MEETING THE CHALLENGE OF BNFL'S DECOMMISSIONING PROGRAMME

A E Sheil,
British Nuclear Fuels plc(BNFL)
Sellafield, Seascale
Cumbria, UK

ABSTRACT

The paper reviews the co-ordinated and integrated programme, adopted by BNFL, in the decommissioning of its radioactive plants. it examines BNFL's approach to the challenges posed by the eventual decommissioning of its 120 plants, its overall strategies, the constraints and the progress achieved to date, drawing on real experience from the 22 completed projects and the 24 projects currently underway.

INTRODUCTION

BNFL operates plants which cover the full nuclear cycle its four nuclear licensed sites. Although the Company was only formed in 1971, from the production wing of the United Kingdom Atomic Energy Authority, its sites date from the earliest days of the nuclear programme in the United Kingdom. Whilst the early plants, constructed in the late 1940s and early 1950s, were devoted to the military programme, the first of the civil power plants was in operation by 1956 and the Company's focus has changed progressively so that civil nuclear power is the main element of operations. The Company sites are licensed under the United Kingdom Nuclear Installation Act and all have decommissioning liabilities.

Capenhurst

Located to the south of Liverpool Capenhurst was the site for enrichment and enrichment development. The first plant was based on gaseous diffusion for the production of high enrichment levels for weapons programmes. The plant was converted for enrichment for civil reactor fuels and this was gradually replaced by the more efficient centrifuge technology. Centrifuge development and production was concentrated at Capenhurst and was integrated into the Eurenco enrichment collaboration. In the early 1990s BNFL's centrifuge operations were sold to Eurenco and no longer form part of the decommissioning liabilities. The decommissioning of the diffusion plant commenced in the mid 1980s initially to create space for additional centrifuge plants. The decommissioning, including the development of novel decontamination techniques, is nearing completion and has been able to free release the majority of the plant materials including several thousand tons of aluminium.

Springfields

Located near Preston in North West England the site has been devoted to fuel fabrication. Initially producing natural uranium aluminium clad fuels it has progressed to oxide fuels for gas and water cooled reactors. The site remains in full operation though several of the early facilities mainly associated with conversion have been decommissioned. It is anticipated that site will continue in operation though the fabrication of natural uranium fuels for the United Kingdom Magnox stations will cease about 2005. There is a modest decommissioning programme currently underway with the next main peak arising at the end of the Magnox programme. Radiologically there are few problems the main challenge being the minimisation of waste arisings.

Chapelcross

Situated in south west Scotland this was the second of the Company's Magnox reactor stations and was commissioned in 1959. The station consists of four reactor units with external boilers served by one fuel cooling pond and one turbine hall. The station is expected to remain operational until about at least 2005.

Sellafield

The largest of the Company's operational sites where the reprocessing operations are undertaken. Initial operations on the site were based on the Windscale Piles for the production of plutonium with the associated cooling, decanning, reprocessing, product finishing and waste management facilities. The Calder Hall Magnox civil power reactor station was opened in 1956 and the full commercial reprocessing of Magnox fuel in support of the United Kingdom civil power programme commenced in 1963. The Thorp plant for the reprocessing of oxide fuels commenced operations in 1993. Mixed oxide fuel for the Fast Reactor programme was also produced at Sellafield. The site has seen enormous development and increased integration with several of the early 1950s liquid effluent treatment facilities still in use serving the latest reprocessing facilities but linked to modern back end plant to significantly reduce environmental discharges. Solid Intermediate level waste (non heat generating but $>$ 12GBq/tonne) and high level liquid wastes have been accumulated and stored on the site since the commencement of reprocessing operations. The recovery and encapsulation of this intermediate level waste is in progress as is the vitrification of the high level wastes.

DECOMMISSIONING STRATEGY

History

Decommissioning primarily to release space for reuse has been carried out since the early days of nuclear operations but it was not until 1980s that decommissioning was seriously acknowledged as a necessary end of life activity for nuclear plants. Initial decommissioning programmes to address the already shut down plants were initiated in the early 1980s but the need to assess liabilities for the electricity supply industry privatisation in 1989 led to the development of a fully costed decommissioning programme for all the Company sites and all the plants, shut down, operational, under construction or just planned, the decommissioning policy review(DPR). A parallel assessment was carried out for the waste management programmes, the waste management policy review(WMPR).

Strategy Development

The decommissioning and waste reviews summarise the strategies and programmes together with the associated costs thus allowing optimisation on a macro scale and the calculation of the necessary financial provisions. WMPR addresses the waste routing and treatment issues together with interim storage. Its aim is to minimise the overall cost by maximising the utilisation of existing facilities and minimising the number of new plants needed. DPR recognises the longer term nature of the decommissioning programme, anticipated to extend beyond 2100, and seeks to prioritise and programme the plant decommissioning to achieve the minimum discounted overall cost recognising such factors as plant risk, surveillance and maintenance costs, waste route availability, interaction with other plants etc.. Not surprisingly the more fragile plutonium facilities attract a higher priority for early dismantling than for example the extremely robust reactors. Decommissioning cost modelling techniques (1) have been developed to facilitate this long term programming.

Development of project strategies

Once identified within the overall decommissioning programme the actual project strategies are developed on a case by case basis recognising the specific features of the plant, any links with operating plant and waste routing. Significant effort is devoted to the front end optioneering as an incorrect decision at this stage may result in significant wasted effort. Multi attribute techniques such as Kipner Traego are utilised to select options which are then subjected to value engineering processes to ensure the minimum necessary is undertaken. There is an acknowledged culture change required for engineers used to designing new plants with long operational lives and safety in depth to be able to produce minimum cost fit for purpose solutions that provide adequate safety and durability for the duration of a decommissioning project. A problem frequently faced is the lack of accurate plant data both construction and radiological. For the older plants the available engineering drawings reflect intent more than as built and often modifications were unrecorded. For plants where access is possible it is not always easy to identify the subtle variations and examples include large connections between glove boxes shown and built as bolted flanges but on decommissioning were found to have been also welded for additional security.

For plants where radiation dose rates preclude or substantially limit man access the acquisition of the necessary data is more difficult. All available techniques are utilised but the result may still be a wide bounding case for which it is difficult to develop an optimum solution. In such cases a phased approach is common with each phase aimed at completing a limited scope of work and acquiring improved data to allow the later stages to be planned. Ideally this approach should avoid the closing off of options for the later stages. The objective should be to allow each phase to be reasonably well defined, both for contractual and safety reasons. A project manager is nominated who is responsible for the overall control of the project and normally for the control and safety of the plant, occasionally this responsibility remains with the existing plant operators if decommissioning is being carried out in a section of an operating plant. It may be necessary to undertake development work in support of the project.

Some typical current decommissiong project examples are::

First Storage Pond

Built in the early 1950s to receive, cool and decan the fuel from the original Windscale Piles, and later adapted to handle Magnox fuel from the Calder and Chapelcross reactors, the plant ceased operation in 1963. The plant consists of two open cooling with an adjacent building housing twelve decanning bays and six withdrawal bays. The pond still contains some 190 skips containing fuel, isotopes, fuel hulls and a mixture of other wastes. Additionally there is a general accumulation of sludge and debris. Within the decanning bays there are overspill wastes from normal decanning operations including fuel rods, graphite and cladding together with residual material from experimental work for chemical decanning and provision of uranium 'pennies' for pilot reprocessing. Due to the period before decommissioning the building no longer achieved modern standards and following substantial stripping out new ventilation, environmental monitoring and cranage has been installed. All equipment has been stripped out from two of the decanning bays to allow the installation of the skip washing and sorting equipment and pre-wash and pre-sorting equipment has also been installed in one of the old winch houses within the pond. Most of the installation involves operations in up to 18' of contaminated water with extremely poor visibility. Commissioning of the equipment to allow sorting of the pond contents is in progress.

First Separation and Head End Plant

Built for the dissolution and chemical separation of the Windscale Pile fuel, including separation of the Plutonium, Uranium, medium active and highly active waste streams, the plant is extremely large being over ten floors (60 metres) high and consisting of four highly active and two medium active cells. The plant continued in operation for the reprocessing of Magnox fuel until 1965 when it was replaced by the Magnox reprocessing plant. The north half was then washed out and permanently shut down but the south side underwent extensive alterations including the removal of metal fuel dissolvers, installation of shearing, dissolver, accountancy and maintenance cells to allow head end operations on oxide fuel utilising part of the existing solvent extraction plant. Decommissioning of the plant poses a particular challenge due to the height of the cells, absence of in cell cranage, no designed access routes for equipment, varying radiological conditions, limited radiological data and absence of accurate as built drawings. A progressive approach is being taken to the decommissioning with the Medium active north(MAN) cell, the least radiologically challenging, being dismantled first followed by the other cells, thus allowing the thorough proving of techniques. Typically for older plants the cell ventilation was inadequate by modern standards and a new fully filtered system has been installed to support all decommissioning operations. A waste handling facility has been constructed adjacent to the MAN cell designed to be able to accept waste from all the plant cells and incorporates automatic remote robotic size reduction, mainly using plasma arc, linked to an integrated control system and 3D modelling. Access for the cell dismantling machine has been provided at high level and incorporates a manipulator system, deployed at the various levels in the cell, and a hoist to lower the cut components to the ground floor export link to the waste facility; wherever practicable standard components are used with the main development effort directed to special tooling and an integrated control system which links from a three dimensional model of the cell to the manipulator and size reduction robots and is aimed at minimising operator fatigue and maximising productivity. A separate project within the same plant is currently recovering fuel hulls and other debris from a silo constructed in the base of the plant to support oxide fuel pilot reprocessing.

Solvent Regeneration Plant

Built for regeneration of the Butex solvent utilised in the original reprocessing plant the plant is about 30 metres high and consists of six cells two of which were fitted out for the process, two were held in reserve, one was for general shielded R&D and one was for post irradiation examination of fuel. The solvent process performed better than expected and the two spare cells were released for other experimental work. Decommissioning of the first of the solvent regeneration cells is underway. There was no installed cell cranage but there were removable cell top concrete panels provided for initial construction. Optioneering concluded that top entry was the best approach and a size reduction facility incorporating cranage, tooling and access arrangements has been constructed and commissioned on top of cells 1 and 2. Following the provision of a filtered extract system it was possible to complete the removal of the residual inventory, particularly the Butex solvent which poses a significant fire hazard. Dismantling of cell 1 utilising manual techniques has been completed though the hazard posed by the possible presence of solvent necessitated special precautions to be taken. Based on the experience gained the cell 2 dismantling is now underway.

Plutonium Purification Plant

Built to purify the plutonium stream from the reprocessing plant the plant is large, being effectively two mirror image cells, four storeys high with a brick wall as the secondary containment, the vessels and pipework being the primary containment. The anticipated level of plant containment was not achieved and several leaks (all contained within the cells) and remedial works have led to a very high level of internal contamination. As the cell extract was not filtered the plant was a major contributor to the site aerial discharges and prior to allowing routine man entry for decommissioning it has been necessary to dismantle several feed system gloveboxes and install a new ventilation system, commissioned in late 1993. Following commissioning of the new ventilation system cell entries were possible and these confirmed the predicted extremely high levels of contamination and also discovered localised radiation sources in excess of 15mSv. Intrusive surveys of the cell vessels is now in progress to assess the amount of residual liquor. Dismantling will be undertaken manually, moving components to a waste handling facility, currently nearing completion, constructed on the South side of the plant, for size reduction and packaging. All external control, sampling and fuel cabinets have been progressively removed. As with many plutonium facilities there is the potential risk of criticality and extensive in situ inventory monitoring will be undertaken prior to the movement of vessels to the size reduction facility.

Plutonium Finishing Facilities

There are several redundant facilities associated with the handling, conversion and finishing of the plutonium product. Currently the most challenging is the third main plutonium finishing line for metal and oxide production which operated from 1963 until 1987. It is constructed in a series of over twenty gloveboxes linked by two conveyor systems and operated through a shielded face. The plant operating life and throughput greatly exceeded design expectations but has resulted in a significant hold up of material, particularly in the concentrate stock tanks, the conveyor systems and the furnaces. Contamination is extensive and radiation levels exceed 10mSv in several areas. Because of the radiation levels it was intended to utilise remote methods but it quickly became apparent that the extremely difficult access and the criticality hazard associated with the high residual inventory would make this approach difficult and costly. Extensive optioneering, modelling and value engineering studies were then applied to optimise the dismantling strategy and in particular the choice of manual in preference to remote dismantling approaches. The manual size reduction is practicable provided boxes are removed from the line and the location chosen for the size reduction facility was that left vacant following the earlier dismantling of the adjacent Co-precipitation Plant. Installation of the size reduction facility and associated tooling has been completed and actively commissioned. The techniques to be used have been well proven on three smaller facilities which covered a similar total area. The use of plasma arc cutting for high plutonium waste was pioneered in this area and the necessary associated fume containment and treatment was developed. The speed at which the other areas have been cleared is a clear demonstration of the success of the process.

Fast Reactor Fuel Facilities

The Co-precipitation and Dry Recovery plants associated with the conversion of recovered plutonium and uranium for the fast reactor programme have already been totally decommissioned. These plants formed the basis for the development of many of the techniques and equipment needed for plutonium plant decommissioning including in situ inventory assay, containment and decontamination, size reduction, and recirculating suit showers with water treatment. The current operations centre on the PFR Fuel Fabrication Facility and the associated Dry Granule Production Plant (DGPP) which provided the mixed oxide fuel granules. The PFR plant converted the granules into pellets which were then loaded into fuel pins and finally assembled into fuel assemblies for shipment to Dounreay. Decommissioning of the final assembly area, pin filling line, vibro-compaction suite and other areas has been completed utilising manual techniques. The final phase of the project, the fuel line where the pellets were prepared, is the most heavily contaminated and with significant dose rates often in excess of 10mSv will require remote dismantling. Following the earlier development work on Co-precipitation and Dry Recovery plants the PFR project can be termed production decommissioning with a large number of plant items to remove against tight financial and timescale targets. The DGPP plant was initially a pilot facility upgraded to full scale production. The result has been a significant decommissioning challenge in terms of residual inventory and dose rates combined with very restricted access. In addition to the techniques used on other projects it has been necessary to develop a manipulator system to allow remote dismantling of the main part of the plant. Following extensive off site development and training, utilising full scale mock ups, the machine is now deployed on the plant, this will be moved to the PFR plant on completion of DGPP. Many of the systems are common with the machines being developed for other projects. In most cases the same control, viewing systems, end effect manipulators and tooling are used, the main differences being the deployment platforms.

WASTE MANAGEMENT

The waste management issues for most of the sites are straightforward with most arisings being of low specific activity and able to be sent to local tips or the Drigg shallow burial site. The Sellafield site however has specific challenges resulting from the reprocessing operations carried out. Historic ILW is stored in silos whilst high level liquid waste is stored in tanks. The Company policy is for current generated waste to be stored in a solid immobilised form which is cementation for ILW and vitrification for HLW and appropriate plants are in operation. The recovery of historic ILW from the wet and dry silos requires the provision of additional plants and integration with current operations. WMPR strategy has been developed over several years to ensure that a cost effective and safe solution is developed which minimises the number of new plants required and maximises the use of plants already operating in support of current reprocessing. The developed strategy is now being implemented.

B38 Wet Silo

The first 6 compartments of B38 were commissioned in the mid 60s to store Magnox fuel cladding and other ILW under water. The corrosion problem for Magnox swarf had been recognised and the salinity of the water was deliberately raised to accelerated this corrosion. Rapid corrosion however led to the evolution of hydrogen and local heating within the waste pile. The later extensions to the complex, undertaken in three phases(compartments 7-12, 13-18 and 19-22) have progressively increased provision for the cooling of the waste and the slowing of the corrosion process. Tipping of waste ceased in the late 80s and the assessment of emptying methods was initiated. Waste from compartments 19-22 with the latest material and reduced corrosion was compatible with the encapsulation plant supporting current reprocessing. A retrieval machine based on a petal grab is being successfully utilised with two compartments now emptied. For the earlier compartments the recovered waste is not compatible with current encapsulation plants and a purpose built plant which will dewater and compact the sludge is currently under construction. Because other waste was tipped which may be difficult to transport the recovery machines must also include sorting and size reduction. These machines are currently being manufactured.

B41 Dry silo

The first ILW silo on the site it consists of 6 compartments linked by an enclosed tipping corridor. In addition to aluminium and Magnox fuel cladding graphite, laboratory and other wastes were tipped with minimal records. Access to the facility is extremely restricted due to later construction and the building structure has deteriorated. Again a dedicated plant will be required to sort, package and encapsulate the waste. The design of this plant and the associated retrieval equipment is at an advance stage.

TECHNOLOGY AND DEVELOPMENT

The projects described depend on the use of a wide range of technologies and techniques to enable them to achieve their objectives. A substantial Research and Development programme (2) was established in support of the Sellafield decommissioning projects in 1989 and has successfully provided important equipment and techniques. Examples of these include the in situ and fixed plutonium inventory assay equipment with significantly increased accuracy and the ability to cope with a variety of isotopic compositions, remote equipment backed up by a range of integrated control, modelling and viewing systems which minimise operator fatigue and improve effectiveness, data acquisition systems including three dimensional imaging, radiation modelling codes allowing the prediction of source data from a limited number of dose rate measurements and advanced decontamination methods which are extremely effective but with near zero discharges. The emphasis of the programme in support of current projects is to continually increase effectiveness and reliability recognising that decommissioning is a production scale operation. Whilst it has been demonstrated that the current decommissioning programme can be achieved with technologies available today the development programme also supports longer term developments, sometimes involving radical and emerging technologies, but all with the overall objective of reducing the cost of decommissioning in an environment when the constraints in the form of regulations, dose targets and discharges are expected to become increasingly more restrictive.

DECOMMISSIONING COSTS AND ACHIEVEMENT

The technical achievement of projects, whilst in itself of satisfaction to the engineers, must be matched by the ability to predict and achieve financial targets. BNFL has since 1988 assessed long term decommissioning costs for all its facilities, shut down, operating, under construction or planned and this is updated on a regular basis. The ability to forecast such long term costs is required to allow for the financial provision for future liabilities both on a global and plant specific basis. BNFL has developed a detailed plant decommissioning costing model (1) which utilises plant construction information, known or estimated radiological data to generate decommissioning costs, manpower and material requirements, decontamination effluent arisings, waste volumes and disposal container requirements. The reference data used in the calculations is based on currently available technology and techniques and where available real experience on decommissioning projects or other experimental or forecast data. The model has been used on twenty two major plants at Sellafield, including THORP where the provision for decommissioning is included in the cost of reprocessing. This long term forecast for all BNFL's liabilities has shown a downward trend, matched by a reduction in the parallel long term forecast of waste management costs. The reductions in the latter are very much due to the integrated site approach to the problem. For the current decommissioning projects up to April 1997 BNFL had completed some twenty two projects or major project phases and this has been achieved at 85% of the originally estimated cost. The current programme encompasses over 20 projects with the latest predicted outturn forecast being 87% of the orriginal forecasts.

INTERACTION WITH REGULATORS

Nuclear licensing arrangements in the United Kingdom include the requirement for the licensee to prepare decommissioning plans and programmes. For Sellafield this has been developed into an agreed 15 year Post Operational, Waste Retrieval and Decommissioning programme updated annually. For each project there is a more detailed interaction with the regulators which varies depending on the assessed level of risk within the project. The more difficult projects will require an overall safety case, detailed safety justifications for each phase and safety documentation for the construction and commissioning of any major facilities in support of the decommissioning. The overall safety case, which is not particularly detailed and is at a safety strategy level, and the first detailed phase submission would normally be required before work could commence. Further detailed phase submissions would be made at the appropriate time. For more simple projects it may be possible to cover all aspects in one document. Additional justification is required for waste generation and discharge authorisations. Particular attention is paid to projected dose uptake during the safety justification stage and formalised ALARP studies are implemented for most projects. A number of dose rate modelling techniques have been developed to assist the process and they allow rapid assessment of benefits achieved by additional shielding or removal of high sources. It is common for regulatory approval to be given in a number of stages with agreed 'hold points' where performance to date can be reviewed. Frequent contact with the regulator 'Site Inspector' is normal.

CONCLUSIONS

The decommissioning of the BNFL's sites presents an ongoing challenge requiring an integrated and co-ordinated programme. The successful completion of a number of projects and the large number of projects currently undergoing practical decommissioning demonstrate that decommissioning and the associated waste management can be successfully and cost effectively accomplished.

REFERENCES

(1) ELDER, W.F., BROTHERTON, C., HUTT, S. Mathematical Modelling of Nuclear Fuel Reprocessing Plants to Assess Decommissioning Liabilities.

(2) WALTERS, C.L. Overview of a Decommissioning Development Programme. Nuclear Decom '92.