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**NuSAC/RG6/08/11**

**HEALTH AND SAFETY EXECUTIVE  
NUCLEAR SAFETY ADVISORY COMMITTEE  
Review Group 6**

**7 OCTOBER 2008**

**EVALUATION OF THE HSC COORDINATED PROGRAMME OF NUCLEAR  
SAFETY RESEARCH 2007-08**

**Paper by HSE and Licensees**

**Introduction**

1. This paper is the report on the annual evaluation of the 2007/08 HSC (now HSE) coordinated programme of nuclear safety research. In a departure from previous years, the evaluation of the HSE Levy and the Licensee programmes, which together constitute the coordinated programme of nuclear safety research, are presented together as a single paper. Detailed evaluations of the programmes by the HSE and Licensees are presented in Annexes 1-5, together with a statement on progress with the commissioning of the 2008-09 programme presented in Annex 6.

**Background to the Evaluation Process**

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 Dounreay Site restoration Ltd. (DRSL) 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. These Evaluation Reports are then presented to NuSAC RG6 at the autumn meeting following the end of the evaluation year.

5. Although HSE does not approve the detail of the Sellafield and DRSL programmes, the contents of programmes declared to HSE are determined by HSE making their safety concerns known to these licensees, who then develop the nuclear safety research components of their programmes to address them. An evaluation of the 2007/08 Sellafield and DRSL programmes are part of this paper and are presented in Annexes 4 and 5 respectively.

### **Summary of the Evaluation of the 2007-08 Programme**

6. The detailed evaluation of the HSE 2007/08 Levy programme is presented in Annex 1. All of the projects are 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.

7. 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.

8. The evaluation of British Energy's contribution to the overall HSE coordinated programme of Nuclear Safety Research is presented in Annex 2. 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.

9. Magnox Electric report in Annex 3 that 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. Magnox Electric, Sellafield Ltd and Dounreay Site Restoration Ltd have all reported examples of where their 2007/08 nuclear safety related research programmes have made actual or potential contributions to nuclear safety or hazard reduction.

### **Action**

10. NuSAC Review Group 6 is invited to note and comment on the paper.

## Annex 1

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

1. Research programmes are evaluated as part of a cycle that leads to feedback and improvements in future arrangements. Public research programmes are also evaluated for reasons of accountability and auditability. This annex presents the results of the evaluation of the HSE levy programme (projects contracted by HSE with costs recovered from the reactor licensees by levy), which is part of the HSE coordinated programme of nuclear safety research
2. This annex presents a summary of Levy Programme project evaluations and also an evaluation with respect to the strategy and objectives of the programme.

#### The Levy Programme content and objectives

3. By voluntary agreement between HSE and the reactor licensees, the nuclear safety research work included in the Levy Programme comprises in principle three research categories:

- International Work: information exchange and collaborative projects. In addition to the research results, this gives benefits of benchmarking and networking.
- Independent Technical Capability (ITC) Support: - the maintenance of NII's access to ITC needed to provide advice to support regulatory assessment.
- 'Punitive top-up' – filling gaps perceived by the regulator in the licensees' programme that the licensees decline to address.

4. The levy programme executes the two supporting objectives of the original DTI Guidelines, on maintaining access to independent capability, and international collaboration. In contrast with the research projects commissioned by the licensees, where the primary objective is the results, the majority of the levy programme has primary objectives such as maintenance of expertise, networking and benchmarking which are generic. It is not straightforward to evaluate these generic objectives in terms of direct safety benefits. (See the remarks about issue closure below.)

#### Levy Programme Financial Outturn

5. The programme is given in table 3. A summary is shown in table 1, and it may be seen that there was one more project than planned and the outturn cost was £23k more than the plan. The reasons for this difference are set out below.
  - 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 however 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 not 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 were not 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 EPRI as training material, resulting in a significant under spend during 2007-08 and the contract having to be extended into 2008-09.

**Table 1 2007-08 Levy programme outturn**

	Planned	Outturn
No. projects	17	18
Cost	£488k	£511k

Note: These figures exclude VAT, management charges and receipts from users of the NEA Databank and USNRC codes.

### **Levy Programme Project Evaluation Process**

6. As many of the projects last more than one year, and also one-year projects started in a financial year may not be completed until some time after the end of the financial year, this report is not a precise evaluation of the 07-08 programme, but rather an evaluation of projects completed since the previous evaluation in October 2007 (7 in number). The projects and details of their evaluation are listed in table 3. The number of contracts that were evaluated in each research category and technical area are shown in table 4. The evaluations were undertaken by relevant ND Project Officers in conjunction with a consultant engaged by ND research unit and include their views on both the benefit of the research they commissioned and the performance of the various contractors concerned. The Project Officers are normally both the research technical area representative and a technical assessor for safety cases in that area, so they are qualified to judge the safety benefits of the research.

7. The questions used were the same as those used for the previous year's evaluation. This process is purely short term immediately after completion at the project level (rather than at programme level). For international collaboration projects, only the levy contract with the UK contractor was evaluated on a stand-alone basis, rather than the whole project, which is obviously an alternative (although one requiring a different approach). The results of most projects would only be implemented on a longer time scale (if at all), and a case can be made for repeating the evaluation later.

## **Evaluation results for safety benefits and meeting programme objectives**

### Issue closure

8. 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.

### Safety benefits generally

9. The quantitative results are summarised in Table 5. 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.

10. There was no particular bias this year towards longer-term benefits as opposed to immediate short-term safety gains. This may be compared with USNRC research policy, where the aim is to have about 80% confirmatory (short-term) research and 20% anticipatory (long-term) research. However there is a greater degree of collaboration in the UK research system. 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 License 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.

11. 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

12. 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*

13. 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

14. The projects are categorised by technical area.

##### *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 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*

15. 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.

16. 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.

#### Gap filling / Punitive top-up

17. No projects came into this category, reflecting the policy of obtaining consensus as far as possible.

### **Evaluation results for contractor performance and commercial considerations**

#### Procurement

18. HSE procurement policy is to use competitive tender for large projects, where the required staff effort may be justified. However, the nuclear field is relatively specialised, and none of the evaluated contracts went through a competitive tender process. This was mainly because of the limited range of contractors and their often unique experience, and the use of proprietary software. In some cases it was because the small value of the project meant it was not worth the expense of a tendering exercise. For ITC support, by definition there is a single team with the appropriate expertise, or a single team has already been selected for support. The declining range of contractors in specifically nuclear fields is the issue that led to the development of the ITC strategy.

19. The distribution of evaluated contractors was:

**Table 2 Contractors**

42%	UK consultancy and research firms.
16%	foreign companies / organisations
42%	universities
0%	licensees
0%	international organisations

20. Contractor performance was in general:

- good for meeting the technical criteria of meeting specification and objectives, scientific quality and all but one contractor provided a good standard of reports. This provides reassurance that the projects are adequately addressing the safety issues identified in the NRI.
- All but one contractor was rated good for financial criteria of value for money, meeting budget costs, meeting timescales and keeping project officers informed.

These results are poorer than the previous year on account of the relatively poor programme management by one contractor.

#### Collaboration

21.30% of the projects involved international collaboration and a further 40% of the projects were undertaken to promote international collaboration. Because of the Magnox closure programme and the future competition regime under NDA in nuclear clean-up, ND is now less concerned about collaboration on operational issues between the reactor licensees, and is more concerned about collaboration on clean-up issues.

#### IPR

22. None of the projects led to IPR exploitable by HSE. In general the work is either too specific or there is an intention to share freely (primarily with the licensees) or publish the results. Normally work which is likely to generate IPR is best commissioned and exploited by the licensees.

#### **Reporting and dissemination**

23. The results for reporting and dissemination are:

- For 42% of the projects it was intended to publish the work in peer-reviewed journals. A further 42% of projects (support for EU FP7 CARBOWASTE bids) are expected to produce results that can be published in peer reviewed journals as this programme yields results.
- All projects are discussed with the licensees at the regular technical exchanges.

- Electronic copies of Levy reports are placed on the ND server, and agreement has been reached with the licensees that levy reports can be placed on the HSE website. Because of HSE resource limitations, this has been started but not yet fully implemented. Licensee reports are placed on the HSE Intranet.
- Although HSE as a whole has been the government department with the highest number of requests under FOI, requests under FOI have had no effect to date on reporting of the nuclear safety research programme. New requirements regarding the security of nuclear information could affect the reporting of the nuclear safety research programme in future.
- As noted above, the quality of the reports was rated as generally good.

## Conclusions

24. The Levy Programme evaluation for 2007/08 is reported.

- 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 3 Levy Programme 07-08**

<b>Project No.</b>	<b>Title</b>	<b>Contractor</b>
CC/1048	ITC - PWR primary side water chemistry#	Moreson International
CC/1047	ITC -: Secondary side corrosion-chemistry issues	Moreson International
CC/1058	Water Chemistry Knowledge Transfer	AMEC
FC/GNSR/51	OECD CABRI High Burn-up Fuel Behaviour	IRSN
FC/GNSR/56	OECD Studsvik Cladding Integrity Project	Studsvik
GRA/GNSR/4	Microstructure/property relationships in nuclear graphite	Univ of Manchester
GRA/GNSR/6	Development of MAN UMAT; Anisotropic behaviour for AGR graphite; improve efficiency of analysis time.#	Univ. of Manchester
NS/GNSR/6	OECD/NEA Databank (UK Subscription)	
PM/GNSR/17	ARTIST Project on SGTR accidents#	PSI (Switzerland)
PM/GNSR/18	USNRC CAMP agreement	USNRC (USA)
PM/GNSR/19	USNRC CAMP agreement Computer Code Administration*	Serco Assurance
PM/GNSR/21	SARNET EU FP6 Severe Accident Research Network#	AMEC
PM/GNSR/22	NEA CSNI PKL Project	Framatome ANP (France)
PM/GNSR/25	NEA ROSA Project	JAERI
PRA/GNSR/25	NEA CSNI International Common-cause Data Exchange (ICDE)	OECD-NEA
WD/1041	Seedcorn Funding for EU FP7 bid#	AMEC
WD/1042	Seedcorn Funding for EU FP7 bid#	Univ. of Manchester
WD/1068	Seedcorn Funding for EU FP7 bid#	Univ. of Manchester

\* Transferred to TSO funding,  
# denotes project evaluated here

**Table 4 - Completed and evaluated projects classified by technical area and research category**

<i>Technical Area</i>	<i>INT'L</i>	<i>ITC</i>	<i>Gap filling</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			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>	5	2	0	7

INT'L International

ERC Essential Research Capability (for licensees)

ITC Independent technical Capability (for HSE)

**Table 5 –Summary of evaluation results**

<i>Research category (%)</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)

<i>Safety benefits to operating stations (%)</i>		<i>(06-07)</i>
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



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## Annex 2

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

#### **INTRODUCTION**

1. The 2007/08 nuclear safety related research programme was produced by British Energy (BE) using the research management arrangements. A Nuclear Research Schedule (NRS) was produced in February 2007 describing the proposed 2006/07 research programme. The research programme was summarised in the HSE paper NUSAC/SCR/07/2, presented at the February 2007 NUSAC/SCR meeting.

2. This Evaluation Report covers the BE 2007/08 research programme. Details are provided of the projects undertaken that addressed open issues in the Nuclear Research Index (NRI) and the associated costs and these can be compared with the intended programme outlined in the BE NRS and NUSAC/SCR/07/2. The report also provides examples of contributions the research programme has made to nuclear safety. This is consistent with the intended approach of evaluating the programme on the basis of the benefit that it provides to nuclear safety.

3. There was also a significant BE research programme undertaken in 2007/08 to address non-NRI related issues (previously known as the Industry Direct programme). Details of the proposed programme were summarised in the February 2007 NRS. Significant benefits from the programme are included in this annex.

4. This annex also discusses a number of issues related to the 2007/08 BE programme and issues for future programmes.

#### **BRITISH ENERGY 2007/08 PROGRAMME**

5. The proposed BE 2007/08 NRI related research programme is summarised in Table 1. → ←

6. The NRI-related projects were progressed in 2007/08 → ←

7. A comparison between the actual projects undertaken and the planned projects and the associated costs, shows the following:

- Outturn costs were close to plan across all technical areas. Both internal BE effort and external spend were close to plan, a change from previous years where BE 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, R66, and the neutron dose benchmark reviews proved to be more onerous than anticipated. These projects have been carried forward into the 2008/09 programme and increased funding has been allocated, in particular to the high temperature materials programmes.
  - There were some minor changes to projects. For example, work on the degradation mechanisms for concrete tanks was extended to include specific work for two stations; a considerable proportion of the work in fault studies and fuel focused on consolidation of existing skills and development of knowledge in recent recruits rather than addressing code/infrastructure obsolescence, which will be a major focus for 2008-09.
8. The costs on the non-NRI related work in the 2007/08 BE research programme were in excess of the plan so that the overall spend → ← was greater than the plan total → ←. It is believed that the programme has been a balanced and adequate nuclear safety related research programme. It has also contributed to the closure of a number of NRI issues.

## **BENEFITS TO NUCLEAR SAFETY**

9. There were major benefits seen in 2007-08 from the research work performed in this and earlier years. Examples of where the research programme has contributed to nuclear safety are provided here.

Chemistry. 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 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.

Civil Engineering. Interim results from the 2007-08 project on assessment of the ageing of PCPV prestressing tendon corrosion protection material ("grease") assisted in the assessment of the integrity of the 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.

Control and Instrumentation. The increased use of smart instruments in C&I 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.

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, PIE of 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.

Graphite. 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.

Human Factors. 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.

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. .

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 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.

Structural Integrity – Thermal Hydraulics. The new mesh generation facilities in 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.

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 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).

Waste and Decommissioning. The work in which BE participates with 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.

## **COLLABORATION AND TECHNICAL EXCHANGES**

10. During 2006/07, British Energy set up alliances with Imperial College and the universities of Bristol, Strathclyde and Manchester. During 2007/08, the alliances were strengthened with 86% of university work now with the alliance universities. There are now four Engineering Doctorate students (two from Strathclyde University, two from Bristol University) working with BE under schemes supported by the Engineering and Physical Sciences Research Council (EPSRC). British Energy is also a member of the Research Centre for Non-Destructive Evaluation, which is a consortium of universities providing support to a wide range of industries on inspection methods with some financial support from EPSRC.

11. Collaboration with Magnox continued in 2007/08 in the areas of Control and Instrumentation, Fault Studies and Fuel, Civil Engineering, Human Factors and Structural Integrity.

12. There was collaboration other than with Magnox on Control and Instrumentation work with AWE and BNG Risley and on Structural Integrity work with Rolls-Royce, Serco Assurance and TWI.

13. The EPRI contract provides a major source of international collaboration with work on a range of topics in the USA. This includes work relevant to AGRs as well as to Sizewell B. The Halden project involves wide international collaboration on fuel performance. British Energy is involved in collaborative European projects. In 2007/08, these included NESC (Network for Evaluating Steel Components), NET (Neutron Techniques for Residual Stress), ENIQ (European Network for Inspection and Qualification) and NULIFE (Nuclear Plant Life Prediction) in the structural integrity area. A Human Factors European project (MMOTION) with BE involvement will start in 2008/09. Other international collaboration occurs on goal based safety justification for C&I equipment with the Swedish, on international standards in C&I, with Japanese organizations on high temperature materials behaviour, through a VAMAS (Versailles Agreement on Advanced Materials and Structures) activity on assessment of high temperature weldments and on structural integrity through staff secondments on both directions with the Australian Nuclear Science and technology Organisation (ANSTO). As well as collaboration on specific projects, British Energy attends international and national working groups in all technical areas. These provide exchange of information and assist in maintaining knowledge up-to-date.

14. Technical Exchanges have continued to be monitored by HSE and the Licensee Research Co-ordinators and have proved to be effective in 2007/08.

## **CONCLUSION**

15. 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.

**TABLE 1**

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## Annex 3

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

#### Annex by Magnox Electric Ltd

#### BACKGROUND

- 1 Magnox Electric Ltd is a Site Licence Company (SLC) currently owned by the Nuclear Decommissioning Authority's (NDA) Management & Operations contractor, Energy Solutions. Since October 2007, the two regions have operated independently for a period of formal 'Shadow Working' in order to demonstrate capability and processes, followed by legal separation and the formation of new SLCs during 2008 – Magnox North Limited and Magnox South Limited. At the time of writing, legal separation was expected within a few weeks.
- 2 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. As discussed in more detail later, the majority of the baseline underpinning R&D is carried out by Magnox North, while Magnox South leads, through the Decommissioning Strategy Organisation (DSO), R&D that could ultimately underpin any future decision to change and improve the baseline technology. This relationship is not unique, with significant sharing and co-operation on R&D occurring with other licensees increasingly co-ordinated through groups such as the Nuclear Waste Research Forum (NWRF).
- 3 Both Magnox North and Magnox South now ensure that waste and decommissioning R&D meet the needs of the "NSD Research Strategy Statement for Decommissioning – Licensees 2007". The NDA also requires that R&D needs are identified so as to demonstrate that the Technical Baseline is secure through to Final Site Clearance. This is demonstrated via a document known as the Technical Baseline and underpinning Research & Development (TBUrd). This document details the technology risks, needs and opportunities in a transparent and auditable manner. Each Magnox North and Magnox South Site is required to publish a TBUrd document.
- 4 The Magnox Electric waste and decommissioning R&D programme for 2007/08, anticipated in mid January 2007, consisted of 43 projects (see Table 1). As noted then, there was uncertainty at the time because the planning process was not finalised. → ←

- 5 The eventual Magnox North R&D programme for 2007/08 consisted of 24 projects - see Tables 1 to 3. The Magnox South programme consisted of 14 projects - see Tables 1 and 4. Of the remaining projects originally proposed, three were funded through other work programmes: 36/07, 37/07 and 41/07, and related to technical support for the TBUrD and Integrated Waste Strategy programme. One project (26/07) was cancelled because a co-ordinated membership of the EPRI decommissioning programme was, at the time, anticipated for all of the NDA's SLCs. A further project (33/07) was cancelled because it was considered no longer directly relevant (it related to early reactor dismantling).
- 6 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. Both Oldbury and Wylfa are managed within Magnox North.

#### **PROJECT EVALUATION – MAGNOX NORTH 2007/08**

- 7 **Waste and Decommissioning.** ⇒ ⇐ The programme was commissioned, executed and delivered broadly in line with the rebased intent described above.
- 8 As outlined in Table 2, all 24 projects for 2007/08 have been declared as being completed. Of these, eight have been assessed to be closed out with no further R&D work planned in 2008/09. Eight projects are assessed as having long-term objectives that continue to be addressed as part of the 2008/09 programme (and potentially beyond). Seven projects have spawned further well-defined work, which are scheduled for completion during 2008/09. The output from five projects is being further developed within other programmes and projects (internal and external to Magnox). Only one project (35/07) is considered not to have fully met its scope. The scope of Project 35/07 included the intention to hold a workshop to share the Magnox TBUrDs with the supply chain; due to external factors this could not be realised during 2007/08. Following discussions at the NWRF, it is understood that this objective will be co-ordinated directly by the NDA for all the SLC's TBUrDs during 2008/09.
- 9 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 2007/08 research programme a brief summary of key findings is provided in Table 3. The output from the programme has been made available to all organisations through the NWRF.
- 10 **General benefits of waste and decommissioning R&D.** The benefits arising from the 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 SLCs (e.g. through the NWRP) and maintenance of profile at national/international waste and decommissioning events.

- 11 **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.

## **PROJECT EVALUATION – MAGNOX SOUTH 2007/08**

- 12 ⇒ ⇐ The fourteen projects, considered largely non-essential, were transferred to Magnox South with an expectation to resource internally. At the time of the transfer, tentative internal resource had been identified to carry out the work. The majority of the projects related to knowledge management activities and collation of existing information generated, in part, from previous years' Magnox-related R&D. None were fully completed during 2007/08. Most of these projects continue into the 2008/09 programme. Project 09/07 (see Table 1 and 4) was subsequently transferred back to Magnox North for inclusion within the funded Magnox North R&D programme 2008/09.
- 13 Magnox South leads, through the Decommissioning Strategy Organisation (DSO), R&D that could ultimately underpin any future decision to change and improve the baseline technology. The primary role of the DSO is to develop and optimise waste management and decommissioning strategies. It is recognised that existing strategies may not be optimum solutions and may not provide the best value for the customer. Work continued during 2007/08 in a number of areas including alternative waste management options for tritiated desiccant and IONSIV treatment.

## **CONCLUSIONS**

- 14 The following are noted
- 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.

## **ACTION REQUIRED**

- 15 Review Group 6 is invited to note and comment on the paper.

**Table 1 – Magnox R&D Programme anticipated in January 2007 (for 2007/08)**

<b>Project</b>	<b>Abridged project title</b>	<b>Notes</b>
01/07	Assessment of active cementation trials (radioactive sludge)	N
02/07	Sorption systems for contaminated oil and problem liquid waste	N
03/07	Optimisation of design, procurement and use of ILW containers	N
04/07	Particulate science of magnesium hydroxide based materials	S
05/07	Supply chain workshop - review of waste sludge management	N
06/07	Review of Magnox ILW stores	S
07/07	Magnesium-hydroxide colloids in ponds wet wastes	S
08/07	Development of systems for Se-79 and Tc-99 ILW	N
09/07	The disposal of neutron sources	S
10/07	Development of a strategy to deploy dummy ILW packages	N
11/07	Long-term monitoring cemented wastes	N,B
12/07	Application of MAGGAS model to cemented wastes	N
13/07	Corrosion assessment of containers of cemented wastes	N,B
14/07	Gamma irradiation of samples of cemented waste	N,B
15/07	Effect of waste package movements on corrosion rates	N
16/07	Long-term integrity of Lewatit DN Immobilised in a cement	N
17/07	Preparation of supporting documentation for waste treatment	S
18/07	Lifetime model for internal corrosion of ILW containers	S
19/07	Review of alternative container materials	S
20/07	Security of supply of strategic materials	N
21/07	Testing of long-term integrity of building cladding panels	N
22/07	Review of chemically hazardous wastes	N
23/07	Reactor archive samples	N
24/07	Options for removal of reactor graphite installed sets	S
25/07	Review of care and maintenance arrangements	N
26/07	EPRI decommissioning technology programme membership	C
27/07	Subscription to journals to support R&D	N
28/07	Determination of radionuclide concentrations in ILW streams	S
29/07	Review of future needs for radiochemical analysis	N
30/07	Handbook: immobilisation of organic IX resin wastes	S
31/07	Handbook: immobilisation of Magnox Fuel Element Debris	S
32/07	Handbook: immobilisation of desiccant waste	S
33/07	Staff exchange (early dismantling of graphite reactors)	C
34/07	Human factors – operational experience feedback	N
35/07	Generic issues workshops	N
36/07*	Support in further development of TBuRD	N*
37/07*	Support for the development of Integrated Waste Strategy	N*
38/07*	Attendance at Conferences to support WM&D R&D	N
39/07	Handbook of sampling methods and techniques	S
40/07	Review and search for unidentified samples in storage	S
41/07	Study to support final site clearance	N*
42/07	Human factors - scoping future R&D needs	N
43/07	SAFEGROUNDS and SAGTA	N
<b>Key</b>		
N	Implemented within the Magnox North R&D programme	
S	Transferred to the Magnox South R&D programme	
B	British Energy co-funded this work	
C	Cancelled or deferred	
*	Implemented within separate non-R&D Magnox North programmes	

**Table 2 – Magnox North 2007/8 W&D Research and Development Programme**

<b>Project Number</b>	<b>Full Project Title</b>	<b>Status</b>
01/07	Assessment of feasibility, cost and benefit of cementation trials on Magnox station radioactive sludge	1,2
02/07	Sorption systems for encapsulation of radioactively contaminated oil and problem liquid wastes	1,3
03/07	Optimisation of design, procurement and use of Nirex ILW containers.	1,2,4
05/07	Supply chain workshop – review of waste sludge properties and processing	1,2
08/07	Development of systems for Se-79 and Tc-99 ILW analysis in ILW to support LoC assessment	1,5
10/07	Development of a specification and strategy to deploy dummy ILW packages in support of the long-term storage safety case	1,2,4
11/07	Long-term monitoring cemented wastes	1,5
12/07	Application of MAGGAS model to cemented wastes	1,3
13/07	Corrosion assessment of containers of cemented wastes	1,5
14/07	Gamma irradiation of samples of cemented waste	1,3,5
15/07	Effect of waste package movements on corrosion rates	1,2
16/07	Further work on the long-term integrity of Lewatit DN immobilised in a CSF/SRPC matrix	1,2,4
20/07	Security of supply of strategic materials used to encapsulate and contain ILW	1,3
21/07	Testing of long-term integrity of building cladding panels under UK severe weather exposure	1,5
22/07	Review of chemically hazardous wastes arising from decommissioning	1,2
23/07	Monitoring, selection and storage of reactor archive samples including steels, graphite and construction materials	1,3
25/07	Review of care and maintenance arrangements	1,2
27/07	Subscription to leading scientific and engineering journals to support WM&D R&D	1,5
29/07	Review of future needs for radiochemical analysis against potential supply limitations	1,3
34/07	Human factors – operational experience feedback study on commissioning activities	1,4
35/07	Workshops to underpin resolution of generic issues at request of NDA	1,4,6
38/07	Attendance at conferences to support waste management R&D	1,5
42/07	Human factors – scoping future R&D needs	1,3
43/07	Magnox membership of SAGTA and SAFEGROUNDS	1,5

- 1 Project works for 07/08 completed;
- 2 Project issue 'closed out'. No new work planned;
- 3 Follow-on R&D activities for 08/09 planned;
- 4 Related follow-on work being carried out elsewhere;
- 5 On-going project (long-term objectives);
- 6 Project scope not fully completed during 2007/08.

**Table 3 – Magnox North 2007/8 W&D Research and Development Programme – Summary Outcomes**

<b>Project Number</b>	<b>Outcome / benefits</b>
01/07	Guidance provided to Magnox Sites when it may be appropriate for active trials to underpin wastefrom development. Potential to reduce dose uptake and costs. Closed out.
02/07	Experiments demonstrated the potential for sorption systems to stabilise oils within cement systems for six representative Magnox oily wastes under disposal conditions for low loadings of waste. New work (2008/09) to optimise waste loadings, and investigate longer term stability and stability under realistic conditions (ie irradiation trials) is planned.
03/07	A concept ILW overpack and retrieval system was designed for the safe management of potentially failed packages. The work is being continued at the Hunterston A Site, and is a key input to a 2008/09 R&D project.
05/07	A cross industry supply chain event on wet ILW was held in October 2007. The challenges faced by SLCs and supply-chain technologies to assist were profiled (see also 35/07).
08/07	On-going PhD study at Loughborough University. Due to complete October 2010.
10/07	Specification developed and peer reviewed. The recommendation that dummy containers should be deployed to demonstrate long-term performance and safety will be incorporated into Magnox guidance during 2008/09.
11/07	The on-going monitoring of 500 wastefrom simulants (in some cases providing over 20 years of history) continues to provide confidence in the long-term stability of Magnox wastefrom formulations.
12/07	The computer program, MAGGAS, was rolled out to Site Users and courses held to promote the awareness of this gas-generation modelling tool to support store safety cases and package designs.
13/07	The on-going monitoring of over 20 'dummy containers' continues to provide confidence in the long term performance of waste containers. Duplex grade materials were added to the programme in anticipation of their potential use in ILW containers.
14/07	The on-going irradiation of simulant wasteforms continues to provide confidence in the radiation stability of current Magnox wasteforms (in many cases multiples of the lifetime dose has been achieved). The stability of the 'comb-superplasticised samples' is suggestive of their potential utility in future formulation development (work continues into 2008/09).
15/07	The results to determine whether the metal-grout interface has re-bonded have proved inconclusive with the experimental set up. The issue of temporary enhanced corrosion, following movements, has been bounded. No further work is proposed.
16/07	The reformulated high-waste loading alternative cement system for Magnox-specific organic ion-exchange resins has been shown to be stable. Long-term monitoring continues into 2008/09.
20/07	The study has highlighted which materials are most at risk from loss-of-supply and potentially threaten future waste packaging plans. A cross-industry workshop to develop coherent mitigation approaches is planned in November 2008.
21/07	The on-going monitoring of building cladding panels, at Dungeness A, continues to provide confidence in the long-term stability of these materials.
22/07	90 potentially problematic waste streams and 11 families of generic decommissioning wastes were identified. The waste management options of each were considered and assessed. The relevant regulations were highlighted. Work closed out.
23/07	An assessment has been carried out on the status of archived samples for the Magnox sites and a review of future requirements for storage made. Work continues to develop a detailed inventory of samples. This work has helped to preserve potentially valuable

<b>Project Number</b>	<b>Outcome / benefits</b>
	samples for future R&D needs.
25/07	A generic specification of arrangements for sites entering care and maintenance was developed following workshops and site specific works. Work closed out.
27/07	Provides ongoing support to R&D activities and support for SQEP maintenance.
29/07	The review highlighted the potential mismatch between requirements for characterisation and the potential supply of services. Work continues to address the gap and determine mitigation strategies.
34/07	A detailed analysis of historic project performance has identified a series of 'lessons learned' for incorporation into training manuals and implementation.
35/07	Discussions with other SLCs held. Planned workshop with the supply chain (TBuRD) was cancelled. Transferred to NWRF / NDA initiative.
38/07	Maintains continued access to international developments and good practice.
42/07	A review concluded that there were no major gaps in the human factor tools and techniques available inside Magnox. Some tools and techniques require updating to meet decommissioning requirements. Implementation of conclusions is planned during 2008/09.
43/07	Maintains continued access to best practice and emerging guidance on a range of contaminated land issues.

**Table 4 – Magnox South 2007/8 W&D Research and Development Programme**

<b>Project Number</b>	<b>Title</b>
04/07	Particulate science of magnesium hydroxide based materials in support of Magnox wet waste processing
06/07	Position statement on design and operational concepts for Magnox ILW stores
07/07	Magnesium-hydroxide colloids in ponds wet wastes (e.g. filtration (SCRU), mobile AETP, MXD)
09/07	The disposal of neutron sources
17/07	Preparation of supporting documentation for waste treatment
18/07	Lifetime model for internal corrosion of ILW containers
19/07	Review of alternative container materials
24/07	Options for removal of reactor graphite installed sets (core moderator samples) during decommissioning
28/07	Approaches to determine the radionuclide concentrations in ILW streams in support of LoC Assessment and BPEO studies
30/07	Handbook of the processing and immobilisation of organic IX resin wastes
31/07	Handbook of the processing and immobilisation of Magnox Fuel element Debris (FED)
32/07	Handbook of the processing and immobilisation of desiccant waste
39/07	Handbook of sampling methods and techniques
40/07	Review and search for unidentified samples in storage

NB The majority of this work has transferred to the 08/09 Magnox South R&D Programme.

## Annex 4

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

### Introduction

1. Sellafield Ltd currently operates the Sellafield, Calder Hall, Windscale and Capenhurst nuclear licenced sites.
2. 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.
3. 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 produced 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. Ten technical areas are considered under the arrangements at present:
  - Civil Engineering
  - External Hazards
  - Human Factors
  - Plant Materials
  - Process Technology
  - Probabilistic Safety Assessment
  - Nuclear Physics
  - Radiological Protection
  - Waste and Decommissioning
  - Control and Instrumentation

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

### **HA Evaporation, Storage and Vitrification**

5. 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 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.
6. 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**

7. 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*

8. 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*

9. 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.

10. 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**

11. 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.
12. 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.
13. 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 at an early stage.

### **MOx Maintenance training**

14. 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.

### **SIXOS Liquid Activity Reduction trial**

15. 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**

16. 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*

17. 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*

18. 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*

19. 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*

20. 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**

#### **ANNEX BY DOUNREAY SITE RESTORATION LIMITED (DSRL)**

#### **INTRODUCTION**

- 1 Dounreay Site Restoration Limited (DSRL) is the Site Licensee Company for Dounreay.
2. At the meeting of the NuSAC Sub-Committee on Research in April 2008, DSRL presented a summary of its nuclear safety related research programme for 2008/9 (1).
3. 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. The evaluation of the benefits of the DSRL research and technology development programme for the key items are summarised below. They are separated into key project R&D and safety development work.

#### **SUMMARY OF PROJECT RESEARCH AND TECHNOLOGY DEVELOPMENT SUCCESSSES**

4. 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.

**Table 1 Project Focused Technology Successes**

	R&TD Successes	Example of Benefit
1	<b>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.</b>	<b>The innovation reduces technical risk and has the potential to significantly reduce budget estimates for reactor dismantling.</b>
2	<b>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.</b>	<b>Reduces the risk of a pressure excursion whilst removing the sodium residues by the water vapour nitrogen process.</b>
3	The Sodium Inventory Disposal (SID)	The plant will clean-up the backlog of

	R&TD Successes	Example of Benefit
	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.	plant items contaminated with alkali metal residues and so reduce the risk of a fire or pressure excursion.
4	<b>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.</b>	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.	<b>Removing radioactive particles reduces the risk of harm to the public</b>
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.	<b>The removal of the sodium-potassium coolant at DFR will reduce one of the biggest safety risks on site.</b>
7	The Shaft & Silo Waste Retrieval project team has been busy conducting R&D activities to reduce technical risk and has achieved the following significant technical successes; <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</li> </ul>	<b>Reduction of risk</b>

	R&TD Successes	Example of Benefit
	<p>cementitious grout in 500 litre drums to the satisfaction of RWMD.</p> <ul style="list-style-type: none"> <li>• Screening of solids in a rotary screen to wash and dewater waste prior to supercompaction and encapsulation.</li> </ul>	
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><b>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.</b></p>

## SAFETY DEVELOPMENT WORK

5. 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.

6. 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.

7. Human Factors assessment also forms part of the Safety Case process. DSRL attends the Working Group for Human and Organisational Factors (WGHOFF) 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.

8. 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.

## **REFERENCES**

1. NuSAC/RG6/08/5 DSRL 2008/09 Programme of Nuclear Safety Related Research, April 2008.

## Annex 6

### Progress with commissioning the 2008/09 Programme

#### HSE Commissioned programme of Nuclear Safety Research

1. The proposed 2008/09 HSE-Commissioned nuclear safety research programme was reported to NuSAC RG6 in April 2008 in Paper 08/01. Most of the projects are making satisfactory progress although protracted contract negotiations have meant that the contracts for UK membership of the USNRC CAMP and CSARP programmes have not been formally let. They are expected to be let in the next two months and in the meantime, the USNRC has continued to allow UK organisations to have access to the computer codes supplied under these agreements.
2. The three proposed waste and decommissioning projects have not yet been let. Again there are issues of contract terms and liabilities surrounding the graphite waste characterisation proposal that need to be resolved. For the two ILW proposals, the project officer is still trying to identify suitable contractors.
3. The UK has agreed to participate in the OECD PRISME project. This is an additional project to the ones reported in April 2008. This project makes use of large experimental facilities at Cadarache to validate fire modelling codes.

#### British Energy Programme

4. The 2008/09 British Energy programme was produced in an unconstrained way by addressing a number of key challenges listed in the 2006/07 review. As a result of the business planning round, the programme has been funded with an increase of →←external spend. The programme is also a 5-year forward look, with increased funding for the programme anticipated over this timescale. By far the largest increase in external spend in 2008/09 relative to 2007/08 is on the lifetime materials project. Long-term operation of AGR components at elevated temperatures requires the creep and creep-fatigue endurances to be estimated, including their ability to tolerate defects, and an understanding of the effects of service exposure on material response.
5. At the end of August, 35% of the planned internal effort on the strategic programme had been expended and 78% of the external budget had been committed. This included setting up a high temperature centre involving British Energy, Imperial College, Bristol University and Serco as a major research alliance on materials behaviour and structural response of high temperature components. Thus, the enlarged 2008-09 programme is being actively progressed within BE. Areas where there have been delays or departures from the planned programme are as follows: a major transformer failure has delayed completion of the Wythenshawe boiler test rig run; there are delays in some Civil Engineering and Chemistry projects where emergent work is affecting both internal resource and the ability to progress external work.

## Magnox Electric Programmes

### OVERVIEW (MAGNOX NORTH)

6. Magnox North declared the intention to carry out 25 projects [see NuSAC/RG6/08/3] as part of the Waste & Decommissioning research programme during 2008/09. These projects were developed to address generic needs, risks and opportunities outlined in the Magnox TBUrDs, and ensure due cognisance of the areas highlighted in the ND Research Strategy Statement for Decommissioning.

7. As at the end of September 2008, 24 of the 25 projects had commenced, with the remaining project due to start by the end of October. ⇒ ⇐ Progress remains broadly in line with expectations (typically within a month of the original schedule). Magnox North is confident that the full works will be delivered by 31 March 2009 as originally scheduled. Progress reports, by project, are compiled monthly. These are distilled and shared with our technical stakeholders as a technical bulletin. It is suggested that we include the Regulators in distribution of this monthly bulletin to improve visibility and transparency of our work.

8. Two of the projects have been delayed due to the need to more fully understand experimental results obtained during 2007/08 to properly specify further work required (and explorative 2008/09 work). At the time of writing, in collaboration with the NDA's RWMD, it was hoped to have fully interpreted the decay products from irradiation of comb superplasticisers and determined additional work needed to obtain a LoC from the RWMD, by the end of September. Thus it is hoped to have commenced the fully scoped project by end of October (three months late). The oil-sorption immobilisation project, following extended long-term testing of the samples created during 2007/08, is expected to commence in late September (approximately two months late).

9. We continue to work through the Nuclear Waste Research Forum (NWRF) to facilitate greater co-ordination of our projects. Three projects that underpin the long-term performance of cemented waste packages are not defined as requirements within the TBUrDs for Magnox North. However, because of their generic benefit we maintain these in our programme until such time that they can be transferred to a more appropriate programme.

10. A number of project milestones are expected in the next few weeks. These include a cross-industry workshop focussed on developing contingency approaches should supply of currently specified cement powders become problematic in the future. An update of the guidance to Magnox Sites for package care guidance is also due in late October.

11. In addition a programme of graphite-related and control and instrumentation-related research continues to underpin the operational safety cases at both Oldbury and Wylfa.

## **SUMMARY OF THE MAGNOX SOUTH RESEARCH PROGRAMME**

12. ⇒ ⇐ Since the funding and resourcing environment remains challenging in Magnox South, the 12 projects proposed have been reprioritised. It is now proposed to carry out at least two of the projects using internal resource during 2008/09. It is considered, following discussions with other SLCs, that the scope of five projects is largely covered by the work of others. A further three projects to produce 'handbooks' are currently on hold and may be carried out later during 2008/09 if internal resourcing becomes viable. Two projects, on magnesium hydroxide colloids, are on hold pending availability of funding routes.

### **Sellafield Ltd Programme**

13. No report.

### **Dounreay Site Restoration Ltd Programme**

14. No report.