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HSC Programme of Nuclear Safety Research Evaluation Report for 2006/07			

Purpose of the Paper

1. This paper is the report on the annual evaluation of the 2006/07 HSC (now HSE) Coordinated programme of nuclear safety research.

Background

2. This programme is overseen by HSE under original guidelines agreed by HSC with the DTI. The objectives of these guidelines include a balanced and adequate programme that maximises contributions to nuclear safety, and disseminates results appropriately. The programme should also support independent capability, and take suitable advantage of international collaboration.

3. The purpose of this evaluation is to assess the efficiency, effectiveness and benefit to nuclear safety of the Nuclear Power Reactor Programme, the Sellafield Nuclear Chemical Plant Programme and the UKAEA Programme which together form part of the HSC's (now HSE's) Nuclear Safety Research (NSR) Programme.

4. HSE coordinates the programme for operating nuclear power reactor sites with the nuclear licensees British Energy (BE) and Magnox Electric (now Magnox North). Arrangements for managing this coordination require that at the end of the annual programme HSE and the nuclear licensees evaluate the effectiveness, efficiency and benefit to nuclear safety of the research that was commissioned and that ND coordinates a report to HSE. Extracts from the Evaluation Reports presented to NuSAC RG6 in October 2007 are presented at annexes 1-3.

5. Although HSE does not approve the detail of the Sellafield and UKAEA programmes, the contents of programmes declared to HSE are determined by HSE making their safety concerns known to these licensees, who then develop a programme to address them. An evaluation of the 2006/07 Sellafield and UKAEA programmes are part of this paper. Extracts from the Evaluation Reports presented to NuSAC RG6 have been attached at Annexes 4 and 5 respectively.

Argument

6. The plan and outturn (excluding VAT and management charges) for the nuclear power reactor sites programme are compared below.

	Plan £k	Outturn £k	Outturn/plan
HSE	687	600	0.87
BE	3000	2800	0.93
Magnox	1300	1300	1.00
Total	4987	4700	0.94

7. A summary of the projects, by technical area and charge category, in the HSE Levy programme that were completed during 2006/07 and evaluated is shown in Table 1 of Annex 1. It may be seen that the cost was 13% less than the plan. This reduced outturn arose from a change in the way that UK participation in the OECD Halden Programme is paid for during the year. This change meant that HSE did not have to raise the money to pay the UK membership fee. Other factors contributing to the lower than expected spend were the strong pound, making participation in International Research programmes cheaper and the cancellation of a proposed new international project to evaluate fire models.

8. In summarising the evaluation of the HSE levy programme (Annex 1) it is concluded that the research was commissioned largely to plan and budget. For the great majority of the research the performance of the contractors was considered good or acceptable and 100% of the research outcomes were made available to the nuclear licensees of which 88% (all but one project) was considered of potential safety benefit to operating nuclear power plants with 75% of the projects yielding results that have already been applied. The Levy research programme was consistent with the declared overall programme strategy and is considered subjectively as having achieved the declared objectives of maintaining capability and taking appropriate benefit of international collaboration.

9. British Energy staff were diverted to major emergent operational issues, resulting in reduced research being undertaken by British Energy internal resource. External spend was, however, very close to the planned budget, although there were some reallocations of external resource. For example, a human factors project on Improved Procedures Development has been carried forward into 2007-08 because of internal resource restrictions and the need to spend more time developing the work specification. The budget for this work was re-allocated to enable a project on Level 2 Probabilistic Safety Analyses for Advanced Gas-cooled Reactors to be progressed.

10. The Nuclear Research Schedule for 2006/07 declared a Magnox Nuclear Research Index related research programme consisting of 53 projects, about half of which were to be undertaken in collaboration with British Energy. The research programme was drawn up and executed and delivered broadly in line with the intent described in this Schedule, against the background of the ongoing Magnox Station closure programme. Although research to support generation activities is still taking place, this is now limited, and, where necessary, is undertaken as part of specific safety case support programmes. The graphite-related, and control and

instrumentation research programmes, required to support generation at Oldbury and Wylfa, are the most significant generation-related research areas.

11. Table 2 of Annex 1 lists the benefits to be derived from research activities. The value of these benefits has to be balanced against the costs of undertaking the research and is dependent upon a number of factors; the ability of HSE's concerns to be addressed through means other than research; the time it will take for the research to bear fruit; the time to make a judgement on reasonable practicability. New research commissioned on the Magnox reactors has largely ceased as the four reactors at the last two generating stations are due for closure in 2008 and 2010. Therefore any safety issues requiring research will be undertaken through ND's regulatory interventions.

Consultation

12. The Nuclear Safety Advisory Committee, through its Review Group on research (NuSAC RG6) reviewed the HSE, British Energy and Magnox Electric evaluation reports at its October 2007 meeting. The Nuclear Decommissioning Authority, Ministry of Defence and DTI (now BERR) also attended the meeting as observers.

Presentation

13. HSE is committed to disseminating research results that have implications for nuclear safety, and has previously developed a strategy for the dissemination of information through the HSE Website, that has been agreed with Nuclear Licensees and endorsed by the NuSAC Review Group 6. Communications directorate has agreed to the presentation implications of this paper.

Financial/Resource Implications for HSE

14. The cost of the research commissioned by HSE and the programme management charges have been recovered by levying the reactor licensees. The costs of oversight of the Sellafield and UKAEA programmes were recovered through the regulatory route. There are no additional financial implications for HSE.

Action

15. The HSE Board is invited to note the evaluation of the 2006/07 programme.

Paper Clearance

16. This paper was cleared by correspondence with the Senior Management Team.

ANNEX 1

EVALUATION OF THE HSE LEVY PROGRAMME

Introduction

Various descriptions of the safety benefit were considered, not mutually exclusive. They were considered to be, in descending order of frequency of mention:

- Maintaining knowledge and expertise in the regulator and licensees
- Long term safety benefits
- Providing information for new safety cases
- Underpinning existing safety cases
- Reducing uncertainties
- Short term safety benefits
- Development of safety standards / guidelines

These descriptions are fairly subjective, and the results were broadly similar to last year. The high position of knowledge maintenance in the list and the preponderance of long-term benefits over short-term benefits were maintained. Research is not the only route for maintaining expertise for the regulator, and other routes include attendance at conferences or working groups of international agencies, and bilateral meetings with other regulators. It could be argued that some of the projects are aimed at informing the regulator generally rather than improving safety directly but this distinction was not considered.

Safety Benefits Generally

1. Compared to previous years there was a greater bias this year towards longer-term benefits as opposed to immediate short-term safety gains. The industry is expected to commission the majority of the short-term research, in order to ensure early and effective impact. ND also uses the support programme for confirmatory work. However despite the Project Officers' responses that more projects were of long-term benefit than of short-term benefit, in 75% of the projects the results could already be applied.

2. 87% of the projects (all but one) were regarded as providing actual or potential safety benefits to operating stations. However it is intrinsic in any true research that the outcome is uncertain, and this is regarded as an acceptable success rate.

Maintenance of expertise projects – ND access to Independent Technical Capability(ITC)

3. The one technical area addressed is.

Chemical Processes

HSE funded ITC work with consultants on both primary and secondary side corrosion chemistry, essentially funding them to attend international conferences. This aided our understanding of technical areas relevant to licensees' safety cases so we can carry out our regulatory duties more effectively.

Conclusions on Independent Technical Capability

4. This is the subject of an annual review by HSE, reported to NuSAC SCR in April 2007 in paper 07/9. This review confirmed that HSE's access to ITC is in a satisfactory state.

International collaboration projects

5. Four technical areas are considered.

External Events

- HSE funded participation in an international evaluation of fire models for nuclear power plants, organised by USNRC. This programme increased knowledge in the field and enabled computational data to be verified with experimental test work. The outcome of the work highlighted the need to generate guidance for the use of fire modelling in NPP applications.

- HSE funded participation in an IAEA Coordinated Research Project, safety significance for near field earthquakes. The purpose of this project was to validate model predictions with the experimental behaviour of structures.

Nuclear Physics

- HSE funded Magnox participation of two contractors in the European Working Group on Reactor Dosimetry. This carries out benchmarking exercises giving increased uniformity in standards, increasing confidence and maintaining awareness in international activities and developments.

Plant Life Management (steels)

- HSE funded a project to develop a Europe-wide database (GAIN – Gap Analysis for long term inspection needs for nuclear plants). This project identified the medium to long term inspection needs of nuclear plant, identified where these can be met by existing research and technological

development work and performed a GAP analysis which will attempt to direct future research.

Plant Modelling

- HSE funded a contribution to the FP6 PERFECT project to predict irradiation damage effects in reactor components. HSE's contribution established the availability of materials data as a precursor to a more extensive fracture modelling programme.

Conclusions on International collaboration

6. Three quarters of the evaluated projects are international. International collaboration is the subject of an annual review by HSE, last reported to NuSAC SCR in February 2007 in paper 07/10.

7. Work in this area is mainly PWR oriented. HSE's approach on PWR safety research has been largely to keep a watching brief on developments abroad and to participate in appropriate international projects when the opportunity arises.

Gap filling / Punitive top-up

8. Only one project came into this category.

External events

HSE funded collaboration of a strategic national project to confirm our understanding of the likelihood of tsunamogenic impacts in the UK with a view to establishing guidance.

Conclusions on Gap filling/ Punitive top-up

9. It is a satisfactory outcome for HSE's policy of obtaining consensus with Licensees as far as possible that only one project falls into this category.

Issue Closure

10. Issue closure is a measure for evaluation of the total (HSE levy and licensee commissioned NRI-related) programme. 50% of the issues related to the evaluated levy projects could be closed, which is the same as the previous year's figure. The levy programme arises mainly from issues of maintenance of capability and maintenance of contact with international activities. Depending how the issues are written, they may be often ongoing for considerable periods of time, and not amenable to closure by a single project, or they may be written for a specific project that was proposed to the UK from abroad. Therefore HSE does not regard issue closure as an important criterion for levy projects.

Table 1- Completed and evaluated projects classified by technical area and research category

Technical Area	*INT'L*	*ITC*	*Gap filling*	*Total*
Chemical Processes		1		*1*
Civil Engineering				*0*
Control and Instrumentation				*0*
External Events	2		*1*	*3*
Fission Products				*0*
Fuel and Core	0			*0*
Graphite		0		*0*
Human Factors				*0*
Nuclear Science	2			*2*
Nuclear Systems & Equipment				*0*
Plant Life Management	1			*1*
Plant Modelling	1	0		*1*
Probabilistic Safety Assessment				*0*
Radiological Safety				*0*
Waste Management & Decommissioning				*0*
Totals	*6*	*1*	*1*	*8*

INT'L International
ITC Independent technical capability (for HSE)
Gap Filling Where HSE commission work the Licensees decline

Table 2 –Summary of evaluation results

Research category	*% 06-07*	*% 05-06*
International activity	76	(67)
ND Independent Technical Capability	12	(27)
Licensee Essential Research Capability	0	(0)
Filling gap in licensee programme	12	(6)
Other	0	(0)

Safety benefits to operating stations	*% 06-07*	*% 05-06*
None	12	(12
Already applied	0	(56)
Immediately applicable	75	(0)
Applicable in next 5 years	0	(19)
Applicable in more than 5 years	0	(0)
When required	13	(13)

Safety benefits generally (%)	
Maintaining knowledge and expertise in the regulator and licensees	63
Long term safety benefits	87
Providing information for new safety cases	12
Underpinning existing safety cases	25
Reducing uncertainties	12
Development of safety standards / guidelines	25
Short term safety benefits	12

ANNEX 2

EVALUATION OF THE BRITISH ENERGY 2006-07 NUCLEAR SAFETY RESEARCH PROGRAMME

Introduction

There were major benefits seen in 2006-07 from the research work performed in this and earlier years. Examples of where the research programme has contributed to nuclear safety are provided here.

Benefits to Nuclear Safety

- In the Chemistry area, CO_2 oxidation test work is providing data to allow improvement in the assessment models for boiler material. This has led to improved predictions for Hartlepool boiler lifetime.
- From the Civil Engineering programme, results from earlier work on ageing of concrete materials assisted in activities to review the ageing of the Pre-stressed Concrete Pressure Vessels at Hinkley/Hunterston to underwrite operation beyond 30 years. Earlier projects on the effects of climate change also provided the basis for work in this area carried out to support new build studies.
- The ability to manufacture neutron flux detectors and cables is only possible because of previous strategic work in the Control and Instrumentation area.
- Access to Seismic Qualification testing data from the EPRI programme continues to be strongly beneficial, and has saved the cost of commissioning seismic qualification tests during the year.
- The Halden project rigs have provided useful fuel performance data. Notably, a series of tests has been very successful in revealing the effects of Loss of Coolant Accident in very high burn-up PWR fuel (80 to 90 GWd/tU).
- Eddy current and deep-hole drilling developments are influencing the strategy for production of the next generation of graphite core inspection equipment
- The results of previous human factors research on situational awareness, accident management training and team skills training have been valuable inputs to the recently completed research project on Modelling Behaviour in Emergencies.
- Previous structural integrity work on the influence of changes in operating temperature on creep crack growth (performed to assess effects in Magnox vessels) has been used to evaluate the effects of reduced temperature on creep crack growth rates in the Hinkley/Hunterston Advanced Gas-cooled Reactor boiler bifurcations.
- The multi-physics finite-element code FEAT, supported by the research programme, has been used in safety cases generally, including Hinkley/Hunterston return to service at 70% power (graphite and bifurcations).

ANNEX 3

EVALUATION OF THE MAGNOX ELECTRIC 2006-07 NUCLEAR SAFETY RELATED RESEARCH PROGRAMME

INTRODUCTION

It is recognised that the benefits provided to nuclear safety are a key indicator in assessing the programme's effectiveness. In order to help evaluate the outcome of the 2006/07 research programme and to provide some further detail of the type of work undertaken, some examples of the projects are provided below together with their actual or potential application in improving nuclear safety.

BENEFIT TO NUCLEAR SAFETY

Control and Instrumentation

Magnox Electric contributes to funding of a wide range of research work in the area of Control and Instrumentation Engineering, including safety-related software. The whole of this programme of research work is carried out collaboratively with British Energy and Sellafield Limited in a programme of work which is now also supported by the Atomic Weapons Establishment (AWE). As British Energy is the major financial contributor to the joint programme, most of the individual projects are managed contractually by British Energy. The highly collaborative approach is efficient and provides tangible benefits to all participants including allowing efficient use of scarce specialist resource by the industry members. It also facilitates open exchange of information and ideas, and a common knowledge base across the nuclear industry sector contributors.

The programme of work is directed and reviewed via the Control and Instrumentation Nuclear Industry Forum (CINIF). The CINIF includes membership from British Energy, Sellafield Limited, Magnox Electric, HSE and AWE. Quarterly meetings are held in order to review the direction of the work, work progress and to review and agree proposals for future work.

During 2006/07, Magnox Electric has contributed to work on all of the projects as identified in the NRS. This included the following projects:

- Software Diversity (DISPO5), at City University.
- Software Diversity - Quantification (New DISPO2), at Bristol University.
- Statistical Systems Testing (New DDT), at Bristol University.
- Safety Implications for the use of PCs in Low Safety Integrity Level (SIL) Systems, at Adelard Ltd.

- Benefits of diverse V&V technique sets (DiVVaTS) at LDRA Ltd.
- Safety implications of using Programmable Logic Controllers (PLCs) in Low SIL Applications, at Advantage Ltd.
- Further Investigations into Legacy Code Analysis (ILCA), at Advantage Ltd.
- Further Assessment of Smart Sensor Software (FEAST), at Adelard Ltd.
- Goal-based assessment of Commercial off The Shelf (COTS) products for safety related systems at Adelard Ltd.
- Formalising goal based safety justifications at Adelard Ltd.
- Generic Component Vendor-Based documents maintenance at Moore Industries Ltd.
- Use of Formal Methods in specification of high integrity safety systems, at York University.

In addition we have supported the following:

- Nucleonics Key Team, at Ultra Limited (formerly Canberra Harwell Ltd).
- Reactor Protection Equipment Key Team, at Alstec Limited (now owned by Babcock International Group plc).

Work on all of the Software projects has been progressed during the year with many reports issued. Currently a high priority within the industry is to establish an agreed approval route for use of SMART instruments at Safety Integrity Level 1 (SIL1) and Safety Integrity Level 2 (SIL2), and several of the projects have delivered results which contribute substantially to this aim. This includes completion of the Generic Component Vendor-Based documents maintenance tool, which is now being applied in assessment of potential suppliers (against IEC61508 etc. requirements), also case studies have been carried out on assessment of typical SMART devices (within the 'FEAST' project), and to apply test methods to sample SMART devices (within the 'New DDT' project). Techniques developed in these projects will be used in future substantiation of SMART devices. Other projects on use of PCs and also on use of PLCs in low Safety Integrity Level applications have produced guidelines covering the likely integrity claimable, and how supporting arguments for use of this type of equipment can be structured. The work on software diversity (DISPO) remains more theoretical, but is providing powerful insights into the nature of diversity claims and how to substantiate them.

The Nucleonics Key Team has carried out an agreed programme of work and has issued reports on several different topics. Notably this has included collation and review of detector on-load test data from each site, work to establish an alternative calibration facility for neutron sensitivity of new and spare detectors, work on small pulse breakdown specification for detector mineral-insulated cables, and initial work on breakthrough current in detectors. In addition, support was provided to current safety case issues, and regarding low sensitivity of some detectors found at Wylfa power station.

The Reactor Protection Equipment Key Team has addressed and issued reports on several different topics, including investigation of the possibilities for improving formality in the design process for hardware protection equipment (in conjunction with York University), and work on component obsolescence issues. Also an extensive investigation of 'noise' problems on trip set-point potentiometers has led to possible solutions to this troublesome operational issue.

The Control and Instrumentation R&D work covers a broad spectrum, and has ranged from relatively 'blue skies' theoretical investigation of software issues, such as aspects of diversity, to much more applied software assessment techniques such as the work on the Generic Component Vendor-Based documents maintenance software assessment tool. We are now increasingly in a position to build on the work done across several projects over many years. The recent and current work programme is now able to use the knowledge gained in order to be much more focussed on development of practical guidance, and techniques and methods which are capable of practical application in order to support software integrity claims made in safety cases.

Within the Key Teams the work is largely focused on applied aspects such as expert investigations of technical issues to support operational problems (equipment failures, obsolescence issues, technical advice to support modifications and safety cases etc.) as well as investigation of potential improvements to add formality to the design process for high integrity hardware. The majority of this work therefore has a direct role in supporting current safety cases and in contributing to understanding of failure modes of safety equipment, so as to maintain a good technical understanding and to facilitate optimal support for operation of existing equipment and modifications.

Recently, both of the specialist contractors who are supported under the Key Teams have been taken over by other organisations. This indicates the potential vulnerability of these specialist teams and underlines the importance of supporting the core capability via the Key Teams, so as to ensure that at least a minimal specialist capability is maintained. This is of strategic importance to Magnox Electric during the generation phase.

Graphite

The objectives, of the Magnox Electric Graphite R&D programme, in 2006/07 were to:

- support core graphite safety cases in generation for Oldbury and Wylfa;
- strengthen the Structural Integrity leg of the safety cases by providing better materials data, improving the understanding of materials behaviour and improving the stress analysis;
- strengthen the Consequences leg of the safety cases;
- strengthen the Inspection leg of the safety cases; and
- maintain stakeholder confidence by demonstrating that a research programme to address the above items is being progressed.

A total of 52 reports, addressing 33 research topics, were issued by the project during 2006/07 to support the graphite core integrity safety cases. The emphasis of the R&D work in 2006/07 was on activities related to Material Properties and Stress Analysis.

Highlights of the 2006/07 work programme included:

- production, testing, validation and endorsement of an improved version of the BEST computer program for prediction of graphite oxidation;

- implementation and testing of a new version of the FEAT-COILU PGA graphite stress analysis macro incorporating modelling of cracks and application of the program to explore the potential effects of hypothetical cracks in Oldbury and Wylfa graphite bricks;

- completion of an experimental feasibility study of candidate techniques for the measurement of Poisson's ratio of irradiated graphite;

- comprehensive review of the Magnox graphite creep model and an alternative model available at the Kurchatov Institute, Russia; and

- initial demonstration that the serial sectioning and imaging capabilities of Focussed Ion Beam microscopy can be used to map pore interconnectivity in graphite and measure pore sizes.

Magnox Electric collaborated with British Energy on selected research topics covering the following areas: development of an eddy current device to inspect for cracks emanating from keyway slots, modelling crack growth in complex heterogeneous brittle materials, microstructural modelling of the elastic and strength properties of nuclear graphite and experimental investigation into the crack initiation process in nuclear graphite.

Waste and Decommissioning

The Waste and Decommissioning section of the NRS forms by far the largest component of the planned research portfolio consisting of over 50% of the cost. Table 1 lists the projects undertaken during 2006/07. Three examples of these projects are described in outline below.

Fire Retardant Polymers for the Immobilisation of ILW (completed)

The immobilisation of Intermediate Level Waste (ILW) into passively safe monolithic waste forms is most commonly achieved using cement based grouts based on blended Ordinary Portland Cement (OPC) systems. However, for some waste types typical grout fluidities may be too low to fully penetrate the waste or there can be chemical compatibility concerns from the use of hydraulic cements. Under such circumstances there may be a case to consider using organic polymer systems.

However, such systems have perceived compatibility problems with the Phased Geological Repository Concept (PGRC). This pertains both to the production of degradation products (in the longer term) which might act to mobilise radionuclides, but also the relatively poor fire resistant properties associated with most organic materials. The fire resistance of waste packages is an important consideration of the disposability safety case during the storage, transport and operational phase of the PGRC.

This “look see” project consisted of a literature review and practical assessment studies to identify potential candidate fire retardant materials. Trials were carried out with polymer systems that have been identified as potential encapsulants of radioactive wastes (e.g. the vinyl-ester system known as VERI, and the epoxy system known as APS). The fire performance of these systems, both with and without addition of various combinations of two inorganic fire retardants – “Firebrake ZB fine” and aluminium hydroxide, was investigated.

While it is considered unlikely that any fire retardant would be able to impart total fire protection to a polymer infilled ILW waste product to withstand temperatures of 1000°C over a one hour period, tangible benefits were observed. Small scale trials (100 ml) with ~40 wt% loading of fire retardant with the epoxy system improved the retained solids from 2% to nearly 50% when heated to 500°C, and 35% at 1000°C for an hour. For the vinyl ester system a similar loading of fire retardant increased the retained solids to a similar extent. Without fire retardant both systems were observed to ignite at ~400°C, whereas the retardants prevented this occurring. Another benefit from the addition of fire retardants was the observed reduction in product exotherm during curing.

Larger scale trials (500 ml scale) of simulant inactive wastes (such as Lewatit and Fuel Element Debris) encapsulated with fire retardant polymer systems at high waste loadings demonstrated the potential applicability of the fire retarded systems to successfully encapsulate wastes.

Guidance for Care & Management of ILW Packages

This project reviewed the document Guidance for Care and Management of ILW Packages (2004) against current knowledge and strategy for management of ILW packages to identify aspects where improvements could be made in Magnox waste stores. Key conclusions include:

- The 500 year container lifetime target introduced as part of the PGRC requirements has challenging implications for the interim surface storage.
- Concerns that the future supply of container materials may have higher levels of impurities giving potentially lower corrosion resistance (e.g. greater recycling of steels).
- Some stainless steels with better corrosion resistant properties than the baseline austenitic steels (typically 316L) may require the guidance to be specifically updated if adopted. However, duplex steels are expected to have similar requirements for care as austenitic steels.
- A "multi-legged" approach is recommended to mitigate container corrosion during storage; the approach includes control of surface finish, and control of environmental conditions.

Long-term Integrity of Packaged Wastes (on-going)

The majority of the work under this general area is covered by three projects jointly funded with British Energy. These projects have been on-going for several years:

(a) Long term monitoring of simulated waste samples. The samples stored under controlled conditions at Winfrith continue to provide confidence in the long-term stability of grouted wastes.

(b) Gamma irradiation. The facility at Harwell continues to provide a route to test the behaviour of materials (encapsulants and waste materials) under conditions that may be encountered in the PGRC and during interim storage.

(c) Corrosion testing. The monitoring of corrosion of container materials at Culham in contact with realistic cement encapsulants continues to provide evidence for the longevity of waste containers and steel samples.

The monitoring work described above provides fundamental information to demonstrate the integrity of waste packages for the anticipated periods during encapsulation, interim storage, transport to the PGRC, emplacement and the early post-closure period following backfilling. The work underpins much of the information required by Magnox to underpin Letter of Compliance (Letter of Compliance) submissions to the Radioactive Waste Management Directorate-Nuclear Decommissioning Agency.

ANNEX 4

EVALUATION OF THE SELLAFIELD 2006/07 NUCLEAR SAFETY RESEARCH PROGRAMME

Introduction

In accordance with the established Sellafield Safety Research Arrangements agreed with HSE, documentation was produced in order to provide confidence to the regulator that technical issues were being addressed. The Technology Baseline and Underpinning Research and Development Document (TB&URD) is produced as part of the Life Time Plan submission to NDA. It has been agreed with NDA and HSE that the TBuRD can be used as an aid in satisfying the Arrangements between Sellafield Ltd and HSE. Work has been taken in this evaluation from the successes highlighted in the TBuRD to provide examples of research activities that impact upon safety.

Examples of Research Activities

Highlights from the TB&URD that address safety related issues highlighted in the review process have been drawn out below.

High Level Waste Plants

Evaporator coil inspections: Evaporator operation is a highly corrosive environment and as they age there is a need to confirm that remnant life is within safety case criteria. A remote inspection system has been deployed to examine wall thicknesses of coils in the Highly Active (HA) evaporators. Development and testing of the equipment in a mock up of the plant demonstrated the safety of the procedure. The results have now been combined with modelling work on the evaporator operating conditions and temperatures and with materials assessments to provide an estimate of the residual life of the evaporators, and underpin the renewal of the Evaporator A operational safety case. This work will support the future use of HA evaporators, enabling continued reprocessing on the Sellafield site.

Nitrate dosing of HA storage tank cooling coils: A cooling capability is essential to maintaining the correct operating temperature in HA storage tanks. Previous work has shown that the cooling water itself has the potential to corrode the coils, which if they fail have to be removed from use. A programme of development work has shown that dosing of the cooling water with nitrate has the ability to passivate the system and prevent corrosion. Work has also been done to show that the transient condition whilst changing to a nitrate dosed regime will not give a significantly enhanced corrosion rate. This outcome provides the best opportunity for maximising the life of the Highly Active Storage Tank fleet unto 2015 when volumes of HA liquor are reduced to buffer levels.

Magnox Container Sampling Rig

Spent Magnox fuel is stored underwater in flasks whilst it awaits reprocessing. Previously it was not possible to know the conditions inside the fuel containers during storage, only when they were opened could assessments be made. To overcome this issue a remote sampling rig has been developed and deployed. Cost effective development was done by using inactive rig hall work. The first deployment of the rig demonstrated that the water chemistry of a particular batch of containers was within the acceptable range for normal processing.

Thorp Assessment of Plant Integrity

Inspection of key plant items within shielded cells using specialised remote viewing equipment, demonstrated their readiness for restart. As an example new techniques were developed to carry out remote inspections of the internal surfaces of the Thorp fuel dissolver vessels, which are highly active. These methods are simple and effective.

Dissolver Thermowells: These are engineered pockets for temperature sensors, which protect them from the corrosive, highly radioactive dissolver contents. Premature failure was predicted from ultrasonic thickness measurement and so engineering modifications have been made. Technical assessment supported development of a new safety case for their use.

Dissolver Heating and Cooling Circuits: Maintaining the integrity of heating and cooling circuits in the dissolvers is essential, as is being able to successfully demonstrate their integrity. Computerised stress analysis and temperature modelling have been used to demonstrate the long term integrity of Thorp dissolver jackets and pipework. In addition, an on-line oxygen monitor has been installed within the dissolver heating circuit to improve process monitoring by demonstrating that water quality is being effectively controlled and thus will not have an adverse effect on plant integrity.

Leak Detection System in TPFL: Work has been carried out on techniques for the detection of small liquid or powder leaks in process plants. Amongst the options being evaluated are techniques that are new to the nuclear industry as well as a completely novel technique. Implementation of the most appropriate method will reduce reliance on visual inspection and so reduce dose received by the workforce.

Site Ion-Exchange Plant (SIXEP) Competing Ions

The effectiveness of the ion exchange material used by SIXEP to remove radioactive caesium and strontium from effluents can be adversely affected by other ions in the waste. Work has been undertaken to further understand the effects of competing ions on that performance. This work has established what controls on donor feeds to SIXEP need to be in place to ensure that they do not have a detrimental effect on SIXEP ion exchange capability and supports minimisation of discharge to the marine environment and will enable

a more informed judgement to be made on the compatibility of decommissioning effluents with the SIXEP process.

Legacy Ponds and Silos (LP&S)

An issue in the Pile fuel storage pond was uncertainty about the sludge settling behaviour and the extent of activity release during sludge mobilisation. This created concerns about pond visibility, the effectiveness of the thickening step, which forms part of the Local Sludge Treatment Plant (LSTP) process, and the challenge to be faced by the LETP. In order to obtain data from the real sludge in situ methods were developed for use in the active pond environment. Sludge sampling and disturbance trials within the pond confirmed that sludge settling behaviour and the extent of activity release during sludge mobilisation will be within the bounds assumed for design purposes and so alleviated the concerns.

First Generation Magnox Storage Pond

A trial has been carried out on the encapsulation of Miscellaneous Beta-Gamma Waste (MBGW) from the pond. MBGW was retrieved, transferred to WEP and encapsulated under the existing Letter of Compliance (LoC). Retrieval of the MBGW involved the use of a cropper and the selected technology has been successfully demonstrated to avoid the crimping of tubular components at the point of cut. This is of importance for packaging, since it allows grout to infill hollow components.

Sellafield Direct Encapsulation

There has been a longstanding issue regarding graphite ignition. The previously threshold of 70°C for graphite waste treatment processes raised the concern that graphite in an encapsulation process could be ignited by the temperatures reached during the grout curing exotherm (demonstrated not to exceed 90°C). A more detailed consideration of the threshold temperature, which derived a limit from catalytic processes rather than directly from graphite chemistry, has led to an increase in the threshold to 100°C. This is a sufficiently high temperature to enable the dismissal of the possibility of graphite ignition during encapsulation. This work is directly relevant to other waste streams containing graphite.

Plutonium Contaminated Material (PCM)

The Waste Treatment Complex is currently constrained by its safety case to processing only drums that contain 50g of plutonium or less. This constraint greatly restricts the proportion of existing PCM waste which can be processed through the plant. The original design intent was for a limit in the range 230-260g, which would enable the plant to process ~95% of current drummed stocks. Technical underpinning and safety case work has supported a proposal that a greater limit was possible and would enable actual plant trials to be undertaken.

Decommissioning Characterisation

Facility Access/Egress: The organisation is continually trying to improve the safe working conditions of persons entering radioactive contaminated areas. Whilst remote technologies may remove some of the hazardous work, it is likely that man entries into these contaminated areas will always be required. A programme to introduce real time remote monitoring of personal vital statistics, such as position, dose uptake and temperature, is in the early stages of development. This will provide real time data to controllers who will be able to monitor the operator's status and provide data to build up a picture of best working practices at a local level.

Together with suppliers, efforts are underway to improve both visual and radiometric characterisation techniques. Gaining increased knowledge of the radioactive content and integrity of plant assists the safe implementation of later phases of work. For example the effective use of a small two dimensional gamma imaging technique has enabled a project team that is dealing with highly active cells in the first generation reprocessing plant to identify which of the internal structures pose the greatest radiological risk, without having to make a man entry into the cell. In a further example Lancaster University are currently engaged to look at novel methods of non-destructive profiling of the depth of radioactive isotopes within concrete structures.

Non-Destructive Examination Techniques: Promising results have been obtained from a recently completed PhD that was sponsored at Imperial College. The work looked at the use of ultrasonics for remote detection of the position of both partial and complete blockages in pipework. With so much pipework at Sellafield inaccessible to direct examination, a technique which can detect blockages from a position which is remote from the blockage could save much time and effort. The work was presented to a cross-industry seminar, along with future proposals for the use of ultrasonic devices to assess sludge properties.

ANNEX 5

EVALUATION OF THE 2006/07 UKAEA PROGRAMME

Introduction

There have been a number of key project focussed research and technology development successes supporting hazard reduction in the site Lifetime Plans. UKAEA has developed tools, methodologies and novel encapsuants to facilitate the cleanout and dismantling of specific facilities. This is consistent with 'ND Research Strategy Statement for Decommissioning Licensees' which underpins this programme. The table below groups the successes under each UKAEA site although some items contain elements of collaboration between the various sites.

Safety Benefits

R&TD Successes	Example of Safety Benefit
Dounreay	
Development of Water Vapour Nitrogen process	Reduced risk of pressure excursions. Reduction in inventory of hazardous material. Caustic effluent neutralised at source**.**
Use of Remote Operated Vehicle for particle detection on areas of the seabed	Eliminates risk faced by divers.
Shaft Isolation project – Development of a technique to isolate radioactive waste from groundwater	Will greatly reduce groundwater entering the shaft and becoming contaminated.
Development of Prototype Fast Reactor Pipe piercing tool	Development of equipment to assist in the draining of sodium from the complex reactor pipe work geometry and hence reduce the inventory of hazardous material.
Development of Prototype Fast Reactor Effluent treatment plant	Abatement of liquid waste discharges as required under the HSE Research Strategy.
Radiation seeking gamma camera to detect and retrieve radioactive material	Improvements to rapid determination of the location of hot spots and general characterisation of plant areas. Facilitates in the early removal of hotspots. Gamma cameras have the potential to reduce operator dose uptake on a variety of decontamination tasks by reducing the need for a hands-on approach.
Dounreay Fast Reactor decommissioning - confined space innovation	Linking a camera in the confined space to a laptop has improved communications between workers and observation teams.
Development of immobilisation techniques for liquid Intermediate Level Waste in cement at Dounreay and Harwell	Reduced mobility of hazard. The final product will be passively safe.

Harwell	
Field trials of soil vapour extraction techniques for chlorinated solvent contamination in chalk geology	The successful development of soil vapour extraction is enabling the removal of significantly greater quantities of contamination in the source term area than can be achieved by the groundwater plant alone and is expected to reduce remediation timescales. This work is of wider interest than the nuclear industry and is applicable to contaminated land remediation more generally.
Successful trialling of the Blast and Vac technique for surface decontamination	The total number of ISO containers consigned to the Low Level Waste Repository (LLWR) from Harwell was reduced affecting the capacity of the LLWR for other wastes. The use of the technique resulted in a reduction in low level waste volume of 85% from the original estimate.
Development of polymer encapsulation for radium contaminated ILW	The use of polymer encapsulation results in a reduction of the emanation of radon gases from the wastes, which will reduce worker exposure to radon and discharges to atmosphere during processing of these wastes to make them passively safe for long term storage.
Large scale grout trials to investigate chronic hydrogen evolution during encapsulation of ILW containing aluminium. Computational fluid dynamics modelling work to assess the impacts of hydrogen evolution on the ventilation systems of the buildings concerned.	The outcome of the R&D activities is a significant reduction in the assessed programme risk relating to hydrogen evolution during the encapsulation of ILW containing aluminium. Hydrogen generation was identified as a potential challenge to the ventilation systems of the Shielded Intermediate Level Waste store and the Waste Encapsulation Plant (WEP). The issue of hydrogen evolution has not been found to be significant for Waste Encapsulation Plant and no significant modifications are required to the Shielded Intermediate Level Waste store ventilation system.
Windscale	
Supporting technical work for the Pile 1 Operational Safety Case (OSC)	A number of technical packages of work were undertaken to support the safety arguments made in the OSC. The related papers were considered by the Windscale Projects Technical Committee. As a result of these studies the OSD was able to demonstrate that neither a criticality event nor a dust explosion event will occur, and that, if present, uranium hydride will not be a significant hazard. The revised OSC has justified reducing the radiological hazard category of the facility from 1 to 2 and facilitated efficient and effective decommissioning.
Development of Pile 1 Fuel and Isotope removal and segregation equipment	Enabling progress to next phase of hazard removal.
Development of tools for remote removal of debris from WAGR Tundish	The debris was removed using remotely deployed tools and packaged for disposal.
Development of Pile 1 Fuel and isotope helical screw liner operation, a novel waste retrieval and packaging concept	Configures waste in box avoiding labour intensive remote pick and place and also avoids criticality incidents in waste packaging operations.

Winfrith	
Develop Scale/Skeletal model of Steam Generating Heavy Water Reactor and Dragon Reactor neutron source environment	Investigation and trialling of various cutting techniques before working on the actual reactor has allowed the resolution of safety issues during practice runs.
Develop remote decommissioning trials to prove the practicality of remotely operated vehicle (ROV) deployment of Brokk tools	ROVs will increase the safety aspect of the process by enabling personnel to be remote from the activated environment and to operate in less restrictive conditions.