THE NUCLEAR SCENE IN THE UK

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ABSTRACT

The commissioning in 1956 of Calder Hall, the world's first commercial-scale nuclear power station, was the start of an industry which is now well established in the UK. The total fuel cycle needs of the industry are met by British Nuclear Fuels plc, including uranium conversion and enrichment, fuel fabrication, irradiated fuel transport, storage, reprocessing and associated waste management activities. These waste management activities include the vitrification of high level waste and the encapsulation in cement of intermediate level wastes. Liquid effluent streams are treated to give very low environmental discharges.

Low level solid waste is currently being disposed to a site at Drigg, and stores are under construction for vitrified high level waste and for cement-encapsulated intermediate level waste. Vitrified high level waste will be stored for at least 50 years before disposal, but intermediate level waste will be disposed to a deep repository as soon as one can be brought into operation.

INTRODUCTION

Calder Hall, commissioned in 1956, was the world's first commercial-scale nuclear power station. It was also built to produce plutonium for weapons. Its basic technology (Magnox) was developed into commercial designs, and nine Magnox power stations were built throughout the UK.

Since then, advanced gas-cooled reactors were developed and built to be followed by PWRs. The UK nuclear industry, including the full range of fuel cycle services has become a respected major component of the industrial scene.

CURRENT STATUS OF NUCLEAR POWER GENERATION

The Magnox stations were designed for a 30 year life. As they approach 25 years, the Regulatory Authority has called for "long-term safety reviews", and several of these have now been completed. Decisions are having to be made whether to back-fit expensive improvements and, in the case of one station, the decision has been taken to shut it down this year at the age of 27 years. The economic case for these stations had been based on an assumed life of 20 years, and there is a general consensus that, with their high life-time availability, they have been a resounding (if rather unsung) success.

The AGRs are (like the Magnox stations) of diverse designs within the general technological concept, and their performance to date has been variable. Some stations have operated at high load-factor, others have been plagued by construction delays and safety problems. At least partly due to this difference, the two "nuclear" generating boards within the UK have quite different perceptions of the success of these stations. Whereas the Central Electricity Generating Board (CEGB), covering England and Wales, is unhappy with its experience, and has announced its intention not to build any more AGRs, the much smaller South of Scotland Electricity Board (SSEB), covering the populous south of Scotland, regards its one AGR station, Hunterston B, as a great success and is pleased to have another, Torness, now operating.

A 1300 MW(e) PWR is under construction at Sizewell B (adjacent to the Sizewell A Magnox Station) for start-up in 1994, and a public inquiry is in progress for a further large PWR station at Hinkley Point.

Tables I and II list these stations. The total nuclear generation in 1987 was some 17.5% of all electricity generated.

A major program of fast reactor development has been undertaken over several decades, with a major prototype (PFR) of 250MW(e) at Dounreay, operating since the mid 1970s. With the timescale for economic viability of this system having gone back into the next century, the national program is being reduced, and PFR is to be shut down in 1994. Continuing R&D, design and assessment work is being undertaken within a European collaborative framework.

A great deal of assessment work is in hand to prepare for the decommissioning of nuclear plants not least to refine the cost estimates. Development effort is focused on the decommissioning and dismantling of the 110 MW(t) "Windscale Advanced Gas-cooled Reactor" at Sellafield, with national and European Community funding. This is going ahead in advance of need, in order to provide a demonstration of the technical and financial feasibility, and as a focus for the development of techniques and equipment.

THE FRONT END OF THE FUEL CYCLE

Fuel enrichment, conversion and fabrication for all these stations has been undertaken in the UK by British Nuclear Fuels plc (BNFL), who will also be making at least the first charge for the Sizewell B PWR. BNFL also has very substantial export business in uranium enrichment, conversion and fuel fabrication.

In the areas of uranium conversion, pellet production and fuel fabrication, the BNFL plants at Springfields are now being replaced by more modern plants designed to take advantage of new technological developments and to handle recycled material while meeting modern radiological standards. The BNFL-developed "integrated dry route" for uranium oxide production using continuous rotating kiln technology has been licensed to several foreign customers. A new oxide fuel complex is under construction for the production of all types of oxide fuels and will incorporate PWR and AGR fabrication plants. A new facility for the production of binderless uranium oxide granules and pellets will enable AGR and PWR fuel to be produced together for the first time on a commercial scale.

TABLE I

UK Operating Nuclear Power Stations

	STATION	GROSS RATING (MW(e))	START-UP DATE
	Berkeley	2 x 167	1962 to shut down March 1989
	Hunterston 'A'	2 x 169	1964
	Hinkley Point 'A'	2 x 282	1965
	Trawsfynydd	2 x 290	1965
MAGNOX	Dungeness 'A'	2 x 285	1965
	Sizewell 'A'	2 x 325	1966
	Oldbury	2 x 313	1967/68
	Wylfa	2 x 655	1971
	Bradwell	2 x 173	1962
	9 Stations	4984	
	Dungeness 'B'	2 x 660	1983/85
	Hinkley Point 'B'	2 x 660	1976
	Hunterston 'B'	2 x 660	1976/77
AGR	Hartlepool	2 x 666	1983/84
	Heysham '1'	2 x 666	1983/84
	Heysham '2'	2 x 660	1988
	Torness	2 x 660	1987/88
	7 Stations	9264	
	Sub-total	14248	

TABLE II

UK Nuclear Power Stations under Construction and Planned

	STATION	GROSS RATING	START-UP DATE MW(e))
	Sizewell B	1 X 1182	1994
	Hinkley Point 'C'	1 x 1182	Planning Inquiry
PWR	Hinkley Point 'D'	3 x 1182	Proposed
	Wylfa B	3 x 1182	Proposed
	Sizewell C	3 x 1182	Proposed

Enrichment is carried out at Capenhurst in centrifuge plants which are built and operated by BNFL on behalf of its majority-owned subsidiary Urenco (UK). BNFL has collaborated with Dutch and German companies since the early 1970s in the development and commercial exploitation of gas centrifuge technology.

As well as serving all the requirements of the UK nuclear power utilities, BNFL has substantial export business in the supply of fuel and enrichment services.

During the 1990s, approximately 2500t of uranium is expected to arise from the reprocessing of spent oxide reactor fuel. This uranium is a valuable resource which offers utilities significant reductions in reactor fuel costs; savings of up to 40% on the cost of using fresh fuel are possible.

These potential savings give a strong incentive to recycle this uranium in thermal reactors as soon as possible to obtain the maximum benefit. The THORP plant at BNFL Sellafield will produce a substantial part of this uranium. Urenco's centrifuge plants are eminently suitable for re-enriching recycled uranium. BNFL and Urenco are, together, offering a complete package of recycle services. This comprises:

- manufacture of UF_6 in a new dedicated plant (ECHO) at Springfields
- enrichment at Urenco centrifuge plants
- manufacture of UO_2 powder, pellets, fuel pins or complete PWR assemblies at Springfields
- management of the process interfaces, including scheduling and transport.

THE BACK END OF THE FUEL CYCLE

Storage of irradiated fuel under water followed by transport to the BNFL site at Sellafield for centralized under-water storage and then reprocessing is the standard route. In the case of the AGR fuel, this is dismantled for more compact storage and reprocessing awaits completion of the Thermal Oxide Reprocessing Plant (THORP) in 1992. This plant is designed to reprocess PWR and BWR fuel, as well as AGR, and contracts from Japanese and several European utilities for the whole of the originally estimated throughput have been signed and a substantial proportion of this fuel has been transported and is in store at the plant.

Transport

The statutory provisions for spent fuel transport stem from regulations and guidance laid down by the International Atomic Energy Agency (IAEA) and the responsibility for ensuring compliance in the UK lies with the Department of Transport.

Spent fuel has been transported extensively through Britain and in complete safety since 1962. In more than 9,000 journeys there have been no accidents involving the release of radioactivity. Currently there are around 500 flask movements a year.

The utilities transport spent fuel by rail to Sellafield in flasks which they own. BNFL is also in the business of transporting spent fuel from customers overseas. For this it uses flasks which it has developed and designed, special purpose ships with elaborate safety provisions and a special marine terminal at Barrow. From Barrow the flasks go the short distance to Sellafield by train. The same fleet of British ships is used to transport spent fuel from Japan to the COGEMA reprocessing plant at Cap la Hague.

Pond Storage of Spent Fuel

Storage of spent fuel under water in 'ponds' is a well proven practice in the UK. In addition to the reactor ponds, large central storage ponds at Sellafield provide the necessary buffer between the reactors and the reprocessing plant.

For example, the pond of the Fuel Handling Plant commissioned in 1985 can store over 5,000 tones of dismantled oxide fuel in water of controlled pH and temperature.

The first storage pond of THORP, with a capacity of 1500 tone, started receiving fuel in 1988. An extension with another 1500 ton will be commissioned later in 1989.

Reprocessing

Reprocessing has been undertaken at Sellafield for well over 30 years, originally for military purposes, but then for both strategic and waste management reasons. Annual throughputs of well over 1,000 tones of uranium have been regularly attained, and over 30,000 tones of uranium have been reprocessed. To date, over 15,000 tons of the uranium recovered by Magnox reprocessing has been recycled, and some 70% of all AGR fuel has been produced from this material, with substantial savings to the UK's bill for uranium import.

The Thermal Oxide Reprocessing Plant (THORP) is under construction at Sellafield for start-up in 1992. The whole of the originally planned throughput in the first ten years of operation (ie 6,000 te) has already been contracted two-thirds of it by foreign utilities. Letters of intent for some of the second ten years of capacity have been signed. Reassessment of capacity in the first ten years has indicated that further throughput could be obtained, and BNFL is now marketing this as well as second decade capacity at very favorable prices.

Radioactive Discharges

The most significant contribution to UK radioactive discharges to the environment comes from the reprocessing of spent nuclear fuel. Discharges from nuclear reactor sites are very low and well within authorization limits. Monitoring at all UK civil nuclear sites is carried out both by the utility and independent Government authorities.

At the Sellafield reprocessing site of BNFL, significant reductions have been made in the liquid discharges to sea over the past few years, mainly due to the introduction of several new plants. SIXEP, the Site Ion Exchange Effluent Plant (1985) treats low level liquid effluent, removing Caesium and Strontium. The Fuel Handling Plant (1986), using improved technology, stores spent Magnox and AGR fuel prior to reprocessing and has a facility to decan the Magnox fuel.

The Salt Evaporator (1986) concentrates salt-bearing liquors for storage and subsequent treatment, reducing the activity discharges to sea. Collectively, these new plants have reduced 'total alpha' and 'total beta' by factors of at least six and thirteen, respectively.

BNFL is spending over £500 million over the next few years to further treat effluents from reprocessing. The UK Radioactive Waste Management Advisory Committee (RWMAC) 5th Annual Report mentions that the expenditure of £250m at Sellafield saves an estimated one or two cancer deaths in the UK over the next 10,000 years, thus going significantly beyond ALARA in expenditure on dose reduction.

The United Kingdom Atomic Energy Authority (UKAEA) reprocess mixed oxide fuel from PFR at Dounreay, on the north coast of Scotland. Discharges from Dounreay are currently well below the authorization limits (under five per cent). There have been significant reductions of discharges over recent years as improved effluent treatment has been applied.

WASTE MANAGEMENT

High Level Waste

The bulk of the High Level Waste (HLW) in the UK is produced from reprocessing operations at Sellafield and comprises some 97-99% of the fission product activity of the original fuel in acid solution. Such liquid is concentrated by evaporation and presently stored in high integrity, shielded and cooled tanks prior to being vitrified in a plant now under construction (Windscale Vitrification Plant WVP). The plant is scheduled for operation in 1990 and its two operating lines will have a capacity to produce 240t of glass each year in 600 containers each of 150 liters capacity. This plant eliminates any requirement for further tanks for the storage of highly active liquor.

HLW liquor will be fed continuously into an inclined rotary calciner, heated along its length. The calciner is discharged into an induction-heated metallic melter together with glass-forming materials. Molten glass is periodically discharged through a freeze valve into 150 litre stainless steel containers. These are then stored for at least 50 years in an associated natural convection air-cooled store.

Intermediate Level Waste

A wide range of waste types falling into the intermediate level waste (ILW) category are stored at nuclear establishments throughout the UK generally in their raw (as-produced) form. This group includes alpha-active wastes which would be classified as TRU in the USA. Storage facilities range from 200 litre mild steel drums, through dry and water filled concrete vaults or silos, to large stainless steel vessels depending on the physical and radiochemical nature of the waste.

The strategy broadly adopted by the UK nuclear industry is that no additional raw waste storage facilities will be constructed: fresh waste will be encapsulated as it arises. Existing wastes will be retrieved for encapsulation on a timescale determined by the condition of existing stores, the capacity of relevant encapsulation plants and the availability of disposal.

A number of plants are at the planning, design or construction/commissioning stage in order to package ILW into a form suitable for disposal. At Dounreay, a plant to cement liquor from a Materials Testing Reactor is being inactively commissioned, whilst at Winfrith a plant is being constructed to cement sludge from the operation of the prototype Steam Generating Heavy Water Reactor (SGHWR), together with solid ILW items, into 500 litre drums. Decommissioning of the prototype Windscale Advanced Gas-cooled Reactor (WAGR) will produce ILW encapsulated in cement within approximately cubic 2m boxes and at least one additional plant will be required to treat the remainder of the ILW produced by UKAEA.

Some reactor operating waste (ion exchange resin) has already been encapsulated by CEGB in a polymer matrix at Trawsfynydd, although future packaging plants at power stations will be based on cement encapsulation in 500 litre drums. Dedicated power station facilities will be provided at the Sizewell B reactor, although mobile plants are being considered for use elsewhere for operation from about 1991 onwards.

The relatively large volumes of ILW produced by reprocessing at Sellafield will be packaged in plants which will come on stream progressively from 1989. The first plant will encapsulate the fresh arisings of Magnox cladding debris in a vented 500 litre stainless steel drum using a specially formulated cement grout. A second plant will encapsulate cladding and sludge wastes from THORP also in cement, whilst a third plant will package a ferric floc produced as a result of reducing the activity content of liquor discharged to sea. Additional treatment plants are under consideration with the expectation that a cement formulation can be used as the encapsulant in all cases. However, progress on a fourth plant designed to package waste containing substantial quantities of organic material is in abeyance until technical studies and assessments are completed. These will quantify the detrimental effects of disposing of organics and also identify the consequences of reducing the organic content of existing and future waste.

Waste Disposal

Within the United Kingdom the major arising of solid low level waste is due to fuel reprocessing carried out at the Sellafield site. BNFL owns and operates a disposal site for this waste at Drigg, which is located in West Cumbria about four miles south of Sellafield. The disposal site, which has been in operation since 1959, not only handles solid low level waste generated as a result of the Company's fuel cycle business, but also provides a disposal service to other producers of solid low level waste including hospitals and universities.

Past operations have involved the use of trenches cut so that a clay layer formed a low permeable base onto which waste was tipped. Infiltrating water was collected via the trench drainage system. Recently, BNFL has embarked upon a major program of improvements at its Drigg site. These include:

- capping of existing trenches and provision of cut-off barriers to limit the ingress of rain and ground water;
- the refurbishment of the trench drainage system;
- compaction of suitable wastes and containerization of all waste;
- construction for concrete lined vaults for future disposals, the first having been completed in January 1989.

The capacity for solid low level waste disposal at Drigg is limited. In addition, no disposal route exists for arisings of intermediate level waste. In 1982, the United Kingdom Government announced that the Nuclear Industry Radioactive Waste Executive (NIREX) was to be established. A main task of NIREX was to develop sites for the future disposal of low and intermediate level waste. Principal shareholders of NIREX consisted of the major waste producers from the nuclear industry, with the Government holding a nominal share.

Following a series of investigations, it was announced in May 1987 that on cost grounds no significant advantage existed for near-surface disposal of low level waste when compared with the marginal cost of disposing of it along with intermediate level waste in a deep repository. Consequently, work was orientated towards concentration on deep disposal routes.

In November 1987, NIREX issued a public consultation document entitled 'The Way Forward'. The national policy for radioactive waste disposal was discussed together with options for a potential repository. Among the main conclusions from the response to the consultation process were:

- safety was judged to be of paramount importance;
- there was little support for an under sea-bed repository accessed from off-shore;
- the monitoring and recoverability of waste was generally deemed to be important.

Immediately prior to the publication of 'The Way Forward', BNFL invited NIREX to include the Sellafield location as part of its program of studies. BNFL explained that it wished to contribute to the search for a deep repository by undertaking a preliminary geological investigation of the area and NIREX agreed. In order to formalize the arrangement BNFL and NIREX subsequently entered into an agreement whereby BNFL would undertake the site investigation work at Sellafield on behalf of and specified by NIREX.

There are two main components of the preliminary geological study. These can be summarized as:

- the drilling of a deep borehole, together with core logging, sampling and various down-hole tests;
- a regional seismic reflection survey both on and off-shore.

Subject to obtaining the necessary statutory approvals the work is expected to be completed within twelve months. A decision will then be made as to whether further expenditure associated with a full site characterization is justified.

THE FUTURE OF NUCLEAR POWER IN THE UK

Privatization of the Electricity Supply Industry

Under the Government's privatization proposals, the CEGB will be split into 3 separate companies: the National Power Company, which will own and operate roughly 70% of existing CEGB capacity including all of the CEGB's nuclear stations, the Power Generation Company, which will own and operate the CEGB's remaining stations, and the national Grid Company, which will own and operate the national high voltage transmission network. The existing regional distribution companies are also being privatized and will own the National Grid Company and importantly will under the new regime be responsible for ensuring security of supply, which will be achieved by a mixture of supply contracts with National Power, Power Generation and other existing or new generators.

In Scotland, the integrated structure of the industry is being left intact with the SSEB and the North of Scotland Hydro Board being privatized essentially as they are at present, albeit with some redistribution of assets including the formation of a joint company to own the Scottish nuclear stations.

Recognizing that strategic and environmental considerations outweigh short term economic and market considerations, the Government is establishing a regulatory framework for the privatized supply industry which not only obliges the distribution companies to purchase all of the capacity available from current UK nuclear stations, but also obliges the distribution companies to purchase the output from the planned initial UK program of 4 PWRs. If the costs of the output from these nuclear stations is greater than that from competing fossil stations, then the extra costs can be recovered from the distribution companies and their customers. In addition, the Government is taking powers to provide special funding for unforeseen increases in well-defined circumstances in the area of decommissioning, reprocessing, waste management and waste disposal. The provision of front-end and back-end services by BNFL to the successors to the CEGB and SSEB will be unchanged in scope and may even expand in some respects.

Reprocessing

The recycle of plutonium in fast breeder reactors is seen as a route to long-term energy independence. Although the likely timescale for commercial operation of fast reactors has receded well into the next century, the use of mixed oxide fuel in thermal reactors can be shown to be economically attractive within a range of cost and economic parameters. This is particularly so if the cost of reprocessing is considered to be justified by waste management considerations. At all events the cost of reprocessing can be partially offset to a significant degree by recycle of both plutonium and uranium. The new front-end plants being installed will process recycled uranium while meeting current and anticipated future radiological standards. The domestic market for mixed oxide fuel is seen as developing following on from experience in operating Sizewell B PWR with enriched uranium. The technology for its production has been well developed in the fast reactor program. With THORP coming into operation in 1992 and with a probable life of at least 20 years ahead of it, the future of reprocessing in the UK is reasonably assured well into the next century.

The Environment

Radioactive discharges from Sellafield having been so substantially reduced over the last decade, the environmental impact of the UK nuclear industry is very small. Public confidence, however, is only just recovering from the knock it received from the Chernobyl accident, which is still resulting in some food restrictions in the UK. Small environmental impact depends on vindication of our confidence that no accident of such a scale will occur in the UK. At the same time, environmental concern has been focusing more strongly on the effects of fossil fuel consumption, firstly acid rain, and more latterly the greenhouse effect. Whilst acid rain can be ameliorated by clean-up of flue gases, this is costly. No such option is available to deal with the greenhouse effect. Public opinion is already showing signs of coming round to considering that (as we have been saying all along) nuclear electricity is the best environmental option. This is a very hopeful development for the future of the industry.

CONCLUSION

Nuclear power (in the sense of nuclear electricity generation) is a well-established industry in the UK. The country is virtually self-sufficient in the fuel cycle, except, of course, that the uranium ore concentrate is imported. The industry makes a vital contribution to the economic health of the UK.

Considerable progress has been made in recent years in technology development and plant design and installation for the immobilization of radioactive wastes and for the reduction of radioactive discharges. Progress is being made towards the development of a disposal facility for intermediate level waste, which is the vital task ahead of us. Public understanding and support are vital pre-conditions. Much effort has been devoted to obtaining and retaining this support. Whilst there is no room for complacency, public opinion does seem to be moving in our direction.