence is vanishingly small."

The fast reactor was inherently stable and docile in operation, Cobb and Smith wrote. Such reactors would be provided with an automatic protection system having a very high reliability, in order to ensure that the reactor was shut down in the event of any loss of coolant flow or abnormal rise in power; engineering design features would be provided to protect against any other ways in which a core disruptive accident might be supposed to occur; after shut down, decay heat would be removed using redundant and diverse systems with very high reliability — the sodium coolant, particularly in reactors of the pool rather than the loop design, provided a very large heat sink capable of absorbing all the decay heat for about 20 hours after shutdown [and see ATOM No. 277, November 1979, on experiments conducted on the Prototype Fast Reactor at Dounreay in decay heat removal].

The conclusions of this paper were echoed in the next, on the status of breeder safety, presented by M.P. Tanguy, Director of the Institut de Protection et de Sûreté Nucléaire, CEA France. The objectives of safety for fast reactors were the same as those for other reactor types, and the methodology for handling them were also the same. The licensing procedure was identical; the safety analysis must demonstrate with a high degree of confidence that for both internal and external events plant accidents would be prevented or — if they did occur — their consequences limited, so as to avoid unacceptable risk to the public and the environment.

M. Tanguy recalled that an International Conference on the Safety of Fast Breeders had been held in August in Seattle, US, under the sponsorship of both the American Nuclear Society and the European Nuclear Society. [This conference will be reviewed in a later issue of ATOM.] "It can be said that there was a general consensus that fast breeders were at least as safe and as reliable as light water reactors," he said. "All countries work on similar lines, with the same emphasis for instance on the high reliability required for shutdown systems and decay heat removal systems. The "Three Mile Island lessons" learned must also be applied to fast breeder design: enough attention must be paid to high probability sequences, with a good consistency with the operating procedures. It can be said that [automatic mechanisms] are already widely used in fast breeders and that the information on the reactor situation presented to the operators is probably in a much simpler form than in the case of light water reactors."

Breeder programmes

The concluding sessions of the conference proper were given over to reports on fast reactor programmes, in Europe, Britain, the Soviet Union, Japan and the United States. The most striking features of these were the emphasis given to cooperative effort — and the high degree of commonality which exists between the programmes in different parts of the world, despite some differences in approach between designs for such components as steam generators and even the adoption of a loop rather than a pool design for the Clinch River project. The potential of the fast reactor for lessening pressure on energy resources was stressed again and again: as, for example, in the paper on the British programme, presented by J. Moore (Director, Fast Reactors, UKAEA Risley). The UK programme had been pursued consistently since the early 1950s, he said, in recognition of the system's ability to make the maximum use of the

reactors. We have a certain difficulty because the fuel elements are not easily visible, being covered mostly with (opaque) sodium: on the other hand, one should not forget that fuel elements for fast reactors are 'items', in the technical language of safeguards. They are not bulk materials — they are easily identifiable units, the integrity of which can easily be controlled. A lot of new developments are under way, such as for example ultrasonic seals for such elements to make it possible to verify that no fuel has been taken out of them. Then, it is possible as with the light water reactor to accompany these fuel elements through their whole lifetime in the reactor, starting with the fresh fuel and ending with spent fuel. . .. Technically it is completely possible to safeguard fast breeders by using the usual means of accountancy, and additionally containment and surveillance to support this.

"We have a small fast breeder experimental plant under safeguards, and we are about to start safeguarding Dounreay; we have this possibility due to the voluntary offer of the United Kingdom; and we are convinced that we will get a lot of further experience in safeguarding with this plant, consisting of a prototype reactor and an attached reprocessing facility.

"In my opinion the main problem of safeguarding fast breeders is not so much the reactor: the situation is rather similar to that at other facilities. The main problem is in safeguarding the bulk handling facilities — the fuel fabrication plant, and the reprocessing plant. We have at the moment sufficient experience to be able to state that it is possble to safeguard such plants, and we have such plants under safeguards. There is only one problem: later on, if we have to safeguard very large bulk handling facilities, maybe there will be a shift in the principle of safeguards from accountability more to the side of containment and surveillance.

"In my opinion the problem of the fast breeders in this century is not exceptional. In the next century more methods will be developed — in part, they are already developed — to safeguard the fast breeder fuel cycle."

A second problem lay in the need for some change in public opinion concerning nuclear energy. "Until the year 2000, for the next 10 or 20 years, I think mankind will get a lot of experience of how dangerous it is to speculate and gamble and make day-to-day politics with questions of energy," said Dr Grümm. "This kind of irresponsible treatment of the energy problem in the political arena is one of the main contributors to increased international political tension, to increasing difficulty in the standard of living of the developed and the developing countries, and therefore a major contributor to the danger of war. If mankind survives the next 20 or 30 years without war we will have a climate which is more favourable to a more responsible understanding of the problems of energy supply. In this respect, therefore, I am of the opinion that mankind has to go ahead with nuclear energy, but under the strictest control and an expanding regime of safeguards."

As a footnote to his presentation, Dr Grümm expressed his real, current concern: that there were now five countries having some nuclear capabilities which were not fully under safeguards. Even in these countries it was not the normal, peaceful fuel cycle which created the danger, however: it was the existence of smaller, dedicated facilities which created the danger of proliferation of nuclear weapons. He was echoed by Dr Franklin, the conference chairman, who said that if we were concerned about proliferation "we should look to concern about processes for the separation of uranium-235 and anxieties about the deployment of laser separation and perhaps other processes which are capable of being operated on a small scale: both the nozzle and the centrifuge processes [of enrichment] are examples." □

available uranium. He recalled that at present 13 per cent of UK electricity was generated in thermal nuclear stations; these gave rise to stocks of plutonium which would be available when required by the fast reactor programme. Additionally, sufficient depleted uranium was now available in Britain for use as breeding stock to equate to 260 years' electricity supply at present consumption rates: the uranium stock was equivalent to five times Britain's North Sea oil reserves.

CDFR design

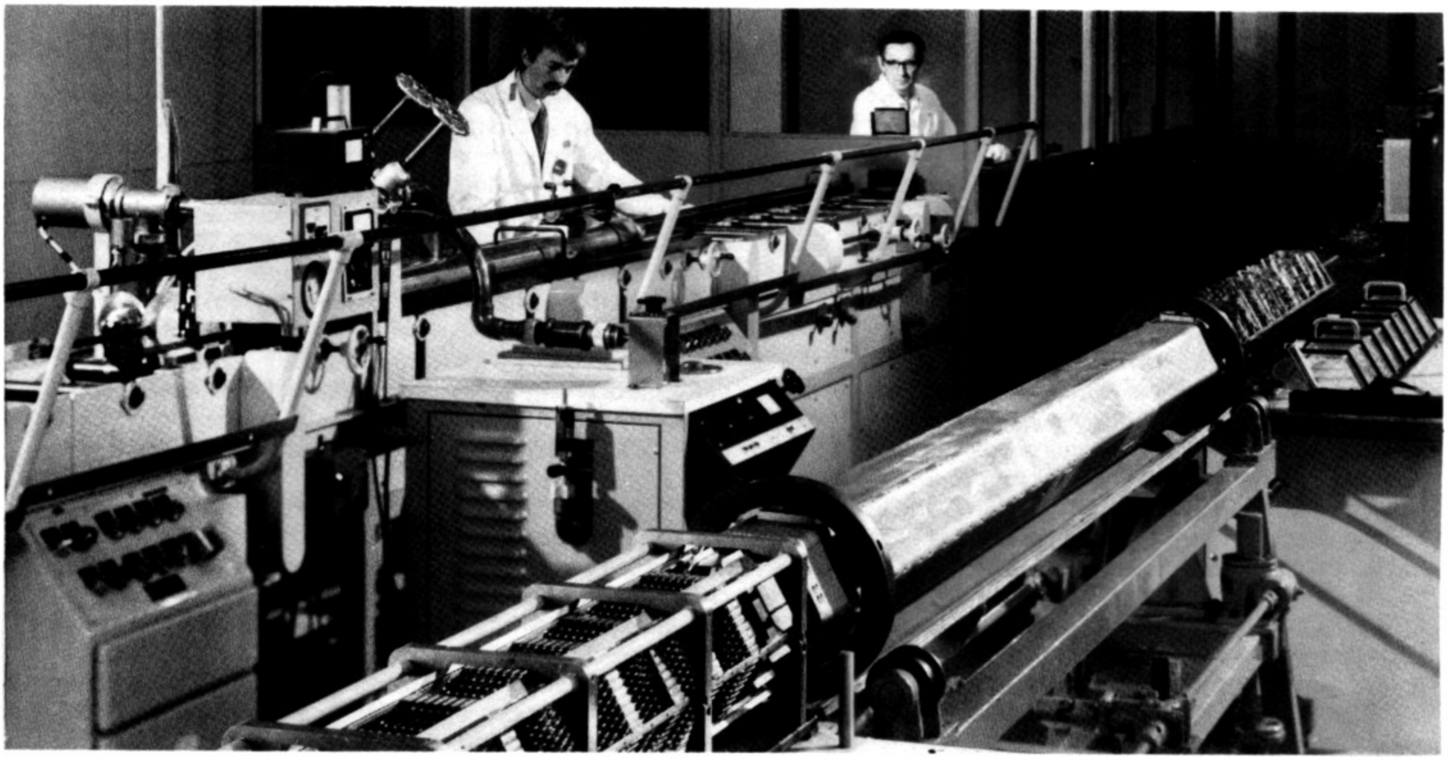
Mr Moore noted that since the completion of the 250 MWe PFR at Dounreay attention in Britain had been directed increasingly to the design of the Commercial Demonstration Fast Reactor — a full commercial-size fast reactor of about 1300 MWe output — and of its associated fuel plants. Design studies and supporting development work were in progress with particular benefit being obtained from experience with the normal operation of PFR and its operation for experimental purposes. "Compared with the large step from DFR to PFR, that from design of PFR to CDFR is relatively small and so development work consists to a large extent of proving specific design features and component design rather than exploring unresolved technical uncertainties," he said. "The purpose of CDFR is to obtain experience of manufacture and construction and of licensing procedures for a full-size plant, so that a programme of commercial fast reactors can be launched with confidence when required. Thus, CDFR does not have as a prime objective the need to demonstrate low cost, but it would provide valuable data relevant to the economics of a series of reactors when built as part of a national programme." The UK Government had stated that CDFR would be preceded by a public inquiry.

Dr L.A. Kochetkov, head of the Atomic Power Station section of the Physical and Power Institute, Obninsk, USSR (with V.B. Lytkin and M.F. Troyanov) surveyed the development of fast reactors in the Soviet Union. Even though the USSR was well-provided with conventional energy resources, he said, "their shortage is already felt now in the European part of the USSR where the greater part of the power produced is consumed, while the main part of energy resources (about 90 per cent fuel and 80 per cent hydro resources) is accounted for by the Asian part of the country." The development of nuclear power on a large scale called for a corresponding enlargement of the resource base: for each 100 gigawatts of electrical capacity introduced or planned, reliable uranium reserves of 400 000 to 500 000 tonnes were required if thermal nuclear reactors only were used. "This could become a serious limiting factor in the way of the nuclear power development, taking into account the relatively small world reserves of rather rich uranium ores which are known for the present," he said. "The introduction of fast breeder reactors into nuclear power and their combined use with thermal reactors allows us to eliminate these limitations."

Research into fast reactor systems had begun in the USSR in 1948, he said. An experimental fast assembly and the first substantiation of the breeding concept had been carried out at Obninsk in 1955, and progress had been steady since then, ending with the construction of a large pool-type reactor known as BN-600, of 1470 megawatts thermal, at Zarechny this year (1979); studies were now being conducted on a 1600 megawatts electrical pool-type reactor to be known as BN-1600.

Robert B. Richards, general manager, Advanced Reactor System Department of the General Electric Co., Sunnyvale, California, recalled that work had similarly been in progress for a long time in the US: a formal proposal to build the small reactor that became known as EBR-1 was submitted in 1946, and the reactor began operation in 1951. This established the feasibility of breeding and gave initial experience and basic information on LMFBR physics, fuels and operation. It was also the first reactor to produce electricity. Development had continued since then; the Clinch River Project had begun in 1973 with the objective of designing, licensing, building and operating a 350 MWe power plant as part of a utility system. Plant design was now 70 per cent complete and the fabrication of components was 42 per cent complete, but no work had begun on site. President Carter had proposed to end the project shortly after he took office but Congress, while it had agreed to a delay, had refused to end the project — "and has continued to refuse to end it."

Mr Richards said he thought the US would have a "fairly substantial" breeder programme in the 80s. "I think we can expect to be able to make substantial contributions to breeder reactor technology in the future," he said. "We are disappointed that we cannot bring



Part of the PFR fuel assembly area at the Windscale works of British Nuclear Fuels Ltd in Cumbria. The honeycomb grid layout of a PFR fuel assembly can be seen in the foreground. The fuel comprises mixed plutonium and uranium oxide pellets in stainless steel cans, and is manufactured at Windscale for use in the PFR at Dounreay.

forward the CRBR on the schedule we had originally intended for it, but I think as far as I am concerned I am approaching it now with a much more optimistic face than was the case several years ago."

The prospect of collaboration

A panel discussion on the prospects for international collaboration was introduced by Dr Franklin, as conference chairman. So far as the future could be forecast, he said, if the use of breeders was socially acceptable in Western European countries there was certainly likely to be a large enough market to allow the establishment of a supply industry for them — but not a supply industry in each country. SERENA (the French-German-Belgian-Dutch-Italian consortium) had already been established, "and it is with this in mind that the UK is in discussion with the SERENA partners at present." On the other hand, it seemed likely that there would continue to be multiple sourcing of major components such as pumps, boilers and so on. "This is a problem which will demand the greatest attention in bringing the breeder reactor when it is developed to the European market in an economic way." Dr D.-J.Wahl, of RWE Essen, said it was necessary that manufacturers and utilities should work together during the introductory phase, as a joint venture; "but in the long term this need not be the final solution. The problem is how to get from this commercialisation phase into a free market phase in the very long run."

With respect to the remaining technical problems, Jack Moore (UKAEA) said it was clearly important to continue with work on safety related research; "but I would like myself to see more work done on minor incidents." He would expect such work to lead to simplification of design rather than making the design more complex. The Commission of the European Communities was discussing safety criteria for the introduction of fast reactors, and this might help in establishing norms for licensing. He was echoed by R. Fillmow, General Manager of the Westinghouse Electric Corporation, Madison, Pennsylvania: "I can't help but agree that less attention should be paid to the large accidents, and more attention paid to small accidents," he said. "If I look at the safety requirements placed on us today there are no insoluble problems, but every one has an impact on cost and schedule . . . A number of generic issues could be settled on an open basis, without having to have a specific plant in a licensing process. What should we design to?"

On costs, Mr Moore said the estimates that were being made in Britain showed a fast reactor capital cost about 1.4 to 1.5 times that of a PWR of comparable size in the long term. He was satisfied that reprocessing and overall fuel cycle costs were less than for the PWR fuel cycle; break-even would be achieved when uranium ore prices were perhaps \$75-\$100 per pound. "But if we all believe the analyses we make about uranium supply and the need for fast reactors, we ought not to be putting the emphasis that I think is being placed in some quarters on the capital cost having to be reduced," he said. "We need to be talking about what sort of nuclear programme is practicable for a reasonable number of decades. As far as we can judge, because of uranium availability the only nuclear programme that is practicable is a thermal *plus* fast reactor system. It is the cost of that system that one needs to examine and compare with the cost of alternative energy sources."

What would be the cost of oil and of coal in a few decades? The Coal Board had estimated that to increase coal output by 40 million tonnes a year by the end of the century would cost about £10 000 million. "So our projections indicate that there is going to be no difficulty in showing the nuclear option to be more economical than the alternative fossil fuel option . . . It will be necessary to include in the judgment of when to go ahead a very strong emphasis on the strategic need for the system, and not too much emphasis on when you break even." □

WORLD ENERGY AND THE EEC

The world has run into trouble over oil supplies faster than expected — and large sections of the public, and Parliaments, do not yet appreciate the implications of this for the rest of energy policy, including nuclear policy.

This was the view expressed by Mr Leonard Williams, Director General for Energy in the Commission of the European Communities, when he spoke at a meeting of the Institution of Nuclear Engineers at the Royal Institution in London on 25 October, on the world energy situation and the response of the EEC.*

Mr Williams — a self-avowed pessimist on energy questions — said too much of the energy debate on energy policy, particularly in America, had been conducted on the basis that we had many options which we could reject or pick up as we wished. "I don't believe that is true," he said, "and I don't believe that we, including America, have the option of rejecting nuclear. We don't even have the option in my view of a go slow on nuclear — but of course we have an absolute obligation to go carefully on nuclear, as we have since its inception. Somehow or other, during the next few years we have to pursue the debate to the extent that nuclear becomes accepted as one of the obvious alternatives to oil, which not many years ago was producing 60 per cent or more of our energy requirements."

A view which shaded toward the pessimistic side was justified because of the dangers of over-optimism, he said. There was a possibility that next year we would move into an apparent oil glut again; but that would be a false signal of what the future would be like unless economic growth turned down almost to zero. "On any sort of politically acceptable forecast of growth — 3 per cent, more or less — we are running into a situation in which I think beyond any reasonable doubt our requirements will overtake future oil discoveries. We are now down in the world to something like 35 years of probable reserves established. That figure is going to tend to fall. Yes, we will get fluctuations to and fro, but I think a downward trend in oil supplies is something we ought to assume. If this proves to be wrong the costs we will have wasted will be far less than if it proves to be right and we have not prepared for it."

No really big oil fields had been discovered for eight years, Mr Williams reminded his audience. But this was not the central point in his argument: "The main point is the fact that OPEC will remain a materially cohesive body. Having discovered that they can maintain their income by producing a decreasing amount of oil, the less oil there is the more the price goes up — because demand is extremely inelastic. That is the main reason why I think I can confidently say we face a permanently tight oil market; therefore we face an increasing cost of oil in real terms, and because of the risk of a repetition of things like the Iranian revolution our oil supply will be not only finely balanced, but also somewhat precarious."

*Mr Williams' lecture, and the discussion which followed it, will be published in a forthcoming issue of the *Journal* of the Institution.

"We need as much coal, nuclear energy and energy saving as possible" — here, the 2000 MWe coal-fired station at Didcot.
Handford

It was interesting to note, he said, that despite the apparent seriousness of the situation OPEC countries had produced more oil this year than they did in the same period last year: the problem lay in the fact that demand for oil had gone on increasing, and it was this continuing increase in demand for oil that was at the root of the problem. "This situation in general terms has been foreseen for many years, but it means that whereas even a year ago people thought we had until the 90s to effect a transition away from oil to other forms of energy, our transition period has got much shorter: we have to make the transition when the crunch is already upon us, when the shortage of gas and oil may be imposing limitations on economic growth," said Mr Williams. "If the industrialised world continues on its present trend of energy growth and oil consumption, then by the mid-80s we shall be at least 2 million barrels a day short of oil, and maybe between 3 and 4 million barrels a day short. Against this background we have to have or get as much coal, nuclear energy and energy saving as possible: the familiar trilogy — new sources coming along well behind because of the lead times involved, and because of the fact that none of them look economic as a large producer yet."

Public education

Public education in the realities of the energy situation had to begin very young. "The schools are not yet getting the right message across about the importance of the energy problem in our economies, our life-styles — that sort of thing." Public education in this country was perhaps getting across a bit: Mr Williams cited the findings of a very recent Gallup Poll. 82 per cent of those polled had heard of the energy shortage; 50 per cent thought it due to the Arab oil producers; 8 per cent thought oil companies. Should the development of nuclear energy be increased? 45 per cent said it should — "but then one comes to the rub. 'What would you do if a nuclear power station were to be built in your area?' 42 per cent would oppose, 24 per cent would not oppose but would feel anxious. That adds up to a pretty formidable body of opinion."

Figures such as these emphasised the need for continued public education in a shifting energy scene. The UK, of course, was in a special position. "It has more options, obviously — but first of all, North Sea oil is limited in quantity. One doesn't know how limited, but I suppose on optimistic predictions you might say North Sea oil might reach its peak around the middle of the next decade. The UK is very dependent on world trade and the health of the world economy, so if the health of the world economy is somewhat impeded by energy problems, the UK would not be stimulated; and even if we have enough North Sea oil for a limited period of time, if one can sell it at $ 23 a barrel, it is rather silly to waste it in this country rather than use export capacity to the full."

A third point which needed to be taken into the reckoning was the recognition of the fact that in dealings with the OPEC countries there was a real wealth transfer. In 1973 the European Communities imported about 590 million tons of oil and paid $ 15 billion for it. In 1979 they would not be importing as much — North Sea oil and other factors had enabled a cut in imports — "but we have imported 470 million tons and paid $ 70 billion for it." The cost of imported oil represented about 3½ per cent of the European Communities' Gross Domestic Product, a hefty slice of the Communities' disposable income. "To put this another way, we are poorer than we were in 1973, before this upward trend in oil prices started. There is no way in which we can pay ourselves more to compensate for the fact that petrol and oil for the motorcar cost more. To the extent that we do, we generate inflation."

The other side of the coin was the size of OPEC financial surpluses, and the growing instability of many of the developing countries. It was going to be an increasingly difficult problem to manage their debt in any realistic way, and to avoid the financial collapse of individual developing countries causing major trouble to the world financial system. This danger was not with us yet — but it was a danger to be borne in mind for the future.

World economic growth would be limited by the availability of energy; to the extent that we could get energy policy right, it would

EEC energy R&D

The Council of the European Communities is to spend about £70 million on a second four-year programme of energy R&D, the Department of Energy announced on 2 October. The money is to be allocated on the basis of shared cost contracts over the period 1979-1983. Research organisations, industrial companies, universities and similar organisations involved in energy research will be eligible to apply.

The money is to be allocated as follows:

	£ million
Energy conservation	18.0
Solar energy	30.7
Geothermal energy	12.0
Production and use of hydrogen	5.3
Energy systems analysis and strategic studies	4.0

Applications for financial support are put before an Advisory Committee, which then makes recommendations to the Commission, the Department says. After a decision has been reached the Commission negotiates the details of a contract with the organisation concerned.

Anyone wishing to discuss participation in the scheme should contact: Dr G. Preston (Department of Energy), tel. London (01) 211 5461; Dr W.M. Currie (Energy Technology Support Unit, Harwell), tel. Abingdon (0235) 834 621 ext. 218. □

be less of a restriction on economic growth. It was against this background that the Tokyo summit had been held in June. Heads of Government had agreed there on goals for the year 1985 which represented, to the extent possible, a reasonable equivalence of effort between major parts of the world — America, Japan, and the Communities. The EEC had undertaken to hold oil imports constant throughout the years until 1985, by increasing North Sea oil, increasing the nuclear contribution and that of gas, and marginally by increasing the role of coal; and by energy saving.

Community energy policy normally received a rather bad press, said Mr Williams; "but we believe we are saving some 70-80 million tons of oil equivalent a year through the savings measures that have been introduced, mostly nationally but with some co-ordination at a Community level. Perhaps most importantly, most Governments are reasonably courageous about the question of energy prices, and are trying to make sure that they continue to bear some relation to the price of oil or energy. For the future, our policy in the Community must be founded on the same trilogy of things. First of all, coal. The Community is still building far too much oil-fired capacity, that was in fact started and approved before the first oil crisis. Something like 18 gigawatts of capacity is still in the pipeline to burn only oil; the Commission has proposed to the Council of Ministers that there should be a subsidy to encourage the conversion of that capacity into coal firing or at any rate dual firing, and the building of new capacity to burn coal. We have also proposed a scheme for interest rate subvention for coal production capacity; Mr Howell (Secretary of State for Energy) suggested at the last Energy Council that all that wasn't enough, and proposed a rather more radical scheme to subsidise investment in coal production capacity, suggesting 250 million units of account a year. We will examine that carefully. . . but one of the problems is that there are really only two countries interested, the UK and Germany, with Belgium and France marginally interested and the rest — to the extent that they are interested — interested in *world* coal."

On the nuclear side, "the record really is bad. When I came to the Commission at the beginning of 1976 the nuclear target for 1985 was 160 gigawatts. It was perhaps ambitious, and might have done harm by being ambitious; perhaps at the time a more realistic target would have been 120 GW. But in the event we have not got much more than 73-74 GW by 1985. By 1990 the main country programmes, if you believe them, will double that to give about 150 GW or more. We don't believe it. We believe that by 1990 the score may be only about 120 GW. To achieve this 120 GW or so, which is far lower than national programmes, the Community would have to begin some 15 nuclear reactors each year for the next three or four years. In the recent past no nuclear reactors have been begun in the Community except in France and now, more recently, in the UK. It would mean a total change of pace if this fairly modest target for 1990 were to be achieved."

Collaboration

What did these figures mean in terms of the proportion of total energy supplied by nuclear? The 1985 figure equated to about 9-10 per cent; the 1990 figure lay between 12 and 15 per cent: not the sort of heavy reliance on nuclear energy which opponents would criticise. Energy saving and work on new sources must of course continue to take a large part of our attention, particularly as at Community level there was good scope for closer co-ordination. The further one looked ahead the easier it was to collaborate internationally; it was harder, the closer one got to the stage of political and commercial commitment. "Our best view is that even with substantial investment in R&D we shall not in fact produce more than between 4 and 7 per cent of energy in the Community from new sources by the year 2000. The investment is very heavy, and the lead time is long."

One of the great difficulties on the energy scene in the future was going to be the increasing energy requirements of the developing countries. Most of them were not yet at the stage of development, or the scale of usage, at which nuclear was remotely appropriate; many of them tended to turn to oil. The fact that they were developing countries meant that for every 1 per cent 'development' they tended to want 1, 2 or 3 per cent more energy. "We have to help the developing countries without oil, both in energy planning, exploration and technology. . .. Since the Community as such is a major trading entity — we negotiate trading agreements with the rest of the world, and have engaged in the latest round of tariff cuts at world level — since that is so under the Treaties, it also makes sense to build up the credit of the Community through forms of aid, in energy as well as in more normal economic aid."

It was important that the current disorder in the oil market be reduced. The official price of OPEC oil had risen by some 55 per cent since the beginning of 1979, and internal consumer prices had risen by about the same amount; but spot market prices had risen by more than 100 per cent, and this fact was used by OPEC as alleged evidence that we could afford to pay more for our oil. Until now the oil market had been entirely free — "One interferes at one's peril." Mr Williams continued: "We have a wide spectrum of opinion in the Community about whether one should interfere in it. At one extreme, the Germans believe strongly one should maintain a free market; at the other extreme the French believe we should try to regulate the market in the same way as they do at home. The UK philosophy is somewhat nearer the German point of view. My own frank view is that the importance of oil and the future problems of oil are such that we shall have to move halfway down the road to making this market far more transparent and amenable to control if control is necessary — subject to some more rigid set of rules than we have at the moment.

Against this background, the Commission was proposing to the Council of Ministers that they should agree that 70 to 75 per cent of electricity should be generated from coal and nuclear by 1990. At present the figure was more like 50 per cent.

They had had on the table for a long time proposals for some concertation or co-ordination of Community effort on the next generation of reprocessing, on fast reactors and on radioactive waste management; and at some time in the future they were going to start to discuss the international management of plutonium. Discussion was already going on on this topic in Vienna, under the auspices of the IAEA; there would have to be a fairly long argument about how much could be performed as a Community function, and how much as a national function, if the scheme ever came to fruition. □

NUCLEAR RESEARCH AND DEVELOPMENT IN THE EUROPEAN COMMUNITY

BY THE OVERSEAS RELATIONS
BRANCH, UKAEA

This article is concerned mainly with the European Atomic Energy Community (Euratom) although much of what is said will also apply to the European Economic Community (EEC).

The Communities undertake research programmes which, in the case of Euratom and the EEC, are split approximately evenly between work done at the Communities' own Joint Research Centre (JRC) and work carried out in national laboratories. Programmes are proposed by the Commission of the European Communities (CEC) and extensively discussed by Committees at several levels until a final decision is reached by the Council of Ministers. The Council is the only authority able to overrule the Commission. Both the Council and the Commission have set up a number of Committees to advise them and to enable national reactions to be explored and defined. The principal ones reporting to the Council of Ministers are the Committee of Permanent Representatives (COREPER) which first considers all questions to be taken by the Council, and, in the R&D field, the Atomic Questions Group which advises COREPER on a wide range of matters arising under the Euratom Treaty. Among the Committees which report to the Commission, the most important in the context of research programmes are the Advisory Committees on Programme Management which enable representatives of Members States to influence the evolution and management of programmes. Once a programme is approved the commission is formally responsible for its execution.

There are two main types of programme — direct action and indirect action. The Communities' own Joint Research Centre carries out direct action programmes. The topics covered are intended to be those which because of their size or the need for a Community focus are best done centrally. The four laboratories which comprise the JRC are at Ispra in Italy, Karlsruhe in the Federal Republic of Germany, Geel in Belgium and Petten in Holland. Ispra, which is the largest of the four, was established in the early 1960s to carry out research on the development of heavy water moderated, organic liquid cooled, natural uranium reactors. This line of research collapsed when most European countries chose light water reactors for their national programmes. Ispra had to diversify and adopted its first non-nuclear programme in 1973. It is now active in many fields such as reactor safety, the management of nuclear materials, the management of radioactive waste, alternative energy sources, and work relating to the environment. The three other laboratories concentrate their work in other areas: Karlsruhe takes the lead in plutonium fuels and actinide research, Petten works in the high temperature materials field and Geel houses the Central Bureau for Nuclear Measurements. All establishments of the JRC also provide the Commission with scientific and technical support. Table 1 shows the 1977-1980 programme of the JRC. The committees of the Council of Ministers are currently considering a programme for the period 1980-1983.

Indirect action projects are centrally managed by the Commission but are contracted out to research organisations in the Member States. The Community's financial contribution to the work varies but is normally about 40 per cent. The programmes cover a wide range of subjects under such headings as energy, raw materials, industrial development and life in society. The most extensive of these is energy. It covers topics such as radioactive waste management and storage, decommissioning of nuclear power stations and nuclear fusion. Typically the projects involve a small number of Commission staff, generally between five and fifteen, to co-ordinate the work done under contract.

The most usual type of indirect action programme is exemplified by the radiation protection programme which was originally adopted in March 1976. The programme is designed to gain understanding of radiation risks in order to evaluate the biological and ecological consequences of the use by man of nuclear energy and to update basic standards for the health protection of both the general public and workers in the nuclear industry. A further example is the programme on light water reactor safety which was approved by the Council of Ministers in March 1979. This embraces research into the consequences of a loss of coolant (LOCA), protection of nuclear facilities from explosive gas clouds arising from conventional industrial plants, and the emission and dispersal of radioactive fission products following an accident. Table II lists the current and proposed indirect action programmes.

The Euratom fusion programme covers all the magnetic confinement fusion work in the Community and constitutes about 20 per cent of the world effort on fusion. The USA and USSR each contribute roughly 30 per cent and the remaining 20 per cent is undertaken by Japan. There have been a succession of Community research programmes on fusion since the initial programme in 1957. The current programme runs from 1976 to 1980 and the Committees of the Council of Ministers are now discussing a new programme to run to 1983.

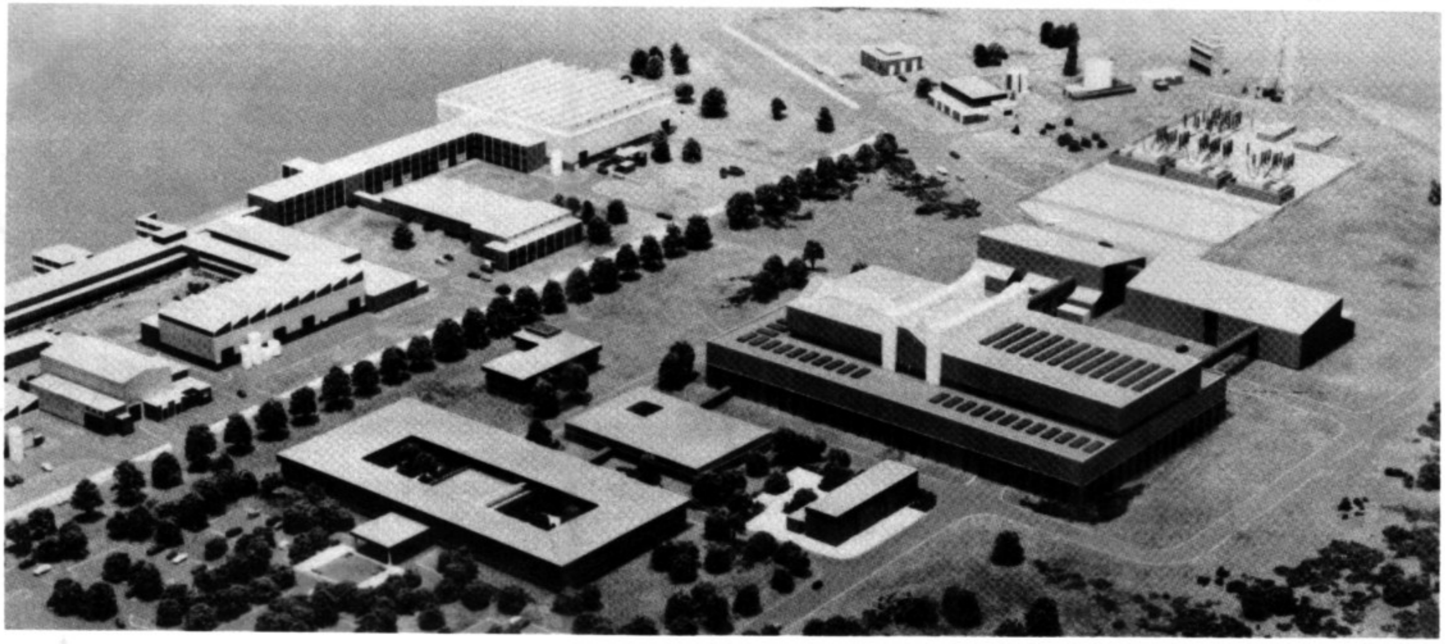
Culham Laboratory is the centre for the UKAEA's research into controlled thermonuclear fusion and its programme is part of the co-ordinated European fusion programme. This is conducted through a series of bilateral "contracts of association" between the Commission and the national fusion laboratories of Member States. Under these contracts the Commission contributes some 25 per cent of the general research expenditure of each associated laboratory and about 45 per cent of the capital investment for large experiments which are recognised as having a special interest for the Community.

As well as taking part in the fusion programme on its own behalf, Culham is also host to the JET Project. The Joint European Torus (JET) Joint Undertaking was formally opened at Culham on 1 June 1978 at a ceremony attended by Dr. Palumbo, Director of the Commission for Fusion and Plasma Physics. The objective of the Project is to construct and operate a

TABLE I: Joint Research Centre Programme: 1977-1980

Area of Work	Laboratories involved
(1) *Nuclear Safety*	
Reactor Safety	Ispra
Plutonium Fuels and Actinide Research	Karlsruhe
Management of Nuclear Materials and Radioactive Waste	Ispra/Patten
(2) *Future Forms of Energy*	
Solar Energy	Ispra
Hydrogen	Ispra
Thermonuclear Fusion Technology	Ispra
High Temperature Materials	Petten
(3) Environment and Resources	Ispra
(4) Measurements, Standards and Reference Techniques	Geel/Ispra/Petten
(5) Service and Support Activities	All
(6) Operation and Utilisation of the high flux reactor*	Petten

*Currently financed by Holland and the Federal Republic of Germany



Almost, before and after: above, a model of the buildings comprising the JET site, with the UKAEA Culham laboratory above the row of trees to the left; below, the JET site as it appeared in late 1979.

large Tokamak fusion experiment. A Joint Undertaking is a type of organisation available under the Euratom Treaty in which various participating national bodies (the UKAEA in Britain's case for the JET Project) join together to create a legal entity governed by the rules applying to industrial and commercial undertakings. The constitution and procedures of the JET Joint Undertaking are prescribed in Statutes approved by the Council of Ministers. The JET Council, on which all members of the Joint Undertaking are represented, is responsible for managing the Undertaking, the JET Executive Committee advises the JET Council on the management of the Project, and the JET Scientific Council advises on scientific and technological matters. The Director of the Project is also responsible to the JET Council.

JET is the largest single joint project yet to be undertaken by the Community and represents some 25 per cent of the total budget for the European fusion programme. The costs of constructing the experiment will be borne by Euratom (80 per cent), the UKAEA as host (10 per cent), with the remaining 10 per cent being divided amongst all the participants (including the UKAEA). An establishment of 320 staff have been agreed. The complex problems and very substantial investment involved in the development of a Tokamak fusion reactor mean that it can best be undertaken by international co-operation and accordingly the Council of Ministers decided to build JET within the Euratom fusion programme. Participation is not confined to Community members and both Sweden and Switzerland are taking an active part in the JET Project. Completion of the Project will mark an important stage in the effort to harness thermonuclear fusion and offers the possibility of realising a prototype reactor by about the year 2000. □

TABLE II:
Community Indirect Action Programmes

Programme	Expiry Date
Solar Energy	1983
Geothermal Energy	1983
Use of Hydrogen	1983
Energy Conservation	1983
Systems Analysis	1983
Plutonium Recycling	*1979
Radioactive Waste Management and Storage	1984
Light Water Reactor Safety	1983
Decommissioning	1983
Controlled Thermonuclear Fusion	*1980
JET	1983
Uranium Exploration	1980
Radiation Protection	*1980

*Programmes currently under review for further extension

LARGER NUCLEAR ROLE 'INEVITABLE'

It seemed inevitable that nuclear power must play a larger role in Britain's future energy policy, Mr Norman Lamont, Parliamentary Under Secretary of State for Energy, told the South West annual conference of local committee members of the electricity supply industry meeting at Exeter University on 27 September.

"I know that many people have anxieties about nuclear development," said Mr Lamont. "Often, these are based on prejudice, superstition or an incomplete appreciation of the facts. Others believe that nuclear power is a virility symbol, something that is good in itself. But we in Government have to seek rational conclusions through hard and clear thinking on a complicated subject. For me it seems inevitable that nuclear power must play a larger role in the future.

"The Department of Energy's projections for the year 2000 suggest a substantial gap between energy demand and indigenous supply. This is after making allowance for substantial savings from energy conservation and for the full exploitation of our coal resources, as well as a major expansion of nuclear power. It implies an energy import requirement that could be over 100 mtce (million tonnes of coal equivalent) at a time when oil supplies in international markets are expected to be becoming increasingly scarce and expensive. Some of these requirements may be able to be met by imports, but on any realistic assumption we shall find it difficult to meet our demand at tolerable prices without a contribution from nuclear power."

Outstanding safety record

Public concern about the safety of nuclear power was understandable, he said; but the actual safety record of the nuclear industry was "outstanding". During 22 years of commercial operation of nuclear power stations in the UK no accidents had occurred that had given rise to significant public hazard. This was a result of the way in which nuclear power stations were designed, licensed, constructed and operated, and of the policy of the electricity supply industry of "defence in depth". "Probably in no other industrial activity is such a wealth of time, expertise and resources devoted to the supervision of safety," said Mr Lamont. "Every effort must be, and will be, made to ensure that high safety standards are maintained and, where appropriate, improved. In fact the annual radiation exposure of the UK population resulting from all the activities of the nuclear industry is less than half of one per cent of the total radiation exposure from all natural and man-made sources.

"To an individual it is less than the radiation received from one diagnostic X-ray a year, and far less than the increase in natural radiation exposure that he would incur by living in a granite area like Aberdeen."

Mr Lamont recalled that the Safety and Reliability Directorate of the UKAEA had summarised the risks of nuclear power in the following terms: "Suppose that an individual decides to reduce his risk of early death from a nuclear power plant accident by moving away from the plant. In UK conditions, if this increases his distance to drive to work by more than 300 yards, it is safer for him to live next to the plant. Put in this way, I think most people would find the risk acceptable." [See ATOM, No. 266, December 1978: *Reactor Accidents and the Environment*, pp. 314-325.] Mr Lamont continued: "The nuclear and electricity supply industries deserve more credit than they have sometimes received for the great attention that has been paid to safety from the earliest days of the nuclear industry."

Adequate and secure energy supplies were essential for the maintenance of a modern society, he said. Even during Britain's period of self-sufficiency in the 1980s the UK could not insulate itself from wider developments in energy markets, and by the 1990s we would be returning to net dependence on imports. "To take no action now to prepare for a larger role for nuclear power might also, perverse as it may seem, lead to increased risk. For if Britain found herself in the 1990s unprepared and facing a serious energy shortage, the Government might then have to embark on a hasty, ill-considered crash programme where safety would come second to keeping the electric lights burning. The way we are proceeding now, the very highest priority can be given not just to existing safety requirements but also to continuously improving them." Of the various energy sources, only nuclear power, coal and energy conservation seemed assured resources for the longer term.

Energy projections 1979

The projections to which Mr Lamont referred — published in October — update the Department's last, which were published in the 1978 Green Paper on Energy Policy (Cmnd. 7101). The introduction to this year's paper notes that the projections do not imply Government commitment to particular levels of energy production: these would depend on decisions that would be taken progressively between now and the end of the century, "as our appreciation of possible future needs and supply prospects develops."

Two scenarios are used. In the first, the UK economy is assumed to grow at about 3 per cent to the end of the century, and in the second, at a lower level of about 2 per cent a year. In both it is assumed that world oil prices will rise significantly above present levels (rising from the current $13.80 per barrel for Saudi Arabian marker crude to around $30 per barrel in terms of 1977 prices by the end of the century). The scenarios are not directly comparable to those of the Green Paper because of differences in the composition of Gross Domestic Product assumed.

The paper says that after incorporation of allowances for energy conservation, which approximate to a reduction of some 20 per cent in demand, total primary fuel requirements in the year 2000 are estimated to lie in the range of 445-510 million tonnes of coal equivalent (mtce), representing an average rate of growth of 0.9-1.5 per cent a year. This compares with a range of from 450 to 560 mtce in the Green Paper projections. The principle differences are:

- A larger component in future economic growth coming from the less energy-intensive service sector, resulting in lower forecast demand, in particular in demand for electricity; and
- reduced estimates of fuel requirements for steel production and for non-energy uses.

Potential indigenous energy supply by the end of the century is estimated in the range 390-410 mtce. This includes a possible installed nuclear capacity of up to 40 gigawatts, approximately a fourfold increase on capacity already installed or under construction; and for indigenous coal production of up to 155 million tonnes a year (compared with the 170 million tonnes planning objective proposed by the National Coal Board in 1977). The projections also take account of the latest estimates of UK continental shelf oil and gas reserves published in the 1979 Brown Book. The range given for indigenous supply in 2000 compares with 474-515 mtce in the Green Paper forecasts, the greater part of the difference being due to changes in the oil and gas estimates.

The Department's summary of the projections say that they highlight the UK's prospective emergence during the later part of the century from a period from 1980 of energy surplus, and the increasing roles which energy conservation, nuclear power and coal will be called upon to play as oil becomes scarcer and more expensive in the international market, and as indigenous oil and gas production declines. "Renewable energy sources are not expected to contribute significantly to supply before the end of the century and, after allowing for energy conservation, major expansion of nuclear power and investment in long-life, economic coal production capacity will be required to prevent an expensive net import requirement from growing rapidly. The upper estimates for coal and nuclear power will not be reached without very great efforts."

The summary says the projections suggest that if these contributions prove realisable, UK net imports in 2000 would be in the range 35-120 mtce, at an annual cost to the balance of payments of £2½-8½ billion in 1977 prices. □

REVIEWS

Radiochemistry — Theory and Experiment

By T.A.H. Peacocke; 274 pp, paper. Published by Taylor and Francis Ltd, Rankine Road, Basingstoke, 1978. £4.95

There is a dearth of simple, well-written books capable of being used in schools or in first-year university courses to introduce students to subjects which are comparatively new to curricula — such as radiochemistry, not a subject which was widely taught even in my day. The Wykeham Science Series, in which this book falls, aims to provide up-to-date accounts of scientific subjects which are at the growth points; they are pitched at the level of a student embarking on a first-year university or other higher education course, or in a senior class at school, and they do fulfil their aim of being intelligible. One could wish that all books were so well written and edited.

This book starts with the discovery of radioactivity and the elucidation of the odd ways in which matter can behave, in the years around the turn of the century, then moves swiftly through the intervening years to a description of the way in which in only six years from the discovery of the fission of uranium nuclear energy was developed for both peaceful and destructive purposes, and so to the meat — the development of reactors; the actinides; the laws of radioactivity; properties of the radiations and decay processes; the detection and measurement of the radiations; errors and their correction; energy determination; uses of tracers in chemistry; miscellaneous applications; radiological safety (good practical stuff, this, with worked examples); and finally details of 35 radiochemical experiments all of which have been fully tested in the laboratories of two schools by advanced sixth-formers. There are, too, useful appendices, including a list of suppliers of radioisotopes, and suggestions for further reading. Worked examples and questions (with answers at the end) are interlarded throughout. The treatment is exact and quantitative but not heavily mathematical, and the emphasis is on the experimental approach to science — learn by doing.

T.A.H. Peacocke, the author, taught chemistry at St John's School, Leatherhead and at Charterhouse over a period of more than 35 years up to 1975. He did much original work in the course of his career, and has published papers and two other books — *Atomic and Nuclear Chemistry* (1967) and *Small Scale Experimental Chemistry* (1960, 1972) as well as making films and broadcasts on chemistry and radiochemistry for schools. Judging by this book, I should say he was a good teacher.

James Daglish

The Non-problem of Nuclear Wastes

Different Drummer Booklet No.7, by Petr Beckmann; available by mail from The Golem Press, Box 1342, Boulder, Colorado 80306, $2 — prepaid orders only.

This booklet by the extraordinary Petr Beckmann will not be to everyone's taste. In particular, it will upset those who persist in regarding the "problem" of disposing of high-level wastes as insoluble; and it will pain especially those who prefer to ignore facts which do not fit their prejudices. Beckmann's approach could not be more different from that of K.D.B. Johnson, of the UKAEA Fuel Processing Directorate, addressing the British Association recently (I shall return to what he said later) — but the conclusions they reach are the same. In brief, there is no problem: not with nuclear wastes, anyway.

No-one denies that the nuclear industry gives rise to wastes. Supporters and opponents of the industry differ over whether we should lose sleep over them. Beckmann doesn't think so, nor does Johnson. "Sunday supplements and pop lecturers have repeated the equation $E = mc^2$ for atomic energy *ad nauseam;* but few people are aware what the *absence* of that equation means for coal and other fossil fuels," Beckmann writes. "It means that no energy is liberated by 'annihilating' mass; it is liberated by a chemical reaction in which the mass of the input products must exactly equal the mass of the output products. In other words, all the tons of coal that go into America's power plants must come out as tons of wastes with not a single ounce forgiven: physical laws admit no exceptions.

One man's lifetime's (simulated) vitrified highly-active waste.

"And just how much coal goes into America's power plants? 480 million tons per year. 913 tons per minute. About 15 tons since you began reading this paragraph. Did you stop reading in surprise? Whether you did or not, there went another 15 tons. But wait! That is just the coal going in; the wastes coming out are more than twice that weight: A power plant consumes not only coal, but also atmospheric oxygen (and a little nitrogen) to produce its wastes. Surprised? There went another *thirty* tons of wastes. . ."*

*Beckmann stresses that we are not in the knocking business. He simply states facts, of which some are unpleasant.

Beckmann does not bother too much with the niceties of fine writing. He attacks the problem of communication with a hammer, and he wins. He is blessed with the gift of knowing what he wants to say, and being able to say it concisely. His most widely read book in Britain is probably *The Health Hazards of NOT Going Nuclear* (reviewed in ATOM No. 244, February 1977), but he has written 11 others and scores of scientific papers; originally working in electromagnetics and probability theory, he became strongly interested in energy some years ago, and now publishes an outspoken monthly newsletter called *Access to Energy* in what time he has to spare from his full-time job as professor of electrical engineering at the University of Colorado.

Enough of the man: what does he say? I have already quoted one passage from this booklet to give the flavour of what he says, and I shall quote just one more, from his introduction. "It may be hard to believe after the ferocious propaganda onslaught against nuclear power, but the vastly superior method of waste disposal is one of the salient advantages of generating electricity from nuclear energy; in fact, if nuclear power were not safer than any other power generation (which it is), if it were not more reliable (which it is), and if it were not more economical (which it would be if it were spared the artificial expenses for delays and licitations), that one advantage of a vastly diminished waste disposal problem might well be enough to give it a decisive advantage over any of its alternatives." Beckmann goes on to list "five well kept secrets":

- It is utterly untrue that no method of waste disposal is known;
- It is utterly untrue that nuclear wastes must be guarded for thousands of years;
- The paramount issue that is being covered up is a simple comparison: Is nuclear waste disposal a significant advantage in safety, public health, and environmental impact over the wastes of fossil-fired power plants (let alone industrial wastes in general) or not?
- Much of the answer to the question above is contained in two simple statistics: For the same power, nuclear wastes are some 3.5 million times smaller in volume; and in duration of their toxicity, the advantage ranges from a few per cent to infinity.
- Nuclear power does not add any radioactivity to the earth; on the contrary, it reduces the radioactivity that Mother Nature would otherwise be producing.

And he proceeds to demonstrate each of these truths.

I mentioned earlier Keith Johnson's paper to the British Association. I want to return to it because, though Beckmann's pamphlet is useful, his facts and figures are primarily relevant to the US case; Johnson uses UK data.

The final section of his paper — in which he reviewed waste management in general in terms which are well-known to ATOM readers — is headed "Mental images and a sense of proportion." Like Beckmann, he lists a few salient points: "(a) The vitrified high-level waste corresponding to supplying nuclear electricity for one person for a whole lifetime has the volume of a polite afternoon tea-cupful. (b) The remainder of the lower-level radioactive conditioned wastes have a volume of less than a bucketful per person per lifetime. (c) In the last decade of this century high-level vitrified waste for the whole of the United Kingdom will be produced at the rate of about three very large dustbinsful each week. (d) Nuclear waste will not look like garbage which can blow about in the wind or be carried away by rats. Except for the very low-level material buried directly it will be massive, solid, incombustible and very difficult for natural or human accident to alter. (e) The cylindrical waste packages are of a size which can be handled. The technology exists by which they can all be placed in the galleries of a modest mine below the land surface, or in the ocean floor. We must all satisfy ourselves of the safety of leaving them there undisturbed. (f) One ton of high-level waste glass is the equivalent in energy terms of about 100 000 tons of coal ash. (g) There is no case of anyone coming to any serious harm in the UK as a result of nuclear waste. Compare this in your own way with the hazards of coal-mining, diving for North Sea oil, hydro-electric dams, gas in the home. Try to be thoughtful, try to be rational."

If the nuclear industry were on trial in a court of law, Beckmann and Johnson could say at that point "I rest my case."

J. Daglish

Radioactive release assessment methodology

A first attempt has been made to establish comprehensive methods for assessing the total health detriment to the population of the European Communities due to liquid and gaseous radioactive effluents released during the normal operation of nuclear plants within the EEC.

They are described in a report* published on 25 October and available free of charge from the Commission of the European Communities. The report is the result of a study carried out jointly by the National Radiological Protection Board and the French Commissariat à l'Energie Atomique under contract to the CEC, undertaken as part of an investigation of the difference in radiological impact of the nuclear fuel cycle if plutonium were to be recycled in Light Water Reactors rather than restricting the fuel to uranium only.

"Total health detriment" has been expressed as the incidence of fatal and non-fatal cancers in the exposed population and hereditary effects in its descendants. The importance of total health detriment, following principles outlined by the International Commission on Radiological Protection, is that it provides a quantitative measure of the radiological effects of a practice and is also an important factor in the process of optimisation of protection in the context of radioactive effluent treatment systems.

Optimisation is a procedure for determining whether a reduction in radiation exposure is "reasonably achievable"; it involves considering on the one hand the increase in cost due to such a reduction and, on the other, the resulting decrease in the cost of detriment. The procedure for optimisation of radiological protection requires in principle a differential cost-benefit analysis of the various costs of different treatment systems to reduce discharges and the corresponding cost of the changes in the associated health effects in the exposed population. The report for the CEC describes the development of mathematical models which enable the health detriment to be estimated and does not include discussion of either the procedure of optimisation or the financial penalties to be associated with a particular health effect.

A generalised approach has been adopted so that the models developed might be applied broadly in the assessment of the radiological consequences of routine radioactive effluent discharges; it may equally find application in other circumstances where the potential exists for releases of radioactivity to the environment. This approach is based on a series of sequential models describing the transfer of radionuclides through the different sectors of the environment, the pathways leading to the radiation exposure of man and the consequential total health detriment.

New features

New features of the models developed are that they have been extended both in space and in time to calculate the complete dose distribution throughout the exposed population. One of the more important advantages of having developed the models is that sensitivity analysis may be undertaken to identify those uncertainties in data which could have a significant effect on the accuracy of results. This will enable priorities to be ascribed logically to research needs and to environmental monitoring data.

The CEC have placed a further contract with the NRPB to establish a computer tape library of results of the concentrations resulting from discharges of standard quantities of radioactive materials to atmospheric and aquatic environments, together with those from standard quantities deposited on the ground, for the range of nuclides considered in the original study. These fundamental matrices will be available throughout the European Community and will enable interested bodies to calculate their own collective doses for releases from the particular site of interest using their own estimates of source terms. □

*NRPB/CEA: *A methodology for evaluating the radiological consequences of radioactive effluents released in normal operations* (Doc V/3011/75 EN), 1979. Available from the Commission of the European Communities, Luxembourg.

'Misconceptions' about nuclear waste

The remarkably small volume of nuclear waste compared with that resulting from other forms of electricity generation was bound to be a considerable advantage when it came to dealing with its disposal, Mr Norman Lamont, Parliamentary Under Secretary of State for Energy, told an Electrical, Electronic, Telecommunication and Plumbing Union shop stewards' course on 16 October.

Mr Lamont said that while the utmost caution had to be exercised when dealing with nuclear wastes a number of misconceptions had arisen.

Mr Lamont. *Camera Press*

"For instance, many people mistakenly believe that radioactive wastes will continue to give off highly penetrative radiation for many thousands of years," he said. "In fact, most of the nuclear waste products which give off highly penetrative radiation have half-lives of less than 30 years and their radioactivity decays to negligible levels relatively rapidly. Radiation from wastes that do have very long half-lives, such as iodine, has very little penetration. These products are only hazardous to man if they are taken directly into the body, for example, the lungs or stomach.

"So the long-term problem is one of dealing with substances with comparatively low levels of radioactivity which are dangerous if taken into the body. This is why we must develop, and are now well on the way to developing, disposal techniques to ensure that these materials cannot reach man's environment in concentrations which are hazardous."

Mr Lamont recalled that vitrification of high-level wastes had been developed and demonstrated on a pilot scale; it had operated successfully in France and would do so in the UK within the next decade. Options for the disposal of vitrified waste were being researched in the UK and abroad, "and I think we can be confident that the route eventually chosen will present no significant safety hazard." □

Advice on dose limits

The National Radiological Protection Board published on 18 October advice to the Heath and Safety Commission on the acceptability of the radiation dose limits contained in the draft European Communities Directive on Radiological Protection.

The advice was given by letter earlier this year and is now formally reproduced in the Board's series Advice on Standards for Protection No. 3 (ASP3*). It was formulated in the light of comments received as a result of a consultative document† being published earlier in the year. NRPB has already endorsed ICRP's system of dose limitation adopted by the European Communities in their draft directive.

In ASP3 the NRPB emphasises the injunction that all radiation doses should be kept as low as reasonably achievable (taking economic and social factors into account) within an annual upper limit of 50 mSv (5 rem) dose equivalent effective to the whole body of the individual.

This system is similar to that already operating in the United Kingdom and which has resulted in an average annual dose equivalent to radiation workers of less than 4 mSv (0.4 rem). Exposure at this level is equivalent to an increased annual mortality risk of less than 10^{-4} and corresponds to that of the average worker in a non-radiation industry with a high standard of safety. Within such industries there will be a distribution of risks above and below the average and few of those that are exposed to the higher risks in any one year will be so exposed consistently throughout their working lives. A similar distribution of risks is produced by the system of radiation dose limitation; this contains principles which will keep average annual doses low.

ASP3 also contains advice in relation to the limitation of doses for controllable exposures; doses to apprentices and students; and doses to women.

Dose limits for members of the public

The NRPB supports the annual dose limit of 0.5 rem contained in the draft Directive and recommends that the limits should apply to the estimated average doses received by particular "critical" groups.

The NRPB also states that it "considers that the use of these limits combined with measures to keep exposures as low as reasonably achievable should, in most cases, result in an average whole body dose equivalent to a critical group of less than 1 mSv (100 mrem) per year of lifelong exposures from all sources of radiation other than from natural background and from medical examination and treatment. Hence the lifetime whole body dose equivalent of an individual member of the public would not normally exceed 70 mSv (7 rem)."

ALARA

In its covering letter to the HSC the NRPB states that it intends to publish advice from time to time on the application of ALARA in various contexts and invites the HSE to examine whether the principle is being followed for any worker who appears to be exposed consistently at or near the dose limits.

It also suggests that "The appropriate level of risk to be accepted by radiation workers should be discussed in the light of the policy developed and decisions taken for other occupational carcinogens, eg, asbestos and toxic chemicals. The question should not be taken in isolation merely because radiation has been recognised as a carcinogen and consequently for many years subject to systematic dose limitation."

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

*ASP3 Advice to the Health and Safety Commission from the National Radiological Protection Board on the acceptability of the dose limits contained within the Draft Euratom Directive (Document 5020/78). HMSO, 10p.

†Joint Consultative Document: Ionising Radiations. Supplementary Proposals for Provisions on Radiological Protection and Draft Advice from the National Radiological Protection Board to the Health and Safety Commission, price 50p plus postage.

Geological investigations at Harwell

Test drillings are proposed at AERE Harwell to ascertain whether the deep geological formations under the AERE site might be suitable for burying radioactive waste.

The Institute of Geological Sciences has been carrying out "desk studies" of the known geology under nuclear sites in the UK. These studies suggest that AERE Harwell may be one of the most promising nuclear sites for the disposal of low and medium level activity wastes. The Oxford clay (at a depth of approximately 1000 feet) and the Kimmeridge clay (at about 700 feet) seem to have the most favourable characteristics. The geological investigations are necessary in order to establish whether these assessments are correct.

The Harwell management will be discussing the proposals with local authorities in the area. The drilling experiments will be purely exploratory, and there is no question at this stage of burying any radioactive waste. Any future decision to do so could be taken only after a full evaluation by the Department of the Environment of the results of the explorations at Harwell and at other possible sites, and after full consultation with local authorities. □

THE 1979 ROYAL SOCIETY ESSO AWARD

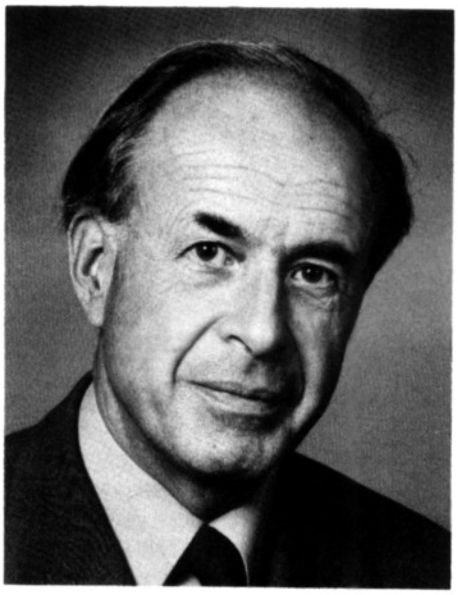
Two scientists — one working in the UKAEA Windscale Nuclear Power Development Laboratories and the other at the Berkeley Nuclear Laboratories of the CEGB — have been awarded the 1979 Royal Society Esso Award for the Conservation of Energy, for their work in improving the utilisation of nuclear fuel in Magnox reactors operated by the CEGB, the South of Scotland Electricity Board and British Nuclear Fuels Ltd.

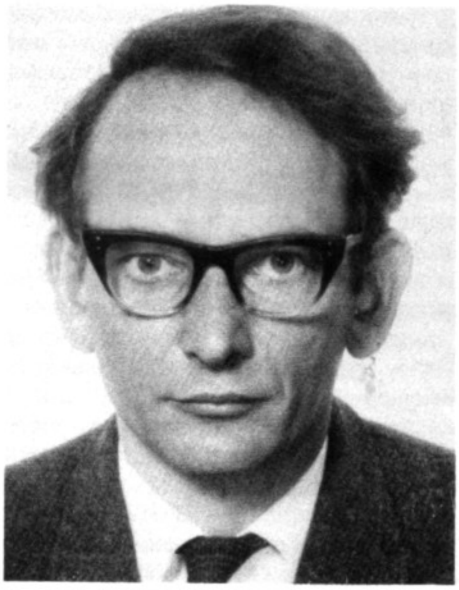
They are Dr V.W. Eldred, head of the Fuel Examination Division at WNPDL, and Dr J.E. Harris, of the Fuel and Core Division at the Berkeley Laboratories. [see box.] Each receives a gold medal to mark the award, and they will share a £1000 prize.

Details of the work which led to this award have been published regularly since as long ago as 1958, when Dr Eldred and co-authors presented a paper on the behaviour of fuel elements under irradiation, at the Second United Nations International Conference on the Peaceful Uses of Atomic Energy. Most electrical utilities operating nuclear plant do not have large technical resources, but rely on plant and fuel manufacturers to carry out R&D work for them. The CEGB, however, took the unusual step in 1959 of setting up the Berkeley Nuclear Laboratories in Gloucestershire, one of its objectives being to monitor the performance of nuclear fuel in specially-equipped 'caves' and to carry out associated basic research. Similar work has been done for even longer at the UKAEA laboratories at Windscale, and in other Authority laboratories — notably those at Springfields, Culcheth and Harwell.

Although there is a strong economic incentive to obtain the maximum amount of energy from each fuel element before it is discharged from the reactor and returned to the BNFL plant at Windscale for reprocessing, the nationally agreed UK policy has been to increase irradiation levels and residence time in the reactor only when evidence has been available from the laboratory examination of irradiated fuel, including elements incorporating material or design modifications aimed at improving performance or endurance, to ensure that increases can be implemented without impairing the safety or the operational efficiency of the different stations and fuel element designs involved. The evidence given by, and the improvements introduced as a result of the post-irradiation examination and critical assessments carried out by the UKAEA/BNFL team directed by Dr Eldred at Windscale and by Dr Harris's team at the Berkeley Nuclear Laboratories, in carefully co-ordinated programmes, have made it possible steadily to increase the irradiation levels and dwell times of fuel in all the CEGB, SSEB and BNFL Magnox reactors with an overall increase in fuel utilisation. The amount of heat extracted from a given quantity of uranium has been more than doubled since the start of the programme: from the initially conservative 1700 megawatt-days per tonne (MWd/te) to around 5000 MWd/te. This corresponds roughly to the annual saving of seven million tonnes of coal equivalent; the annual direct saving in fuel cost may exceed £10 million, but the increased flexibility in the fuel cycle, which has helped to avoid expensive outages, is regarded as being much more important.

The savings made by increasing burn-up are of course not once-for-all. By the time the Magnox reactors of the British programme have completed their design lifetimes the total savings achieved will exceed £100 million. Dr Eldred and Dr Harris pay a gracious tribute to BNFL, noting that they have placed the national interest first and have consistently and freely supported efforts to improve fuel utilisation — even though the outcome has been that they now sell less fuel to the generating boards. □





The recipients

Dr Vernon Eldred (left) was educated at Bishop Vesey's Grammar School, Sutton Coldfield and St Catharine's College, Cambridge. He began his career in atomic energy early in 1947 at AERE Harwell on transfer from the Fuel Research Station of the Department of Scientific and Industrial Research. He returned later to Cambridge and did extra-mural research for Harwell in the Department of Metallurgy, leading to a dissertation on interactions between solid and liquid metals and alloys. After a period at the Nelson Research Laboratories of the English Electric Co. at Stafford he took up an appointment with the UKAEA at the Windscale Laboratories in 1955, where he became Research Manager in charge of the team responsible for the examination and assessment of irradiated Magnox fuel elements from the Calder Hall and Chapelcross reactors and, in a joint programme with the Berkeley Nuclear Laboratories and BNFL, from the CEGB and SSEB nuclear stations. Since 1976 he has been Head of the Fuel Examination Division at WNPDL with responsibility for all post-irradiation examination work there on thermal reactor fuel elements.

Dr John Edwin Harris (right) attended Parkfield Grammar School at Chepstow then studied industrial metallurgy at Birmingham University. He joined AEI-John Thompson at Rugby in 1956 shortly after they had been awarded the contract to construct the Berkeley nuclear reactors. His work was concerned mostly with developing magnesium alloys, and with few interruptions he has been associated with studies related to the Magnox fuel element throughout his working career. He joined the staff of the then newly formed Berkeley Nuclear Laboratories of the CEGB in 1959, being seconded initially to Sheffield University. He moved to Berkeley in 1961. For a considerable proportion of the years since then he has been in charge of the team responsible for monitoring the performance of the Magnox fuel element, in close collaboration with BNFL and the UKAEA.

Dr Harris's personal research has been concerned principally with studying the high temperature deformation and fracture mechanisms in Magnox type alloys and he was awarded the degree of D.Sc from Birmingham University in 1973 for this work and associated publications. □

Windscale not responsible for leukemia increase

Factors other than radiation from Windscale are likely to be the cause of an increased incidence of leukemia in Lancashire, according to the Chief Medical Officer of British Nuclear Fuels Ltd, Dr Geoffrey Schofield.

In a letter published in the medical magazine *The Lancet* on 13 October, Dr Schofield said there had been a general increase in leukemia throughout Britain over the past 30 years. Some of this rise was due to the general ageing of the population, some to better diagnosis and some to environmental factors.

In a recent article in *The Lancet** a team from Manchester University reported a doubling in myeloid leukemia cases in Lancashire between two consecutive six-year periods beginning in 1965. They said this represented a substantially greater increase than in Britain as a whole over the same period.

Dr Schofield listed in his letter a number of reasons why he considered it unlikely that the leukemia rate in Lancashire could be linked with radioactivity in the Irish Sea resulting from Windscale operations. Radioactive discharges from the plant were maintained within limits set by Government authorising authorities; and no member of the public had exceeded the permitted radiation exposure of 500 millirems in any one year. Even in West Cumbria, close to Windscale, typical members of the public received no more than 5 millirems a year radiation exposure from locally caught fish. The radiation exposure for the public in Lancashire would be even less. Yet natural background radiation to which the whole population was exposed amounted to about 100 millirems a year, and this figure varied by as much as 40 per cent in different parts of the country.

If all the quoted increase in leukemia in Lancashire were due solely to radiation received from fish caught in the Irish Sea it would require an increase by a factor of nearly a thousand in the causation of leukemia by radiation compared with the conclusions of the International Commission on Radiological Protection, which were based on 50 years' study of the relevant data. If this were the case, it could be expected that effectively all the deaths of Windscale workers would be leukemia. In fact there had been four cases of myeloid leukemia out of a total of about 600 deaths among employees since the start of operations in 1951. Despite the proximity of Windscale there was no evidence of any increase in the incidence of leukemia in Cumbria comparable to that reported in Lancashire.

"While it is probable that part of the general increase in leukemia has been caused by environmental pollutants, I would suggest that there is a real need to examine factors other than radiation in the same detail as that which has been accorded to radioactivity," said Dr Schofield.

Mr Peter Mummery, BNFL's Director of Health and Safety, has estimated that the radiation exposure a typical Cumbrian would receive from fish from the Irish Sea in the course of a year was no more than that received from cosmic radiation in the course of making a single jet flight across the Atlantic. □

*'Incidence of myeloid leukemia in Lancashire', by Colin G. Geary, R.T. Benn and Ian Leck (Departments of Clinical Haematology and Community Medicine, University of Manchester): *The Lancet*, 15 September 1979.

The Development of Atomic Energy

In 1974 *Independence and Deterrence: Britain and Atomic Energy 1945-52,* Professor Margaret Gowing's second book of atomic energy history, was published. This two-volume work contained as an appendix a chronology covering world events in general, both military and political, and events of importance in the worldwide development of atomic energy.

This chronology has now been extended backward in time to 1938, when Hahn and Strassman discovered nuclear fission by bombarding uranium with neutrons, and forward to the end of 1978, and has been published by the Information Services Branch of the UKAEA as a self-contained, 52-page, A4 booklet. Appendices show changes in Ministerial responsibility for the British nuclear programme, and list Members of the UKAEA from its formation in 1954 to the present day.

The Development of Atomic Energy is available free of charge from the Information Services Branch, UKAEA, 11 Charles II St, London SW1Y 4QP. Tel. London (01) 930 5454, ext. 377 □

Dr J.B. Taylor

Dr Bryan Taylor, Chief Physicist and Head of the Theoretical Physics Division at the UKAEA Culham Laboratory, was presented with the Max Born Medal and Prize by the President of the German Physical Society at a ceremony at the University of Ulm in early October.

The award, instituted in 1972 by the Institute of Physics and the German Physical Society, is made in turn by the Councils of each of the societies to a physicist selected from a list of nominees submitted by the other. Dr Taylor received the award for "his outstanding contributions to the understanding of plasmas confined by magnetic fields." □

Membership boom for reliability centre

Membership of the UKAEA National Centre of Systems Reliability has boomed in the last year with 22 new associate members representing major companies from all over the world.

The National Centre, based at Culcheth near Warrington, Cheshire, leads the world in the evaluation of safety and reliability risks in all types of industry ranging from North Sea Oil to the manufacture of heart pace-makers. It maintains an international data bank of information and experience and exchanges information with its associate members.

More than 70 firms and organisations from all over the world use the Centre's services and exchange information with the Centre's massive computer data bank. Just over half the Centre's members are overseas based but only about one-third of the members are engaged in the nuclear field. The majority are in the chemical, petrochemical and oil industries.

New members include the Brookhaven National Laboratory, New York; Air Products Ltd., USA; Technical University of Berlin; Westinghouse Nuclear International; Nukem, West Germany; Chevron Petroleum (London) and Statoil Stavanger, Norway. □

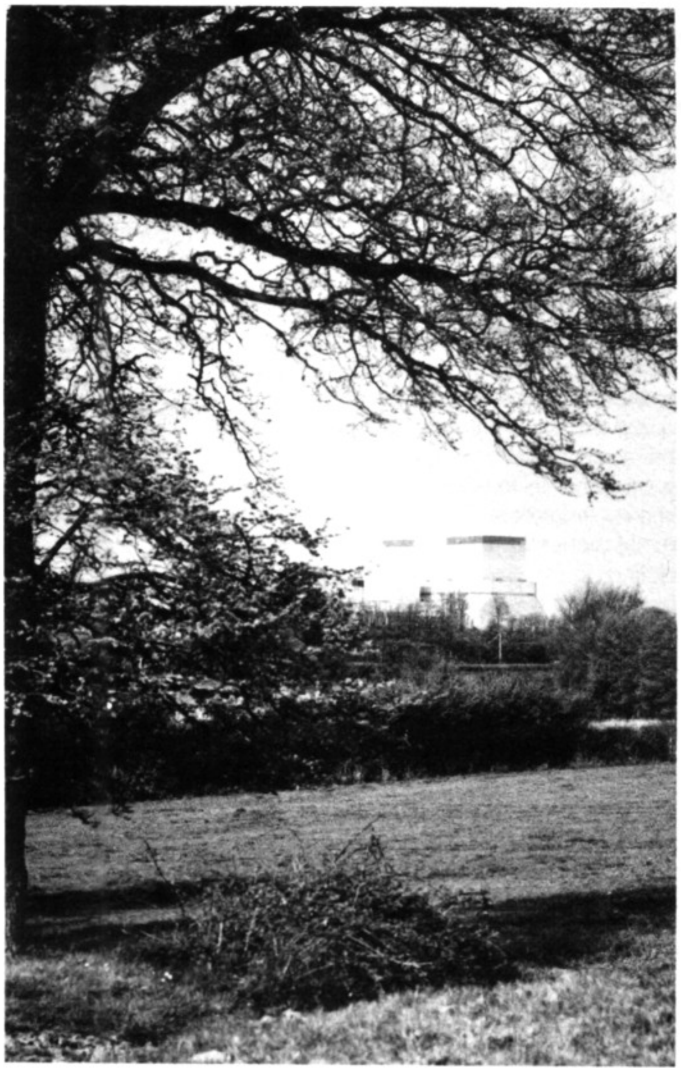
Nominations invited for ICRU Gray Medal

The International Commission on Radiation Units and Measurements is seeking nominations for the fourth award of the Gray Medal, established by the ICRU in 1967 and awarded every four years for outstanding contributions in scientific fields of interest to the ICRU to honour the late Louis Harold Gray, former member and vice-Chairman of the Commission.

The first award of the medal was to Dr Lewis V. Spencer in 1969 for his work on the theory of charged particle penetration. The second award was to Dr John W. Boag in 1973 for a number of outstanding scientific contributions including work on the theory of recombination taking place in ionisation chambers. The third award was to Dr Mortimer M. Elkind in 1977 for his work leading to the identification of repair in cells. It is expected that the fourth award will be made at the time of the XVth International Congress of Radiology in 1981.

Nominations may be made by any person or organisation; they must include a complete c.v. of the nominee, reprints or any other scientific data which show significant contributions by the nominee, and the proposer's personal evaluation of the importance of the contributions. Nominations should be addressed to the Chairman of the ICRU, Suite 1016, 7910 Woodmont Avenue, Washington D.C. 20014, and must be received by the ICRU no later than 1 June 1980. □

Hinkley Point B performance and costs



The two-reactor Hinkley Point B AGR station has been running at more than 80 per cent of its design output and producing electricity as economically as the CEGB's modern, fully-commissioned coal and oil-fired stations, Mr Glyn England, CEGB chairman, told the inaugural meeting of the Central London district of the Institution of Electrical Engineers on 3 October.

Mr England recalled that the first of the CEGB's current programme of four AGR stations, at Hinkley Point, raised power from its first unit in February 1976. The second unit began producing power six months later. Construction work on the station, which had begun in 1968, was actually completed six years later in 1974; but excessive vibrations of reactor gas-circuit components were discovered during commissioning tests and these took two years to overcome. Teething troubles with some of the station's non-nuclear plant — the turbo-alternators and boilers, which have novel design features — then arose during early operation, but these too had now been overcome.

"We are now, however, faced with a further problem," said Mr England. "This has been posed by the need to ensure adequate cooling of the fuel elements as they are discharged on-load. It has been aggravated by an incident which led to damage to one of the graphite sleeves which surround the fuel elements. As a result, the refuelling procedures are being reviewed and for the time being we are carrying out all refuelling operations off-load. This has reduced the station's availability, because it was designed for on-load refuelling.

"In addition, experience has shown that improvements to the fuel handling facilities are required to ensure that high output can be achieved for long periods. We have begun to make these improvements, but they will take a few years to complete.

Brighter side

"That is the dark side of the coin. The brighter side is that during the last few weeks, apart from a planned shut-down of one reactor for refuelling, Hinkley Point B had been producing just over 1000 MW — more than 80 per cent of its design output. If this level can be maintained over the next few months it will be an encouraging pointer to the station's future performance.

"Now for a word about costs. The second reactor at Hinkley Point B was commissioned at 400 MW, the same rating as the first, midway through the last financial year. The station's unit costs for that year, calculated in the same way as we calculate those for other types of station, and published in the Annual Report, were almost the same as those for modern fully-commissioned coal- and oil-fired stations, namely 1.3 pence per unit. This means that Hinkley Point B, which has still to reach its full output potential, is producing power as economically as our modern fully-commissioned coal- and oil-fired stations.

"These costs are, of course, the amounts relating to the financial year which we have had to meet and for which the consumer has had to pay for electricity from those sources during the year. They are not appropriate as a basis for making investment decisions."

Mr England said the remaining three AGR stations in the CEGB's current programme — Dungeness B, Hartlepool and Heysham — were not yet complete: they were between four and nine years behind schedule. In common with other major construction sites there had been problems arising from the low productivity of contractors' workforces. "Neither those who erect equipment on these sites, nor the clients for that equipment (the CEGB), nor the ultimate consumer of the product can be at all satisfied with experience over recent years," he said. "The truth is that although many ways have been tried no-one has yet found solutions to the difficulties of management and payment systems on large sites that deal effectively with the combination of inflation and slow economic growth.

"Although much work remains to be done at Hartlepool and Heysham, generating units at both stations are now due to produce power in 1981. At Dungeness B, the construction phase is virtually complete, and fuel loading is scheduled for early next year. I shall regard it as one of the high spots of my period of office when the station begins to generate power. This is now expected to be at the end of 1980.

"In pressing ahead with the next AGR project, the second station at Heysham, we are doing all we can to learn from past experience. We are keeping basically to the proven Hinkley Point design. We also aim to reduce construction delays by ensuring that as much design work as possible is completed before site work begins. This, we expect, will be next year. We shall also learn from the pioneer work on construction site management now being introduced during the completion of the Drax coal-fired station.

Future programme

"Heysham is, of course, part of the country's nuclear strategy, which is more flexible than its predecessors. In announcing it in January of last year [1978] on behalf of the former administration, Mr Tony Benn, the then Secretary of State for Energy, said that the Government considered that the UK's thermal reactor strategy should not at that stage be dependent upon an exclusive commitment to any one reactor system, and that in addition to the AGR we must develop the option of adopting the PWR system in the early 1980s. Mr Benn also endorsed the intention to order a PWR provided that design work was satisfactorily completed and all necessary Government and other consents and safety clearances had been obtained. Although we at the CEGB have given lower priority to the PWR, we are now setting about the task that will lead to the formal process of applying for these consents and clearances." □

Renewable energy technology for development

A seminar on renewable energy technology for development is to be held at the University of Strathclyde from 24-28 March 1980 with the joint support of the British Council, and the University of Strathclyde Energy Studies Unit, Applied Physics Department and Continuing Education Department. Participants will discuss the application of renewable supplies to societies faced with problems of limited resources in both the developed and the developing world; consider the earth's constantly renewable supplies of energy and materials; study the science and technology of renewable energy devices (solar, wind, wave, hydro etc.) with an emphasis on working experience; study the importance of agriculture and forestry for the supply of energy and materials to locally-based industry; and link technological application with social, economic and health requirements.

Further information may be obtained from the organisers, Dr Malcolm Slesser and Dr John Twidell, c/o Continuing Education Office, University of Strathclyde, Glasgow G1 1XQ. □

The 1979 Achievement Award for Scientific Instrument Development has been given to Dr Harry Freeman, of AERE Harwell (seen here left) for his work on laboratory scale heavy ion accelerators for isotope separation and ion implantation.

The Award is made annually by the Worshipful Company of Scientific Instrument Makers for an outstanding British or Commonwealth achievement in the scientific instrument field. Previous award-winning achievements have included the development of the electron microscope, contributions to holography and the development of the X-ray medical scanner.

Dr Freeman was responsible initially for the development of a novel ion source (the 'Freeman Source') capable of providing high intensity ion beams, which is now a standard feature of many high intensity accelerators. This facilitated the construction of very small high performance isotope separators for nuclear applications, which included a further novel technique (the variable geometry magnetic analyser) for improving beam manipulation.

These features were incorporated subsequently into high current ion implantation equipment for the semi-conductor industry, for which Dr Freeman developed a second acceleration stage to obtain higher beam energy, and a mechanical scanning system to obtain high doping uniformity. The latest implantation machines have been highly automated and optimised for industrial use, but they are still based largely on these innovative developments.

The commercial exploitation of high current ion implantation machines has been taken up successfully by Lintott Engineering Ltd, to whom Harwell's accelerator technology was licensed at an early stage. One of the company's major achievements has been the extensive redesign and development of the equipment to meet the exacting requirements of the electronics industry, where ion implantation of silicon has become an essential part of semi-conductor fabrication. The company has sold large numbers of its implantation machines in the UK, Europe, Japan and the USA, and now occupies a leading position in the world market for such facilities.

Harwell has maintained its interest in ion implantation technology for both semi-conductor manufacture and for the treatment of engineering materials to improve their surface properties.

Dr Freeman received his award at the Worshipful Company's Admission Court dinner on 23 October from Mr Harry Drew, CB, Deputy Master of the Worshipful Company. □

Prof. Abdus Salam awarded Nobel Physics Prize

Dr Abdus Salam, Professor of Theoretical Physics at Imperial College, London, and Director of the International Centre for Theoretical Physics since its foundation in Trieste in 1964, has been awarded the 1979 Nobel Prize for Physics, jointly with Prof. Steven Weinberg and Dr Sheldon Glashow, for their work in developing a unified theory uniting the four fundamental forces of nature.

Dr Salam was born in 1926 in Pakistan. He attended the Punjab University and St John's College, Cambridge, where he received a double first in mathematics and physics. In 1952 he was awarded a Ph.D. in theoretical physics from Cambridge; while there he was awarded Smith's Prize for the most outstanding pre-doctoral contribution to physics and he won numerous awards during the period 1958-78.

In 1964, largely due to his efforts, the International Centre for Theoretical Physics was established in Trieste, Italy, as an institution devoted to assisting physicists and advancing physics in developing countries. The ICTP, jointly sponsored by the IAEA, UNESCO and the Italian Government, quickly developed a reputation for excellence; today, scientists working there produce about 100 original papers in physics each year.

Dr Salam divides his time between the ICTP and Imperial College. He has written about 200 scientific papers on the physics of elementary particles, and others on science and education policy for Pakistan and other developing countries. □

Professor Otto Robert Frisch

The Authority have learned with regret of the death of Professor Otto Frisch — the ebullient Austrian-born physicist who coined the term "nuclear fission" and who played a seminal role in the development of the use of atomic energy.

A memoire of his life and work will be published in a forthcoming issue of ATOM. □

IN PARLIAMENT

QUESTION TIME

Euratom loans

22 October 1979

Mr Frank Hooley asked the Secretary of State for Energy if he would oppose in the Council of Ministers the proposal of the EEC Commission to raise the ceiling on loans from Euratom for nuclear projects from £335 million to £670 million, pending a thorough reappraisal by the EEC of policy on nuclear power.

Mr Lamont: The European Council meeting on 21-22 June this year agreed that nuclear programmes in the Community must be given fresh impetus. I therefore see no reason for the Council to make any further reappraisal of the Community's nuclear policy before deciding on the Commission's proposal to raise the ceiling on Euratom loans from 500 to 1500 million units of account.

Three Mile Island accident

22 October 1979

Mr Arthur Palmer asked the Secretary of State for Energy when he would make available to members the report of the team sent by the Central Electricity Generating Board to study at first hand the accident at Three Mile Island nuclear power station in the US.

Mr Howell: The Atomic Energy Authority, the Nuclear Installations Inspectorate and the Nuclear Power Company, as well as the CEGB, are assessing the implications of the Harrisburg nuclear incident. As I told the House on 11 June, I will consider the suitability and timing of the publication of these studies, but it would seem best to be able to consider the report of the President's Commission in the United States, and the fullest availability of the facts, before considering the publication of reports in the UK.

Jet funding

23 October 1979

Mr Frank Hooley asked the Secretary of State for Energy what the total EEC contribution to the JET fusion project would be in 1979-80 and 1980-81; and what would be the British contribution in cash and as a percentage, all figures expressed in £ sterling.

Mr John Moore: Eighty per cent of the cost of the JET fusion project is borne on the Community budget. Ten per cent is borne by the UKAEA as the host organisation. The remaining ten per cent comes from the participating organisations (including the AEA) in proportion to the size of their fusion programmes. In total the AEA bears about 11.5 per cent of the cost. Since the JET project is budgeted in calendar years, the following figures are also in calendar rather than financial years. In 1979 expenditure is expected to be £26.1 m, of which £20.9 m is borne on the Community budget and £3.0 m by the AEA. Corresponding figures for 1980 are estimated as £36.5 m, £28.9 m and £4.1 m, and in 1981 as £34.6 m, £27.7 m and £4.0 m respectively. In addition, the AEA are providing some buildings and site services on which the JET project will pay rent.

Decommissioning

23 October 1979

Mr Hooley asked the Secretary of State for Energy whether the discussions in the Energy Council in Luxembourg on 9 October covered the problems and costs of decommissioning.

Mr Moore: There was no discussion on this subject at the Energy Council meeting on 9 October 1979.

Spending on energy R&D

23 October 1979

Mr Hooley asked the Secretary of State for Energy if he would list the amount of public expenditure on research and development into nuclear power, thermal reactors, fast breeder reactors, wave power, tidal power, solar energy, wind power, biomass energy projects and photovoltaic cells respectively, during 1979-80 and the projected figures for 1980-81.

Mr Moore: In 1979-80 the UKAEA expect to spend around £150 m (net) on nuclear energy research and development. Of this about £15 m is for research and development directly related to thermal reactors and their safety, and some £60 m is expected for fast reactors and their safety, though other parts of the R&D programme are also relevant to both thermal and fast reactor development.

For 1980-81 expenditure on both systems is expected to remain at about the same level in real terms.

In 1979-80 the Department of Energy expects to spend the following sums on R&D programmes on energy sources as listed:

	£ 000
Wave power	3,150
Tidal power	298
Solar Energy	898
Wind power	451
Biomass energy	119

Expenditure allocations in respect of the above energy sources for 1980-81 have yet to be settled.

Responsibility for research and development on photovoltaic cells rests with the Department of Industry. The Department of the Environment and other Departments also have solar energy programmes.

Nuclear station building

24 October 1979

Mr Richard Shepherd asked the Secretary of State for Energy if he would make a statement on the building of nuclear power stations.

Mr Moore: The Government believe that nuclear power has a vital role to play in energy policy and that continuing orders for nuclear power stations are essential for meeting this country's long-term energy requirements.

Plutonium nitrate shipment

24 October 1979

Mr George Foulkes asked the Secretary of State for Energy when the Health and Safety Executive Report on the transport by road of plutonium nitrate, completed in June, would be published.

Mr Moore: The Government is giving careful consideration to all aspects of the UKAEA's proposals on the shipment of plutonium nitrate by road and by ship from Dounreay to Windscale, including the advice contained in a report prepared by the Health and Safety Executive. The report will be published and the Government's decision on the AEA's proposals announced in due course.

Returns on investment

24 October 1979

Mr Nigel Forman asked the Secretary of State for Energy how much electricity was produced or saved in a full year if £1000 million was invested in: (a) a new nuclear power station of the kind to be built at Torness or Heysham, (b) a new coal-fired power station similar to Drax B, (c) a new oil-fired power station similar to the Isle of Grain and (d) energy conservation measures using existing technology to economise in the final use of electricity.

Mr Moore: Investment decisions on generating plant are taken in the light of total lifetime costs and benefits and no meaningful comparison can be related solely to capital investment or to a particular year. Similar considerations apply to the appraisal of opportunities for investment in energy conservation, which are not normally specific to electricity, and whose costs and benefits vary. Meeting longer term UK energy needs will require substantial investment both in the energy industries and in energy conservation.

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Dr P.M.S. Jones to a Sixth Form Conference at Kingsbury High School, Brent.

Radioactive waste-policy and perspective
Dr Lewis Roberts to the British Nuclear Energy Society In London.

Nuclear materials accounting

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The Nuclear Challenge
Book review by L.G. Brookes

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The Richard Dimbleby Lecture by Lord Rothschild.

Safe working with plutonium
by Dr B.A.J. Lister.

Energy R&D in the United Kingdom
Report of a speech by Sir Hermann Bondi to the Institution of Nuclear Engineers in London.

Wave Energy: problems and promise
First Wave Energy Conference, London.

Nuclear power, politics and public opinion
Con Allday to the British Nuclear Energy Society.

The Nuclear Disaster
Book review.

Radiation exposure of the UK population

Nuclear power in Canada

European Safeguards Research and Development.
by A.S. Adamson

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The safe transport of radioactive materials
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Future Energy
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Nuclear energy and its international implications
A report of the speech by Dr Sigvard Eklund given as the 1979 Presidential Lecture of the Institution of Nuclear Engineers in London.

Fuel policies
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"The Non-problem of Nuclear Wastes"
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L. Williams to the Institution of Nuclear Engineers in London.