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<b>HSE Programme of Nuclear Safety Research Evaluation Report for 2007/08</b>			

### Purpose of the Paper

1. This paper is the report on the annual evaluation of the 2007/08 HSE Coordinated programme of nuclear safety research where ND reports on how the research has been utilised in the cause of nuclear safety.

### 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 Research Programme, the Sellafield Nuclear Chemical Plant Research Programme and the Dounreay Site Restoration Limited (DSRL) Research Programme which together form part of the HSE's (formerly HSC'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 (now re-named Research Review Group (RRG)) in October 2008 are presented at Annexes 1-3.
5. HSE does not approve the detail of the Sellafield and DSRL programmes. The contents of programmes declared to HSE are required to take account of safety concerns raised by HSE with each licensee. An evaluation of the 2007/08 Sellafield and DSRL programmes form part of this paper. Extracts from the Evaluation Reports presented to NuSAC RG6 have been attached as Annexes 4 and 5 respectively.

## Argument

- 6 The plan and outturn (excluding VAT and management charges) for the 2007/08 nuclear power reactor sites research programme are compared below.

	Plan £k	Outturn £k	Outturn/plan
HSE	488	511	1.05
BE	5100	5145	1.01
Magnox	1600	1000	0.63
Total	7188	6656	0.93

7. A summary of the projects, by technical area and charge category, in the HSE Levy programme that were completed during 2007/08 and evaluated is shown in Table 1 of Annex 1. In summarising the evaluation of the HSE levy programme (Annex 1) it is concluded that the research was commissioned largely to budget and the plan was implemented wherever possible, although there were a number of delays which were outside HSE's control. Programme adjustments were made during the year resulting in one more project than originally planned being commissioned and the outturn cost being £23k more than the plan. The reasons for this are as follows:
- Extension of the contract giving the UK access to the OECD NEA Nuclear databank was agreed during the year. This resulted in a significant increase in the levy programme costs. This increase was substantially offset by the cancellation of and delays to other planned projects.
  - The proposed contract for making a contribution in kind to the EU FP6 PERFECT programme was cancelled on account of the expected benefits from the work being judged as too little.
  - The take-up of seed corn funding by UK organisations wishing to make bids for participation in the European Union Framework 7 was substantially less than provided for. Three contracts were let under this programme.
  - The contracts for participation in the OECD PKL and ROSA thermal hydraulics project extensions were delayed by the NEA and could not be let during 2007-08 although they are expected to be let during 2008-09.
  - The subscriptions for participation in the USNRC CAMP and CSARP programmes could not be paid during 2007-08 because of protracted contract negotiations. They are expected to be paid during 2008-09 together with the arrears for the previous year.

- The two proposed water chemistry knowledge transfer contracts were consolidated into a single one. This programme could not start until late in the financial year because of delays in obtaining permission to use documents written by Electric Power Research Institute (EPRI) as training material, resulting in a significant underspend during 2007-08 and the contract having to be extended into 2008-09.

For the great majority of the research the performance of the contractors was considered good or acceptable although one contractor was marked lower on reporting standards, project management and financial control. All of the projects are evaluated as having delivered actual or potential safety benefits with 70% of the projects yielding results that have already been applied or can be applied immediately. 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.

8. For British Energy, outturn costs were close to plan across all technical areas. Both internal British Energy effort and external spend were close to plan, a change from previous years where British Energy staff were diverted to major emergent operational issues. There were minor delays to some projects relating to updates to the high temperature assessment procedure, R5, and the AGR materials handbook, R6, and the neutron dose benchmark reviews proved to be more onerous than anticipated. These projects have been carried over to the 2008/09 programme. The British Energy 2007/08 Nuclear Research Index related research programme continued to support a balanced and adequate nuclear safety research programme and made a positive contribution to nuclear safety.
9. The only significant underspend within the overall programme lay within the Magnox Programme. The RG6 paper produced on behalf of Magnox electric for 2007/08 declared a Magnox Nuclear Research Index related research programme consisting of 43 projects, 24 relating to Magnox North and 14 pertaining to Magnox South. Of the remaining projects 3 were funded through other work programmes and 2 were eventually cancelled. As noted within the paper the planning process at the time of writing, in January 2007, had then yet to be completed. The necessary funding to carry out all projects externally was not made available; the Magnox South projects were then earmarked to be carried out on a best endeavours basis when and where appropriate internal resource was available. Where internal work was carried out no estimate was made of the value of the completed work. The majority of the 2007/08 nuclear safety related research programme in waste and decommissioning proceeded as planned within the Magnox North R&D programme. Where work was not carried out most of this was transferred into the 2008/09 programme. ND considered that the funding was adequate to cover all urgent issues and concluded that in the short term no additional funding was required. Though 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.

10. As Annex 4 shows, Sellafield Ltd has undertaken significant R&D work that directly supports safety related issues across a wide range of technical areas. Annex 5 highlights that DSRL can demonstrate a number of key research and technology development successes supporting hazard reduction in the Dounreay Lifetime Plan. The safety research largely matches up with that documented through prior agreement within the TBUrDS.
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 and the time to make a judgement on reasonable practicability. In the 2007/08 programme new research commissioned on the Magnox Reactors had largely ceased as the plan was to close in 2008 and in 2010 the four reactors at the last two generating stations. This has now been superseded by the present programme as work is now planned to secure life extension.

### **Consultation**

12. The Nuclear Safety Advisory Committee, through its Review Group on research (NuSAC RG6) reviewed the HSE, British Energy and Magnox North evaluation reports at its October 2008 meeting. The Nuclear Decommissioning Authority and DTI (now BERR) also attended the meeting as observers. The Ministry of Defence did not attend. The Chief Scientist sent a representative to attend the meeting and had sight of this paper.

### **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 cleared the approach for disseminating the programme information.

## **Financial/Resource Implications for HSE**

14. The full 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 Dounreay Site Restoration Limited research programmes were recovered through the regulatory route. There are no additional financial implications for HSE.

## **Conclusions**

15. All of the projects within the HSE 2007/08 Levy Programme have been evaluated as having delivered actual or potential safety benefits with 70% of the projects yielding results which have already been applied or can be applied immediately. The Levy 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. The British Energy 2007/08 NRI related research programme is concluded to have continued to support a balanced and adequate nuclear safety research programme and to have made a positive contribution to nuclear safety. Magnox reported that the majority of the 2007/08 nuclear safety related research programme in waste and decommissioning proceeded as planned within the Magnox North R&D programme. Where work was not carried out most of this was transferred into the 2008/09 programme. Sellafield Ltd and Dounreay Site Restoration Limited have both reported examples of where their programmes have made actual or potential contributions to nuclear safety or hazard reduction.

## **Action**

16. The HSE Board is invited to note the evaluation of the 2007/08 programme.

## **Paper Clearance**

17. This paper was cleared by the Senior Management Team on 3 June 2009.

## **ANNEX 1**

### **Evaluation of the HSE 2007-08 Levy Programme**

#### **Introduction**

Various descriptions of the safety benefit were considered, not mutually exclusive. They were considered to be:

- 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. All of the levy projects that were evaluated were judged as contributing to knowledge maintenance in the regulator and licensees. Almost half of the projects evaluated were considered to be useful to the development of safety standards and guidelines. The evaluated projects contributed evenly to short- and long-term safety benefits and to underpinning existing safety cases, providing information for new safety cases and reducing uncertainties. Research is not the only route for maintaining expertise for the regulator. 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**

The projects have been broken down by technical area and category and detailed in Table 1. Details of the application of the research have been summarised in Table 2. There was no particular bias this year towards longer-term benefits as opposed to immediate short-term safety gains. In the past, the industry was expected to commission the majority of the short-term research, in order to ensure early and effective impact with the regulator commissioning longer term research. However, nowadays British Energy, the Nuclear Decommissioning Authority and its Site Licence Companies take a long-term strategic view of the benefits of research, so the even distribution of research effort towards short- and long-term safety gains is not unexpected. The regulator also uses the support programme for confirmatory work.

All of the projects 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.

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

The projects are categorised by technical area.

### *Chemical Processes*

HSE funded ITC work with a consultant on primary side corrosion chemistry, essentially funding him 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.

### *Graphite*

HSE funded ITC work with the University of Manchester to implement anisotropic constitutive relationships for AGR graphite and make improvements to graphite modelling codes. This work has aided the assessment of Oldbury graphite brick stress analyses by NII and Magnox Electric.

### *Conclusions on Independent Technical Capability*

This is the subject of an annual review by HSE, last reported to NuSAC RG6 in April 2008 in paper 08/09 as being in a satisfactory state. There are no extra conclusions arising from this evaluation.

## **International collaboration projects**

Three technical areas are considered.

### *Plant Modelling*

HSE funded participation in the OECD ARTIST project on steam generator tube rupture accidents at the Paul Scherrer Institute. The results of this work allowed a full plant scale investigation into secondary side radionuclide retention mechanisms during design basis and severe LWR accidents. The results have been used by overseas regulators but the project officer believes HSE would have got more benefit from this project if it had been able to send someone to project meetings.

### *PSA*

HSE participated in the EU FP6 SARNET:JPAZ activities. The purpose of this programme was to address the fragmentation that exists in the area of Level 2 PSA between different R&D organisations, harmonise methodologies applied for assessing risk and improve level 2 PSA tools. Participation in this programme has supported Essential Research Capability (ERC) in British Energy as well as enabling the further development of Level 2 PSA for Sizewell B.

### *Waste and Decommissioning*

HSE provided seed corn funding to two UK organisations to support their making bids to the EU FP7 programme for funds for the CARBOWASTE proposal. The bids have been successful in attracting FP7 funds to a Europe-wide consortium, including a number of UK organisations, to undertake research into the characterisation, treatment and disposition of irradiated graphite waste.

### *Conclusions on International collaboration*

Three quarters of the evaluated projects are international. International collaboration is the subject of an annual review by HSE, and its international strategy was last reported to NuSAC RG6 in April 2008 in paper 08/06. There are no extra conclusions arising from this evaluation.

These projects were oriented towards PWR and radioactive waste management. 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. Participation in international radioactive waste management programmes is a cost-effective way to get research results when several countries share common waste issues.

### **Issue Closure**

Issue closure is a measure for evaluation of the total (HSE levy and licensee commissioned NRI-related) programme. Only one of the issues related to the evaluated levy projects could be closed. This is a reflection of the maturity of the research needs in most areas of the NRI. Most of the research now required relates to the collection of data and intelligence with which to benchmark and underpin established models, codes, standards and methodologies for use in nuclear safety assessments. These represent a continuing duty by HSE and the nuclear licensees for as long as there are operational power reactors. The levy programme arises mainly from issues of maintenance of capability and maintenance of contact with international activities. Depending on 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.

### **Conclusions**

The Levy Programme for 2007/08 has been evaluated and the results are provided above. In summary:

- The results of the project evaluation are broadly in line with previous evaluations and are regarded as acceptable, especially given the uncertain nature of research outcomes.

- All of the projects are evaluated as having delivered actual or potential safety benefits.
- 70% of the projects yielded results which have already been applied or can be applied immediately.
- The Levy 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.
- None of the 07-08 levy projects involved HSE's Health and Safety Laboratory (HSL). It is now HSE policy to maximise the use of HSL as a source of scientific expertise. However although this will apply more to support contracts rather than to ND levy contracts, given the largely international nature of the levy projects, there may be potential for enhancing HSL's involvement in areas such as fire and thermal hydraulics testing and CFD modelling.

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

<i>Technical Area</i>	<i>INT'L</i>	<i>ITC</i>	<i>Total</i>
Chemical Processes		1	1
Civil Engineering			0
Control and Instrumentation			0
External Events			0
Fission Products			0
Fuel and Core			0
Graphite		1	1
Human Factors			0
Nuclear Science			0
Nuclear Systems & Equipment			0
Plant Life Management			0
Plant Modelling	1		1
Probabilistic Safety Assessment	1		1
Radiological Safety			0
Waste Management & Decommissioning	3		3
<i>Totals</i>	<i>5</i>	<i>2</i>	<i>7</i>

INT'L International

ITC Independent technical Capability (for HSE)

NB: There was no requirement to commission research that licensees declined to undertake.

**Table 2 –Summary of evaluation results**

<i>Research category (%) 2007/08</i>		<i>(2006-07)</i>
International activity	72	76
ND Independent Technical Capability	21	12
Licensee Essential Research Capability	7	0
Filling gap in licensee programme	0	12
Other	0	0

<b>Safety benefits to operating stations (%) (07-08)</b>		<b>(06-07)</b>
None	0	12
Already applied	45	0
Immediately applicable	14	75
Applicable in next 5 years	0	0
Applicable in more than 5 years	0	0
When required	42	13

<i>Safety benefits generally (%)</i>	
Maintaining knowledge and expertise in the regulator and licensees	100
Long term safety benefits	28
Providing information for new safety cases	14
Underpinning existing safety cases	14
Reducing uncertainties	12
Development of safety standards / guidelines	42
Short term safety benefits	14

## ANNEX 2

### EVALUATION OF BRITISH ENERGY 2007/08 NUCLEAR SAFETY RELATED RESEARCH PROGRAMME

#### **Introduction**

The 2007/08 nuclear safety related research programme was produced by British Energy (BE) using the research management arrangements. There were major benefits seen in 2007/08 from the research performed in this and earlier years. Examples of where the research programme has contributed to nuclear safety are provided below.

#### **Benefits to Nuclear Safety**

In the Chemistry area, the Wythenshawe boiler rig results underwrite the present and future operating chemistry of AGR station especially operation with wetted superheaters. The results of the other rig tests on Pressure Vessel Cooling Water (PVCW) corrosion, off load corrosion and CO<sub>2</sub> steel oxidation will be used to optimise the chemistry of these systems and minimise uncertainties in metal loss estimates.

From the Civil Engineering programme, interim results from the 2007-08 project on assessment of the ageing of PCPV pre-stressing tendon corrosion protection material ("grease") assisted in the assessment of the integrity of the Pre-stressed Concrete Pressure Vessel (PCPVs) before restart after outages. Results from earlier work on the properties of PCPV concrete materials under multiaxial stress states and elevated temperatures has informed the analysis of the boiler closure units (BCUs). The results from the research programme have not been formally codified into an analysis code, but knowledge of the results has assisted in the approach to the BCU analyses.

The increased use of smart instruments in Control & Instrumental nuclear applications had prompted further research on smart sensor justification. A case study assessment had been carried of an actual smart sensor, where evidence availability and requirements were reviewed and which produced a cost estimate of the smart sensor justification process. A further study on 'Smart Instruments Substantiation Infrastructure' was undertaken, resulting in a report on the guidance of dynamic and static analysis techniques for smart sensors. Guidance on using MS Windows operating systems, which covered system configuration, testing and migration to later versions, had been produced. This followed on from earlier research on the use of non-safety assured PCs in applications with modest integrity requirements.

With the work on Fault Studies and Fuel, there were major benefits in codes and infrastructure. There was a new version of the PANTHER-ENIGMA link

(which is an integral part of station compliance routes) and an issue of MACE. The Halden project continued to deliver data that will be of direct relevance to current Sizewell B improvement safety cases and other issues. In particular, Post Irradiation Examination (PIE) of Loss of Coolant Accident (LOCA) test fuel rods was reported, demonstrating the fragmentation behaviour of the fuel pellets in the clad balloon. This is of direct relevance to the proposal to increase fuel burnups at Sizewell B.

Improved understanding and modelling of the behaviour of polycrystalline graphite under simultaneous neutron irradiation and radiolytic oxidation has led to a new integrated framework for defining and modelling graphite property behaviour. This has led to improved predictions for material properties measured from trepanned samples and for changes in brick shapes. The new model has been used to review the observations and predictions of cracking in AGR fuel bricks, in particular the time for the onset and development of keyway root initiated cracking.

The Human Factors design guidance document on Design of Interfaces in Station Control Rooms, developed under the strategic programme, has been used as one of the two key references for the review of displays and controls against modern standards carried out as part of the Periodic Safety Reviews for the AGRs. The results from the project on Human Factors in Safety Cases have provided useful benchmarking information on the methods and approaches used by high hazard industries in assessing and integrating human contributions to safety.

With the work on Structural Integrity (Assessment Methods), methods developed for reducing conservatism in treating defects under combined primary and secondary loadings have been widely used for plant applications and have mitigated the effects of increased creep crack growth rates measured in long-term tests. The development of expertise in numerical simulation of welding residual stresses in austenitic steels has contributed significantly to progress on the boiler spine safety case. This has included the use of improved material constitutive models. .

With the work supporting Structural Integrity (Inspection), the writing of technical justifications for bifurcation and tailpipe inspections used strategic work on production of Handbook of Evidence and participation in European Network on Inspection Qualification (ENIQ). Similarly, the review of capability of construction radiography for an AGR gas baffle used the Pollitt spreadsheet developed previously under the strategic programme. These examples illustrate a key point that the benefits of strategic work may not be immediate but the infrastructure of knowledge set up can have unforeseen benefits in the longer term.

With the work on Structural Integrity (Thermal Hydraulics), the new mesh generation facilities in Finite Element Code (FEAT) have provided powerful semi-automated tools for providing 3d finite element meshes for arrays of tubes with bifurcations such as those in AGR serpentine boilers. The existing mesh generation facilities have been extended to allow material types to be

set and propagated and to provide a labelling facility for edges, both of which have recently been invaluable in the development of the thermal model of the BCU to investigate hot gas release faults. Large changes have been made to the graphite modelling capabilities of FEAT to allow more detailed modelling of the effects of irradiation, temperature and oxidation on graphite properties. This permits more accurate modelling of graphite weight loss, dimensional changes and internal stresses.

With work related to Structural Integrity (Materials), for two stations, a significant underestimate in the neutron dose estimates for components within the core restraint structure was identified during the year. The dosimetry research work improved the confidence and understanding of the revised neutron dose assessments. The Ageing Community tool was also used to support judgements made when considering the embrittlement of core restraint structures. The report on flux levels provides a characterisation of the effect of dose rates, particularly for Sizewell B (SXB) surveillance programme, where the effect of flux on surveillance specimens is shown to be small (i.e. their embrittlement is representative of the plant).

In the areas of Waste and Decommissioning, the work in which BE participates with British Nuclear Group (BNG) is important in the context of submissions for Letters of Comfort for disposal to a repository and the design/operation of ILW stores on power station sites. The plant trial currently underway at Dungeness B is assisting in the investigation and remediation of the biological growth problem throughout active effluent treatment plant. The Sizewell B Dry Fuel Store work is now forming a reference to the implementation project for the Sizewell B Spent Fuel Management.

## **Conclusions**

The British Energy 2007/08 NRI related research programme continued to support a balanced and adequate nuclear safety research programme and made a positive contribution to nuclear safety.

## ANNEX 3

### **EVALUATION OF THE MAGNOX 2007/08 NUCLEAR SAFETY RELATED RESEARCH PROGRAMME**

#### **Introduction**

During 2007/08 Magnox North and Magnox South had separate, but complementary, Research and Development (R&D) programmes. To ensure efficient realisation of the R&D projects, since there is substantial overlap between the R&D needs of both North and South, there is co-ordination of the waste and decommissioning R&D.

In order to help evaluate the outcome of the 2007/08 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 safety.

#### **Benefit to nuclear Safety**

##### Waste and Decommissioning

The benefits arising from this R&D programme were assessed at a technical stakeholder workshop held in February 2008. The following benefits were identified: maintenance of regulatory confidence; underpinning of the technical baseline; mitigation through improved understanding of technical risks; optimisation of the technical baseline; demonstration of sustainability of ILW packages; underpinning Letter of Compliance (LoC) and Radioactive Waste Management Cases (RWMC); supporting NDA legal requirements (e.g. skill development); motivation and development of technically oriented staff; training of practitioner and Intelligent Customer / Design Authority capability; information exchange with other Site Licence Companies (SLCs) (e.g. through the NWRP) and maintenance of profile at national/international waste and decommissioning events.

##### Graphite

The Graphite R&D Project is part of a programme of graphite safety case work. The overall objective of the Graphite Safety Case Programme is to establish a robust long-term position to secure generation to end of declared site lifetimes including: return to service of Oldbury Reactor 1 (R1); continued operation of Oldbury Reactor 2 (R2); continued operation of Wylfa reactors (without an extended outage) and maintaining stakeholder confidence.

The objectives of the Graphite R&D project are to: (a) support core graphite safety cases in production; 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; and maintain stakeholder confidence

by demonstrating that a research programme to address the above items is being progressed; (b) to mitigate against threats that may emerge from work undertaken over the period to plant closure; and (c) to demonstrate to the regulator and external parties that Magnox remains a learning organisation in managing the reactor core safety cases to the end of operating life.

Four research themes of the R&D were:

- Material Properties;
- Analysis, Inspection and Monitoring;
- Development of Failure;
- Methodology and Databases.

Within these themes, work has been carried out on 36 packages of work which collectively address the full scope of work (defined in the Detailed Volume). Major pieces of work included Poisson's ratio and density measurements; and modelling of dimensional change, creep and weight loss. In the area of fractures, an experimental programme of mechanical tests to improve the understanding of fracture initiation was completed. Additionally, a detailed review of crack-tip damage models has been carried out. In the area of inspection, a collaborative programme in conjunction with British Energy had the aim of developing an eddy current technique to detect graphite cracks that are not surface breaking.

## **Conclusions**

- The majority of the 2007/08 nuclear safety related research programme in waste & decommissioning proceeded as planned within the Magnox North R&D Programme. Where work was not carried out most of this has been transferred into the 2008/09 programme.
- Outline benefits as to how the research has contributed to nuclear safety, or is expected to do so in the near future, have been provided.
- Significant effort to collaborate with other SLCs and nuclear organisations continues to feature as a major theme of the waste & decommissioning R&D programmes.

## **ANNEX 4**

### **EVALUATION OF THE SELLAFIELD LTD 2007/08 NUCLEAR SAFETY RELATED RESEARCH PROGRAMME**

#### **Introduction**

The Technology Baseline and Underpinning Research and Development Document (TB&URD) for Sellafield is produced as part of the Life Time Plan submission to NDA. It has been agreed with NDA and NII that the TB&URD can be used as an aid in satisfying the Arrangements between Sellafield Ltd and NII for demonstrating that appropriate safety related research is being undertaken.

The basic review process involves the establishment of key technical contacts at NII and within the Sellafield Ltd organisation meeting to discuss technical issues. The results of these discussions and issues arising are used to produce Technical Strategies that are formally issued by NII to the organisation for consideration and if necessary for addressing through the establishment of further research work within the LTP.

#### **Examples of Research Activities**

Items from the TB&URD that address safety related issues have been drawn out below:

##### HA Evaporation, Storage and Vitrification

Significant R&D work has been carried out involving development and deployment of remote inspection devices, corrosion science laboratory testing, and complex computer modelling to predict the integrity and remaining safe asset lifetime for Highly Active (HA) evaporators and HA Storage Tanks. The evaporator studies have enhanced the fundamental understanding of the corrosion mechanisms occurring in HA liquor within steam heated stainless steel vessels. The radionuclide content of the liquors has been shown to have a complex effect on the corrosion rate, and the evidence indicates that oxide HA liquors from Thorp are more aggressive than Magnox HA liquors. Increased understanding of these mechanisms has allowed an accurate prediction of corrosion rates in areas of the evaporators which can not currently be accessed for remote inspection.

Corrosion experimental work has also provided an increased fundamental understanding of localised corrosion mechanisms relevant to HA storage tanks (HASTs) and the challenges associated with inhibiting waterside localised corrosion in high gamma radiation fields. Unique corrosion and inhibition studies have been carried out and peer reviewed by Regulators and worldwide corrosion experts, and are now being used to inform HAST strategy.

## Magnox Commercial Fuel Reprocessing

Sellafield had been contracted to process Aluminium clad fuel through Fuel Handling Plant (FHP) and Magnox Reprocessing, but there was concern that corrosion of the clad could occur during in-pond storage at Sellafield and result in damage to the ion exchange beds in SIXEP. Experimental work involving laboratory testing, ion exchange rig trials, and advanced analysis was carried out and showed that the risk to SIXEP was low.

## LP&S Clean-up

### *Silo Cooler Pumping Solution*

The plan to empty the silos involves reducing the level across all the silo compartments in two steps, to increase the ullage space above the waste and thus reduce the risks associated with hydrogen release. It is important during this process to continue pumping silo liquor through the water cooling system to keep the liquor cool and thus reduce corrosion rates and associated hydrogen generation in the silo. One of the successes this year has been to produce a process which will allow this cooling to be maintained through the process of emptying the whole silo, thus confirming the baseline design and allowing the hazard reduction project to progress.

### *Legacy Ponds*

The Pile Fuel Storage Pond work-stream encompasses a number of ponds and projects on the Sellafield Site. Within this stream, the local effluent treatment plant has been installed in the pond as a mitigator of the risk of uncertain activity release during sludge retrieval, and a concept Letter of Compliance for repository disposal has been obtained for the polymeric encapsulation of the resulting ion exchange cartridges. Small scale active and full scale inactive trials in support of an in-drum mixed grouted sludge product have shown that the presence of zinc compounds and algae in the sludge will not have an unacceptable effect on grout curing and product quality. Tests on the potential solubilisation of plutonium by the degradation products of algae have shown that this material is no worse than cellulose in this respect and it is therefore expected to be acceptable for repository disposal, and an interim Letter of Compliance submission has been prepared. Within the First Generation Magnox Storage Ponds stream, work has continued to improve understanding of sludge rheology, with trials continuing in support of sludge resuspension within the sludge buffer tank. Direct in-pond sampling and disturbance trials are to be initiated to improve confidence in estimates of the likely extent of activity release during retrieval. The competitive dialogue process for sludge packaging has progressed to the option development stage. The three surviving options are all based on intimate mixing with conventional grout, although high temperature and other processes were included in the previous phase. A consequence of this is that the product will contain small quantities of reactive metals and work is in progress to confirm that this will not give rise to long term disposability issues resulting from expansive corrosion.

## Legacy Silos

Within the Magnox Swarf Storage Silo stream, work has continued to resolve the issue of a potential hydrogen deflagration during retrievals. Empirical trials have shown that overpressures from an air-based deflagration exceed those predicted from the original model and could in some circumstances threaten the building structural integrity. However, another model is available which is known to be pessimistic but which otherwise gives results consistent with the empirical data. Both models indicate that deflagration overpressures are significantly lower in a reduced (but not immediately life-threatening) oxygen atmosphere and this has now been confirmed by laboratory trials. The intention is to extend this work to a full scale mock-up to provide the firmest possible underpinning for ALARP arguments balancing the options of air-based, reduced oxygen and inerted approaches against the need to mitigate the hazard posed by the waste as rapidly as possible.

The waste from the Magnox Swarf Storage Silo is to be conditioned and packaged in grout in the Silos Direct Encapsulation Plant. The waste contains substantial quantities of Magnox metal and, in some cases, metallic uranium and the packaging concept therefore includes a double skinned box with the annulus between the two skins initially left ungrouted. Considering Magnox alone, package lifetimes are expected to lie between hundreds and thousands of years. Trials are in progress to gain a better understanding of the behaviour of metallic uranium in grouted products. A submission for an interim Letter of Compliance has been made.

Within the Pile Fuel Cladding Silo stream, work has continued to gain a better understanding of the way in which the waste will have evolved during storage in the silo. Analysis of external dose rate measurements around the silo has been carried out. In combination with other inferential evidence, this is now expected to result in a substantial reduction in the best estimate of the uranium content of the silo, although it may not be possible to underpin this with sufficient rigour for use in safety cases. Modelling and actual drop-test trials of the project-specific box to be used for buffer storage of the Pile Fuel Cladding Silo waste have shown generally good performance, although some design refinement is still needed. Optioneering for the eventual packaging process is still at an early stage.

## Maintenance training

The UCF rig has been used to plan and practice on-plant maintenance tasks, such as removal of a large discharge valve from under the pellet mill. The ability to train and practice off-line has led to reduced down-time on the SMP plant.

## Liquid Activity Reduction trial (SIXOS)

An on-plant R&D trial has been carried out to assess how the SIXEP water treatment facility will perform when it is challenged with liquor from the Magnox swarf storage silo. The trial was needed because there was a risk that the very high level of Cs-137 activity within the silo liquor, or inactive chemicals e.g. magnesium and potassium could react with the ion exchange medium used in SIXEP and cause a reduction in efficiency, or even a reversal of the ion exchange effect and a release of activity. This project was called the Liquid Activity Reduction (LAR) trial and involved: analytical sampling, pH control, and proactive management of flow rates during the trial. Modelling using the chemical ion exchange model was key to underpinning the Environmental Impact Assessment for the trial, hence demonstrating to regulators that the environmental risk was acceptable. The aim of the work was to assess if it was feasible to remove contaminated water from the silo and replace it with clean water ahead of the retrieval of the solids, because this will allow early removal of the majority of the mobile hazard from the old silo. The trial successfully demonstrated the ability of SIXEP to treat silo liquor, thus opening the possibility of commencing reduction in the mobile hazard four years ahead of plan.

## Effluent and Encapsulation plants

Soluble salts are currently washed from Bulks floc down to a target of 1 g/l and discharged to sea. R&T has shown that floc will be successfully encapsulated at significantly higher salts concentrations - up to 5 g/l. This significantly reduces the amount of washing required and therefore the number of discharges to sea. This has led to reduced:

- on-plant dose uptake
- analysis costs
- batch cycling [ ~45 hr/batch less electricity]
- water usage [~45 m<sup>3</sup> wash water per batch]
- plant cooling
- environmental impact.

## Infrastructure and support services

### *Analytical Services*

An improved technique for C-14 analysis has been developed which ensures capture of both organic and inorganic carbon species. This technique will replace a time consuming wet analysis process and will provide both a faster output and increased accuracy and precision of results. The technique is to be implemented by Analytical Services during 2008.

### *EHS&Q Nuclear Codes Development*

Nuclear Codes Development work has been undertaken for a number of years collaboration with SERCO Assurance. This arrangement covers codes used for criticality and shielding applications and provides a means to help protect a scarce UK capability. Techniques have been developed which will

improve the effectiveness of shielding and criticality calculations including a new graphical visualisation and editing tool called Visual Workshop, which uses modern IT methods to allow the shielding and criticality assessor a means of creating, checking and visualising models; and a novel method of managing temperature effects in shielding and criticality calculations, which allows realistic calculations to be performed over the full range of typical process temperatures.

#### *Decommissioning Laser Scanning*

The degrading internal structures of the Highly Active North Outer (HANO) cell in the Primary Separation and Head End Plant have been imaged without the need for man access using a laser scanning system. The system was inserted through an engineered hole in the cell wall. The resulting images showed the degrading structure within the cell in three dimensions with sub-millimetre resolution. It is envisaged that this technique will be deployed in a number of cells where the condition of the contents are unknown.

#### *Stabilisation Grout*

The HANO cell pipes and vessels were unstable due to acid corrosion of the steel supporting structures. The lower section of the HANO cell has been filled with a low density stabilisation grout to prevent further movement of the items contained within. The grouting has removed the significant risk of a collapse of process plant.

## ANNEX 5

### EVALUATION OF THE DSRL 2007/08 PROGRAMME OF NUCLEAR SAFETY RELATED RESEARCH

#### Introduction

Dounreay Site Restoration Limited (DSRL) is the Site Licensee Company for Dounreay.

DSRL produces a Technical Baseline and Underpinning R&D (TBURD) document for the NDA in support of site Lifetime Plans. The document also identifies the safety related research addressing HSE's issues of interest, but it is difficult to separate this from the fundamental development work undertaken to support waste management and decommissioning.

#### Safety Benefits

There have been a number of key project focussed research and technology development successes supporting hazard reduction in the Dounreay Lifetime Plan. The table below summarises the main successes.

	R&TD Successes	Example of Benefit
1	An innovative purpose built device, nicknamed "Cyclops" has been used to measure radiation levels and video scenes in the extreme environment of the PFR reactor vessel. It was designed by DSRL's specialist design team.	The innovation reduces technical risk and has the potential to significantly reduce budget estimates for reactor dismantling.
2	PFR decommissioning has taken another significant step towards dismantling the reactor with the successful completion of the diagrid drilling. The holes allow additional sodium to drain to the reactor bottom for ease of removal. The project team was innovative by modifying the existing plenum drilling rig to reach the required target area.	Reduces the risk of a pressure excursion whilst removing the sodium residues by the water vapour nitrogen process.
3	The Sodium Inventory Disposal (SID) facility at PFR was successfully commissioned and is operating. The pioneering facility uses the Water Vapour Nitrogen (WVN) process developed at the Janetstown Off-Site Test (JOST) facility to destroy tritiated alkali metal residues from plant and vessels made redundant by decommissioning work.	The plant will clean-up the backlog of plant items contaminated with alkali metal residues and so reduce the risk of a fire or pressure excursion.

	R&TD Successes	Example of Benefit
4	To ensure that the latest beach monitoring equipment is more than capable of detecting particles, COMARE – the Committee on Medical and Radiation in the Environment – carried out beach monitoring trials at Dunnet beach in 2007 assisted by members of DPAG, SEPA and UKAEA. The results of the tests of “Groundhog Evolution” found that it was capable of meeting, and even exceeding the performance specified by SEPA. Preliminary data suggests that “Groundhog Evolution 2” performed even better under trial conditions.	Increased probability of detecting particles on the beach, thus reducing the risk to public health.
5	Trials using remotely operated vehicles (ROVs) on the seabed to detect and remove radioactive particle, were successful.	Removing radioactive particles reduces the risk of harm to the public
6	The plant being developed to remove and destroy the alkali metal coolant in the DFR reactor and primary circuits, the DFR NaK Disposal Plant (NDP), successfully completed inactive commissioning and is undergoing active commissioning.	The removal of the sodium-potassium coolant at DFR will reduce one of the biggest safety risks on site.
7	<p>The Shaft &amp; Silo Waste Retrieval project team has been busy conducting R&amp;D activities to reduce technical risk and has achieved the following significant technical successes;</p> <ul style="list-style-type: none"> <li>• Demonstration of X-Ray Tomography system to qualitatively and quantitatively characterise the waste in the 200 litre bins.</li> <li>• Successful encapsulation of supercompacted pucks in cementitious grout in 500 litre drums to the satisfaction of RWMD.</li> <li>• Screening of solids in a rotary screen to wash and dewater waste prior to supercompaction and encapsulation.</li> </ul>	Reduction of risk

	R&TD Successes	Example of Benefit
8	<p>Dounreay's waste shaft is now surrounded on all sides by a 10-metre wide band of grouted-up rock.</p> <p>The volume of water that needs to be pumped daily from the shaft to maintain its water level below that of sea-level has reduced from 15 m<sup>3</sup> at the start of grouting two years ago to 1.3m<sup>3</sup> today.</p>	<p>The amount of solid intermediate level waste generated from the process of removing radionuclides from the water, will be reduced. This reduces risk and dose to workers.</p>

### Safety Development Work

The assessment of risk from radiation is an integral part of assessing the safety of radioactive waste retrieval, processing and nuclear plant dismantling. There is an on-going need to maintain expertise in the field of Radiological Protection including understanding developments in the UK and overseas into research in radiobiology, radiation protection and epidemiology, to support risk assessments and secure compliance with IRR99. The overall approach includes but is not limited to membership of national and international bodies, attendance at networking for a, dissemination and adoption of cross-industry best practice and continuous professional training, e.g. DSRL is a member of the UK Working Party on Criticality and the Working Group for Shielding.

Monitoring of development requirements in Hazard Identification and Fault Modelling and Probabilistic Safety Analysis is provided and co-ordinated through Assurance Unit and promulgated through the updating of the Safety Assessments Handbook (SAH) and the safety case process. There is a three year rolling programme to review, maintain and update the SAH. In addition DSRL is part of the NDA Site Licence Company Safety Case forum and the SLC Peer Review forum. The aim of the safety case forum is to develop inter-SLC agreement on ways forward for common problems. These include the current challenge areas of safety case resource, methodology etc.

Human Factors assessment also forms part of the Safety Case process. DSRL attends the Working Group for Human and Organisational Factors (WGHO) to exchange information and experience about safety relevant human and organisational issues, including benchmarking when appropriate; reviewing where further research is needed; collaboration with other groups as necessary.

For Control and Instrumentation issues the approach includes but is not limited to, membership of national and international bodies, attendance at networking fora, dissemination and adoption of cross-industry best practice and continuous professional training.

### Conclusions

DSRL recognises the fundamental importance of appropriate nuclear safety research, although it is difficult to separate this from the fundamental development work being undertaken to support waste management and decommissioning. The

many technology successes throughout 2007/08 highlight that DSRL is at the forefront of innovation and development within the nuclear decommissioning industry. All of these activities are progressing continued hazard reduction.

The arrangements are underpinned by close and detailed exchanges with regulators for both technical and co-ordination issues and by continued dialogue with the NDA, other Site Licence Companies, national and international organisations.