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講演メモ

The UK and the Fast Breeder Reactor

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Outline History of the UK Fast Reactor Programme

The UK government took the decision in April 1945 to set up its own programme of nuclear energy development, separate from those of the USA and Canada with whom the UK had co-operated during the 1939-45 War. Fast-reactor development work became part of the UK nuclear programme as early as 1951, even before any firm decision had been taken to use nuclear power for electricity production. This was because it was quickly recognised that access to secure supplies of uranium at reasonable prices might be a problem for the UK, a small island off the edge of Europe with limited mineral resources of its own, though probably of less concern to the USA and Canada.

The British fast-reactor programme quickly gathered pace, using the Zephyr and Zeus low power reactors, and a decision to build a power-producing fast reactor in the UK was taken in 1954. Because of the lack of practical experience, anywhere in the world at that time, of the stability and control characteristics of a high-power, fast reactor core, it was considered prudent to locate the new fast reactor in a low population area. Dounreay in the north of Scotland was chosen, in part as a result of local pressure to bring new work to northern Scotland. The Dounreay Fast Reactor (DFR), producing 60MW of thermal power and 14MW of electricity, was started up in 1959. The DFR was always intended to be purely an experimental reactor, using enriched uranium metal fuel and a sodium/potassium alloy coolant, but it worked well for some 18 years, closing in 1977.

By the mid 1960s the UK had built and was operating several thermal reactor power stations and the UKAEA believed it was ready to take fast reactor technology a stage further. It obtained UK government agreement in 1966 to build another fast reactor, eventually called the Prototype Fast Reactor (PFR) and again sited at Dounreay. This reactor was intended to be much closer in design to that which would be needed for the commercial application of fast reactor technology, somewhat analogous to your Monju reactor.

In particular, it

- was much larger, producing 250MW of electricity;
- used a fuel assembly design optimised for the even larger commercial-sized fast reactors envisaged in the future;
- used oxide fuel, allowing higher thermal efficiency and higher fuel burn up;
- used plutonium instead of enriched uranium in the driver fuel, essential to close the fast reactor cycle and realise the promise of fast reactors to make better use of natural uranium;
- included plutonium breeding regions around the core and was linked to a small fuel reprocessing plant at Dounreay, to demonstrate completion of the fuel cycle;

was cooled by sodium rather than sodium/potassium alloy.

PFR first reached criticality in March 1974 and eventually ceased operating in 1994.

Meanwhile, parallel programmes of research and development into fast reactor technology and into reactor and fuel plant design, also funded by the UK government, continued throughout these years, eventually as part of the joint European Fast Reactor programme. Many UK nuclear organisations participated with UKAEA in fast reactor development; BNFL in fuel, NNC in plant design, Nuclear Electric and Scottish Nuclear through their interest in licensing, safety and economics. The main government-funded, research and development programme was concluded in 1993, to be replaced by a much smaller programme, now funded and managed by British Nuclear Fuels and supported by NNC and AEA Technology plc. Part of UKAEA's current work on decommissioning includes programmes to decommission DFR and PFR.

Achievements of the UK programme and the current status of the technology

By the time of the closure of PFR in 1994 the UK had demonstrated that fast reactors were a realistic technical option for electricity generation for the UK, should our electricity generating companies need to make use of them. The key achievements of the British programme were:

- The PFR proved very stable and docile, with negative power and temperature coefficients providing powerful safety features in addition to those deriving from the large pool of liquid sodium.

- Although it was a first-of-a-kind, one-off reactor, the lifetime average availability of the PFR reactor core as a heat source had been quite good, 64% over the 20 years of operation.

- Plutonium-uranium, mixed-oxide, fast reactor fuel was successfully developed and 17 tonnes were manufactured, largely by BNFL at Sellafield, with up to 32% plutonium concentration.

- Some 93,000 fuel pins were used in PFR with only a handful of failures. The target for fuel burn-up (originally 5%) was handsomely exceeded. Many thousands of pins exceeded 10%, and several hundred reached 20% and lead pins reached 23½% (a world record I believe) without failure.

- A large number of spent fuel and breeder sub-assemblies (more than 18 tonnes so far) from PFR were disassembled and reprocessed by UKAEA at Dounreay, with separated plutonium being sent to BNFL at Sellafield for assembly into fresh fuel, thus closing the fuel cycle.

- Problems with the steam generators in PFR (not a nuclear component at all) had seriously hampered electricity generation in the early years of operation but were gradually solved. The load factor of the power station, although one-off, first-of-a-kind with entirely new technology, was around 40% over the last ten years of operation and 93% over the final, few-month operating period.

In concert with our French and German partners, many improvements had been made in fast reactor technology and a full design had been developed for a commercial scale power station.

As a consequence of these achievements the UKAEA believes, and I think the view is quite widely shared, that the UK fast reactor development programme was a quite successful one. It demonstrated at realistic scale all aspects of fast reactor technology, and solved some of the difficulties present in the early systems, particularly steam generator reliability.

It demonstrated the whole fast reactor fuel cycle using plutonium, from fresh fuel through very-high-burn-up in the reactor and subsequent reprocessing to separating out the plutonium for fresh fuel. Certainly, the previous UK government's position was that the fast reactor concept has been proven on an industrial scale and it is now up to the UK electricity generation industry to take the technology to the market if and when it sees fit. For very good reasons we do not now expect Britain to be first to do this.

External factors influencing the use of nuclear power in the UK

British governments of both political complexions have valued diversity in electricity supply. Over the past 40 years they have consistently sought to use nuclear electricity generation as an important contribution to such diversity. In the 1940s and early 1950s the principle concern was a heavy dependence on sometimes unreliable indigenous coal supply. In the late 1960s and 1970s nuclear power was seen, by Britain as by most of the OECD countries, as important in avoiding a heavy dependence on middle-east oil. In the early 1980s a potential over-dependence on coal was again the concern.

As a result, nuclear electricity is now an important contributor in Britain, our dependence on it is about 30%, up from about 20% around 1980 but not having grown as much as was envisaged in the energy shortage years of the 1970s and early 1980s. It is not expected to grow further in the near future. There are several reasons which have combined to limit its growth in the UK:

> Partly as a result of our having an oil-production-supported currency from 1975 to 1985, the balance of the British economy moved strongly towards services, away from

more energy intensive manufacturing. As in other countries, British manufacturing industry has also greatly improved its efficiency, often with the help of Japanese management. Overall electricity demand has consequently grown much more slowly over the last 20 years than in earlier decades.

During the 1980s Britain therefore had a surfeit of electricity generation capacity, with coal and nuclear in routine use and oil stations available if necessary, as during the coal miners strike in 1984. There was little new construction and therefore little change in the balance of electricity supply at this time. Furthermore, during the 1990s the de-regulation of electricity supply, coupled with plentiful supplies of cheap natural gas from the North Sea, has caused significant further investments in electricity generation but always using combined-cycle gas turbine (CCGT) power stations. In 1997, gas seems likely to provide nearly 30% of electricity generation, about the same as nuclear. For new power stations, which I stress are not **essential** for the UK at present, CCGTs powered by gas are significantly more attractive financially than new nuclear or coal stations, both in terms of commercial risk and expected overall rate of return on investment. They cannot compete, of course, and are not replacing existing nuclear stations but they are replacing older coal plants with high running costs.

The UK Conservative governments have consistently taken the line that energy is just another 'traded good' and that it is for suppliers of the energy market to decide which technology they invest in next, not the government. The break up and privatisation of the UK electricity generation industry, including last year of the modern nuclear stations to British Energy plc, has created highly competitive electricity supply companies. These new companies have focused all their attention on improving the overall efficiency of their existing stations, where they have been spectacularly successful, and on building the financially very attractive and environment-friendly CCGT stations.

As in other OECD countries, the accidents at Three Mile Island and especially at Chernobyl strengthened the hand of those who believe nuclear power is inevitably a dangerous technology. The UK industry had always believed that Russian RBMK reactors were inherently unsafe but had not said so clearly to the British public, who then found it very hard to accept that British and other western reactors would be safe.

Public support also reduced in the UK as a consequence of the privatisation of electricity generation, during which the costs of nuclear power, especially the estimates of eventual decommissioning costs, became part of the bargaining between government and the managements of the prospective companies.

In summary, Britain has a diverse electricity supply system with an important but stable nuclear component. The significant opportunities offered by cheap gas and excellent CCGT technology in a deregulated market have effectively prevented investment in more nuclear stations. Public concern following Chernobyl contributed by making the process of obtaining permission for new nuclear stations more difficult and expensive.

The possible use of fast reactors in the UK

I should stress that the decision by the UK government to bring its fast reactor development programme to an end did not come from a detailed evaluation of the technology but from its economic and industrial policies, including of course its wish to reduce government expenditure.

In summary it concluded that:

- the UKAEA had proved the fast reactor concept at industrial scale; government had therefore completed its main task of creating another electricity supply option for the UK.

- although certainly practical and, as expected, extremely efficient in its use of uranium, at current uranium prices the fast reactor is more expensive overall than light water reactors. The government does not expect that external circumstances will change this in the foreseeable future and believes that it is for the electricity supply companies to decide if and when fast reactors should be used.

There are other well-known factors which may come into play and bring forward fast reactors. In the UK, as elsewhere in the world, we originally saw fast reactors solely as a means to use natural uranium much more efficiently than thermal reactors can, and as a means to create more fissile material than they used. That is they would save their owners buying uranium and paying to enrich it in U235. Neither of these advantages are as important right now as they were expected to be in earlier decades; uranium is cheap, enrichment is cheap.

But fast neutron reactors do have other features which may also prove valuable in nuclear power generation in the future. They can easily be designed, if required, to burn plutonium much more quickly than in thermal reactors and have been suggested as the best way to manage plutonium stocks. Also, fast neutrons cause fission in even isotopes of heavy atoms as well as odd ones. Coupled with the very high burn-up possible with fast reactor fuel this means fast reactors could be used to incinerate a large fraction of the long lived actinides which are the cause of much concern in the geological disposal of spent fuel or separated waste materials. There is even the possibility of using fast reactors to incinerate the small amounts of very-long-lived fission products produced in thermal reactor power stations, using the intermediate energy neutrons which are inevitably present in a poorly moderated fast reactor.

As a consequence, I believe that fast reactors create a number of options in nuclear electricity generation which should not be forgotten, even if it is not sensible for most OECD countries, including Britain, to invest heavily in fast reactor power plants at present.

My personal opinion is that Britain does retain access to all the major skills which would be required to use fast reactors if necessary. The British Energy and Magnox Electric companies retain the skills of operating several different types of power station. European engineering companies such as GEC/NNC, Rolls Royce, Framatom and Siemens, as well as US and Japanese companies, would be capable of the design and build work if required. British Nuclear Fuels (and Cogema) have growing experience in spent fuel reprocessing and mixed oxide fuel fabrication, which is essential to exercise any of these options. BNFL continues to invest significantly in advanced reprocessing development work designed to service Fast Reactor as well as thermal systems. UKAEA has experience of reprocessing high burn-up, high-plutonium fuels and increasingly of the practicality of decommissioning fast reactors.

It is also my personal opinion that it is also important for Japan to be able to exercise these options if and when circumstances make it sensible for you to do so.

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