Magnox

Summary of the Magnox Limited Response to Lessons Learned from the March 2011 Japanese Earthquake and Tsunami

JULY 2014

Executive Summary

On 11th March 2011 a magnitude 9.0Mw mega-thrust earthquake struck off the east coast of the Japanese island of Honshu. That earthquake generated a sequence of tsunamis that devastated many communities along the Japanese east coast with the confirmed loss of nearly 16,000 lives. Among the widespread destruction wrought by these extreme natural events was the considerable damage that supervened at the Fukushima Dai-ichi and Dai-ni nuclear power plants, primarily as a consequence of tsunami inundation.

Compared with Japan, the United Kingdom resides within a relatively benign environment for natural hazards. Replication of the type and severity of the natural events that caused the Fukushima accident is not generally considered credible within the UK. Furthermore, significant differences exist between the technologies employed in the nuclear facilities affected by the Japanese accident and those operated by Magnox Limited.

Nevertheless, natural hazards, including those of seismological, meteorological and hydrological origin, do affect the British Isles. It is essential that all aspects relating to safety of the sites and facilities operated by Magnox Limited are kept under review to ensure that the highest standards of safety are maintained. This includes learning from operating experience garnered from events elsewhere in the world, despite evident and significant technological and environmental differences.

Accordingly, Magnox Limited, as a learning organisation, has sought to learn lessons from the events in Japan, a purpose shared with nuclear operators, regulators and governments worldwide; the collective aim being to further diminish the likelihood of nuclear accidents, from whatever cause, occurring in future. Recognising that the likelihood of such accidents, although considered to be already very low, can never be reduced to zero, a further objective has been to ensure that utilities and supporting agencies become even better prepared to mitigate accident consequences and lessen any societal and environmental impacts.

There remains only one operating nuclear reactor within the Magnox Limited fleet: Reactor 1 at Wylfa, for which final shutdown is planned in 2015 subject to regulatory approval. Two other sites, Oldbury and Sizewell A, are presently undergoing defuelling. The remaining seven sites are already defuelled and in various stages of decommissioning, progressing towards a care and maintenance phase in which all remaining radioactive material is either removed or held in a passively safe state.

The overarching aim of the Magnox Limited response to lessons learned from the Japanese events has, therefore, been to implement reasonably practicable and proportionate enhancements that deliver tangible safety improvements swiftly and pragmatically across the ten sites and support functions.

Magnox Limited has conducted wide-ranging reviews of the resilience of its sites and operations, particularly against extreme events that lie outside the plant design basis, as well as questioning whether the design basis for extreme events remains valid. These reviews have generally shown that the existing position for Magnox Limited sites is robust. This is in large part a testament to the rigorous UK nuclear regulatory regime. In particular, the drive for timely completion of ten-yearly Periodic Safety Reviews (including compliance with modern engineering design standards and good engineering practice), and the adoption of 10^{-4} per annum exceedance frequency (1 in 10,000 year) events as the plant design basis, has put UK nuclear plants in a strong position. As an example, more than £100million has been spent assessing and upgrading the Wylfa plant during past Periodic Safety Reviews.

Nevertheless, the reviews carried out following the Japanese earthquake and tsunami have identified opportunities for further enhancing resilience across the Magnox Limited fleet. Consequently, many physical and procedural enhancements have been implemented. As would be expected, more substantial and wider-ranging enhancements have been implemented at Wylfa, the only site with an operating reactor. The scope of enhancements implemented across the sites has been proportionate with the remaining nuclear, radiological and environmental safety risks posed by each site in its current and projected future states.

A significant source of lessons learned has been the series of reports produced by the Office for Nuclear Regulation, including those arising from the European Council Stress Tests. Magnox Limited has responded to all applicable recommendations and findings contained within those reports. In accord with its overarching aim, Magnox Limited has sought to interpret these recommendations and findings in very tangible and practical ways with a focus on converting the recommendations and findings into improvements that can be delivered in a timely manner so as to maximise the safety benefits given the limited period of high hazard operations remaining.

The programme of review and enhancement has continued within Magnox Limited for a period of over three years as additional lessons from the Japanese events have emerged. Although it is anticipated that useful information will continue to arise as the programme of stabilisation and remediation at the Fukushima Dai-ichi nuclear power plant progresses, the specific Magnox Limited response programme is now being drawn to a conclusion. Future learning within Magnox Limited will be taken forward through established business processes.

All resilience reviews associated with lessons learned to date from the Japanese earthquake and tsunami have been completed. The vast majority of identified site enhancements have also been completed. Some short-term and longer-term on-going work items have been identified. These items will be pursued under specified normal business arrangements following closure of the specific response programme. On-going work items that are to be progressed under normal business arrangements will continue to be monitored by the Chief Nuclear Officer.

The Japanese events will have an enduring impact within Magnox Limited. The company will continue to maintain the highest standards of nuclear, radiological, environmental and industrial safety, learning from experience and identifying opportunities to improve. In so doing, Magnox Limited will seek to protect the public, its workers and the environment from potentially harmful effects should extreme events impact on our sites in the future.

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1. Introduction

On 11th March 2011 a magnitude 9.0Mw mega-thrust earthquake struck off the east coast of the Japanese island of Honshu. That earthquake generated a sequence of tsunamis that devastated many communities along the Japanese east coast with the confirmed loss of nearly 16,000 lives. Among the widespread destruction wrought by these extreme natural events was the considerable damage that supervened at the Fukushima Dai-ichi and Dai-ni nuclear power plants, primarily as a consequence of tsunami inundation.

Key to the unfolding nuclear accident was the total loss of electrical power to four of the six reactor units at Fukushima Dai-ichi. This disabled engineered safety systems, particularly those associated with reactor core and spent fuel cooling. Plant damage and power loss also hampered information availability and short term mitigating actions. Ultimately core meltdown occurred in the three reactors that were operational at the time of the event. Most visibly, the reactor building superstructures were destroyed by exploding hydrogen that had been evolved via chemical reactions brought about by overheating and fuel exposure within the reactor vessels. In combination with damage to reactor containment structures and other components, and deliberate containment venting actions, these consequences led to the release of both waterborne and airborne radioactive contamination to the environment. An exclusion zone has been maintained around the plant to protect the public from radiation exposure. As a result, in excess of 160,000 people have been displaced from their homes.

The Fukushima Dai-ichi nuclear accident rates Level 7: Major Accident, the highest level, on the International Atomic Energy Agency's International Nuclear and Radiological Event Scale: "a major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures".

Compared with Japan, the United Kingdom resides within a relatively benign environment for natural hazards. Replication of the type and severity of the natural events that caused the Fukushima accident is not generally considered credible within the UK. Furthermore, significant differences exist between the technologies employed in the nuclear facilities affected by the Japanese accident and those operated by Magnox Limited.

Nevertheless, natural hazards, including those of seismological, meteorological and hydrological origin, do affect the British Isles. It is essential that all aspects relating to safety of the sites and facilities operated by Magnox Limited are kept under review to ensure that the highest standards of safety are maintained. This includes learning from operating experience from events elsewhere in the world, despite evident and significant technological and environmental differences.

Accordingly, Magnox Limited has sought to learn lessons from the events in Japan, a purpose shared with nuclear operators, regulators and governments worldwide; the collective aim being to further diminish the likelihood of nuclear accidents, from whatever cause, occurring in future. Moreover, recognising that the probability of such accidents, although considered to be already very low, can never be reduced to zero, a further objective has been to ensure that utilities and supporting agencies become even better prepared to mitigate accident consequences and lessen any societal and environmental impacts.

As soon as the severity of events in Japan became evident, Magnox Limited instigated a project to understand the implications for the company. Initially this involved knowledge gathering and responding to enquiries from internal and external stakeholders. Over the following days and weeks the emphasis changed to distilling relevant lessons that could be learned and undertaking resilience reviews of the Magnox Limited sites and systems in the light of escalating events in Japan to identify opportunities for enhancement. This programme of review and enhancement has continued within Magnox Limited for a period of over three years as additional lessons from the Japanese events have emerged.

Although it is anticipated that useful information will continue to arise as the programme of stabilisation and remediation at the Fukushima Dai-ichi nuclear power plant progresses, the specific Magnox Limited response programme is now being drawn to a conclusion. Future learning within Magnox Limited will be taken forward through established business processes.

The purpose of this report is to document the progress that Magnox Limited has made in responding to lessons learned from the impacts of the Japanese earthquake and tsunami on nuclear facilities.

Section 2 describes the current status of the Magnox Limited sites to give context for the company strategy for responding to lessons learned from the Japanese events. Section 3 provides an overview describing how the response has been structured, the specific programme aims, and highlighting the major components comprising the response programme.

A substantive source of lessons learned has been the reports produced by the Office for Nuclear Regulation (ONR) which provided many recommendations and findings that UK nuclear licensees, including Magnox Limited, were charged with addressing. Section 4 details the Magnox Limited response to each applicable ONR recommendation and finding.

Section 5 summarises items of on-going and further work that will be progressed under normal business arrangements following closure of the specific Magnox Limited response programme.

Finally, Section 6 draws general conclusions regarding the Magnox Limited response to the Japanese events.

2. The Magnox Limited Fleet

Magnox Limited is the nuclear site licensee responsible for the management and operation of ten UK nuclear sites: Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A, Oldbury, Sizewell A, Trawsfynydd, and Wylfa. These sites, now owned by the Nuclear Decommissioning Authority, comprise all but one of the first generation of commercial nuclear power stations in the UK. The location of the nuclear licensed sites managed and operated by Magnox Limited is shown in Figure 1.

2.1 Description of Magnox Power Stations

Magnox power stations generate electricity by using the heat from a nuclear reactor to produce steam to rotate steam turbines connected to alternators. The nuclear reactors at Magnox stations comprise a large, roughly cylindrical, array of graphite bricks located within a reactor pressure vessel. There are thousands of vertical channels across the reactor core that variously contain the nuclear fuel elements, control rods and other equipment. Nuclear fuel elements in Magnox reactors are roughly 1m in length and are formed from a natural or slightly enriched uranium bar encased in magnesium alloy ("Magnox") cladding. Fuel elements are typically stacked 8-high within the fuel channels.

Upon reactor start-up, a nuclear fission chain reaction occurs within the reactor core that produces heat. This heat is transferred from the fuel by pressurised carbon dioxide (CO_2) gas that is circulated around the reactor pressure vessel by powerful fans known as gas circulators. The carbon dioxide gas transfers the heat from the fuel to large heat exchangers, also called boilers. These gas flows within the reactor pressure vessel form the primary pressurised gas cooling circuit. In the boilers water flows through small tubes that sit within the flow of hot carbon dioxide. In this way the water is heated and boils to form steam. The steam is then piped to the turbo-alternators where it turns the turbine blades (thereby generating electricity) and is condensed back to water. The resulting hot water is returned to the boilers to be converted to steam once more. This water/steam flow through the boilers to the turbines and back forms the secondary water/steam cooling circuit. The primary pressurised gas cooling circuit of the reactor is separate from the secondary water/steam cooling circuit.

The nuclear fission chain reaction in the reactor core is controlled primarily by varying the height of control rods within the reactor. Reactor shutdown, cessation of the chain reaction, is achieved by insertion of sufficient control rods into the core. The control rods are designed so that they will drop fully into the core under gravity if a plant fault occurs.

In the early Magnox reactors the reactor pressure vessel is a large steel cylinder or sphere within a thick concrete biological shield with the boilers being external to the reactor pressure vessel and biological shield. The later Magnox reactors (those at Oldbury and Wylfa) combined the functions of reactor pressure vessel and biological shield by having a massive pre-stressed concrete pressure vessel with the boilers being within the pressure vessel.

A Magnox reactor has a low power density compared with light water reactor designs such as the boiling water reactors at Fukushima Dai-ichi. Due to the very large mass of the graphite moderator and other reactor structures there is a high thermal inertia. This means that following shutdown, with the reactor pressurised, reactor cooling requirements are relatively modest with extended timescales available to restore cooling in the unlikely event that normal cooling systems are lost.

Spent nuclear fuel is discharged from the reactors into temporary storage in spent fuel ponds or dry stores to allow a period of cooling before being shipped to Sellafield for reprocessing. During the lifetime of each power station radioactive wastes have been accumulated. Such wastes include debris from the stripping of external features from the fuel elements before shipping (known as fuel element debris), other components that have been activated in the reactor (replaced reactor components for example), spent resins and desiccants associated with conditioning of reactor gas or spent fuel pond water, and other contaminated waste materials. These wastes, generally classified as intermediate or low level wastes, are normally stored passively in massive shielded vaults, tanks or containers that are well-protected from naturally occurring hazards.

Stringent Magnox Limited company standards require that barriers are in place and are maintained to protect the safety of the public and workers should a plant fault occur from whatever cause. Such barriers include multiple diverse and redundant systems for meeting the cooling requirements of the reactor in the event of a plant fault. This is in addition to the strict controls, procedures and operating instructions that are in place to prevent such faults occurring.

[1]Calder Hall, the other UK site having reactors of the Magnox design, is not operated by Magnox Limited and is, therefore, not covered by this report.

2.2 Status of Magnox Limited Sites

Only one Magnox Limited nuclear reactor remains operational: Reactor 1 at the Wylfa site on the north coast of Anglesey, North Wales. Continued operation of that reactor is limited by the availability of Magnox nuclear fuel and final shutdown is currently planned no later than December 2015.

All other Magnox Limited reactors are permanently shut down. Post-shutdown removal of nuclear fuel is currently in progress at the Oldbury and Sizewell A sites. Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A and Trawsfynydd are defuelled and preparing for a prolonged care and maintenance (C&M) phase before final site clearance around the end of this century.

The status of the Magnox Limited sites is summarised in Table 1. More details of the planned lifecycle of the sites are available in Reference 1.

2.3 Safety of Magnox Limited Sites

Magnox Limited sites have operated safely for well over 50 years. Safety will continue to be given the highest priority, in co-operation with our owners and regulators, as the sites progress through their lifecycle. In accordance with nuclear site licence conditions and associated Magnox Limited company standards and processes, regular reviews are undertaken and measures implemented to ensure that the radiological risks posed by operations at the sites are as low as reasonably practicable.

The magnitude of the potential radiological risk posed by a site decreases progressively as the site moves through its lifecycle from reactor operation, through defuelling, care and maintenance preparations, care and maintenance, and final site clearance.

A very substantial reduction in a site's radiological inventory is effected during the defuelling phase by the transfer of all nuclear fuel to Sellafield for reprocessing. During the care and maintenance preparations phase dismantling work is undertaken with the aim of removing both radioactive and non-radioactive materials, plant and buildings where radiological benefit cannot be achieved from deferral. Structures and any waste materials that are to remain during the subsequent care and maintenance lifecycle phase are put into a passively safe and secure state. The site care and maintenance phase allows the radiation levels associated with remaining radioactive structures and materials to decay naturally enabling safer, simpler and lower-cost dismantling and decommissioning during the final site clearance phase.

Even in the relatively short time since the March 2011 Japanese earthquake and tsunami, significant changes of state have occurred, as planned, within the Magnox Limited fleet. In particular:

- Both reactors at Oldbury were permanently shut down (Reactor 2 June 2011, Reactor 1 February 2012) and defuelling has commenced;
- Wylfa Reactor 2 was permanently shut down in April 2012;
- Defuelling at Dungeness A was completed in April 2012;
- Defuelling at Chapelcross was completed in February 2013.

In addition to these major changes, considerable progress has been made with defuelling at Sizewell A and Oldbury. Defuelling at Sizewell A is planned for completion by September 2014 and both reactors at Oldbury are more than 35% defuelled. Substantial progress has also been made across the decommissioning sites with legacy waste management.

Following permanent reactor shutdown the dependence on active safety systems rapidly diminishes and thus the risks posed by possible loss of such systems is also reduced. For example, forced gas circulation to cool the reactors at Oldbury was declared no longer necessary in April 2013; natural circulation of air at atmospheric pressure is now sufficient to remove decay heat from the remaining fuel in the reactors. Furthermore, even where active safety systems are required the timescales for restoring such systems should their operation be interrupted lengthens as the fuel cools. At present, for example, water is only supplied intermittently to boilers to remove heat from the Oldbury reactors and, if lost, the time required to restore water supplies is at least seven days.

Similarly, the reactors at Sizewell A have now been shut down for over seven years. The remaining nuclear fuel in the reactors and pond is long-cooled and requires minimal active management. Even if the few remaining safety-related systems (reactor temperature and pressure instrumentation, cooling, ventilation and pond water treatment) were to fail completely then significant radiological issues would not arise for a period of at least several weeks, and in some cases not at all, allowing ample time for restoration even in the most extreme events.

The remaining sites (Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A and Trawsfynydd) are defuelled. The residual radioactive material takes the form of various wastes that accrued during station operation including fuel element debris, miscellaneous activated components, sludges and resins. Generally speaking such materials are passively stored in shielded vaults and tanks or within what were the spent fuel ponds. Typically, the only active safety systems are associated with ventilation of waste facilities for the purpose of preventing build-up of combustible gases and/or controlling moisture and humidity. Again, if such systems were to fail there is ample time available for restoration or providing alternative means of ventilation and, in any case, the worst credible off-site radiological consequences of not restoring the systems are minor.

Nevertheless, despite these reductions in risk, care is taken to ensure that diverse and redundant systems remain available to assure the safety of the plant and radioactive material contained therein and thereby prevent radiological consequences as a result of faults and hazards including extreme natural events.

During all lifecycle phases the risks associated with radioactive material will continue to be reviewed regularly and reasonably practicable measures will be implemented to control and manage such risks.

3. Overview of the Magnox Limited Response to the Japanese Earthquake and Tsunami

Magnox Limited is a learning organisation that seeks continual improvement, particularly in matters affecting nuclear, radiological, environmental and industrial safety. Nuclear site licence conditions and company standards and processes require that site safety cases are regularly reviewed, maintained and updated via planned periodic safety reviews and ad hoc reviews following events of particular potential significance to nuclear safety, the Boxing Day 2004 Indian Ocean tsunami for example.

Furthermore, operating experience feedback processes are established within the company to ensure that experience from within Magnox Limited, from other UK and international nuclear licensees and from other industries is analysed and that relevant lessons are learned to minimise the likelihood of similar safety-related incidents or "near-misses" occurring or re-occurring at Magnox Limited sites.

In this context, the events surrounding the March 2011 Japanese earthquake and tsunami and the consequential effects on nuclear facilities, particularly the Fukushima Dai-ichi nuclear power plant, present many learning opportunities.

Accordingly, as soon as the significance of these events began to become clear, indeed only hours after the first news from Japan, Magnox Limited initiated a work programme to assess the implications for the company of those events and to effect appropriate responses.

The work programme was initially focused on information gathering to facilitate a response to the many stakeholder questions that arose both from within and outside the company. For the longer term, the emphasis has changed to learning lessons from the Japanese events with a view to identifying and implementing enhancements to Magnox Limited plant and processes.

During the period that has elapsed since March 2011, the events and their causes, both natural and man-made, have been subjected to intense international scrutiny. Many potential learning points have been derived from these analyses. Primary sources of such learning that have influenced the Magnox Limited response programme are:

- Magnox Limited in-house workshops;
- Discussions with other UK nuclear licensees;
- Office for Nuclear Regulation reports;
- International Atomic Energy Agency (IAEA) reports;
- Tokyo Electric Power Company incident reports;
- Japanese Government reports;
- European Council Stress Tests (including the ONR National Final Reports);
- World Association of Nuclear Operators (WANO) Significant Operating Experience Reports;
- Institute of Nuclear Power Operations report;
- United States Nuclear Regulatory Commission reports.

3.1 Magnox Limited Objectives in Responding to Lessons Learned from the Japanese Events

In responding to the events in Japan, particularly the accident that unfolded at the Fukushima Dai-ichi nuclear power plant, Magnox Limited's key objectives have been three-fold:

- To consider implications of these events for the Magnox Limited sites and identify lessons to be learned;
- To initiate work programmes applying relevant learning to Magnox Limited sites and, thereby, to deliver safety improvements;
- To respond to information requests from stakeholders.

As outlined in Section 2, there is only one remaining operational nuclear reactor in the Magnox Limited fleet: Reactor 1 at Wylfa, which is due for final shutdown in 2015. The emphasis at Wylfa is to maintain and improve the already high standards of reactor safety over the residual operating life. This limited residual operating life dictates that any enhancements implemented must be delivered to a timescale consistent with realising a tangible safety benefit before final shutdown. Thus, for example, embarking on long term investigative or research programmes would not be compatible with this constraint. Similarly, the scale of physical plant enhancements that can be delivered within such timescales, even if such enhancements are desirable and can be justified, is very restricted, recognising also that plant modifications can pose risks to nuclear safety if inadequately conceived or executed, despite their object being to effect improvement.

All other sites are engaged in a gradual and controlled process of risk reduction firstly by removal of nuclear fuel (at Oldbury and Sizewell A) and through the retrieval, conditioning and passivation of remnant waste material. Environmental and conventional safety risks are also steadily being reduced. It is clear that these on-going work programmes are, in the long term, the best means of minimising the totality of the residual risks posed by Magnox Limited sites.

Taking account of the above considerations, the overarching aim of the Magnox Limited response has been to seek to implement reasonably practicable and proportionate enhancements that deliver tangible safety improvements swiftly and pragmatically across all ten Magnox Limited sites and support functions. A supporting principle has been that such enhancements should not themselves have the potential to cause a significant nuclear safety detriment, or delay defuelling or waste passivation.

When considering the proportionality of possible enhancements, account has been taken of the widely differing nuclear safety risk across the Magnox Limited fleet. As would be expected, more substantial and wider-ranging enhancements have been made at Wylfa, the only site with an operating reactor. The scope of enhancements implemented at other sites has been proportionately smaller.

3.2 Structure of the Magnox Limited Response Programme

Within the Magnox Limited response programme, work has been implemented primarily through the sites with assistance being provided by appropriate specialists from central functions. This site-focussed structure accords with the overarching aim of seeking to deliver tangible safety enhancements swiftly and pragmatically across the fleet, but in a manner proportionate with the remaining level of risk at each site.

Every site nominated a representative to act as a focal point for executing work items allocated to the site and reporting progress. Many sites also appointed a project manager to manage the execution of allocated tasks through to completion.

Central co-ordination has been provided by Engineering Function under the leadership of a senior programme manager and sponsorship of the Engineering Director. The programme as a whole has reported to a director-level steering group chaired by the Chief Nuclear Officer and attended by the Chief Operating Officers and Engineering Director through whom the company executive has been kept informed.

The role of the steering group has been to oversee and agree the Magnox Limited response strategy and to ensure that timely progress has been made with implementing agreed enhancements. To this end the steering group initiated an audit of each site’s response to programme-related actions early in 2013 to provide assurance that the sites had identified and were implementing safety enhancements proportionate with the level of site risk. This audit resulted in a number of corrective actions that were completed by the sites.

Further independent scrutiny has been provided by the Magnox Limited Nuclear Safety Committees, bodies with both company and independent membership legally constituted to provide formal advice on nuclear safety issues to the company under terms of reference in accordance with the nuclear site licence conditions. The Nuclear Safety Committees have been briefed at key points during the programme.

A close working relationship has been maintained with other UK nuclear licensees throughout the duration of the response programme. Cross-licensee dialogue has been facilitated through the establishment of a topic specific sub-group by the Safety Directors’ Forum. That sub-group has successfully promoted a consistency of approach across licensees in responding to the challenges posed by the Japanese events and has provided opportunities for collective discussion with the Office for Nuclear Regulation.

Another important aspect of the relationship between licensees is in the area of accident management and response. Should an incident requiring off-site emergency support occur, agreements are in place between licensees for mutual strategic co-operation and assistance at both local site and corporate levels. In this manner augmented resources and expertise will be made available to successfully manage any event that might occur. Such arrangements are regularly exercised and demonstrated as part of the national emergency exercise programme.

3.3 Key Elements of the Magnox Limited Response

The Magnox Limited response to lessons learned from the Japanese earthquake and tsunami has comprised several key elements. The most significant of these components are outlined below.

These elements did not progress in isolation from one another. For example, the site resilience reviews described in Section 3.3.1 were predicated to a significant extent on the questions raised in the European Council Stress Tests (Section 3.3.3), the recommendations of early WANO Fukushima-related Significant Operating Experience Reports (Section 3.3.4), and the conclusions and recommendations from the ONR Interim Report on implications of the Japanese events for the UK nuclear industry (Section 3.3.5).

3.3.1 Site Resilience Reviews and Enhancements

Fundamental to the Magnox Limited response to the Japanese events has been the programme of site resilience reviews instigated by the company in the weeks following 11th March 2011. The objectives were to review the resilience of site safety-related structures, systems, components and operations against beyond design basis hazards to identify pragmatic and effective means of further enhancing resilience. The outcome of these reviews has formed the basis for the majority of the resilience enhancements that have since been delivered across the Magnox Limited fleet.

The initial vehicle for these reviews was a series of structured, facilitated workshops held between June and September 2011:

- Generating Reactors (Oldbury and Wylfa) three workshops June and July 2011;
- Spent Fuel Ponds (Dungeness A, Chapelcross, Oldbury and Sizewell A) August 2011;
- Dry Fuel Stores (Wylfa) August 2011;
- Intermediate Level Waste (all sites) September 2011.

To achieve the workshop objectives, attendance across a broad range of disciplines was secured. Site Engineering Departments (responsible for maintaining the site safety case and long-term health of the plant) were strongly represented including a mix of site system engineers, senior engineering consultants and safety case experts. Site Operations Department (responsible for the day-to-day plant operation) involvement included operations managers and shift charge engineers. Health physics, emergency preparedness and site inspection staff attended on behalf of the Environment Health Safety Security & Quality Department (responsible for ensuring compliance with company standards and other legal requirements). In addition to site staff, personnel from corporate functions also attended the workshops including managers, safety case and hazards specialists from Engineering Function and Emergency Planning staff from the Operational Resilience Team.

Inspectors from the Office for Nuclear Regulation attended several of the early workshops in an observer capacity to provide feedback on the process and outcome.

The workshops considered a wide range of potential hazard events that could impact upon the sites. Specific ways (involving plant, operations or people) in which each hazard-type could, if sufficiently severe, challenge the provision of one or more safety functions (cooling, containment, control, monitoring, shielding etc.) were identified. Identification of "cliff-edges" in radiological consequences, if any, for events incrementally more severe than those considered within the site design basis was considered to be a fundamental outcome. Measures that could enhance plant resilience against the hazards, thereby preventing or mitigating the identified challenges, were then brain-stormed and sentenced in accordance with agreed criteria.

The output from each workshop was a list of potential enhancement opportunities to be taken forward by each relevant site for further consideration and development.

Following rationalisation to eradicate repetition, the potential enhancement opportunities identified by the workshops were converted into an action list for each site.

The number and scope of actions placed on each site depends on site status. For example, the Wylfa action list comprised actions arising from the Generating Reactors, Wylfa Dry Fuel Stores and Intermediate Level Waste workshops. The action lists for those sites that were fully defuelled at the time of the workshops (Berkeley, Bradwell, Hinkley Point A, Hunterston A and Trawsfynydd) only contained proposed enhancements from the Intermediate Level Waste workshop.

Oldbury had a generating reactor at the time of the workshops and the action list for that site comprised proposed enhancements from the Generating Reactors, Spent Fuel Ponds and Intermediate Level Waste workshops. Following final shutdown of both Oldbury reactors some of the Generating Reactors workshop actions were no longer relevant. It is noteworthy, however, that Oldbury site had already addressed many of the Generating Reactors actions by the time Reactor 1 was shut down in February 2012 despite the very limited remaining period of generation.

Defuelling has been completed at Chapelcross and Dungeness A in the period during which those sites were addressing their action lists. Thus some of the Spent Fuel Ponds workshop actions became redundant for these sites.

Each site action arising from the workshop process has been tracked to completion. In the majority of cases the site actions have not resulted in any change to plant or procedures because existing resilience provisions have been found, following site-specific review, to be adequate to meet the intent of the enhancement opportunity raised at the workshop.

Nonetheless, substantive enhancements have been implemented, examples of which are summarised below.

Wylfa

- Construction of a new emergency equipment compound on higher ground adjacent to the main site (Figure 2);
- Provision of new diesel-driven fire pumps (two on trailers (Figure 3) and four others), any one of which would meet the boiler feed requirements for the operating reactor;
- Provision of alternative pumping-in points for boiler feed including procurement of all necessary connection equipment, stored adjacent to the plant together with connection procedures;
- Procurement of one road tanker (Figure 4) and hire of a second until final shutdown of Reactor 2, to facilitate transport of additional water supplies to site, if required;
- Provision of additional pipework pressure sealing equipment, stored in diverse locations;
- Procedures for back-feeding electrical supplies to site from the local low voltage distribution system prepared in conjunction with the regional electricity supply company;
- Procurement of two large mobile diesel generators (Figure 5) complete with connection cables and bowsers with sufficient fuel for around 72 hours and procedures for connecting to station switchboards;
- Procurement of four small generators (Figure 5) with emergency lighting sets, leads and connectors;
- Installation of an alternative, totally diverse, monitoring system for a small subset of essential reactor parameters, independent of site electrical supplies with wireless data transmission to the new emergency equipment compound (Figure 6);
- Increase in fuel oil stocks held on site, suitable for the gas turbine generators and all diesel generators and pumps on site (replacement of a fuel oil storage tank at Wylfa to achieve this enhancement is planned for completion in the summer of 2014);
- Provision of additional stocks of personal protective equipment, dose meters, contamination probes and respirators, stored in diverse locations;
- Procurement of two submersible sump pumps for flood alleviation (Figure 7);
- Complete restructuring and revision of emergency and severe accident procedures and development of new fuel route and radioactive waste accident management guidelines;
- Procurement of a new fire tender (Figure 8) to supplement existing fire-fighting provisions;
- Procurement of an earthmover (Figure 9), tractor, chainsaws, breaker hammers and ladders to assist with post-event access;
- Provision of additional staff welfare packs.

Oldbury

- Provision of increased stocks of carbon dioxide and fuel oil prior to final reactor shutdown;
- Provision of two additional back-up boiler feed pumps together with hoses and couplings (Figure 10), elevated above ground level, and additional pipework protection;
- Provision of further pumps stored within equipment containers (see below) located at the highest point of the site;
- Installation of a new filling line (Figure 11) allowing water to be added directly to the spent fuel ponds by gravity feed alone if necessary from a point external to the building;
- Procurement of a new mobile crane with increased load carrying capacity and other equipment to aid debris clearance (Figure 12);

- Identification of generator and electrical connection points and provision of associated instructions;
- Installation of three independent passive pond water depth indicators that can be read external to the ponds building;
- Development of new fuel route and radioactive waste accident management guidelines;
- Provision of four containers (Figure 13) of site-specific emergency equipment, including equipment to seal or minimise leakage from the spent fuel ponds following a beyond design basis event;
- Provision of increased stocks of staff welfare equipment (chemical toilets, emergency rations, camp beds, radiation monitoring equipment, radiation protection equipment), stored in diverse locations (Figure 14);
- Identification of two site locations where alternative emergency control centres can be established, and provision of appropriate materials at those locations.

Sizewell A

- Installation of a new fuel pond filling line (Figure 15) enabling water or foam to be pumped directly into the pond from a diverse source, together with diesel driven and electric submersible pumps and connectors;
- Development of new fuel route and radioactive waste accident management guidelines.
- Provision of two containers (Figure 16) of site-specific emergency equipment containing additional stocks of personal protective equipment, radiological monitoring equipment, tools, pumps, generators, concrete repair consumables, foam concentrate, plastic sheeting and sand bags;
- Enhancements to address an additional concern, not specifically identified in the resilience workshops, relating to the capability to measure the depth of water remaining in the spent fuel pond following an event:
  - » installation of two full range ultrasonic probes for the east and west ponds;
  - » installation of a new plant information workstation in the emergency control centre;
  - » installation of a closed circuit television system, linked to the existing plant information data network, allowing pond conditions, including pond water level, to be observed from various locations on site including the main control room and emergency control centre.

Decommissioning Sites (Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A and Trawsfynydd)

The enhancements implemented at the decommissioning sites have been at a lower level, reflecting the low residual risks and adequate existing resilience, noting the largely passive manner in which remaining radiological material is stored. Nevertheless, enhancements have, depending on site-specific requirements, included:

- Provision of additional portable generators and pumps, stored in resilient locations;
- Provision of additional personal protective equipment and radiation monitoring equipment, stored in diverse and resilient locations;
- Provision of portable flood barriers for local deployment to inhibit water entry into buildings at identified points;
- Development of new radioactive waste accident management guidance.

All Sites

All sites have been provided with:

- Two satellite telephones for emergency communications (Figure 17);
- Two portable GPS-equipped radiation monitoring cones to provide supplementary local radiation monitoring capability;
- A beyond design basis emergency equipment container (Figure 18) including first aid/medical equipment, a wide selection of hand and power tools, pumps, generators, specialist tools, batteries, personal protective equipment, basic communication equipment, stationery, lifting and moving equipment.

The emergency equipment container supplied to each site has a common inventory and can serve as a remote backup for another site should the need arise in an emergency situation.

The summary above is by no means exhaustive.

Each site has reviewed its resilience to an appropriate extent and has implemented proportionate improvements.

3.3.2 Seismic Walkdown Validation

In addition to the programme of resilience workshops described in Section 3.3.1, Magnox Limited initiated other work shortly following the Japanese events aimed at validating previously assessed resilience against natural hazards.

The most challenging natural hazard considered for Magnox Limited sites is that associated with earthquakes that could simultaneously affect all structures, systems and components on site as well as causing off-site infrastructure disruption.

Seismic events were not part of the original design basis for the Magnox Limited sites. Considerable effort has been expended since the early 1980s to complete assessments, plant modifications and strengthening work necessary to ensure that essential reactor safety functions can be maintained following seismic events with an exceedance frequency of 10^{-4} per annum (or, equivalently, a return period of 10,000 years) with a margin to address less frequent events. For example, more than £100million has been spent assessing and upgrading the Wylfa plant during past Periodic Safety Reviews. A substantial proportion of that expenditure was associated with improving resilience against extreme events, and seismic events in particular.

Following the Japanese earthquake and tsunami Magnox Limited commissioned a targeted programme of seismic walkdown assessments on its plants. The aim of those walkdowns was to verify the existing seismic capability claims against design basis events and to improve the understanding of vulnerability to events beyond the design basis.

The walkdown assessments were restricted to the operating Magnox Limited power stations at Oldbury and Wylfa. Given that Oldbury Reactor 2 ceased operation permanently in June 2011 the assessment for Oldbury was restricted to systems available for the protection of Reactor 1.

The scope of plant considered included that which is claimed to provide protection against the consequences of the most severe design basis seismic events having an exceedance frequency of 10^{-4} per annum.

Given that this assessment was intended to verify the continuing validity of conclusions drawn from earlier assessments, the focus of the new assessment was on identifying potential areas where changes that had occurred in the period since those earlier assessments (plant degradation or change in plant configuration, for example) could have potentially diminished the claimed seismic capability.

An additional aspect of the new walkdown assessments was to identify any specific items within the assessed plant systems that exhibit particular vulnerabilities and that could, as a consequence, represent specific limitations on the ability of those systems to withstand more severe seismic events beyond the normal design basis.

In general the condition of the plant inspected was found to be of a good standard to meet the existing seismic capability claims. A number of recommendations resulted from the assessments requiring further verification or minor remedial work. None of the issues identified by the assessment at Wylfa or Oldbury were considered by the assessment contractor or Magnox Limited to present an immediate threat to nuclear safety. This gave confidence that previous plant seismic robustness claims, and thus the site seismic safety case, remained valid.

3.3.3 Response to the European Council Stress Tests

In the light of the accident at the Fukushima Dai-ichi nuclear power plant as a consequence of the 11th March 2011 Japanese earthquake and tsunami, the meeting of the European Council on 24th March 2011 ordered that the safety of all nuclear plants within the European Union should be reviewed “on the basis of a comprehensive and transparent risk assessment (“stress tests”)”.

The European Council requested that the European Nuclear Safety Regulators Group (ENSREG) and the European Commission develop a scope and procedure for this targeted reassessment of the safety margins of nuclear power plants making use of the expertise available within the Western European Nuclear Regulators Association (WENRA).

On 13th May 2011 ENSREG and the European Commission published a specification and timetable for the performance of the stress tests. Specifically, the scope of the safety reassessment was in outline:

- to evaluate the response of each nuclear power plant to design basis and beyond design basis earthquakes, flooding events and extreme weather, including limits of the capacity to withstand beyond design basis events;

- to evaluate the consequences of loss of electrical power (including "station black out") and loss of ultimate heat sink, or a combination of both;
- to review the adequacy of provisions for all aspects of severe accident management.

Accordingly, the Office for Nuclear Regulation wrote to Magnox Limited on 31st May 2011 requesting the company to undertake the stress tests. Although the intent of the ENSREG specification was that stress tests should be undertaken for nuclear power plants (that is, for plants with operating nuclear reactors), the ONR expanded the scope to all UK nuclear licensed sites to the extent that the tests were appropriate for each facility. Thus the stress tests were to cover not only the operating Magnox Limited power stations (Wylfa and Oldbury at that time) but also the remainder of the Magnox Limited fleet including shutdown defuelling sites and decommissioning sites.

In response to this requirement Magnox Limited prepared a stress test report for each site (Refs. 2 to 11) based around a standard template that addressed the totality of the scope defined by the ENSREG/European Commission specification, taking account of additional guidance provided by WENRA in August 2011. Some interpretation was required to extend the stress tests in a meaningful way to non-power-generating sites because the stress test questions were heavily biased towards operational nuclear power plants. Final stress test reports for each site were submitted to the ONR by 31st October 2011 as required by the ENSREG stress test schedule.

The site stress test reports (Refs. 2 to 11) give a detailed evaluation of each site's resilience to the types of challenge covered by the ENSREG/European Commission specification. Those reports also identified a number of "Stress Test Considerations" which encapsulated the programme of further work to be undertaken by each site in response to the resilience reviews discussed in Section 3.3.1, above. The resilience review workshops were being held concurrently with the production of the stress test reports and were heavily influenced by consideration of the questions posed in the ENSREG/European Commission stress test specification.

The topic areas covered by the Stress Test Considerations closely mirror the enhancement opportunities derived from the resilience workshops. Examples of resulting resilience enhancements are listed in Section 3.3.1.

Following the submission of Stress Test reports by Magnox Limited and other UK licensees in October 2011, the Office for Nuclear Regulation published two reports:

- "European Council Stress Tests for UK Nuclear Power Plants – National Final Report" (December 2011, Ref. 12) covering operating and defuelling power plants including Wylfa, Oldbury, Chapelcross, Dungeness A and Sizewell A (noting again that Oldbury still had an operating reactor at that time and Chapelcross and Dungeness A were in the process of defuelling their reactors).
- "Stress Tests for UK Non Power Generating Nuclear Facilities" (May 2012, Ref. 13) covering all remaining Magnox sites.

These reports stated that the ONR was content with the adequacy of the Stress Test programme undertaken by Magnox Limited and concluded that the reviews undertaken for the Stress Tests did not indicate any fundamental weaknesses in the definition of design basis events or the safety systems to withstand them. This concurred with the conclusions of the earlier Chief Inspector's Interim and Final reports on the implications of the Japanese earthquake and tsunami for the UK Nuclear Industry (Refs. 14 and 15, see Section 3.3.5, below).

Nevertheless, the ONR re-iterated their expectation regarding implementation of enhancements to strengthen the resilience of nuclear facilities within an appropriate timescale. To reinforce specific expectations, the ONR made 22 "Stress Test Findings" applicable to Magnox: 18 relevant to fuelled sites and 4 relevant to other sites (Refs. 12 and 13). These were additional to the earlier 26 Chief Inspector's Interim Report recommendations (Ref. 14) and 12 Final Report recommendations (Ref. 15). These findings and recommendations are discussed in more detail in Section 3.3.5 and Section 4.

During the spring of 2012 ENSREG undertook a peer review of the Stress Test National Final Report considering the adequacy of the report against the stress test specification and the adequacy of the national Regulatory response. Magnox Limited provided substantial support to the ONR during the peer review process. The ENSREG peer review team published its UK Country Peer Review report (Ref. 16) and the over-arching European Union Peer Review report (Ref. 17) in April 2012.

Following completion of the peer review process, ENSREG published an Action Plan in July 2012 (Ref. 18). The aims of that Action Plan were to ensure that the conclusions from the stress tests and their peer review result in improvements in safety across European nuclear power plants, and to ensure that the recommendations and suggestions from the stress test peer review are addressed by national regulators and ENSREG in a consistent manner.

A requirement of the ENSREG Action Plan was that the ONR provide a UK National Action Plan for implementing lessons learned from the Japanese earthquake and tsunami within the UK nuclear industry. Magnox Limited again provided support to the ONR in the development of this UK National Action Plan. The Action Plan was published by the ONR in December 2012 (Ref. 19). The national action plans for all participating countries, including the UK, were peer reviewed at a workshop held by ENSREG in April 2013 (Ref. 20).

3.3.4 Response to WANO Significant Operating Experience Reports

Magnox Limited belongs to the World Association of Nuclear Operators. WANO is an international organisation that facilitates and encourages sharing of operating experience and implementation of improvement measures among the global nuclear operating community. The organisation exists to help its members accomplish the highest levels of operational safety and reliability through a series of programmes which include peer reviews, technical support and access to a global library of operating experience.

One of the vehicles that WANO uses to share operating experience and encourage adoption of best operating practice is Significant Operating Experience Reports (SOERs) whose purpose is to identify the principal contributors to significant events or trends in types of events and provide recommendations that members are expected to implement to prevent similar events at their plants. In most cases operating companies are expected to provide responses to WANO detailing how recommendations have been implemented or specifying timescales and plans for future implementation.

To date WANO has issued four SOERs relating specifically to lessons learned from the Fukushima Dai-ichi nuclear accident.

SOER 2011-2: (March 2011) Fukushima Dai-ichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami.

This SOER proposed immediate actions to be taken by operators as a result of the Fukushima Dai-ichi accident. Such actions included:

- verifying readiness of existing capabilities to mitigate adverse conditions that might arise as a result of the occurrence of beyond design basis events including testing, inspections and training;
- verifying readiness and functionality of systems to mitigate loss of off-site electrical power supplies (station blackout);
- verifying functionality of designed capability to mitigate internal and external flooding events;
- carrying out walkdown inspections of emergency equipment to identify ways in which such equipment could be rendered ineffective by seismic events, and developing mitigation strategies if necessary.

Magnox Limited's response to these recommendations concentrated primarily on the sites with operating reactors: Wylfa and Oldbury at that time. At those sites a programme of walkdown inspections covering back-up and emergency systems, including those providing back-up electrical supplies, was completed. During those walkdown inspections the vulnerability to external hazards was also reviewed. Active testing was carried out on a subset of these systems to demonstrate readiness. Reviews of relevant operating instructions and emergency procedures were completed in conjunction with a review of relevant staff training records. Generally no deficiencies were identified. The few potential improvements identified were addressed by the sites.

Inspections at the remaining fuelled sites (Chapelcross, Dungeness A and Sizewell A at that time) focused on fuel pond equipment because of invulnerability of the entirely passive nature of cooling for residual long-cooled fuel in the reactors. Again some minor improvements were identified that were addressed by the sites.

Magnox Limited provided a complete response to WANO regarding work completed to address the recommendations of SOER 2011-2 in mid-May 2011.

WANO issued an Addendum to SOER 2011-2 in April 2012 which reinforced the need to manage, maintain and undertake periodic training and exercising in the use of equipment provided for emergency response purposes. Magnox Limited had already built these requirements into normal business arrangements.

SOER 2011-3: (August 2011) Fukushima Dai-ichi Nuclear Station Spent Fuel Pool/Pond Loss of Cooling and Makeup.

This SOER made recommendations aimed at providing assurance that sites have adequate awareness and readiness to effectively respond to events that challenge fuel pond cooling. Those recommendations required operators to:

- establish timescales for fuel ponds to reach unacceptable temperatures;
- ensure that cooling equipment is adequately protected and controlled commensurate with necessary timescales for restoration of cooling;
- verify adequacy of equipment and procedures for mitigating loss of fuel pond cooling or loss of pond water, including monitoring of water levels following extreme events that challenge the site in general;
- verify that an adequate testing regime exists for equipment preventing siphoning of pond water.

From a Magnox Limited perspective this SOER was applicable only to those sites that had fuel in the ponds at that time: Dungeness A, Sizewell A and Oldbury. The Magnox Limited response to this SOER established that for Oldbury it would take more than 100 days for pond temperatures to reach unacceptable levels with an expectation that such limits would never be reached because equilibrium between heat input and loss would be established at a lower temperature. At the time of this SOER the heat input from the long-cooled fuel in the ponds at Dungeness A and Sizewell A was sufficiently low that the temperature could not approach a level of concern (defuelling has subsequently been completed at Dungeness A).

In the light of such long timescales, no requirements were identified for special measures to protect pond cooling equipment. Similarly, by design any siphoning that might occur from the ponds cannot result in safety-significant loss of pond water and no special testing of anti-siphoning equipment was deemed necessary above and beyond normal maintenance. The intention to install an emergency pond filling line at Oldbury was noted (see Section 3.3.1, above; this improvement has now also been implemented at Sizewell A). Furthermore, where not already included, operating instructions relating to actions to be taken in extreme events were revised to include actions to monitor pond water levels.

A comprehensive response to this SOER was provided to WANO in January 2012.

WANO issued a supplement to SOER 2011-3 in April 2012 containing an analysis of the response data obtained from operators identifying common gaps and areas of good practice. Magnox Limited considered these results and noted that many of the enhancements that were already in hand or had been completed as a result of the resilience workshops (Section 3.3.1, above) addressed the identified gaps or were good practice.

SOER 2011-4: (December 2011) Near Term Actions to Address an Extended Loss of All AC Power.

SOER 2011-4 recommended the confirmation or development of contingency arrangements for protecting sites against adverse effects from extended loss of electrical power supplies of the kind that occurred at the Fukushima Dai-ichi nuclear power plant. Specifically, sites were to:

- have arrangements in place to supply emergency power, where required, to equipment providing essential reactor and fuel pond safety functions for an extended period without significant off-site support; this was to include power for essential plant monitoring and communications;
- provide adequate consumable stocks, diesel fuel for example, to cope with extended loss of power;
- ensure that appropriate arrangements exist for regular testing of plant and equipment necessary to provide safety-related functions in the event of loss of electrical supplies.

The Magnox Limited response to this SOER covered all ten sites. The response explained that all sites except Wylfa and Oldbury have no safety-related requirements for electrical power. Similarly, there are no short-term safety-related requirements for electrical power at Oldbury since both reactors had by this time been permanently shut down (see Section 2, above). Nevertheless, prudent measures had been implemented to increase the back-up capability for essential safety functions such as provision of additional standalone generators and pumps together with increased stocks of diesel and petrol fuel to power this equipment.

The response for Wylfa noted that, in most circumstances, standalone systems independent of off-site or on-site electrical supplies are sufficient to ensure reactor safety. For the limited conditions under which electrical supplies would be required, diverse and redundant on-site generation capacity is available to meet those needs and this capacity had been bolstered by the provision of additional diesel fuel stocks and standalone generators following the Japanese events.

It was confirmed that at all sites necessary monitoring can be undertaken independent of the availability of electrical supplies.

Multiple, diverse, systems are available to provide emergency communications with battery back-up to maintain operability during extended power loss. A further layer of diversity has been afforded following the Japanese events by the provision of standalone satellite telephones to all sites.

Sufficient diesel fuel was available at all sites to meet safety requirements for a period in excess of 72 hours in the event of loss of off-site electrical supplies.

Testing arrangements for all plant and equipment claimed as necessary to provide safety-related functions were confirmed.

A full response to the SOER 2011-4 recommendations was provided to WANO at the end of March 2012.

As with SOER 2011-3, in September 2012 WANO issued a supplement to SOER 2011-4 containing an analysis of the operator response data and identifying common gaps and areas of good practice. Once again Magnox Limited reviewed this response data but no further actions above and beyond those already in hand, or completed, as a result of resilience workshops (Section 3.3.1) were identified

SOER 2013-2: (March 2013) Post-Fukushima Dai-ichi Nuclear Accident Lessons Learned.

This SOER, published some two years after the Japanese events, contained wide-ranging recommendations encapsulating learning across areas not covered by the earlier SOERs. The general topics covered are:

- Safety Culture and Senior Leaders
- Evaluation of Challenges to Design Basis Assumptions for External Events
- Safety System Isolation Logic
- Emergency/Accident Response
- Knowledge, Skills and Proficiency
- Human Resources
- Equipment Resources
- Industry Response to Major Accidents

The lessons summarised in this SOER, in so far as they are relevant to Magnox Limited, were already embedded within Magnox Limited provisions and business processes. Appropriate resilience reviews and enhancements had been completed, as necessary, in response to earlier learning derived from the resilience workshops (Section 3.3.1) and recommendations and findings from the Office for Nuclear Regulation (Sections 3.3.3, 3.3.5 and 4). No new enhancement opportunities were identified as part of Magnox Limited's review of this SOER.

In accordance with the timescale requested by WANO, in January 2014 Magnox Limited returned a comprehensive response covering all of the SOER 2013-2 recommendations relating to the topic areas above.

3.3.5 Response to ONR Recommendations and Findings

On 14th March 2011, three days after the Japanese earthquake and tsunami, the Secretary of State for Energy and Climate Change wrote to HM Chief Inspector of Nuclear Installations requesting a review of the circumstances of the Fukushima accident to identify lessons that could be learnt to enhance the safety of the UK nuclear industry. In response to that request the Office for Nuclear Regulation, under the leadership of HM Chief Inspector and supported by UK nuclear site licensees including Magnox Limited, produced two reports. An Interim Report (Ref. 14) was published in May 2011 with the Final Report (Ref. 15) being issued four months later in September 2011.

Those reports provided a comprehensive overview of the circumstances and causes of the Fukushima Dai-ichi accident, as understood at that time, and a review of their relevance to the UK nuclear industry. The reports drew a number of conclusions and made a large number of recommendations.

Specifically, the ONR saw no reason to curtail the operation of nuclear power plants or other nuclear facilities in the UK as a direct response to the events in Japan. That conclusion was based on a number of observations:

- that the UK has in place a rigorous regulatory regime for the nuclear industry that is independent both of the industry and of Government;
- that the UK approach to identifying the design basis for extreme events against which to design and assess UK nuclear facilities, being based on 10^{-4} per annum exceedance frequency (1 in 10,000 year return period), is sound;
- that UK nuclear licensees are required to perform Periodic Safety Reviews at least every ten years involving comparison against modern standards, including current engineering design standards and good engineering practice, and the implementation of reasonably practicable enhancements to improve plant safety.

These features underpin a sustained high standard of nuclear safety based on the principle of continuous improvement which is enshrined in UK law.

Notwithstanding the above conclusion, the ONR reinforced the need to learn lessons from the Japanese events as part of the drive for continuous improvement in matters affecting nuclear safety.

To emphasise primary learning points the ONR reports made recommendations for further reviews to be carried out to determine whether reasonably practicable improvements could be made to the safety of the UK nuclear industry. These recommendations were to be addressed variously by the UK Government, the ONR itself, the nuclear industry, specific licensees and other bodies.

Of the 26 recommendations within the Interim Report (Ref. 14), 20 were directed at the UK nuclear industry. For ease of reference Interim Report recommendations are designated by the prefix “IR”. The Final Report (Ref. 15) added a further 12 recommendations (designated by the prefix “FR”) of which 7 were aimed primarily at the UK nuclear industry.

Magnox Limited has been working to address the ONR recommendations since the Interim and Final reports were published. A comprehensive update on progress with each recommendation, together with updates on progress with the Stress Test Findings (designated by the prefix “STF”, see Section 3.3.3), was provided to the ONR in June 2012.

Based on that update, subsequent clarification, discussions and assessment, the ONR issued an Implementation Report (Ref. 21) in October 2012 that discussed progress with implementing lessons learned from the Japanese events and in addressing the recommendations and findings from the earlier ONR reports (Refs. 12, 13, 14 & 15). With respect to Magnox Limited that report concluded:

> *“Overall, ONR considers that Magnox’s responses to the recommendations, findings and considerations demonstrate an appropriate commitment to implementing lessons from the Fukushima accident. The responses also provide satisfactory reassurance that real progress is being made for most recommendations and findings, and that reasonable programmes of work to address other areas are either in progress or in the planning stage. ONR will continue to monitor all of these workstreams and will engage in further discussions with Magnox to ensure an appropriate outcome.”*

The ONR noted the Magnox Limited intent to complete most work during 2013 with the possibility of a small residue of work continuing into 2014. The ONR considered these timescales to be appropriate given the nature of the solutions being implemented.

Magnox Limited continued to engage with the ONR during the latter half of 2012 and 2013 through a comprehensive programme of technical meetings and site inspections to keep the ONR abreast of progress and to clarify details of the ONR vision embodied within the various recommendations and findings.

The ONR recognised (Ref. 21) the need for the Magnox Limited response to be proportionate with the limited remaining timescale for reactor operation and the diminishing nuclear safety risks across the fleet (see Section 2). In this respect the ONR made the following statement within Reference 12:

> *“The short remaining periods for both operation and subsequent defuelling act as a practical constraint on the overall safety benefit that could arise from potential improvements resulting from the stress tests reviews and recommendations in HM Chief Inspector’s report. Magnox Ltd has recognised this and has initiated reviews and optioneering studies to determine if enhancements can be implemented in a timely manner in order that a real safety benefit is realised.”*

This accorded with Magnox Limited’s overarching aim (Section 3.1) of seeking to implement reasonably practicable and proportionate enhancements that deliver tangible safety improvements swiftly and pragmatically across all ten Magnox Limited sites and support functions. Thus Magnox Limited has sought to interpret the ONR recommendations and findings in very tangible and practical ways with the focus on converting the recommendations and findings into improvements that can be delivered in a timely manner so as to maximise the safety benefit.

A detailed summary of the Magnox Limited response to each applicable ONR recommendation and finding is given in Section 4.

All of the recommendations relating to Wylfa have been addressed appropriately and closed-out.

Reactor operation at Oldbury ceased shortly after completion of the walkdown assessments thereby rendering the majority of recommendations redundant because of the greatly reduced demands on active safety-related systems following permanent reactor shutdown. For this reason closure of the walkdown recommendations has not been pursued further for Oldbury although a number of items have been addressed.

4. Response to ONR Recommendations and Findings

This section summarises the Magnox Limited responses to each recommendation or finding made by the Office for Nuclear Regulation in its Interim, Final and National Stress Test Final Reports (Refs. 12 to 15) that is directed primarily at "the UK nuclear industry", "Licensees" or "Magnox Ltd". Sections 3.3.3 and 3.3.5, above, describe the origins of these recommendations and findings.

Specifically, the recommendations and findings addressed in the sections that follow are:

Section 4.1, HM Chief Inspector's Interim Report (Ref. 14) recommendations:

IR-4, IR-8, IR-9, IR-10, IR-11, IR-12, IR-13, IR-14, IR-15, IR-16, IR-17, IR-18, IR-19, IR-20, IR-21, IR-22, IR-23, IR-24, IR-25 & IR-26.

Section 4.2, HM Chief Inspector's Final Report (Ref. 15) recommendations:

FR-1, FR-2, FR-3, FR-4, FR-6, FR-11 & FR-12.

Section 4.3, ONR National Stress Test Final Report (Ref. 12) findings:

STF-1, STF-2, STF-3, STF-4, STF-5, STF-6, STF-7, STF-8, STF-9, STF-10, STF-11, STF-12, STF-13, STF-14, STF-15, STF-16, STF-17 & STF-19.

Section 4.4, ONR National Non-Power Plant Stress Test Final Report (Ref. 13) findings:

STF-20, STF-47, STF-83 & STF-94.

There is not a simple one-to-one correspondence between aspects of the Magnox Limited response to lessons learned from the Japanese events and the ONR recommendations and findings. This is largely because there is much overlap between the various recommendations and findings, with some covering multiple topics. A substantial degree of repetition is, therefore, inevitable in the responses presented in subsequent sections.

4.1 HM Chief Inspector's Interim Report Recommendations

IR-4 Both the UK nuclear industry and ONR should consider ways of enhancing the drive to ensure more open, transparent and trusted communications, and relationships, with the public and other stakeholders.

Magnox Limited Response to IR-4

Magnox Limited robustly believes in strong, open, transparent and trusted communications arrangements. To achieve this Magnox Limited has been working with the Nuclear Decommissioning Authority (which owns the sites managed by Magnox Limited) to seek the views of stakeholders, in particular the Site Stakeholder Groups, on openness and transparency to identify learning opportunities. Magnox Limited supports industry-wide approaches to openness and transparency led by the Nuclear Industry Association, the nuclear industry trade body. Magnox Limited is also supporting the ONR in their drive to enhance openness and transparency in their relationships with the public and other stakeholders.

Magnox Limited has improved its website to include an automated newsletter to help keep interested stakeholders up to date with key events at Magnox Limited sites. Magnox Limited continues to monitor usage statistics for its website and to keep the website functionality and content under review. Magnox Limited has also established a modest social media presence consistent with security requirements.

Through the Site Stakeholder Groups, Magnox Limited senior officers have responded to requests for information, briefings and in some cases extended discussions on the events at Fukushima Dai-ichi and the implications for Magnox Limited sites. Magnox Limited has also facilitated the participation of the ONR in such debates. In addition to Site Stakeholder Group meetings, Magnox Limited has established a regular twice-yearly meeting between the Managing Director and the Site Stakeholder Group Chairs where a wide range of issues is discussed. Feedback from these meetings is discussed at the Magnox Limited Executive.

Magnox Limited will continue to support industry-wide initiatives through the Nuclear Industry Association and, where appropriate, will work with other industry bodies to support their transparency initiatives. This includes continuing to host media visits and, subject to security requirements, other stakeholder visits to Magnox Limited sites.

Magnox Limited has supported the World Association of Nuclear Operators in its move to define its emergency role more clearly. This includes incorporating emergency preparedness as a core peer review area and introducing greater accountability for member obligations.

Given the remaining lifespan of the nuclear sites operated by Magnox Limited it is not considered that reopening of visitor centres at Magnox Limited sites, where the facilities still exist, is appropriate.

Conclusion

Magnox Limited has considered ways of enhancing the drive to ensure more open, transparent and trusted communications, and relationships, with the public and other stakeholders. The improvements identified above have now been incorporated into Magnox Limited's normal business arrangements.

IR-8 The UK nuclear industry should review the dependency of nuclear safety on off-site infrastructure in extreme conditions, and consider whether enhancements are necessary to sites' self-sufficiency given the reliability of the grid under such extreme circumstances.

This should include:

a) essential supplies such as food, water, conventional fuels, compressed gases and staff, as well as the safe off-site storage of any equipment that may be needed to support the site response to an accident; and

b) timescales required to transfer supplies or equipment to site.

Magnox Limited Response to IR-8

The key aspect of Recommendation IR-8 is that sites should be self-sufficient for an adequate period during a nuclear emergency when, under extreme circumstances, off-site electrical supplies could be lost and the provision of materials from off-site might not be possible. This theme has much in common with Recommendations IR-17, IR-18 and IR-19 and with Stress Test Finding STF-9.

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined materials which are normally required on the site, additional materials and equipment required to respond to an incident, and provisions to ensure the continued welfare of people who may be required to remain on the site. The aim has been to ensure that each site is self-sufficient for at least 72 hours. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of actions placed at those workshops, site-specific reviews relating to site self-sufficiency have been completed. These site-specific reviews have identified opportunities for enhancing self-sufficiency. Examples of resilience enhancements that have been implemented to increase the self-sufficiency of sites are summarised below

All Sites

Emergency Equipment

Before the Japanese events containers with stocks of beyond design basis emergency equipment were maintained at Wylfa and in central England ready to be transported to any affected site. Following resilience reviews Magnox Limited has provided all sites with a dedicated beyond design basis emergency equipment container including first aid/medical equipment, a wide selection of hand and power tools, pumps, generators, specialist tools, batteries, personal protective equipment, basic communication equipment, stationery, lifting and moving equipment. These containers provide a basic level of site self-sufficiency in the area of equipment that may be useful in tackling the immediate consequences of an incident and in preventing potential incident escalation. The containers are stored on or near each site in a location resilient to flooding and damage from collapsing buildings

Staff Welfare

All sites had pre-existing arrangements to maintain the welfare of staff required to remain on site for an extended period in the event of a pandemic. The arrangements covered basic commodities, food supplies, temporary accommodation, cleaning and infection control. These arrangements have been reviewed for each site and enhanced where considered beneficial, taking into account the number of people that might be required to remain on site and possible site conditions.

Wylfa

Emergency Equipment

Wylfa has established a new beyond design basis emergency equipment compound, located off-site but with easy access to the site, on ground that is 5m higher than the site itself.

Also within the compound are containers that hold additional emergency response equipment, and a further container holding stocks of general tools, special tools, pumps, generators and other equipment including radiological protection equipment. Ladders, torches and temporary lighting, and additional health physics equipment and consumables (including dose meters, contamination probes, respirators, coveralls and gloves) have been procured and are stored in the compound. One of the site fire tenders is also located in the compound together with an earthmover to facilitate access to and around the site following a beyond design basis event.

Staff Welfare

To ensure the welfare of staff remaining on site for an extended period, emergency welfare packs have been procured to provide emergency food rations, drinking water, first-aid kits etc., which are stored in the beyond design basis emergency equipment compound.

Conventional Fuels

The site has numerous diesel fuel storage tanks associated with the various gas turbines and diesel engines. The fuel is compatible for use in any of the plant. Two additional bowsers have been procured for moving fuel around site should the need arise. The opportunity has also been taken to increase diesel fuel storage capacity. When complete, the resulting increased fuel stocks will enhance resilience against loss of off-site or on-site electrical supplies and improve operational flexibility, particularly under emergency conditions.

Cooling Water

To increase the availability of water for reactor cooling the site initially purchased one road tanker and hired a second to aid transportation of clean water to site if necessary. The number of tankers has now been reduced to one following shutdown of Reactor 2. Possible sources of treated water and lake water that could be used following a serious event have been identified. The road tanker is stored adjacent to the beyond design basis emergency equipment compound. Additional pumps and hoses have been procured to allow the water to be moved within the site.

Compressed Gases

Stocks of carbon dioxide (the primary reactor coolant) available on site have been reviewed. The site holds in excess of four times the minimum operating requirement for two operating reactors. Only one reactor is now operating and requiring carbon dioxide. Therefore, ample stocks of carbon dioxide to maintain control of reactor gas composition under emergency conditions already exist on site. Procurement of additional carbon dioxide stocks is not warranted.

Oldbury

Emergency Equipment

Additional beyond design basis emergency equipment containers have been provided at Oldbury including extra equipment for debris clearance, spare ladders, lighting and torches, general tools, radiological protection equipment and items to aid staff welfare. The containers are located at the highest point of the site.

Staff Welfare

To ensure the welfare of staff remaining on site for an extended period, additional on-site stocks of food and welfare supplies (such as beds and bedding) have been purchased for emergency teams and/or stranded staff of up to 30 people for 36 hours. These are stored in a resilient elevated location.

Conventional Fuels and Compressed Gases

Oldbury was still a generating site for approximately one year following the Japanese earthquake and tsunami. As a prudent measure during that generating period, Oldbury increased the minimum stock holding of carbon dioxide for reactor cooling, kerosene fuel for the gas turbines and diesel for other pumps and generators. Both Oldbury reactors are now permanently shut down, filled with air, and have minimal active cooling requirements with long timescales for restoring cooling should it be lost. All bulk carbon dioxide has therefore been removed from site and the kerosene minimum stock level reduced back to its previous value. These measures minimise holdings of potentially hazardous substances on site while maintaining adequate kerosene stocks to meet normal and emergency requirements.

Cooling Water

While generating, in addition to that specifically stored for post-trip cooling in the Back-Up Feed System (BUFS) tanks, boiler quality water was potentially available in the reserve feed water tanks, the deaerator or the turbine condenser. Previous plant modifications and equipment purchases had been made to enable recovery of this water for use via the BUFS if needed post event. Refresher training on deployment of the BUFS system specifically including recovery of water from these diverse locations was delivered to all appropriate operations staff. Following permanent shutdown of both reactors the decision was taken not to use the deaerator or condenser as potential water sources due to building loadings and the possibility of water contamination.

With both reactors shut down the normal cooling requirement has reduced to intermittent circulation of water through the boilers only, with no external cooling applied and no boiling taking place. Supplies remain available from the reserve feed water tanks and the BUFS tanks with the option of taking supplies from a large towns water tank or recommissioning a bore hole on site if other water sources are rendered unserviceable. The current availability of water stocks is considered adequate given the current and reducing demand.

Sizewell A

Emergency Equipment

Additional emergency equipment containers have been provided in a resilient location. Equipment in those containers includes generators, sand bags, polythene sheet, repair materials, basic items for manual measurement, and additional personal protective equipment. Radiological personal protective equipment and additional health physics instrumentation are held in a satellite store in the reactor building above site ground level.

Staff Welfare

The emergency equipment containers described above include a stock of self-heating military-style rations for emergency teams and/or stranded staff.

Water and Compressed Gases

The cooling of the reactors and the spent fuel pond is achieved passively without the use of powered systems or boiler feed water. Compressed gases are no longer required as the reactors are in an air atmosphere. Water in the spent fuel pond is now required to provide radiation shielding only. Additional pumps have been procured specifically for use in emergency situations to abstract water from other sources and an emergency pond filling line, accessible from outside the pond building, has been installed. An additional trailer- mounted generator has been procured to support the provision of alternative water supplies to the pond.

Decommissioning Sites

All other Magnox sites have been fully defuelled and do not depend on off-site supplies to ensure safety in the short to medium term following an event. No specific opportunities to enhance self-sufficiency were identified for these sites. Nevertheless, as noted above, all sites have been supplied with a dedicated beyond design basis emergency equipment container that provides equipment specifically to facilitate recovery from an extreme event where circumstances might involve isolation of the site from external supplies for a limited period.

Conclusion

Magnox Limited has reviewed the dependence of the safety of its sites on off-site infrastructure and supplies under extreme conditions. Proportionate enhancements have been implemented to increase the sites’ self-sufficiency.

IR-9 Once further relevant information becomes available, the UK nuclear industry should review what lessons can be learnt from the comparison of the events at the Fukushima-1 (Fukushima Dai-ichi) and Fukushima-2 (Fukushima Dai-ni) sites.

Magnox Limited Response to IR-9

Although the Fukushima Dai-ichi and Fukushima Dai-ni sites are only 12km apart along the Japanese coast the consequences of the March 2011 earthquake and tsunami were very different. At Fukushima Dai-ichi the accident resulted in reactor meltdowns in Units 1, 2 and 3 and other problems leading to continuing releases of radioactive material. By contrast, the reactors at Fukushima Dai-ni were brought safely to a cold shutdown condition within a few days.

This disparity can be understood by examining evidence presented within the report of the International Atomic Energy Agency fact-finding mission to Japan undertaken in late May and early June 2011 (Ref. 22) and the Interim Fukushima Nuclear Accident Analysis Report published by the Tokyo Electric Power Company in December 2011 (Ref. 23).

When the earthquake struck, three reactors (Units 1, 2 & 3) at Fukushima Dai-ichi were operating, one reactor (Unit 4) was defuelled and the other two reactors (Units 5 & 6) were preparing for start-up following a maintenance outage. All four reactors at Fukushima Dai-ni were operating.

The earthquake affected both sites. There is evidence that the ground shaking was more severe in the vicinity of Fukushima Dai-ichi than at Fukushima Dai-ni (Refs. 22 and 23). Post-event walkdowns (Ref. 23) indicate that no significant damage to safety-related systems on either site occurred as a result of the earthquake. However, the earthquake caused electricity supplies from off-site sources to be completely lost at Fukushima Dai-ichi (as a result of a combination of circuit breaker damage in switch yards, arcing between transmission lines and towers, collapse of a transmission tower as a result of landslip and malfunction affecting back-up supply lines) (Ref. 23). Crucially, one of the four lines supplying off-site electrical power to the Fukushima Dai-ni site remained in service following the earthquake (of the other three supply lines: one was out of service for inspection, one suffered damage to lightning arrestors, and supplies were lost from the other as a result of circuit breaker damage in an off-site switch yard) (Ref. 23). By the following day three lines supplying off-site electrical supplies to Fukushima Dai-ni had been restored (Ref. 23).

As a consequence of the total loss of off-site electrical power supplies to Fukushima Dai-ichi following the earthquake, the site became reliant on supplies from on-site emergency diesel generators to provide essential reactor and spent fuel cooling functions. At Fukushima Dai ni, because off-site supplies were maintained, albeit in a degraded state, there was no need to bring the on-site emergency diesel generators into service.

Less than one hour after the earthquake the first tsunami wave struck both sites. There is evidence that the tsunami wave that struck Fukushima Dai-ichi was about 4m higher than that at Fukushima Dai-ni (that difference being attributed to a chance consequence of interference between multiple waves initiated within the earthquake fault region). The ground level at the Fukushima Dai-ichi site around Units 1 - 4 is approximately 2m lower than that at the Dai-ni site. Ground level around Fukushima Dai-ichi Units 5 and 6 is about 3m higher than that surrounding Units 1 to 4. The combination of the lower ground level and higher tsunami wave meant that damage and flooding affecting particularly Fukushima Dai-ichi Units 1 to 4, but also Units 5 and 6 to a lesser extent, was much more severe than that suffered by the Fukushima Dai-ni site.

In particular, damage and flooding at the Fukushima Dai-ichi site rendered it impossible to remove heat from Units 1 to 4, power to all electrical equipment was lost, control and instrumentation in the control rooms were lost, emergency communication equipment and lighting became inoperable. One emergency diesel generator on Unit 6 survived and via cross-connection was subsequently used to restore some power supplies to Units 5 and 6. Of great importance was the fact that on Units 1 to 5 all high voltage power panels for both normal and emergency systems suffered flood damage. Therefore, electric power could not have been supplied to the necessary equipment even if off-site power or emergency diesel generators had been functional.

At the Fukushima Dai-ni site the tsunami damage was much less severe. Loss of emergency sea water system pumps occurred on Units 1, 2 and 4. This prevented residual heat being removed through normal means from those reactors. Some emergency supply panels were lost on Unit 1 but none of the panels were lost on the other units. It was, therefore, possible to supply off-site power to equipment through emergency power supply systems and, thus, to use alternative low pressure water injection for cooling purposes. By using mobile power trucks, temporary power cabling and installing procured motors to replace those that had been damaged by flood water, the function of the ultimate heat sink was recovered. Furthermore, control and instrumentation functions were retained in the control rooms throughout the event.

Following the earthquake and tsunami the event progression at the Fukushima Dai-ichi and Fukushima Dai-ni sites differed significantly. The plant conditions and operator actions were correspondingly different. At Fukushima Dai-ichi events progressed much too fast for the operators to respond in an organised manner under the conditions with which they were presented. By contrast the lesser extent of damage at the Fukushima Dai-ni site meant that more recovery options were available with more time to implement them.

The International Atomic Energy Agency Mission Report (Ref. 22) concludes that although "all four units at Dai-ni were brought to a safe configuration they were perilously close to a serious situation" and that this was averted by the recovery efforts of the workers in reconnecting power supplies and replacing pump motors. Such recovery actions were precluded at Fukushima Dai-ichi by the extent and severity of the tsunami damage and the loss of off-site power supplies.

It appears then that the vast difference in outcomes at the two sites was primarily a matter of chance in the severity with which the natural hazards conspired to affect the two sites. It is not clear, on the basis of the available evidence, that there are lessons of significance for Magnox Limited sites to be learned specifically from a comparison of the events at the two Fukushima sites. What is clear, however, is that providing adequate levels of resilience against challenges that could negatively impact the ability to maintain plant safety functions is key to assuring safety. This is the Magnox Limited aim in responding to the Japanese events as discussed in Section 3 of this report. The specific issue of electrical supplies resilience is discussed under Recommendations IR-17, IR-18 and Stress Test Finding STF-11, although this is not a lesson learned specifically from the comparison between the differing event progressions affecting the two Fukushima sites.

Conclusion

Magnox Limited has considered the circumstances that led to the differing outcomes at Fukushima Dai-ichi and Fukushima Dai-ni. That a severe accident ensued at Fukushima Dai-ichi whereas a safe cold shutdown state was successfully achieved at Fukushima Dai-ni appears primarily to have been a consequence of chance factors influencing the severity with which the earthquake and tsunami affected the sites, coupled with small differences in site elevation, rather than any purposeful engineering or organisational causes. Magnox Limited has also collaborated with other UK licensees (see the response to Recommendation IR-15) to consider these issues collectively.

No particular lessons have been derived from these considerations that are additional to those already being addressed by the Magnox Limited response to the Japanese events as detailed elsewhere in this report.

IR-10 The UK nuclear industry should initiate a review of flooding studies, including from tsunamis, in light of the Japanese experience, to confirm the design basis and margins for flooding at UK nuclear sites, and whether there is a need to improve further site-specific flood risk assessments as part of the periodic safety review programme, and for any new reactors. This should include sea-level protection.

Magnox Limited Response to IR-10

Magnox Limited has completed a comprehensive critical review of the design basis flooding hazard assessments, including tsunamis and sea level protection, for all ten sites. This included a detailed review of the basis for the existing flood hazard level assessments for each site, an evaluation of the methods employed in deriving those hazard levels against modern standards, and a comparison with estimated flood levels predicted for adjacent non-Magnox Limited nuclear sites and more widely around the UK coastline in recent coastal flooding studies.

That review found that the sources of potential flooding identified in individual site assessments are generally consistent with modern standards. Some shortfalls against modern standards were noted in the methodologies employed in evaluating design basis flood hazard levels. Reasonable consistency was typically found with flooding hazard levels predicted for adjacent sites.

Based on the totality of information available, the review concluded for the majority of Magnox Limited sites that the existing design basis hazard levels represent reasonable best-estimates of the off-site flooding hazards at the present time. For those sites it was considered that the likelihood of significant accumulation of water on site reflected in the current safety cases is consistent with that which would be derived from a revised assessment carried out in accordance with modern standards.

It is particularly noteworthy that in most respects the existing flooding assessment for Wylfa, Magnox Limited’s only remaining operating reactor site, is judged to be well-founded and generally in accordance with modern standards. Furthermore, the assessment demonstrates ample margins between extreme 10^{-4} per annum exceedance frequency sea conditions and levels that would lead to site flooding of an extent that could credibly threaten reactor safety (see also the response to Stress Test Finding STF-5).

The two exceptions to the above conclusion identified by the review are Oldbury and Trawsfynydd sites. For these sites it was judged, on the basis of the available evidence, that the risk of significant accumulation of flood water on site might be underestimated within the current safety cases.

In the case of Oldbury it was identified, by comparison with recent flooding studies carried out on behalf of the Environment Agency, that the combined height of extreme tide plus storm surge events affecting the Severn Estuary at an exceedance frequency greater than 10^{-4} per annum could be sufficient for water levels to rise to the site level around the peak of the tidal cycle. By contrast, the existing site-specific flooding assessment for Oldbury indicated that an adequate margin would be maintained between the site level and the 10^{-4} per annum high water level.

Trawsfynydd is an inland site next to the shore of a man-made lake with water retained by a number of dams. The review found that the consequences of failure of the concrete gravity dam closest to the site had not been rigorously evaluated in the existing safety case with the consequent possibility that, in the unlikely event of dam breach or over-topping, lake water could flow onto the site.

A primary recommendation arising from the review was, therefore, that external flooding and site resilience for Oldbury and Trawsfynydd should be reassessed unless it could be argued that the maximum consequences of credible external flooding, including allowance for uncertainty, are low and insensitive to flood hazard levels.

Such flooding hazard reassessments have been completed for both sites including re-evaluations of the likelihood of site flooding and detailed consideration of potential consequences of flooding, supported by comprehensive site walkdowns. Following these reassessments both sites have issued revised external flooding safety cases that demonstrate that the radiological consequences of site flooding are already adequately low and will continue to diminish as the sites progress towards the planned care and maintenance condition (see Section 2).

Nevertheless, further practical measures have been taken to reduce the risks associated with flooding, particularly for the Oldbury site which is currently in its defuelling phase following final shutdown of the reactors in 2012. Proportionate enhancements to site flooding resilience that have been implemented at Oldbury have included:

- provision of an additional back-up boiler feed pump per reactor, located higher than credible flood levels, together with other suitable pumps stored in containers located at the highest point of the site;
- provision of means to isolate and re-power electrical systems above the flood level;
- provision of enhanced instructions for actions to be taken by site operations staff in the event of flood warnings;
- procurement of dam boards and sand bags to assist with reducing water ingress into buildings.

Minor enhancements are being implemented at Trawsfynydd to reduce the likelihood of release of radioactive materials in the unlikely event that dam failure and consequential flooding occurs. These enhancements are proportionate with the relatively low radiological risk posed by the waste materials remaining on the Trawsfynydd site and the anticipated imminent completion of waste passivation.

In addition to the specific assessments referred to above, actions were placed on all sites as a result of the site resilience workshops described in Section 3.3.1 to consider resilience against beyond design basis flooding events. Flooding resilience was also considered under the work carried out to address WANO SOER 2011-2 (see Section 3.3.4). In most cases no specific concerns have been raised because the worst credible consequences of flooding are very benign for the sites in their current states. Some sites have implemented modest enhancements to improve resilience. For example, some sites have identified and secured potentially buoyant items that could cause damage in an extreme flooding event. Other sites have provided sand bags to reduce water ingress into buildings and new pumps have been provided to assist with recovery operations should flooding occur in a beyond design basis event.

A specific example of work carried out to confirm flooding resilience is afforded by Dungeness A. Further work carried out by EDF, which operates the adjacent Dungeness B power station, to quantify sea defence over-topping during extreme events has indicated that site flooding may be more severe than previously assessed. As a direct response to these assessment findings the Dungeness A site has reviewed the resilience to a flooding event giving rise to a flood water depth greater than those indicated by the latest EDF analyses. A comprehensive assessment of all remaining facilities containing radioactive waste materials has confirmed that the worst off-site radiological dose that could arise as a result of such an event is very low. However, measures have been taken to further reduce the radiological risk.

Flooding risks affecting Magnox Limited sites will continue to be evaluated during future regular Periodic Safety Reviews with consideration being given to the implications of new data, methodology developments and improved understanding of flooding hazards. As noted previously, the removal and passivation of the remaining radiological hazards on the sites will steadily diminish the already low risks from beyond design basis flood events as the sites progress towards their planned care and maintenance condition.

Conclusion

Magnox Limited has completed a comprehensive review of flooding studies, including flooding from tsunamis and sea level protection. As a consequence the likelihood of flooding at the Oldbury and Trawsfynydd sites has been reassessed and revised safety cases issued. The resilience of all sites against beyond design basis flooding has been reviewed and proportionate resilience enhancement measures have been implemented. Flooding risks affecting Magnox Limited sites will continue to be evaluated during future regular Periodic Safety Reviews.

IR-11 The UK nuclear industry should ensure that safety cases for new sites for multiple reactors adequately demonstrate the capability for dealing with multiple serious concurrent events induced by extreme off-site hazards.

Magnox Limited Response to IR-11

Recommendation IR-11 does not apply directly to Magnox Limited as it will not be building any new reactors. However responding to an event at a site with multiple reactors is included within current emergency plans. A neighbouring EDF site exists adjacent to the Magnox Limited sites at Sizewell, Hunterston, Hinkley Point and Dungeness. In all cases the Magnox Limited reactors are long-cooled and depressurised and, with the exception of Sizewell A, the sites have been defuelled.

Magnox Limited has carried out a thorough review of existing emergency arrangements in addressing Recommendations IR-22, IR-23 and FR-2. This included a review of processes and equipment that relate to locations with neighbouring sites.

Where relevant, current emergency arrangements take cognisance of the proximity of another site. In the event of an incident, full musters of staff on both sites take place under the leadership of the affected site in a single-site driven scenario. Such co-ordination would also occur in a multi-site event. Should an incident requiring off-site emergency support occur, agreements are in place between licensees for mutual strategic co-operation and assistance at both local site and corporate levels. In this manner augmented resources and expertise will be made available to manage any event that might occur. Such arrangements are regularly exercised and demonstrated as part of the national emergency exercise programme.

This recommendation does not apply to Magnox Limited's remaining single site locations. With the exception of Wylfa, the reactors at these sites are permanently shut down, long-cooled and depressurised; all reactors except those at Oldbury and Sizewell A are defuelled.

Wylfa now only has a single operating reactor; the other reactor being permanently shut down and depressurised. Emergency arrangements at Wylfa provided the capability to deal with concurrent events when both reactors were operational. With one reactor permanently shut down and depressurised there is now greater inherent capacity to address concurrent events. The likelihood of significant concurrent events is also substantially diminished.

Conclusion

Recommendation IR-11 does not apply directly to Magnox Limited as it will not be building any new reactors. Nevertheless appropriate arrangements are in place at sites with adjacent nuclear reactors operated by EDF. These arrangements are proportionate with the relatively low risk now posed by the Magnox Limited facilities at such sites. Furthermore, at Wylfa, the only remaining Magnox Limited site with an operating reactor, there is greater inherent capacity for dealing with concurrent events now that the second reactor on that site is permanently shut down and depressurised.

IR-12 The UK nuclear industry should ensure the adequacy of any new spent fuel strategies compared with the expectations in the Safety Assessment Principles of passive safety and good engineering practice.

Existing licensees are expected to review their current spent fuel strategies as part of their periodic review processes and make any reasonably practicable improvements, noting that any intended changes need to take account of wider strategic factors including the implications for the nuclear fuel cycle.

Magnox Limited Response to IR-12

The current strategy for spent Magnox fuel (Ref. 24) has been set by the Nuclear Decommissioning Authority, which owns the Magnox Limited sites, in accordance with UK Government policy. Spent Magnox fuel is managed through a number of lifecycle phases from fuel in the reactor, discharge of fuel from the reactor into temporary on-site storage, transport from site to Sellafield, further storage at Sellafield, and then reprocessing of the spent fuel and final disposition of the reprocessing products and waste.

Reprocessing is the only presently accepted technology for managing spent Magnox fuel (Ref. 24). The nuclear decommissioning strategy is to reprocess all Magnox fuel in accordance with the Magnox Operating Programme. Magnox Limited is accountable for delivery of its part of the Magnox Operating Programme, specifically the management of spent fuel whilst it is on Magnox Limited sites and despatch of spent fuel for reprocessing at Sellafield.

The Nuclear Decommissioning Authority does not currently intend to adopt any new spent fuel strategies for Magnox fuel.

Spent fuel remains on only three Magnox Limited sites: Wylfa, Oldbury and Sizewell A. The resilience of facilities for managing spent fuel (the fuel route, including spent fuel ponds and dry stores) has been reviewed for those sites as part of the Magnox Limited programme responding to the Japanese events. Relevant reviews and enhancements that have been completed are summarised in Sections 3.3.1 and 3.3.4 of the present report. The responses to Recommendations IR-14 and IR-20 and Stress Test Findings STF-13 and STF-16 are also relevant.

The safety of spent fuel facilities on Magnox Limited sites will continue to be reviewed as part of the Periodic Safety Review programme (see the response to Recommendation FR-1) and as necessary when modifications are proposed to such facilities in accordance with nuclear site licence conditions.

Should, in future, the UK Government or Nuclear Decommissioning Authority revise the strategy for spent Magnox fuel, and should this revised strategy impact upon the use or configuration of spent fuel facilities at Magnox Limited sites, then the safety of such proposals will be assessed in accordance with established processes for control of modifications under the nuclear site licence conditions. It would be expected that this would include comparison with the principles of passive safety and good engineering practice. It is reiterated, however, that it is not currently proposed to adopt any new spent fuel strategies for Magnox fuel.

Conclusion

The Nuclear Decommissioning Authority does not currently propose to adopt any new spent fuel strategies for Magnox fuel. Should such proposals be made in future, then the safety of such proposals will be assessed in accordance with established processes for control of modifications to assure their safety.

Magnox Limited has reviewed the resilience of facilities for managing spent fuel on its sites and has implemented reasonably practicable improvements. Magnox will continue to review the safety of these facilities during future Periodic Safety Reviews or as required by established review processes

IR-13 The UK nuclear industry should review the plant and site layouts of existing plants and any proposed new designs to ensure that safety systems and their essential supplies and controls have adequate robustness against severe flooding and other extreme external events.

Magnox Limited Response to IR-13

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined possible hazards, safety requirements and plant, people and processes needed to meet these requirements. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of the actions placed at those workshops, site-specific reviews of the resilience of safety-related systems and their essential supplies and controls against severe flooding and other extreme external events have been completed. These site-specific reviews have identified opportunities for enhancing resilience against severe flooding and other extreme events. Examples of resilience enhancements that have been implemented are summarised below.

All Sites

All sites have been provided with:

- Two satellite telephones for emergency communications;
- Two portable GPS-equipped radiation monitoring cones to provide supplementary local radiation monitoring capability;
- A beyond design basis emergency equipment container including first aid/medical equipment, a wide selection of hand and power tools, pumps, generators, specialist tools, batteries, personal protective equipment, basic communication equipment, stationery, lifting and moving equipment.

Individual sites have implemented further resilience enhancements.

Wylfa

- Construction of a new beyond design basis emergency equipment compound on higher ground adjacent to the main site;
- Provision of six new diesel-driven fire pumps, any one of which would meet the boiler feed requirements for the operating reactor;
- Provision of alternative pumping-in points for boiler feed including procurement of all necessary connection equipment, stored adjacent to the plant together with connection procedures;
- Procurement of one road tanker, and hire of a second prior to final shutdown of Reactor 2, to facilitate transport of additional water supplies to site, if required;
- Provision of additional pipework pressure sealing equipment, stored in diverse locations;
- Procedures for back-feeding electrical supplies to site from the local low voltage distribution system, prepared in conjunction with the regional electricity supply company;
- Procurement of two large mobile diesel generators complete with connection cables and bowsers with sufficient fuel for around 72 hours and procedures for connecting to station switchboards;
- Procurement of four small generators with emergency lighting sets, leads and connectors;
- Installation of an alternative, totally diverse, monitoring system for a small subset of essential reactor parameters, independent of site electrical supplies with wireless data transmission to the new emergency equipment compound;
- Increase in fuel oil stocks held, suitable for the gas turbine generators and all diesel generators and pumps on site;
- Provision of additional stocks of personal protective equipment, dose meters, contamination probes and respirators, stored in diverse locations;
- Procurement of two submersible sump pumps for flood alleviation;
- Procurement of an earthmover, tractor, chainsaws, breaker hammers and ladders to assist with post-event access;
- Procurement of a new fire tender to supplement existing fire-fighting provisions;
- Provision of additional staff welfare packs.

Additional specific reviews of resilience against seismic events have been carried out at Wylfa. More details are given in Section 3.3.2 and in the response to Stress Test Finding STF-4.

Oldbury

- Provision of increased stocks of carbon dioxide and fuel oil prior to final reactor shutdown;
- Provision of two additional back-up boiler feed pumps together with hoses and couplings, elevated above ground level, and additional pipework protection;
- Provision of further pumps stored within equipment containers (see below) located at the highest point of the site;
- Installation of a new filling line allowing water to be added directly to the spent fuel ponds by gravity feed alone if necessary from a point external to the building;
- Procurement of a new mobile crane with increased load carrying capacity to aid debris clearance;
- Identification of generator and electrical connection points and provision of associated instructions;
- Installation of three independent passive pond water depth indicators that can be read external to the ponds building;
- Provision of four containers of site-specific emergency equipment, including equipment to seal or minimise leakage from the spent fuel ponds following a beyond design basis event;
- Provision of increased stocks of staff welfare equipment (chemical toilets, emergency rations, camp beds, radiation monitoring equipment and radiation protection equipment), stored in diverse locations;
- Identification of two site locations where alternative emergency control centres can be established, and provision of appropriate materials at those locations.

Specific reviews of the resilience of the Oldbury site against external flooding have been completed resulting in an updated safety case. More detail is given in the response to Recommendation IR-10.

Sizewell A

- Installation of a new fuel pond filling line enabling water or foam to be pumped directly into the pond from a diverse source, together with diesel-driven and electric submersible pumps and connectors;
- Procurement of two containers of site-specific emergency equipment containing additional stocks of personal protective equipment, radiological monitoring equipment, tools, pumps, generators, concrete repair consumables, foam concentrate, plastic sheeting and sand bags;
- Enhancements to address an additional concern, not specifically identified in the resilience workshops, relating to the capability to measure the depth of water remaining in the spent fuel pond following an event:
  - » installation of two full range ultrasonic probes for the east and west ponds;
  - » installation of a new plant information workstation in the emergency control centre;
  - » installation of a closed circuit television system, linked to the existing plant information data network, allowing pond conditions, including pond water level, to be observed from various locations on site including the main control room and emergency control centre.

Decommissioning Sites

All decommissioning sites have reviewed their resilience against extreme events. Some actions that have been implemented on these sites to improve resilience are:

- Provision of additional portable generators and pumps, stored in resilient locations;
- Provision of additional personal protective equipment and radiation monitoring equipment, stored in diverse and resilient locations;
- Provision of portable flood barriers for local deployment to inhibit water entry into buildings at identified points.

Conclusion

Magnox Limited has completed comprehensive reviews of the plant and site layouts for its sites to ensure that safety systems and their supplies and controls have adequate robustness against extreme external events. Many enhancements to site resilience have been implemented.

As part of normal business the resilience of safety systems against extreme external hazards will continue to be reviewed as the sites progress through their lifecycle to ensure that adequate levels of resilience are maintained (see also the response to Stress Test Finding STF-47).

IR-14 The UK nuclear industry should ensure that the design of new spent fuel ponds close to reactors minimises the need for bottom penetrations and lines that are prone to siphoning faults. Any that are necessary should be as robust to faults as are the ponds themselves.

Magnox Limited Response to IR-14

Magnox Limited will not be building any new spent fuel ponds. Therefore, Recommendation IR-14 does not apply directly. The intent of the recommendation has, however, been considered for the two Magnox Limited sites that have spent fuel ponds containing fuel: Oldbury and Sizewell A.

The spent fuel ponds store fuel that has been discharged from the reactors prior to off-site despatch for reprocessing. Water in the ponds provides radiological shielding and, where necessary, cooling for the spent fuel. The provision of pond water make-up under accident conditions is discussed in the response to Recommendation IR-20.

It is relevant to note that a pipework failure associated with the Sizewell A pond water recirculation system occurred early in 2007. That failure led to a reduction of pond water depth of about 330mm before the water loss was halted by operator action. Following that incident the ponds safety cases were reviewed for all Magnox Limited sites with ponds, including Oldbury and Sizewell A. Enhancements were implemented to prevent a recurrence of such a pond water loss event at any site. The types of concern raised in Recommendation IR-14 were therefore essentially addressed for Magnox Limited sites at that time. The current position for Oldbury and Sizewell A is summarised below.

Oldbury

Oldbury spent fuel ponds are in full service and will remain so until defuelling is completed. Defuelling is currently expected to be completed by the end of 2016. The current operational storage level is much lower than the maximum pond capacity. Sufficient spent fuel is stored in the ponds to maintain a buffer stock so that planned despatches from site can occur during periods when fuel cannot be discharged from the reactors. The quantity of fuel stored will vary but fuel is discharged from the reactors to the ponds at a rate designed to match the rate of fuel despatch from site.

The ponds are presently actively cooled primarily to mitigate long term fuel corrosion. With the current level of fuel decay heat and pond stocks, the rate of rise of pond water temperature would be less than 1°C per day and is expected to reach an equilibrium temperature well below boiling point.

Pond penetrations and pipework have been comprehensively reviewed. It is concluded that there are no physical means by which siphoning from the Oldbury spent fuel ponds could significantly affect shielding or cooling of the stored fuel.

Sizewell A

Sizewell A spent fuel pond is in full service and will remain so until defuelling is completed. Defuelling is currently expected to be completed by the end of September 2014. The current operational fuel stock is significantly lower than the safety case limit. It is desirable to maintain a buffer stock of fuel to ensure that planned despatches from site can occur during periods when fuel cannot be discharged from the reactors.

The reactors at Sizewell A have been shut down for nearly seven years, so the fuel in the pond has very low decay heat. As a consequence the pond is no longer actively cooled and the fuel no longer needs to be held underwater to provide adequate cooling. The safety function of the pond water is therefore solely to provide radiological shielding.

Pond penetrations and pipework have been comprehensively reviewed. It is concluded that the possibility of siphoning water from the Sizewell A pond to leave the stored fuel without adequate shielding can be discounted.

Conclusion

Magnox Limited has reviewed the design of the spent fuel ponds that contain fuel with respect to the existence of bottom penetrations and the potential for siphoning faults. It is concluded that it is not credible, due to the plant design, for a significant loss of water from spent fuel ponds to occur as a result of pipe failure or siphoning.

IR-15 Once detailed information becomes available on the performance of concrete, other structures and equipment, the UK nuclear industry should consider any implications for improved understanding of the relevant design and analyses. The industry focus on this recommendation should be on future studies regarding the continuing validation of methodologies for analysing the seismic performance of structures, systems and components important to safety. This should include concrete structures and those fabricated from other materials.

Magnox Limited Response to IR-15

Only limited information is currently available on the performance of structures, systems and components important to safety during the March 2011 Japanese earthquake. The primary source of information about the performance of the plants at the Fukushima Dai-ichi and Dai ni sites are the post-event analysis reports published by the Tokyo Electric Power Company, particularly Ref. 23. Extensive assessments and walkdowns have been carried out on the accessible parts of those plants and it has been concluded (Ref. 23) that safety-related structures, systems and components at both sites maintained their safety functions during and immediately following the earthquake. Furthermore, even equipment of lesser importance, and therefore designed to a lower standard of seismic capacity, appears to have suffered little damage and retained its functionality. Overall, there is at present no evidence that the earthquake had any adverse impact on the functionality of structures, systems and components important to safety on the Fukushima nuclear sites. Indeed, it appears that structures, systems and components design to lesser standards performed better than would have been expected.

It is clear, however, that full information is yet to emerge. As the severely damaged structures at Fukushima become more accessible, further pertinent information regarding the seismic performance of safety-related structures, systems and components may come to light.

Magnox Limited has been collaborating with other UK nuclear licensees, to identify implications of the Japanese events in the areas of External Hazards and Civil Engineering. A group of technical specialists has been established, initially with a focus on reviewing and analysing performance feedback and lessons learned from the Japanese earthquake and tsunami events relevant to the response of structures, systems and components to seismic and flooding hazards.

Members of this forum share information and understanding derived from a wide range of national and international sources including:

- World Association of Nuclear Operators;
- Earthquake Engineering Field Investigation Team;
- UK Engineering Institutions;
- American Society of Civil Engineers;
- American Concrete Institute;
- Construction Industry Research and Information Association;
- Concrete Society;
- Seismic Qualification Utility Group;
- Steel Construction Institute;
- British Standards and Eurocode Committees;
- International Atomic Energy Agency;
- Organisation for Economic Co-operation and Development's Nuclear Energy Agency.

The aim of this forum is to ensure that implications are distilled, understood, shared and made available to inform future design, assessment and safety case work undertaken by the UK nuclear industry. This grouping of technical specialists has been meeting approximately twice per year and it is anticipated that it will continue to meet at a similar frequency to discuss emerging information and other matters of common interest. Magnox Limited is represented by senior external hazards and civil engineering specialists.

Through this forum, and other industry forums, publications and meetings, Magnox Limited expects learning points relevant to the seismic performance of structures, systems and components to be identified.

The relevance of such information to Magnox Limited operations will be evaluated by company technical specialists and applicable learning points will be used, as appropriate, to inform future design or assessment.

It is noted, however, that Magnox Limited is unlikely to design and construct new facilities requiring high levels of seismic robustness. Similarly, given the diminishing nuclear and radiological safety risks on Magnox Limited sites, the seismic robustness claims for existing structures will reduce as the sites progress towards a care and maintenance state (see Section 2.3). Thus, while Magnox Limited will maintain awareness of developments in this area, their relevance to Magnox Limited operations is expected to be limited.

Conclusion

Currently available information suggests that safety-related structures, systems and components performed well during and following the March 2011 earthquake with no damage being suffered that adversely impacted on its functionality. No specific lessons have so far been identified that impact upon the current design or assessment practices for Magnox Limited safety-related structures, systems and components. However, further relevant information may emerge in future as the Fukushima Dai-ichi plant becomes more accessible to survey teams.

Magnox Limited is collaborating with other UK licensees to share emerging information gleaned from national and international organisations. The aim is to assimilate appropriate enhancements in understanding into future design and assessment of safety-related structures, systems and components within Magnox Limited. A cross-industry technical exchange forum has been established for this purpose. Magnox Limited will continue to engage with this forum, and to gather relevant information from other sources, as part of normal business.

IR-16 When considering the recommendations in this report the UK nuclear industry should consider them in the light of all extreme hazards, particularly for plant layout and design of safety-related plant.

Magnox Limited Response to IR-16

As described in Section 3.3.1, Magnox Limited has completed a programme of site resilience reviews as part of its response to the Japanese earthquake and tsunami. The objectives were to review the resilience of site safety-related structures, systems, components and operations against beyond design basis hazards to identify pragmatic and effective means of further enhancing resilience.

Those reviews, initially conducted in a series of workshops and carried forward as review actions by individual sites, considered a wide range of potential hazards that could impact upon the sites.

These reviews have resulted in substantive resilience enhancements being implemented across the Magnox Limited fleet. Further detail is provided in Section 3.3.1 and in the responses to other ONR recommendations.

Conclusion

Magnox Limited has considered a wide range of potential hazards in its response to the Japanese events and in considering other ONR recommendations.

IR-17 The UK nuclear industry should undertake further work with the National Grid to establish the robustness and potential unavailability of off-site electrical supplies under severe hazard conditions.

Magnox Limited Response to IR-17

Magnox Limited has contributed to an industry wide approach to Recommendation IR-17 through membership of a review group comprising nuclear licensees, potential future licensees and transmission system owners including National Grid Electricity Transmission (NGET). The key objectives of the review group were to:

- Consider the level of resilience currently afforded by the industry standards;
- Review the beyond design basis circumstances where failure of a network may occur and to consider how mitigation against, and response to, the event may affect restoration of supplies to safety-critical systems;
- Assess the available responses with regard to their influence on nuclear site supplies;
- Identify areas requiring further consideration.

The areas for further consideration arising from the review group have been reviewed and sentenced by Magnox Limited specialists.

The Magnox Limited response focusses on Wylfa, the only remaining generating site, and the fuelled sites: Oldbury and Sizewell A (see Section 2). All other Magnox Limited sites are defuelled and have adequate on-site provisions to cope safely for an extended period without off-site electrical supplies.

Wylfa, Oldbury and Sizewell A do not make any claim on off-site electrical supplies to support essential safety systems. Loss of off-site electrical supplies is considered a frequent fault. Safety cases and protection measures commensurate with the assumed fault frequency have been developed such that a prolonged period without off-site electrical supplies can be tolerated.

The review group noted the historically good performance of the transmission system but conceded that this is not necessarily indicative of the system response following an extreme event. The review group considerations highlight potential areas for increasing resilience and robustness of off-site electrical supplies.

Magnox Limited has responded to each consideration, taking into account the level of risk consistent with the lifetime position of Wylfa, Oldbury and Sizewell A (see Section 2), the claims on off-site electrical supplies and the provision of on-site electrical supplies.

It is relevant to note that availability of on-site electrical supplies was considered in depth by the site resilience workshops described in Section 3.3.1. As a consequence of those workshops significant enhancements to on-site electrical supplies provision have been implemented across the Magnox Limited fleet as summarised in Section 3.3.1.

Further actions have been completed or are in progress specifically to enhance the availability of off-site electrical supplies and address specific review group considerations:

- Wylfa has reached agreement with Scottish Power Energy Networks (SPEN) and NGET that would potentially allow Wylfa to derive supplies from the lower-voltage SPEN 132kV system following the loss of the 400kV NGET connection.
- Oldbury has a contract in place for provision of an 11kV electrical supply to site from the Distribution Network Operator. This is a planned measure, not associated with the response to the Japanese events, to provide electrical supplies to the site in the long term when the present NGET supplies are disconnected. Once implementation works have been completed by the Distribution Network Operator, this will provide some diversity of off-site supplies in the short to medium term.
- Sizewell A site has previously investigated a supply from the Distribution Network Operator. However, following initial work, this was deemed prohibitively expensive with the potential to disrupt local stakeholders. Sizewell A is in the process of deriving site supplies from Sizewell B, the adjacent power station operated by EDF. Again this work is not associated with the response to the Japanese events.

It is reiterated that Wylfa, Oldbury and Sizewell A do not make claims on off-site electrical supplies to support essential safety related equipment. Nevertheless, the above measures to enhance the availability of off-site supplies may assist with post-event recovery actions. Further measures are being implemented to enhance emergency communications with NGET.

Conclusion

The three fuelled Magnox Limited sites do not rely on off-site electrical supplies to support critical safety functions. Therefore, Magnox Limited has concentrated on increasing the resilience of on-site back-up means of supply (see the response to Recommendation IR-18). Nevertheless measures have been put in place to increase the resilience of off-site electrical supplies to assist with post-event recovery actions.

IR-18 The UK nuclear industry should review any need for the provision of additional, diverse means of providing robust sufficiently long-term independent electrical supplies on sites, reflecting the loss of availability of off-site electrical supplies under severe conditions. This should be considered along with Recommendation IR-8 within the wider context of "on-site resilience".

Magnox Limited Response to IR-18

The resilience of off-site electrical supplies is considered within the response to Recommendation IR-17. The loss of off-site electrical supplies to Magnox Limited sites is assessed to be a "frequent" fault. Measures are in place commensurate with the assessed fault frequency to ensure plant safety when off-site supplies are lost. The focus of the Magnox Limited response to Recommendation IR-18 has been on reviewing and enhancing the resilience of on-site electrical supplies.

Existing on-site gas turbine or diesel-driven back-up electrical supply systems are independent of off-site electrical supplies and provide a level of redundancy and diversity. The overall availability of these back-up systems is governed by equipment reliability and the availability and integrity of fuel oil supplies.

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined the adequacy of on-site electrical supply provisions including consumables relevant to those systems. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of the actions placed at those workshops, site-specific reviews of on-site emergency electrical supply provisions have been completed. These site-specific reviews have identified opportunities for enhancing resilience of electrical supplies. Examples of resilience enhancements that have been implemented are summarised below.

All Sites

Each site has been provided with a beyond design basis emergency equipment container. A variety of equipment has been supplied in these containers including generators. These are small, portable units that can be easily positioned to provide supplies to a range of equipment or plant depending on the specific event.

Wylfa

Two new large transportable diesel generators have been procured which are stored in the new beyond design basis emergency equipment compound. In an emergency these could be connected to any suitable switchboard. A list of suitable switchboards has been produced along with a basic procedure for connecting to any switchboard. These generators could be used to restore lighting or run ancillary plant. One generator could also be connected to charge batteries which could then power a reactor gas circulator pony motor for a limited period.

The site has also procured four small diesel-driven generators to power hand tools, portable lighting, monitoring equipment etc. These are stored in the new beyond design basis emergency equipment compound.

In addition, on-site fuel oil storage capacity is being increased by replacing a redundant gas turbine fuel oil storage tank thereby increasing the resilience of the site to extended loss of off-site supplies. Two additional bowsers have also been provided for transporting fuel to where it is needed on site.

Oldbury

Oldbury has procured seven additional generators. Some are fuelled with diesel and others with petrol. The generators are stored in a resilient location and have wheel kits or trailers as appropriate to facilitate transportation. Procedures for connecting generators to equipment to provide emergency supplies have been provided and are held in the site emergency control centre and designated alternative locations.

The availability of diesel fuel has been enhanced such that stocks held are well in excess of the minimum operational requirement.

Sizewell A

A trailer-mounted diesel generator has been purchased and stored within an emergency equipment container, primarily to provide power for submersible pumps that might be used to recycle pond water should the pond be leaking to the secondary containment afforded by the adjacent basement. This generator could also be available for other duties.

Decommissioning Sites

All decommissioning sites have reviewed their on-site electrical supply provisions. Proportionate actions that have been implemented on these sites to enhance resilience and availability of on-site electrical supplies, taking account of site requirements and existing provisions, include:

- Bradwell - relocation to a more resilient position of existing emergency diesel generators together with mobile air extraction units for restoration of fuel element debris vault ventilation;
- Dungeness A - procurement of an additional portable diesel generator to supply power tools and emergency lighting if required;
- Hinkley Point A - identification of connection points for a back-up diesel generator to the waste vault ventilation system and an existing generator has been overhauled, tested and a maintenance regime established;
- Hunterston A - development of a procedure for connecting a portable generator to the waste bunker monitoring system.

Conclusion

Magnox Limited has reviewed the resilience of on-site electrical supplies. Enhancements have been implemented across the fleet consistent with the lifecycle position, dependence on electrical supplies, and existing provisions at individual sites.

IR-19 The UK nuclear industry should review the need for, and if required, the ability to provide longer term coolant supplies to nuclear sites in the UK in the event of a severe off-site disruption, considering whether further on-site supplies or greater off-site capability is needed. This relates to both carbon dioxide and fresh water supplies, and for existing and proposed new plants.

Magnox Limited Response to IR-19

Only Wylfa and Oldbury require coolant supplies. Other Magnox Limited sites do not require cooling water or carbon dioxide supplies.

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined the adequacy of coolant supplies at Wylfa and Oldbury. Following the workshops, actions were placed on these sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating or defuelling) and the particular plant design.

As a result of the actions placed at those workshops, site-specific reviews of coolant supply provisions have been completed. The outcome of these site-specific reviews and examples of resilience enhancements that have been implemented are summarised below.

Wylfa

Carbon Dioxide

Stocks of carbon dioxide (the primary reactor coolant) available on site have been reviewed. The site holds in excess of four times the minimum operating requirement for two operating reactors. Only one reactor is now operating and potentially requiring carbon dioxide. Therefore, ample stocks of carbon dioxide to maintain control of reactor gas composition under emergency conditions already exist on site. Procurement of additional carbon dioxide stocks is not warranted.

Cooling Water

To increase the availability of water for reactor cooling the site initially purchased one road tanker and hired a second to transport clean water to site if necessary. The number of tankers has now been reduced to one following shutdown of Reactor 2. Possible alternative sources of treated water and lake water that could be used following a serious event have been identified. The road tanker is stored adjacent to the beyond design basis emergency equipment compound. Additional pumps and hoses have been procured to allow the water to be moved within the site.

Oldbury

Carbon Dioxide

Both reactors at Oldbury are permanently shut down and are now in an air atmosphere. Carbon dioxide supplies are no longer required and have now been removed from the Oldbury site as part of the hazard reduction programme.

Cooling Water

Both Oldbury reactors now only require intermittent boiler feed to maintain the desired core temperature and currently this is applied once every two weeks to a pair of boilers, each pair therefore has water circulated once a month. On Reactor 2 this frequency is determined by the requirement to circulate the water for corrosion control condition monitoring rather than a need to apply reactor cooling.

Availability of sufficient and suitable water supplies on site is considered adequate noting that modifications had previously been made, while Oldbury was still a generating site, to allow water to be recovered from the reserve feed water tank, deaerator or the turbine condenser for use by the back-up feed system. This was in addition to the dedicated back-up feed system water tanks and towns main reservoir. Following permanent shutdown of both reactors, the decision has been taken not to use the deaerator and turbine condenser as potential sources of water due to building loadings and potential water contamination issues. The site also has an engineered borehole that could be used as a source of water in an emergency.

Conclusion

Magnox Limited has reviewed the need for, and the ability to provide, longer term coolant supplies to the sites. Only Wylfa and Oldbury require coolant supplies. Proportionate resilience enhancements have been implemented at these sites

IR-20 The UK nuclear industry should review the site contingency plans for pond water make up under severe accident conditions to see whether they can and should be enhanced given the experience at Fukushima.

Magnox Limited Response to IR-20

Recommendation IR-20 applies to the two remaining Magnox Limited sites with spent fuel ponds that still contain fuel: Oldbury and Sizewell A.

The spent fuel ponds store fuel that has been discharged from the reactors prior to off-site despatch for reprocessing. Water in the ponds provides radiological shielding and, where necessary, cooling for the spent fuel. The potential for loss of pond water as a result of pipework breaches or siphoning is discussed in the response to Recommendation IR-14.

Magnox Limited has conducted a number of hazard-based workshops specifically looking at the resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. Of particular relevance to Recommendation IR-20 is the workshop held to consider resilience of spent fuel ponds. Following that workshop, actions were placed on the relevant sites to undertake further resilience reviews of specific areas of potential risk consistent with the plant design.

As a result of actions placed at that workshop, site specific reviews relating to ponds resilience have been completed at Oldbury and Sizewell A. Examples of enhancements that have been implemented to increase spent fuel pond resilience are summarised below.

Oldbury

Oldbury spent fuel ponds are in full service and will remain so until defuelling is completed. Defuelling is currently expected to be completed by the end of 2016. The current operational storage level is much lower than the maximum pond capacity. Sufficient spent fuel is stored in the ponds to maintain a buffer stock so that planned despatches from site can occur during periods when fuel cannot be discharged from the reactors. The quantity of fuel stored will vary but fuel is discharged from the reactors to the ponds at a rate designed to match the rate of fuel despatch from site.

The ponds are presently actively cooled primarily to mitigate long term fuel corrosion. With the current level of fuel decay heat and pond stocks the rate of rise of pond water temperature would be less than 1°C per day and is expected to reach an equilibrium temperature well below boiling point. Therefore, significant loss of pond water will not occur by evaporation or boiling. Siphoning mechanisms cannot lead to a significant loss of water from the ponds (see Recommendation IR-14). Significant water loss can only occur as a result of a severe mechanical failure of the pond structure.

Enhancements to improve spent fuel ponds resilience at Oldbury include:

- Installation of a new filling line allowing water to be added directly to the ponds by gravity feed alone if necessary from a point external to the building;
- Provision of site-specific emergency equipment, stored in a resilient location, including equipment to seal or minimise leakage from the ponds following a beyond design basis event;
- Provision of specific accident management guidelines for accidents affecting the fuel route including pond damage leading to loss of pond water (see also the response to Stress Test Finding STF-16);
- Installation of three independent passive pond water depth indicators that can be read external to the ponds building.

Potential sources of water for pond make-up have been investigated. Preferred sources of water having appropriate quality have been identified as the Back-Up Feed System tanks and the reserve feed water tanks. Other sources of water include the towns water tank. A further supply could be obtained by re-commissioning a site bore hole if the preferred sources are rendered unserviceable. Given the much reduced requirement for cooling water supply to the reactors in their permanently shut down and long-cooled state (see Section 2.3 and the response to Recommendation IR-8), a greater proportion of water from the identified on-site sources would be available, if required, for pond make-up.

Sizewell A

Sizewell A spent fuel pond is in full service and will remain so until defuelling is completed. Defuelling is currently expected to be completed by the end of September 2014. The current operational fuel stock is significantly lower than the safety case limit. It is desirable to maintain a buffer stock of fuel to ensure that planned despatches from site can occur during periods when fuel cannot be discharged from the reactors.

The reactors at Sizewell A have been shut down for nearly seven years, so the fuel in the pond has very low decay heat. As a consequence the pond is no longer actively cooled and the fuel no longer needs to be held underwater to provide adequate cooling. The safety function of the pond water is therefore solely to provide radiological shielding.

Alarms and trips are in service to stop the water extraction pumps in the event the pond water level falls by more than a few centimetres below design height. Sump alarms, the pond water level alarms and associated pump trips are tested regularly. Significant loss of pond water by evaporation is not credible. Similarly loss by siphoning has been discounted (see the response to Recommendation IR-14). Only a severe mechanical failure of the pond structure could cause a safety-significant loss of pond water.

Enhancements to improve spent fuel pond resilience at Sizewell A include:

- Installation of a new fuel pond filling line enabling water to be pumped directly into the pond from a diverse source, together with diesel driven and electric submersible pumps and connectors;
- Provision of site-specific emergency equipment, stored in a resilient location, including equipment to seal or minimise leakage from the pond following a beyond design basis event;
- Provision of specific accident management guidelines for accidents affecting the fuel route including pond damage leading to loss of pond water (see also the response to Stress Test Finding STF-16);
- Enhancements to address an additional concern, not specifically identified in the resilience workshops, relating to the capability to measure the depth of water remaining in the spent fuel pond following an event:
  - » installation of two full range ultrasonic probes for the east and west ponds;
  - » installation of a new plant information workstation in the emergency control centre;
  - » installation of a closed circuit television system, linked to the existing plant information data network, allowing pond conditions, including pond water level, to be observed from various locations on site including the main control room and emergency control centre.

Potential sources of water for pond make-up have been investigated. Should pond leakage occur, leaked water is likely to collect within basement areas. Submersible pumps and necessary ancillary equipment have been provided to enable recirculation of such collected water back into the pond. As a last resort, should normal sources of water become unavailable, water could be pumped into the pond from the sea. A diesel pump has been provided with sufficient capacity to pump water into the pond from the sea, together with a sufficient length of hose. However, because fuel stored in the pond at Sizewell A is now long-cooled, total loss of pond water would not lead to an escalating fault and the potential detriment arising from sea water injection would probably outweigh the safety benefit. Injection of sea water is therefore unlikely to be undertaken.

Conclusion

Magnox Limited has reviewed spent fuel pond resilience, including contingency plans for pond water make-up under severe accident conditions, for the two remaining sites with ponds that contain fuel. At each site enhancements have been made to emergency pond filling equipment, including installation of new filling lines, and emergency procedures for ensuring that adequate water levels are maintained in the ponds.

IR-21 The UK nuclear industry should review the ventilation and venting routes for nuclear facilities where significant concentrations of combustible gases may be flowing or accumulating to determine whether more should be done to protect them.

Magnox Limited Response to IR-21

Magnox Limited has completed a review of facilities on its sites where combustible and/or toxic gases could be generated either during normal operation or in fault or accident conditions.

Combustible gases are present on sites in gas bottles as part of normal operating activities. These include hydrogen for cooling electricity generating turbo-alternators, methane for injection into an operating reactor to inhibit radiolytic oxidation of graphite and propane for cutting torches (on decommissioning sites). The use of such gases and the prevention of flammable mixtures are covered by statutory regulations and are not discussed in this response.

Many potentially combustible gases are formed in operating Magnox nuclear reactors as a consequence of radiation-induced reactions between the coolant and the moderator materials. Most such gases are, however, only formed in trace quantities and cannot reach a concentration that would support combustion.

Potentially significant sources of combustible gases on Magnox Limited sites are outlined below.

Hydrogen Generation from Fuel Element Debris Vaults

Nuclear fuel elements used in Magnox reactors are clad with a magnesium alloy, called “Magnox”, from which the reactor type takes its name. Fuel elements are equipped with shaping features to direct the coolant gas flow around the element while in the reactor. Historically, at all sites except Wylfa and Chapelcross these shaping features have been mechanically removed from spent fuel prior to despatch for fuel reprocessing.

The consequent Magnox detritus, known as “fuel element debris”, has been stored in vaults whose design varies from site to site. Some sites have vaults that are below ground level and which are susceptible to water ingress. Water may also be carried over into the vaults from the mechanical stripping process which is carried out under water. Magnox alloys react with liquid water and water vapour. One of the reaction products is hydrogen. To prevent the build-up of hydrogen, debris vaults are monitored and ventilated.

A comprehensive review of hydrogen generation in debris vaults has been completed. It is concluded that existing ventilation arrangements and timescales for restoration are adequate on all sites and that there is no requirement for enhancement of fuel element debris vault ventilation systems. Nevertheless resilience enhancements have been implemented at some sites to improve site procedures for the restoration of vault ventilation or monitoring in the event of loss of electrical supplies.

A further theoretical mechanism for generating hydrogen in a fuel element debris vault has been identified. In the very unlikely event that fuel element debris was to catch fire, the heat generated could liberate water in the form of steam from the surrounding concrete vault walls. That steam could then react with the fuel element debris to form hydrogen. Guidance is in place to mitigate fuel element debris fires and this guidance has been formalised within new waste accident management guidelines (see the response to Stress Test Finding STF-83).

Hydrogen Generation from Magnox Dissolution Plants

Magnox dissolution plants only exist at Dungeness A and Bradwell.

Dungeness A

Dungeness A has successfully operated a plant that dissolves fuel element debris (see above) using carbonic acid. A by-product of the dissolution reaction is hydrogen. While all debris arising from operations at Dungeness A has been processed, the dissolution plant is currently being used to process debris from the Bradwell site and is thus a current source of hydrogen at Dungeness A.

The Dungeness A dissolution plant has the theoretical potential to generate explosive atmospheres rapidly. For this to occur, however, would require simultaneous failure of multiple independent safety systems that are installed specifically to prevent this occurrence, together with a breach of the reaction vessel. The review has determined that additional measures, beyond those already in place, to prevent hydrogen build-up are unnecessary.

Bradwell

A dissolution plant is currently being constructed at Bradwell that will have a faster reaction rate than the plant at Dungeness A. Again, a by-product of the dissolution reaction will be hydrogen. Multiple robust measures to control the concentration of hydrogen are part of the design and have been justified in accordance with modern standards. No additional measures are considered necessary.

Hydrogen Generation Resulting from Water Ingress into a Magnox Reactor

Water could enter a Magnox reactor as a result of a failure of boiler tubes. Such moisture could cause corrosion of the magnesium alloy cladding of fuel within the reactor leading to hydrogen generation in a similar manner to that discussed above in the context of fuel element debris.

The potential for hydrogen generation to occur during a severe accident has also been assessed.

Water Ingress to an Operating Reactor

The risk of forming flammable mixtures as a consequence of boiler tube leaks has been re-assessed recently for Reactor 1 at Wylfa. It is assessed that the bounding boiler leak case considered will not produce a flammable mixture. There is, therefore, no requirement for enhanced ventilation.

Water Ingress into a Shut Down Reactor

Ordinarily the water concentration in the air atmosphere of a shutdown reactor is controlled by passing make-up air through a drier. If the drier were to fail then moist air could be injected into a reactor. In this case the maximum concentration of hydrogen that could be achieved is well below the lower flammability limit.

In the event of a major boiler leak, provided that the make-up air system remains functional (or can be restored within an adequate timescale) then the hydrogen concentration would again be maintained well below the lower flammability limit. If the make-up air system were to fail, coincident with a large boiler leak, then scoping calculations suggest that it would be many days before the hydrogen concentration reached the lower flammability limit. Ample time would be available to restore adequate air flow to control the hydrogen concentration under such circumstances.

Hydrogen Generation in Severe Accidents

A bounding assessment of the potential for hydrogen generation under severe accident conditions has been carried out considering a scenario in which a severe fault occurs with rising fuel temperatures in an air-filled reactor with significant ingress of water. Such a scenario now only applies to the operational reactor at Wylfa. In such a case there is the potential for hydrogen to be produced both from the reaction between water and fuel cladding and also from the reaction between water and the graphite moderator. The assessment indicates that in such extreme and improbable circumstances the evolution of high hydrogen concentrations within a few hours cannot be ruled out. The purpose of the plant design, operating rules, limits and procedures, and accident management guidance is to prevent the plant from reaching such a condition. Nevertheless, in extremis, it is recognised that such phenomena are physically possible.

The potential for such phenomena has been taken into account in the revision of the Severe Accident Guidelines (SAGs, see the response to Stress Test Finding STF-16) for Wylfa to make the operators aware that hydrogen generation may be a risk under specific severe accident scenarios.

Hydrogen Generation from Spent Fuel Ponds

In normal operation the rate of corrosion of the magnesium alloy cladding of fuel stored in ponds is very slow as a result of pond water chemistry management. An assessment has been made of the maximum rate of corrosion, and hence hydrogen generation, that could occur if water chemistry control fails. It is estimated that it would take in excess of 100 days for the hydrogen concentration in a pond building to reach the lower flammability limit even under the unrealistic assumption of a complete lack of ventilation. Ample time is therefore available to re-establish water chemistry management and, if necessary, adequate ventilation.

Carbon Monoxide Generation under Severe Accident Conditions

In a theoretical very severe accident that leads to the graphite moderator catching fire within an air-filled Magnox reactor there is the potential to generate large quantities of flammable and toxic carbon monoxide. The circumstances that might lead to such an event are difficult to envisage. The potential for such phenomena has been taken into account in the revision of the Severe Accident Guidelines (SAGs, see the response to Stress Test Finding STF-16) for Wylfa to make the operators aware that carbon monoxide generation may be a risk under specific severe accident scenarios.

Conclusion

A comprehensive review of the potential for generating combustible gases on Magnox Limited sites under normal, fault and accident conditions has been completed. Existing arrangements for controlling the build-up of such gases have been generally found to be adequate. Nevertheless, resilience enhancements have been implemented at some sites to improve site procedures for ventilation restoration and monitoring.

It is recognised that particular severe and highly improbable accident conditions specific to the single remaining operating Magnox reactor at Wylfa could lead to the evolution of flammable or explosive concentrations of combustible gases or the evolution of toxic gases. For these cases the Severe Accident Guidelines have been revised to make the operators aware of the risks associated with combustible and toxic gases under specific accident conditions.

IR-22 The UK nuclear industry should review the provision on-site of emergency control, instrumentation and communications in light of the circumstances of the Fukushima accident including long timescales, wide spread on and off-site disruption, and the environment on-site associated with a severe accident.

Magnox Limited Response to IR-22

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined possible hazards, safety requirements and plant, people and processes needed to meet these requirements. Additionally, command and control, operator actions, protected routes and refuges have also been considered. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of the actions placed at those workshops, site-specific reviews of the resilience of on-site emergency control, instrumentation and communications against extreme external events have been completed. More details of the outcome of the resilience reviews that have been undertaken at each site are given in the site summary reports (Refs. 16 to 25). These site specific reviews have identified opportunities for enhancing resilience against extreme events. Examples of reviews that have been completed and associated resilience enhancements are summarised below.

All Sites

All sites have been provided with:

- Two satellite telephones for emergency communications;
- Two portable GPS-equipped radiation monitoring cones to provide supplementary local radiation monitoring capability;
- Beyond design basis emergency equipment containers including basic communication equipment and supplies to enable setting up of ad hoc command and control arrangements should the need arise.

Individual sites have implemented further specific resilience enhancements to the provision of on-site emergency control, instrumentation and communications, examples of which are described below.

Wylfa

To supplement the normal control and instrumentation systems and existing back-up instrumentation, an alternative, totally diverse, monitoring system for a small subset of essential reactor parameters has been installed. That system is independent of site electrical supplies and is equipped with wireless data transmission to the new beyond design basis emergency equipment compound.

A gap analysis has been completed between current provisions with respect to control room, remote emergency indication centre and emergency control centre facilities at Wylfa and the recently-updated International Atomic Energy Agency expectations for the design of new nuclear power plants (Ref. 25). That workshop identified a number of potential opportunities for enhancing existing provisions subject to feasibility and reasonable practicability. As a result the following enhancements have been implemented:

- Ventilation systems supplying the central control room have been enhanced to ensure leak tightness and damper function and improved maintenance arrangements have been put in place;
- An addition has been made to the site Emergency Handbook to clarify the process for initiating emergency response actions should the central control room be untenable;
- Alternative resilient command and control facilities have been identified should the normal site facilities be untenable;
- New gamma and contamination monitors have been installed in the central control room and remote emergency indication centre.

In addition assessments have been completed of potential toxic or explosive gas hazards to the central control room and remote emergency indication centre. Those assessments concluded that there are no unaddressed toxic or explosive gas hazards for these facilities.

The equipment required to provide an emergency health physics service during the initial seven days of an incident has been reviewed. On-site supplies of health physics equipment and consumables were found to be adequate but additional supplies have been procured and are stored in the new off-site beyond design basis emergency equipment compound. These supplies include dose meters, contamination probes, respirators and personal protective equipment.

A further review of the resilience of Magnox Limited emergency communications systems has been completed including comprehensive consideration of on-site emergency communications at Wylfa. The review provided an in-depth assessment of the resilience of both the required information flows and the communication systems technology that supports those information flows. The review concluded that there is sufficient diversity within the communications systems to achieve robustness against common cause failures thereby ensuring that essential information flows can be maintained between key emergency response facilities in most cases under hazard conditions of a scale or magnitude that could reasonably be expected in the UK. A small number of potential vulnerabilities were noted that could result in the loss of some lines of communication under extreme conditions. Opportunities for enhancing the resilience, including addressing the identified vulnerabilities, have been identified. These opportunities have been reviewed and sentenced by Wylfa site Engineering and Emergency Planning staff. Enhancements considered to be reasonably practicable and providing significant benefit have been carried forward for further development and implementation. These are being progressed by the Wylfa site under normal business arrangements.

Oldbury

Oldbury has a central control room that provides monitoring for reactor temperatures. Such information may also be obtained directly from marshalling and monitoring cubicles. However, with both reactor cores now cooled by natural circulation it would take many days without boiler feed for the reactors to reach Operating Rule temperature limits and longer to reach actual safety limits. Should all reactor temperature indications be lost then existing instructions require feed water to be supplied to the boilers within seven days as a precautionary measure.

The Oldbury reactors are currently being defuelled. Fuel is discharged via the spent fuel ponds. Water within the ponds provides cooling and radiological shielding of the discharged fuel although the cooling requirement is now minimal. It is, therefore, desirable that pond water levels are maintained. To ensure that water levels can be monitored if normal indications are lost without the need to access the ponds building, a simple pond water level indication system has been installed that can be monitored from outside the pond building and which does not require a power supply.

Oldbury has an emergency control centre. To provide additional resilience, two alternative on-site areas have been equipped with necessary supplies and communications equipment to run a command centre. Documents relevant to the tasks performed by the emergency control centre staff have also been provided in these locations.

The storage of health physics monitoring equipment including personal dose meters has been reviewed and stocks are now held in more resilient locations.

Sizewell A

Sizewell A is now in a state where there are few systems necessary to maintain safety. Reactor cooling is now achieved by passive means. Similarly the fuel pond no longer requires active cooling. Long timescales, several weeks, are available to take action to restore safety-related systems.

At Sizewell A spent fuel is discharged from the reactors to the pond. It is desirable to maintain pond water levels for shielding purposes as an off-site radiological consequence could be apparent at or near the site boundary as a result of total loss of pond water. The following enhancements have been implemented relating to the capability to measure the depth of water remaining in the spent fuel pond following an event:

- installation of two full range ultrasonic probes for the east and west ponds;
- installation of a new plant information workstation in the emergency control centre;
- installation of a closed circuit television system, linked to the existing plant information data network, allowing pond conditions, including pond water level, to be observed from various locations on site including the main control room and emergency control centre.

Should the site emergency control centre become untenable multiple locations have been identified that could be used as alternative emergency control centres.

Decommissioning sites

At the decommissioning sites, the remaining wastes are generally stable in nature and stored in robust containments that are routinely inspected and maintained to confirm that they are in an acceptable condition. For these sites, there are no short-term operator actions, power supplies or control and instrumentation systems that are essential to prevent or limit a release of radioactivity. Consequently the emergency response requirements to ensure that the sites remain safe following an extreme event are minimal. All sites currently have emergency control centres. Resilience enhancements relevant to the subject matter of Recommendation IR-22 have been implemented primarily by the provision of beyond design basis emergency equipment containers, satellite telephones and radiological monitoring cones to all sites, outlined above. Individual sites have reviewed their on-site control, instrumentation and communications requirements taking account of specific site arrangements. Where considered beneficial and appropriate to local circumstances additional resilience enhancements have been implemented. For example,

- Dungeness A has procured a portable hydrogen monitor to supplement existing gas monitoring for the Magnox fuel element debris dissolution plant (see also the response to Recommendation IR-21);
- Hunterston A has implemented enhancements to facilitate the restoration of hydrogen monitoring within the waste bunkers using a portable generator.

Conclusion

Magnox Limited has completed comprehensive reviews of the provision of on-site emergency control, instrumentation and communications against the effects of extreme external events. Appropriate and proportionate enhancements to site resilience have been implemented. Further opportunities to enhance on-site emergency communications at Wylfa have been identified and these are being progressed under normal business arrangements.

IR-23 The UK nuclear industry, in conjunction with other organisations as necessary, should review the robustness of necessary off-site communications for severe accidents involving widespread disruption. In addition to impacting communications, it is possible that external events could also affect off-site centres used to support at site in an emergency. Alternative locations should be available and they should be capable of being commissioned in an appropriate timescale.

Magnox Limited Response to IR-23

In the event of an accident or natural disaster at a nuclear site there is a need to promulgate an alert and to pass information between the site and external responders and stakeholders. Particularly important communication paths are those between the site, Strategic Coordinating Centre, the Central Emergency Support Centre and the responding emergency services. Further details of these facilities, their role and emergency communication systems are presented in the site responses to the European Council Stress Tests (Refs. 2 to 11).

Communications

Resilient communications are available based on diverse land lines from operating sites to the public telephone system and between the public telephone system and the Central Emergency Support Centre and Strategic Coordinating Centres. These provide voice, fax and data links between the sites, the centre and the local and national responders.

The emergency services that will operate on the affected sites have their own resilient communications and command and control systems.

Emergency responders can be contacted by the Site Event Reporting System using a commercial pager system. This is a robust system having two independent servers at different sites each linked to a different telephone exchange. Either system is capable of initiating a pager alert and sending messages to voice mail for company responders or sending dial and deliver messages to external agencies. In the unlikely event of a Site Event Reporting System failure the pager system can be initiated from any working telephone.

In response to Recommendation IR-23 Magnox Limited has undertaken a review of communications systems that would be called upon in the event of a site emergency, including communications with the emergency services.

The Magnox Limited emergency communications system is multi-layered, diverse and redundant and is considered to be highly resilient. Nevertheless, recognising that terrestrial communications may be disrupted by the event that causes a site emergency, the communications system has been augmented by the provision of two satellite telephones to each Magnox Limited site and central emergency support facilities. This provides a further layer of communications diversity.

In addition, Magnox Limited has conducted a further review of emergency communications resilience covering on-site emergency communications at Wylfa, the sole remaining Magnox Limited site with an operating nuclear reactor, and off-site emergency communications.

That review has included in-depth assessment of the resilience of off-site communications systems. The assessment has concluded that there is sufficient diversity within the communications systems to achieve robustness against common cause failures thereby ensuring that essential off-site information flows can be maintained following events of a scale and magnitude that could reasonably be expected in the UK. Magnox Limited employs primary, secondary and, in some cases, tertiary and quaternary systems as a means of supporting essential information flows. No significant generally applicable opportunities for enhancing the resilience of off-site emergency communications systems have been identified. Some Wylfa-specific enhancement opportunities have been identified. These opportunities have been reviewed and sentenced by Wylfa site Engineering and Emergency Planning staff. Enhancements considered to be reasonably practicable and providing significant benefit have been carried forward for further development and implementation under normal business arrangements.

Off-site Emergency Support Centres

The Central Emergency Support Centre is based in Gloucestershire. The remit of the Central Emergency Support Centre is to:

- Relieve the affected site of the responsibility for liaison with outside bodies on off-site issues;
- Take over from the affected site at an early stage the task of directing the off-site monitoring teams and assessing their results;
- Provide the requisite technical advice on off-site issues to all stakeholders in the Strategic Coordination Centre and those agencies represented in the Central Emergency Support Centre;
- Provide regular authoritative company briefings for the media on all aspects of the emergency;
- Co-ordinate advice and support from within the affected company and other parts of the nuclear industry to the affected site.

It is considered unlikely that the Central Emergency Support Centre would be adversely affected by any event that also affects one of Magnox Limited's operational sites as it is about 20 miles from Berkeley, the nearest site. The Central Emergency Support Centre has a backup facility at another location on the same site to provide some diversity and also extra capacity in the event of a multi-site emergency. The Central Emergency Support Centre functions can also be performed from the event management centre at Magnox Limited's Berkeley Centre or, in extremis, from any of the emergency control centres at other Magnox Limited sites. The back-up facilities have been exercised and proven adequate for managing the response to an off-site nuclear emergency at a Magnox Limited site.

Conclusion

Magnox Limited has reviewed the resilience of off-site emergency communications systems and has augmented the existing systems by providing satellite telephones to all sites and central emergency support facilities.

Magnox Limited has reviewed the provision of off-site emergency support centres. Alternative facilities to the primary Central Emergency Support Centre are available and have been proven adequate for managing the response to an off-site nuclear emergency at a Magnox Limited site.

IR-24 The UK nuclear industry should review existing severe accident contingency arrangements and training, giving particular consideration to the physical, organisational, behavioural, emotional and cultural aspects for workers having to take actions on-site, especially over long periods. This should take account of the impact of using contractors for some aspects on-site such as maintenance and their possible response.

Magnox Limited Response to IR-24

Magnox Limited recognises that the ability of staff to respond to a major incident in a calm and measured way is integral to the successful implementation of an emergency response strategy.

Magnox Limited has, therefore, sought to understand the organisational and human factors aspects that contributed to the accident at the Fukushima Dai-ichi nuclear power station and the subsequent emergency response. A particular source of learning was a meeting of international experts arranged by the International Atomic Energy Agency in May 2013 on the subject of Organisational and Human Factors in Nuclear Safety in the Light of the Accident at the Fukushima Dai-ichi Nuclear Power Plant which Magnox Limited attended. At that meeting, representatives from the Tokyo Electric Power Company (the company that operates Fukushima Dai-ichi) and the Japanese nuclear regulator highlighted lessons learned in the following areas:

- Positive aspects of the emergency response;
- Precursor and latent organisational failures contributing to the accident severity;
- Specific human factors contributing to the difficulty of post-accident response;
- Pre-accident regulatory factors contributing to difficulties in responding to the accident.

These lessons have been examined by Magnox Limited as part of its response to this recommendation. Magnox Limited has also collaborated with other UK licensees to identify relevant lessons to take forward from the Japanese experience.

Magnox Limited has reviewed its emergency arrangements and training in the light of lessons learned regarding organisational and human factors from the Japanese events. The various aspects of that review are summarised below.

Review, Revision and Development of Accident Management Guidance

As described in the response to Stress Test Findings STF-16 and STF-83, Magnox Limited has completed comprehensive reviews of the Symptom Based Emergency Response Guidelines and Severe Accident Guidelines, now only relevant for Wylfa, and has developed new fuel route and radioactive waste accident management guidelines.

A research project was commissioned to investigate the human factors aspects of emergency procedures. This project included examination of relevant research and experience from other national and international organisations. The insights gained have been incorporated into the revision and production of Magnox Limited accident management guidance.

The human factors specialist that undertook that research project has been an integral part of the project to review, revise and develop Magnox Limited accident management guidance. Human factors considerations specifically included:

- presentation, content and format;
- user feedback;
- lessons from wider operational experience feedback;
- accident management guidance developments in other licensees.

The same human factors specialist has been actively involved in the workshops held to review and develop the guidance and has provided input to all stages of the development of the revised and new guidance. In this way human factors good practice has been incorporated directly into the revised and new guidance.

Emergency Actions and Equipment

Specific human factors assessments to substantiate the operator/plant interfaces associated with actions advised by the revised accident management guidance for Wylfa have been completed. More details of the scope of these assessments are given in the response to Stress Test Finding STF-3. The assessments identified opportunities for enhancing the clarity of the accident management guidance; these enhancements have been incorporated into the documents before final issue (see also the responses to Stress Test Findings STF-3 and STF-16). Some opportunities have also been identified for improving the availability and operability of equipment or facilities. Consideration of these further enhancement opportunities is being progressed by Wylfa under normal site arrangements.

As part of its response to the Japanese events, Magnox Limited has furnished all sites with additional emergency response equipment either to facilitate specific actions or to assist with general post-event recovery activities. To ensure that all such equipment remains in a state of readiness for deployment Magnox Limited has undertaken a "proof of concept" assessment across all sites. That assessment includes, where applicable, simulated equipment usage to ensure readiness and usability. Further details are provided in the response to Stress Test Finding STF-3.

Training

The current arrangements for training have been reviewed in the light of lessons learned from the reported response of personnel during the Fukushima Dai-ichi accident. The current "command and control" training given to emergency controllers is considered to be adequate for personnel expected to manage incidents affecting Magnox Limited sites. It is recognised, however, that fatigue and stress inherent in addressing large-scale disasters can impact decision making capacity and capability to take necessary actions. To improve the awareness of these issues and their potential effects, training has been enhanced by the development of a training module in the area of stress and fatigue management. This augments existing training packages for emergency controllers.

Use of Contractors in Emergency Response

The role of contractors in emergency conditions has been reviewed. All contractors employed by Magnox Limited undergo site induction training to reinforce expected behaviour if an emergency is declared. This includes the requirements to muster and evacuate if instructed to do so. All contractors are involved in emergency exercises that take place on sites.

Through contracts with suppliers Magnox Limited has made best endeavours to anticipate essential equipment and services that may be required during an emergency. It is recognised, however, that such contractual arrangements can never be fully robust.

Welfare Arrangements for Personnel

On-site personnel welfare arrangements under emergency conditions have been considered by Magnox Limited Occupational Health Department and each site has reviewed and, where appropriate, has enhanced its existing provisions. Examples of enhancements that have been implemented in this area are summarised in the response to Recommendation IR-8.

Magnox Limited also has, via a contract with an external specialist service provider, arrangements in place for provision of post-event care for personnel including post-trauma care, psychological and psychiatric support.

Corporate Communications

The Magnox Limited corporate communications team has taken part in national discussions considering wider stakeholder communications during an extended emergency. That team is part of the national UK strategy for emergency communications.

Conclusions

Magnox Limited has conducted wide-ranging reviews of contingency arrangements and training for accident conditions including the physical, organisational, behavioural, emotional and cultural aspects for workers having to take actions on-site possibly over extended timescales. Where appropriate, existing arrangements have been extended and enhanced.

It is anticipated that lessons in the area of organisational and human factors will continue to emerge from the Japanese experience. Magnox Limited will continue to identify emerging lessons by engaging with external agencies and through internal organisational learning arrangements.

IR-25 The UK nuclear industry should review, and if necessary extend, analysis of accident sequences for long-term severe accidents. This should identify appropriate repair and recovery strategies to the point at which a stable state is achieved, identifying any enhanced requirements for central stocks of equipment and logistical support.

Magnox Limited Response to IR-25

Recommendation IR-25 is only relevant to Wylfa as that is the only Magnox Limited site with an operating reactor and, hence, the only site at which a severe accident (involving a significant off-site release of radioactive material) is considered credible. Similar issues with respect to provision of guidance and equipment, relevant to all Magnox Limited sites are addressed in the response to Stress Test Findings STF-16 and STF-83 and Recommendation IR-8.

As part of the general review of accident management guidance (described in the response to Stress Test Finding STF-16) specific consideration was given to the transient analysis that underpins the advice. That review sought to identify aspects of the methodology, input data or phenomenological understanding that may have changed since the analyses were originally completed, and the effect these changes might have on the predicted timescales available to establish a minimum level of cooling to prevent reactor core damage. While the review recommended that consideration be given to undertaking further analysis, it also judged that the minimum post-trip cooling requirements were unlikely to vary significantly from the earlier predictions.

As a consequence of that review recommendation, the transient analyses have been subject to further review by company experts. That further review concluded that the existing analyses are adequate for the purpose of supporting severe accident management guidance. Furthermore, given the time that it would take to achieve any significant improvement in understanding, further analysis is not practicable. Delaying production of enhanced accident management guidance pending completion of any revised analysis would be inappropriate.

Reviews have, therefore, been undertaken against the current understanding of transient behaviour to inform the revision and development of accident management guidance.

As described in the response to Recommendation FR-4, Magnox Limited has developed and applied a methodology based on Level 2 Probabilistic Safety Analysis techniques to investigate potential long-term severe accident sequences. That investigation included detailed consideration of existing recommended mitigation strategies and the availability of emergency equipment and other resources to implement such strategies. Wide-ranging potential enhancements to existing accident management guidance have been identified. These have been taken forward as part of the programme of work to review and revise the Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs) for Wylfa, as described in the response to Stress Test Finding STF-16.

Reviews of site self-sufficiency and consequent enhancements to the provision of emergency equipment and consumables to support accident mitigation have been completed (see the response to Recommendation IR-8). These enhancements have been taken into account in the revision of SBERGs and SAGs. Complementary reviews of the human capabilities and capacities to ensure the ability to respond to accidents are covered by the responses to Recommendation IR-24 and Stress Test Finding STF-3.

Conclusion

Magnox Limited has carried out a review of the transient analyses that underpin the accident management advice for Wylfa. That review concluded that the existing analyses are adequate for the purpose of supporting severe accident management guidance. Magnox Limited has investigated potential long term severe accident sequences as described in the response to Recommendation FR-4. This has led to substantial revision and enhancement of the accident management guidance and procedures (Stress Test Finding STF-16). Associated reviews have led to provision of enhanced stocks of emergency equipment and consumables to support accident mitigation (Recommendation IR-8).

IR-26 A response to the various recommendations in the interim report should be made available within one month of it being published. These should include appropriate plans for addressing the recommendations. Any responses provided will be compiled on the ONR website.

Magnox Limited Response to IR-26

The Interim Report (Ref. 14) was issued by the Office for Nuclear Regulation on 18th May 2011. Within one month of the issue of the Interim Report, on 16th June 2011, Magnox Limited provided a preliminary response to all 26 recommendations. That response discharged the requirement of Recommendation IR-26. The response provided details of the arrangements under which further reviews and assessments to address the Interim Report recommendations would be carried out and a high level programme for that further work.

Conclusion

Recommendation IR-26 was fully discharged by the response provided by Magnox Limited to the ONR in June 2011.

4.2 HM Chief Inspector's Final Report Recommendations

FR-1 All nuclear site licensees should give appropriate and consistent priority to completing Periodic Safety Reviews (PSR) to the required standards and timescales, and to implementing identified reasonably practicable plant improvements.

Magnox Limited Response to FR-1

Magnox Limited remains fully committed to the Periodic Safety Review process, including the timely implementation of reasonably practicable plant improvements. In accordance with Nuclear Site Licence Condition 15, the requirement to carry out Periodic Safety Reviews is embedded in the Magnox Limited management control procedure for management of the safety case. Major reviews of the reference safety case are to be undertaken at a period no longer than ten years or as agreed with the Office for Nuclear Regulation. The procedure sets out detailed requirements for major Periodic Safety Reviews. The procedure also declares the intent that all changes identified by Magnox Limited during such reviews should be completed before the end of the ten year period within which the review takes place. Any further work to address ONR findings relating to the review is to be closed-out in accordance with a programme agreed between Magnox Limited and the ONR.

A full review of the Periodic Safety Review process has recently taken place including dialogue with the ONR. The primary objective of that work was to improve the review process for decommissioning sites, building on corporate learning from recent Periodic Safety Reviews. The programme schedule for future Periodic Safety Reviews of Magnox Limited sites has been shared with the ONR.

Conclusion

Magnox Limited remains fully committed to the aims and values of the Periodic Safety Review process and continues to carry out such reviews to the required standards and timescales and to implement identified reasonably practicable plant improvements. The requirements of Recommendation FR-1 are met by this commitment that is further reinforced within company management control procedures.

FR-2 The UK nuclear industry should ensure that structures, systems and components needed for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, are adequately protected against hazards that could affect several simultaneously.

Magnox Limited Response to FR-2

Plant control rooms play a diminishing role in terms of site resilience as Magnox Limited sites progress into decommissioning. Only Wylfa and Oldbury now have plant control rooms from which significant operator actions are initiated.

Each Magnox Limited site has an emergency control centre to facilitate command and control of emergency situations.

The Central Emergency Support Centre that would provide centralised post-accident support to any Magnox Limited site is based in Gloucestershire. It is considered unlikely that the Central Emergency Support Centre would be adversely affected by any event that also affects one of Magnox Limited's operational sites as it is about 20 miles from Berkeley, the nearest site. The Central Emergency Support Centre has a back-up facility at another location on the same site to provide some diversity and also extra capacity in the event of a multi-site emergency. The Central Emergency Support Centre functions can also be performed from the event management centre at Magnox Limited's Berkeley Centre or, in extremis, from any of the emergency control centres at other Magnox Limited sites. The back-up facilities have been exercised and proven adequate for managing the response to an off-site nuclear emergency at a Magnox Limited site.

Magnox Limited does not maintain hardened facilities for post-accident command and control. Command and control functions can be exercised wherever information can be collated and decisions made and promulgated. If a facility becomes untenable for any reason then the function will be taken to a different location. Command and control facilities at Magnox Limited sites serve as a communications centre and their resilience is more a matter of the resilience of communication than location. Indeed, an emergency control centre could be moved to a location off-site provided communication links are maintained. Communication resilience is addressed in the response to Recommendations IR-22 and IR-23.

Site resilience workshops held by Magnox Limited (see Section 3.3.1) have reviewed the resilience of post-accident command and control provisions. The workshops examined possible hazards, safety requirements and plant, people and processes needed to meet these requirements. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design. As a result of the actions placed at those workshops, site-specific reviews of the resilience of command and control provisions have been completed.

Wylfa

The main control room at Wylfa is located in a secure location within the reactor buildings and has robust design and construction. Under normal circumstances the main control room provides plant monitoring and reactor control functions.

A remote emergency indication centre provides a subset of indications for monitoring reactor conditions from a location external to the reactor buildings and independent of the main control room. The remote emergency indication centre systems and building are seismically qualified and have their own electrical supply from a dedicated diesel generator.

Reactor control cannot be exercised from the remote emergency indication centre but the plant design allows for local manual interventions to be made if control functions are required and the main control room is untenable.

Wylfa has a fully equipped on-site emergency control centre. An alternative emergency control centre is located off-site on higher ground. It is unlikely that both the primary and alternative facilities would be damaged by an event that necessitated their use. The alternative emergency control centre is adequately equipped to take over from the primary emergency control centre on demand. The transfer of command and control from one facility to another during an event has been exercised. There is also a second back-up facility on higher ground at a nearby off-site location, equipped with suitable communication facilities, which would be used if the other two emergency control centres are not tenable.

Following site resilience reviews, a new off-site beyond design basis emergency equipment compound has been constructed within which a large quantity of additional emergency equipment is stored. This compound is readily accessible from the diverse command and control facilities and provides a further location from which limited command and control functions could be performed. An alternative, totally diverse, monitoring system for a small subset of essential reactor parameters has been installed. That system is independent of site electrical supplies and provides wireless data transmission to the new emergency equipment compound.

Magnox Limited has not identified any reasonably practicable enhancements that can be implemented to provide supplementary hardened command and control facilities. Such modifications cannot be achieved to deliver significant safety benefits within the remaining time of reactor operation at Wylfa. Nevertheless, an analysis has been undertaken of gaps between current provisions with respect to control room, remote emergency indication centre and emergency control centre facilities and the recently-updated International Atomic Energy Agency expectations for the design of new nuclear power plants (Ref. 25). That analysis identified a number potential opportunities for enhancing existing provisions subject to feasibility and reasonable practicability. As a result the following enhancements have been implemented:

- Ventilation systems supplying the central control room have been enhanced to ensure leak tightness and damper function and improved maintenance arrangements have been put in place;
- An addition has been made to the site Emergency Handbook to clarify the process for initiating emergency response actions should the central control room be untenable;
- Alternative resilient command and control facilities have been identified should the normal site facilities be untenable;
- New gamma and contamination monitors have been installed in the central control room and remote emergency indication centre.

In addition assessments have been completed of potential toxic or explosive gas hazards to the central control room and remote emergency indication centre. Those assessments concluded that there are no unaddressed toxic or explosive gas hazards for these facilities.

Oldbury

Oldbury has a central control room from which plant conditions are monitored and reactor operations managed. However, with both reactors now cooled by natural circulation, it would take many days following a failure of boiler feed and pressure vessel cooling to reach Operating Rule temperature limits and considerably longer to reach actual safety limits. Plant operating instructions require the application of boiler feed after seven days in the event that all indication of core temperatures is lost. If necessary, required actions can be taken independently of the central control room.

Oldbury has a fully equipped emergency control centre. Nevertheless, following resilience reviews, recognising that the emergency control centre could be vulnerable in the unlikely event that the site is flooded, two alternative diverse and elevated locations on site have been equipped to enable the emergency control centre command and control functions to be relocated if necessary.

Other Sites

For other Magnox Limited sites, no short-term operator interventions would be required to maintain safety. Thus there is no requirement to maintain protected central control rooms or supplementary control rooms. Each site has an emergency control centre. Given the relatively low level of risk posed by these sites and the ample timescales to restore the, now limited, safety-related functions, the need to have alternative facilities is replaced by the requirement to have a contingency plan against loss of facility.

Each site has been provided with a beyond design basis emergency equipment container which provides equipment that can be used to establish basic short-term command and control functions from a suitable location on site should the primary emergency control centre become untenable. The container is stored at a resilient position on each site.

Conclusion

Magnox Limited has reviewed the arrangements for managing and controlling actions in response to an accident to ensure that sites are adequately protected against hazards that could affect several sites simultaneously. This review has concluded that Magnox has diverse and redundant arrangements consistent with the lifecycle position of each site such that adequate command and control functions can be exercised in the event of primary facilities being rendered untenable. A number of resilience enhancements have been implemented.

FR-3 Structures, systems and components needed for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, should be capable of operating adequately in the conditions, and for the duration, for which they could be needed, including possible severe accident conditions.

Magnox Limited Response to FR-3

Wylfa is the only Magnox Limited site for which a severe accident is a credible fault consequence, or that could potentially require short-term operator intervention to control an accident under possibly harsh environmental conditions.

As detailed in the response to Recommendation FR-2, Wylfa has diverse facilities both on-site and off-site from which post-accident command and control can be exercised. Each of these facilities is adequately equipped to operate as a command and control centre. Managed transfer of these functions from one facility to another has been exercised.

Similarly, the diversity and resilience of off-site emergency response centres has been discussed in the response to Recommendation FR-2.

Following resilience workshops and subsequent site-specific resilience reviews (see Section 3.3.1) enhancements have been implemented that supplement the existing operational resilience of post-accident command and control functions and facilities at Wylfa. The resilience reviews have taken account of the conditions under which such functions must be performed and the duration for which they may be required. Examples of enhancements implemented include:

- A resilient off-site beyond design basis emergency equipment compound has been constructed within which a large quantity of additional emergency equipment is stored. This compound is readily accessible from the diverse command and control facilities and provides a further location from which limited command and control functions could be performed;
- An alternative, totally diverse, monitoring system for a small subset of essential reactor parameters has been installed, independent of site electrical supplies, with wireless data transmission to the new emergency equipment compound.
- New portable diesel generators have been provided and are stored in the new emergency equipment compound. Stocks of diesel fuel held on site have also been increased. These generators can be used to restore lighting or run ancillary plant thereby increasing the resilience of post-accident command and control functions.
- Additional supplies of health physics equipment including dose meters, contamination probes, respirators and personal protective equipment have been procured and are stored in the new emergency equipment compound. These could be used to provide essential radiological monitoring as part of post-accident command and control.
- Additional emergency welfare packs have been procured to provide emergency food rations, drinking water, first aid kits etc., supplementing existing site arrangements. These welfare packs are stored in the new emergency equipment compound.
- Two satellite telephones have been provided to facilitate communications between the site and off-site emergency support agencies should normal terrestrial communication channels be lost. Satellite telephones have also been provided to off-site emergency support centres.

In addition to the above enhancements, an analysis has been undertaken of gaps between current provisions with respect to command and control facilities and the recently updated International Atomic Energy Agency expectations for the design of new nuclear power plants (Ref. 25). That analysis identified a number of potential opportunities for enhancing existing provisions subject to feasibility and reasonable practicability. Feasibility studies and further assessment work to support these potential enhancements have been completed and the following enhancements have been delivered:

- Ventilation systems supplying the central control room have been enhanced to ensure leak tightness and damper function and improved maintenance arrangements have been put in place;
- An addition has been made to the site Emergency Handbook to clarify the process for initiating emergency response actions should the central control room be untenable;
- Alternative resilient command and control facilities have been identified should the normal site facilities be untenable;
- New gamma and contamination monitors have been installed in the central control room and remote emergency indication centre.

In addition assessments have been completed of potential toxic or explosive gas hazards to the central control room and remote emergency indication centre. Those assessments concluded that there are no unaddressed toxic or explosive gas hazards for these facilities.

Furthermore, recognising the importance of communications to effective post-accident command and control, Magnox Limited has conducted a further review of emergency communications resilience including comprehensive consideration of on-site and off-site emergency communications at Wylfa. The review provided an in-depth assessment of the resilience of both the required information flows and the communication systems technology that supports those information flows. The review concluded that there is sufficient diversity within the communications systems to achieve robustness against common cause failures thereby ensuring that essential information flows can be maintained between key emergency response facilities in most cases under hazard conditions of a scale or magnitude that could reasonably be expected in the UK. Some potential vulnerabilities were noted that could result in the loss of some lines of communication under extreme conditions. Opportunities for enhancing resilience, including addressing the recognised vulnerabilities, have been identified. These opportunities have been reviewed and sentenced by Wylfa site Engineering and Emergency Planning staff. Enhancements considered to be reasonably practicable and providing significant benefit are being progressed by the Wylfa site under normal business arrangements.

Conclusion

In conjunction with reviews carried out to address Recommendation FR-2, Magnox Limited has reviewed the operational capability of facilities required for post-accident command and control. These reviews have concentrated on Wylfa, the only Magnox Limited site for which a severe accident is a credible fault consequence, or that could potentially require short-term operator intervention under possibly harsh environmental conditions to control an accident.

Significant enhancements have been implemented to improve the security of post-accident command and control functions.

FR-4 The nuclear industry should ensure that adequate Level 2 Probabilistic Safety Analyses (PSA) are provided for all nuclear facilities that could have accidents with significant off-site consequences and use the results to inform further consideration of severe accident management measures. The PSAs should consider a full range of external events including "beyond design basis" events and extended mission times.

Magnox Limited Response to FR-4

Probabilistic safety analyses for nuclear power plants attempt to quantify the risks associated with plant operation. Three levels of analysis are commonly recognised. A Level 1 probabilistic safety analysis considers the probability of initiating events (plant failures, operating errors, or external events, for example) and their subsequent development to plant damage states that could result in radiological releases. Level 2 probabilistic safety analysis considers the probabilities associated with accident progression from the plant damage states defined by the Level 1 analysis to occurrence of a radiological release. Level 3 analysis then considers the radiological release source terms defined by the Level 2 analysis and attempts to quantify the probabilities associated with consequences in terms of health effects and property damage, for example.

The reactors at all Magnox Limited sites apart from Wylfa are permanently shut down and the risk of an accident that could lead to significant off-site consequences at these defuelling and decommissioning sites is now very low or zero. It is considered, therefore, that the single remaining operating reactor at Wylfa (Reactor 1) is the only Magnox Limited facility for which a Level 2 probabilistic safety analysis approach could provide benefit in informing further consideration of severe accident management measures.

Hybrid Level 1 probabilistic safety analyses have been progressively carried out for operating Magnox Limited reactors, including Wylfa, since the mid-1980s. The hybrid Level 1 probabilistic safety analysis process assesses consequential off-site radiation doses (similar to the end-point of a Level 2 analysis), but does not explicitly consider the progression of severe accidents leading to those radiological consequences in the detail required to meet Level 2 (and Level 3) criteria. The existing hybrid Level 1 probabilistic safety analyses also include some treatment of internal and external hazards.

The overall Magnox Limited aim in addressing Recommendation FR-4 has been to apply Level 2 probabilistic safety analysis techniques to extend the understanding of credible accident progression for Wylfa Reactor 1 in a way that informs improved severe accident management measures that can be delivered and provide safety benefits on a timescale consistent with the remaining planned period of reactor operation.

Limited quantitative analysis exists for accident progression and phenomenology within Magnox reactors and to obtain comprehensive analyses of the type normally used to support Level 2 probabilistic safety analyses would not be possible on a timescale consistent with delivering any benefit within the remaining operational life of Wylfa Reactor 1.

Nevertheless, a viable methodology to achieve the above aim, within the timescale and knowledge constraints, was devised in consultation with company and external experts. In outline, the methodology included the following steps:

i. Select a limited set of plant damage states that are both risk-significant (from the existing Level 1 probabilistic safety analysis) and, more importantly, are expected to place the demands upon the existing accident management guidance to the greatest extent possible.
ii. Develop accident progression event trees for each selected plant damage state based on the advice and phenomena in the existing accident management guidance, incorporating other existing knowledge and expert judgement.
iii. By analysing the accident progression event trees, including the practicality of achieving accident mitigation at each stage based on existing accident management guidance, identify potential areas for enhancement of that guidance, including:
    a. Identifying potential enhancements that would provide significant improvements in the likelihood of arresting accident progression;
    b. Identifying, and if possible removing, the largest uncertainties within the existing accident management advice.

Plant damage states were selected (step i, above) by an expert panel including Magnox Limited staff (Wylfa Site and Engineering Function) and independent consultants, considering the Level 1 probabilistic safety analysis fault groups and beyond design basis faults. The definition of each state included specific assumptions about the nature of the damage and availability of plant.

Being artificial aggregates of distinct damage scenarios the selected plant damage states are not realistic. However, they were designed to satisfy the requirement for exploring existing accident management guidance to the greatest possible extent, particularly that focused on prevention or mitigation of severe core damage. They are also considered to represent and bound damage states that could credibly result from the occurrence of beyond design basis external hazards. To ensure full consideration of the effects of extreme external hazards, the deliberations regarding accident progression included the possibility of collateral damage to on-site and off-site infrastructure that might have been caused by the same initiating event that led to the assumed plant damage state.

Initial accident progression event trees for each plant damage state were constructed based on the phenomena and advice contained within existing accident management guidance. These then underwent iterative development through a series of workshops. Technical issues and assumptions relevant to the development of the accident progression event trees were documented during this process.

Quantification of the accident progression event trees by assigning success probabilities to mitigating actions using event and fault tree analysis techniques was initially intended. However, after some attempts to do this, achieving a meaningful quantification was found to be an encumbrance in developing the accident progression event trees. Nevertheless, the final qualitative development of the accident progression event trees was sufficient to prompt the identification of wide-ranging and potentially beneficial enhancements to the existing accident management guidance, thereby achieving the aim for this analysis.

The output from the analysis is a series of detailed observations that identify potential enhancements to existing accident management guidance. These observations have been taken forward within the associated programme of work to review and revise accident management guidance. That work programme is described in the response to Stress Test Finding STF-16.

Conclusion

Magnox Limited has developed and applied a methodology based on Level 2 probabilistic safety analysis techniques that has successfully identified wide-ranging potential enhancements to accident management guidance. These have been taken forward as part of the programme of work to review and revise the existing accident management guidance.

Recognising that it would not have been possible to complete a full Level 2 probabilistic safety analysis for Wylfa Reactor 1 on a timescale consistent with delivering safety benefit before final shutdown, Magnox Limited considers that the intent of Recommendation FR-4 has been met in a proportionate manner.

FR-6 The nuclear industry with others should review available techniques for estimating radioactive source terms and undertake research to test the practicability of providing real-time information on the basic characteristics of radioactive releases to the environment to the responsible off-site authorities, taking account of the range of conditions that may exist on and off the site.

Magnox Limited Response to FR-6

As part of the current emergency arrangements for its nuclear sites, Magnox Limited has in place procedures which, in the event of an off-site aerial release of radioactivity from any site, would be used to estimate the airborne concentrations, surface concentrations of deposited radioactivity and the consequential doses which could be received by members of the public in the surrounding area. These procedures can be used to determine whether it would be appropriate to consider prompt countermeasures such as sheltering or evacuation in particular areas to limit the dose the public could potentially receive. Off-site doses are calculated using current weather data and forecast data provided by the UK Meteorological Office and can take account of changes in those data. The procedures incorporate a library of source terms for potential faults, each giving data for the quantities of individual radioactive nuclides that could be expected for that fault. Initially, the most appropriate source term is used for the fault conditions that have been identified.

Each site has an installed system of radiation detectors that provide information on the magnitude of any off-site aerial release of activity from the site. In the event of such a release, mobile units are sent from the site to determine the airborne concentrations of activity at specific locations. These measurements can be used to modify the initial source term data to provide a better estimate of the activity release from the site and better estimates of the doses that would be received by people in the surrounding areas.

Magnox Limited has an agreed action level, an airborne radioactivity concentration at which, in the absence of further information, evacuation of the area would be recommended. This allows rapid decisions to be made on the need to evacuate areas to protect the public.

A review led by the ONR in response to Recommendation FR-6 identified the requirement to improve the process by which timely dose consequence advice can be provided to the UK Government in the event of a nuclear emergency. The ONR is leading a project to establish this capability in collaboration with the UK Meteorological Office, Public Health England and the Radioactive Incident Monitoring Network (RIMNET). It is intended that the dose assessment would be carried out using an atmospheric dispersion modelling computer programme run by the Meteorological Office.

Magnox Limited and other UK licensees have worked with the ONR to develop a library of source terms for a range of plant states at UK sites that have the potential for significant consequences beyond the immediate vicinity of the plant.

Although Magnox Limited has ten sites, Wylfa is the only site with an operational nuclear reactor. There are no potential fault conditions that could require consideration of prompt countermeasures, except in the immediate vicinity of the site, at any of the nine Magnox Limited sites without operating reactors. The Magnox Limited response to Recommendation FR-6 therefore concentrates on Wylfa.

Magnox Limited has produced a source term library for a range of potential fault conditions at Wylfa, including faults that would be considered to be severe accidents. In addition, guidance has been developed on the choice of appropriate source terms from that library and on the way in which source terms can be refined using data from the system of radiation detectors installed around the Wylfa site boundary. This will allow real-time information on the off-site activity release rate to be used with the Meteorological Office computer code to provide better real-time assessments of the radiological impact of any event at the site.

It is anticipated that the developed source terms and guidance will provide input into enhanced national arrangements for development of extended off-site countermeasures should an event occur where this becomes necessary. Further work to develop, agree and establish such arrangements is beyond the scope of the specific Magnox Limited programme responding to lessons learned from the Japanese events. Such further work will be carried out as part of normal business arrangements between Magnox Limited, other licensees, the ONR and UK Government departments and agencies.

Vehicles containing activity sampling and dose rate measurement equipment are based at each Magnox Limited site. Under current emergency arrangements, in the event of an off-site release of radioactivity from a site, those vehicles would be sent to appropriate predetermined off-site locations in the surrounding area to measure the local dose rate and airborne radioactivity concentration. Suitably qualified and experienced members of staff are always available. The results of those measurements are transmitted to the site and to the Central Emergency Support Centre. Advice on off-site countermeasures is based on these measurements, used directly and as input data for the computer code used to predict current and future dose rates at other locations.

Following resilience reviews carried out after the events at Fukushima Dai-ichi, Magnox Limited has purchased deployable radiation monitoring cones that can be left in position, either on-site or off-site, and will automatically transmit their position and the local dose rate into the existing UK RIMNET system. The information from these detectors (and other RIMNET detectors) will be readily available within the site emergency control centre, the Central Emergency Support Centre and to all RIMNET users. These stand-alone monitoring cones can be used to supplement the mobile vehicle-based units. The monitoring cones have their own power supply and can be controlled and interrogated remotely. If necessary, additional detectors can be brought relatively quickly to the area around the affected site. The provision of these stand-alone monitoring cones has a number of advantages:

- monitoring cones can be placed in strategic positions, depending on the nature of the incident and the weather conditions, and provide continuous dose rate measurements at those locations;
- data from the monitoring cones are readily and widely available through RIMNET;
- in locations where the dose rate is significant, the use of a stand-alone detector rather than vehicle-based equipment avoids exposure of an operator.

Conclusion

Magnox Limited has produced a library of source terms for potential plant states that would result in significant airborne activity releases from Wylfa power station. Following an accident, these source terms may be used as input data for a computer code operated by the UK Meteorological Office in collaboration with other UK Government agencies to assess the activity releases and off-site radiological consequences resulting from an event at the site.

In addition Magnox Limited has developed guidance on the most appropriate source term to use in given circumstances and on the use of data from the existing monitoring system installed around the site to refine the source term data.

It is anticipated that the developed source terms and guidance will provide input into enhanced national arrangements for developing extended off-site countermeasures should an event occur where this becomes necessary. Further work to develop, agree and establish such arrangements is beyond the scope of the specific Magnox Limited programme responding to lessons learned from the Japanese events. Such further work will be carried out as part of normal business arrangements between Magnox Limited, other licensees, the ONR and UK Government departments and agencies.

Magnox has purchased “stand-alone” radiation monitoring cones which, in the event of an incident at any Magnox Limited site, can be placed in appropriate off-site locations to provide continuous measurements of the local dose rate and the airborne concentration of released activity. This equipment complements the existing vehicle based equipment, providing greater flexibility and resilience.

FR-11 The UK nuclear industry should continue to promote sustained high levels of safety culture amongst all its employees, making use of the National Skills Academy for Nuclear and other schemes that promote "nuclear professionalism".

Magnox Limited Response to FR-11

Magnox Limited recognises that high levels of safety culture are fundamental to the operation of its business. Magnox Limited has always striven to embed safety culture at the heart of its operations and will continue to do so as a business priority. The enhancement of nuclear professionalism is seen as crucial to the success of the business, particularly as the sites transition from operational to decommissioning phases.

The maintenance and enhancement of nuclear safety culture within Magnox Limited is managed through an established annual Nuclear Safety Improvement Plan in conjunction with the company's oversight processes. Magnox Limited has regularly assessed the safety culture climate within the company. Findings from these assessments inform improvement plans and are included within the annual Environment, Health, Safety, Security and Quality plan.

The plan has a strategic objective to build on the excellent safety and environmental performance of Magnox Limited. A number of specific target areas for improvement are identified in the plan including conduct of operations and maintenance, operational decision making, organisational resilience and human performance.

Nuclear professionalism is at the heart of the Magnox Limited programme and all staff within the company have received human performance training to raise awareness of error avoidance techniques. The programme is based on internationally-recognised strategies and techniques to reduce and minimise the consequences and severity of errors. Senior managers are also trained to ensure director-level understanding.

The promotion of nuclear professionalism is a significant outcome of the company's extensive engagement with National Skills Academy for Nuclear which is seen as a key enabler for this objective.

Discussions with other UK nuclear licensees have taken place to plan measures that make use of the National Skills Academy for Nuclear and other schemes that promote nuclear professionalism. These discussions have resulted in a cross-industry project to develop a nuclear industry training framework that will drive training excellence and provide a framework to enhance and maintain nuclear professionalism across the sector.

Conclusion

Magnox Limited continues to promote high levels of safety culture among employees at all levels using schemes that promote nuclear professionalism, including those developed in conjunction with the National Skills Academy for Nuclear.

FR-12 Reports on the progress that has been made in responding to the recommendations in this report should be made available to ONR by June 2012. These should include the status of the plans, together with details of improvements that have been implemented by that time.

Magnox Limited Response to FR-12

On 26th June 2012 Magnox Limited provided to the ONR a comprehensive report on progress made with responding to the Final Report (Ref. 15) recommendations including all information requested in Recommendation FR-12.

Conclusion

Recommendation FR-12 was fully discharged by the submission made by Magnox Limited to the ONR in June 2012.

4.3 European Council Stress Tests for UK Power Plants National Final Report Findings

STF-1 Licensees should provide ONR with the decision-making process to be applied to their Considerations along with a report which describes the sentencing of all their Considerations. The report will need to demonstrate to ONR that the conclusions reached are appropriate.

Magnox Limited Response to STF-1

All Magnox Limited Stress Test Considerations (see Section 3.3.3) were carried forward for further assessment and development by the relevant sites. The submission made by Magnox Limited to the ONR in June 2012 provided a matrix that cross-referenced each Stress Test Consideration to work programmes under which the Considerations were being addressed.

The outcome of each site's work programme including the way in which the Stress Test Considerations have been addressed and enhancements that have been delivered in response to the Stress Test Considerations is summarised in Section 3.3.1 of the present report. Explicit cross-referencing of Stress Test Considerations with site work programmes has been provided to the ONR.

Proportionate and reasonably practicable enhancements have been made to address all Magnox Limited Stress Test Considerations.

Conclusion

All Magnox Limited Stress Test Considerations have been addressed and appropriate enhancements have been implemented across the Magnox Limited fleet. Details of how individual sites have developed and implemented potential enhancements implied by the Stress Test Considerations have been provided to the ONR.

STF-2 The nuclear industry should establish a research programme to review the Seismic Hazard Working Party (SHWP) methodology against the latest approaches. This should include a gap analysis comparing the SHWP methodology with more recent approaches such as those developed by the Senior Seismic Hazard Analysis Committee (SSHAC).

Magnox Limited Response to STF-2

The Seismic Hazard Working Party methodology for undertaking probabilistic seismic hazard analyses has been used historically to inform the choice of the design basis seismic hazard used for assessment and design purposes at each Magnox Limited site. The only remaining Magnox Limited site with active cooling requirements and for which long timescales are not available for restoring cooling is Wylfa which has the single remaining operating reactor in the Magnox Limited fleet. Considerable time, effort and financial resources have been expended since the mid-1980s in demonstrating the seismic adequacy of safety-related structures, systems and components at all Magnox Limited sites and at Wylfa in particular (see also Section 3.3.2).

Definition of the seismic design basis at Wylfa was most recently re-assessed during the Periodic Safety Review completed in 2004. To ensure robustness of the site-specific seismic hazard definition two hazard studies were commissioned. One of those studies was carried out by the Seismic Hazard Working Party in accordance with their methodology. The other, independent, hazard analysis was carried out by the British Geological Survey using a different methodology. Both studies derived hazard models based on an analysis of historical seismic events coupled with seismological and geological evidence. Supplementary studies were carried out by both groups to investigate the sensitivity of the resulting hazard estimates to uncertainties inherent in the models that were developed.

These two independent hazard studies produced estimates for the 10^{-4} per annum exceedance frequency seismic ground motion parameters that are sufficiently close to give confidence that the pessimised ground motion definition adopted as the site seismic design basis is robust. It is also noteworthy in this respect that, prior to the 2004 Periodic Safety Review and the results of the site-specific seismic hazard analyses, a more onerous seismic hazard definition had been used in assessing the seismic capability of safety-related structures, systems and components. In particular that more onerous hazard definition has been used in the seismic assessment of reactor internal structures.

In response to Stress Test Finding STF-2, EDF commissioned an independent “gap analysis”, on behalf of the UK nuclear industry, comparing the Seismic Hazard Working Party methodology with modern practice, including approaches developed by the Senior Seismic Hazard Analysis Committee. That gap analysis identified several areas in which the Seismic Hazard Working Party methodology differs from modern practice. The most potentially significant differences identified by the gap analysis are in the areas of ground motion modelling and choice of seismic source zone parameters.

In the context of the choice of design basis for the Wylfa site it is evident that the two independent hazard studies addressed these aspects of the hazard analysis in different ways. In particular, the British Geological Survey hazard analysis employed different, more recently derived, ground motion models compared with the Seismic Hazard Working Party study. Furthermore, the characterisation of source zone parameters was carried out using distinct methodologies.

It is considered, therefore, that the impact of the differences between the Seismic Hazard Working Party methodology and modern practice identified by the recent gap analysis have been adequately addressed by the precautionary approach taken in informing the choice of design basis seismic ground motion by undertaking two independent studies employing different methodologies. On this basis, and coupled with a further pessimised choice of design basis, Magnox Limited considers the seismic design basis adopted for Wylfa to be robust. Considering the robustness of the adopted Wylfa hazard, the time that would be required to complete new hazard studies relative to the limited operating period remaining at Wylfa, and the engineered robustness demonstrated for safety-related structures, systems and components, Magnox Limited does not consider it to be reasonably practicable to undertake further seismic hazard studies.

Conclusion

A gap analysis comparing the Seismic Hazard Working Party methodology with modern practice in probabilistic seismic hazard assessment has been completed on behalf of the UK nuclear industry. Magnox Limited has reviewed the results of that analysis and considers that the precautionary and conservative approach to choice of design basis seismic ground motion for Wylfa, the only remaining site with an operating reactor, adequately addresses the most significant potential shortfalls identified by the gap analysis. As part of normal business arrangements Magnox Limited will continue to maintain awareness of developments in UK seismic hazard assessment methodology. However, Magnox Limited does not consider further seismic hazard studies to be reasonably practicable.

STF-3 Licensees should undertake a further review of the totality of the required actions from operators when they are claimed in mitigation within external hazards safety cases. This should also extend into beyond design basis events as appropriate.

Magnox Limited Response to STF-3

Wylfa is the only Magnox Limited site where there is significant safety-related dependence on operator actions in the short to medium term following an event that may challenge normal plant integrity or functionality (see Section 2). For this reason the Magnox Limited response to Stress Test Finding STF-3 has concentrated primarily on Wylfa.

The operator actions claimed within external hazards safety cases have been assessed within past Periodic Safety Review probabilistic safety assessments. The actions modelled within these assessments were those that derive from station operating instructions and other supporting procedures and therefore, in general, relate to actions claimed in response to design basis events. Such actions include detection of fault conditions and the commissioning and operation of equipment to secure safety functions including post-trip cooling and monitoring. The operator actions claimed in the safety cases have been substantiated qualitatively and quantitatively by specific human factors assessments based on the implementation of the available station operating instructions and operating procedures and task analysis.

Within these assessments the ability of operators to carry out claimed actions was taken into account based on the design basis external hazard fault consequences. The totality of such operator actions has been comprehensively reviewed within this existing work. There is considered to be little benefit to be gained from repeating these relatively recent analyses of operator actions claimed in response to design basis events.

As described in the response to Stress Test Finding STF-16 guidance for managing beyond design basis accidents at Wylfa, Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs), have been reviewed and comprehensively revised. The revised SBERGs, in particular, are supported by a suite of newly-developed Emergency Operating Procedures (EOPs) each of which describes actions to be taken by operators to achieve specific objectives indicated within the accident management guidance. Such objectives include sealing of breaches in the reactor pressure boundary, securing reactor hold down by insertion of additional neutron absorbing materials, management of forced gas circulation within the reactor, management of boiler feed, securing emergency electrical supplies etc.

Human factors assessments to provide qualitative substantiation for the operator/plant interfaces associated with actions advised by the EOPs have been completed. The advice contained within the EOPs supports the philosophy of the SBERGs and is therefore based on addressing the symptoms that arise generically following a fault rather than addressing specific external hazard scenarios. The scope for the qualitative human factors assessment included:

- Identification and location, through review of documents and drawings and discussions with site personnel, of all plant interfaces and components, plus dedicated response equipment that is required to support the response actions within the EOPs.
- Determination of a set of general plant environmental conditions that might result from fault or accident scenarios (including those that might arise from external hazards) and affect the capability to undertake actions.
- Reviewing the identified plant and equipment through plant walkdowns, discussions/task talk-throughs with operators, drawing reviews, etc. as appropriate to assess the usability in normal circumstances and accessibility/continued usability under postulated degraded conditions. For newly-acquired response equipment consideration has been given to the clarity of its use including its intended purpose, supporting documentation and training.
- Capturing any human factors issues and identifying enhancements that would help resolve or lessen the impact of such issues.

The assessments identified opportunities for enhancing the clarity of the EOPs; these enhancements have been incorporated into the documents before final issue (see also the response to Stress Test Finding STF-16). Some opportunities have also been identified for improving the availability and operability of equipment or facilities. Consideration of these further enhancement opportunities is being progressed by Wylfa under normal site arrangements.

Events that result in a severe accident with the potential for significant off-site radiological release would be mitigated by utilising strategies based on the SAGs. Fault sequences and operator responses under severe accident conditions have been explored in response to Recommendation FR-4 using a methodology based on Level 2 probabilistic safety analysis techniques. That assessment provided an opportunity to review the feasibility of severe accident mitigation strategies and associated operator actions advised by the SAGs. Observations derived from that work have been taken forward into the revision of the SBERGs and SAGs. More detail is given in the responses to Recommendation FR-4 and Stress Test Finding STF-16.

As part of its response to the Japanese events, Magnox Limited has equipped all sites with additional emergency response equipment to either facilitate specific actions or to assist with general post-event recovery activities. To ensure that all such equipment remains in a state of readiness for deployment Magnox Limited has undertaken a "proof of concept" assessment across all sites. The aim of this assessment has been to demonstrate that robust schemes are in place for managing the emergency equipment. Specifically, the assessment requires for all equipment that:

- the equipment has been installed and commissioned with appropriate advice and training provided;
- formal handover to the long term equipment owner is complete;
- a future maintenance regime has been established in accordance with Magnox Limited standards;
- a replenishment regime has been established, where applicable, in accordance with Magnox Limited standards;
- equipment usage has been simulated, where applicable.

Conclusion

Operator actions claimed in the mitigation of the effects of external events at Wylfa have been extensively assessed as part of recent Periodic Safety Reviews and safety case development.

Guidance for mitigating beyond design basis consequences, including those that might arise from external events, has been extensively revised as part of Magnox Limited's response to the Japanese events. Human factors assessments for explicit operator actions identified within that revised guidance have been completed and enhancements have been incorporated into the guidance before final issue. Opportunities have also been identified for improving the availability and operability of equipment or facilities that are being progressed by Wylfa under normal site arrangements.

A "proof of concept" assessment has been undertaken at all sites to ensure that additional emergency equipment provided as part of the response to the Japanese events remains in a state of readiness for deployment.

STF-4 Licensees should undertake a further systematic review of the potential for seismically-induced fire which may disrupt the availability of safety-significant structures, systems and components (SSC) in the seismic safety case and access to plant areas.

Magnox Limited Response to STF-4

Although seismically-induced fire is a potential issue at all Magnox Limited sites, the primary concern is for Wylfa which has an operating reactor with significant post-seismic event active reactor cooling requirements. Wylfa has a safety case against seismic events that has been developed through a comprehensive programme of assessments and plant enhancements. A further confirmatory programme of systematic seismic walkdowns covering key systems related to post-trip cooling and monitoring has been completed following the Japanese events (see Section 3.3.2). The potential for seismically-induced fire has been recognised in the development of the existing safety case but no specific concerns have been raised in this respect.

In response to Stress Test Finding STF-4 Magnox Limited commissioned a further targeted systematic assessment of the potential for seismically-induced fire to affect the availability of key systems and components at Wylfa.

The scope of the assessment was limited to plant supporting the operating reactor, Reactor 1 and, subject to that limitation, covered the same systems and components as the prior confirmatory walkdown assessments described in Section 3.3.2.

Specifically, the assessment considered the potential for seismically-induced fire to disrupt the post-event availability of components that collectively comprise the reactor gas pressure boundary including reactor pressure vessel penetrations and attached pipework external to the vessel up to the first support beyond the first point of normal isolation on each line. In-line equipment up to that point was also included. Assessment of the pre-stressed concrete pressure vessel and its internal structures was not required. The assessment also covered the structures and components that comprise the Back-up Feed System and Tertiary Boiler Feed System external to the reactor pressure vessel together with all plant items necessary for post-event operation of these systems. In addition, all plant and equipment external to the reactor pressure vessel necessary to facilitate monitoring of pressure and temperature within the vessel and neutron flux in the reactor core via the remote emergency indication system were included.

The assessment comprised:

- Identification of plant items and areas/adjoining areas;
- Identification of flammable inventory and ignition sources;
- Identification of fire barriers and their qualification level;
- Identification of fire suppression systems and their qualification level;
- Evaluation of the overall risk to plant items and local access to plant areas.

The assessment was carried out by suitably qualified and experienced hazards walkdown engineers primarily by systematic walk-throughs of site areas containing, or adjacent to, plant within the scope. Threat identification was undertaken based on guidance developed by the Electric Power Research Institute in the United States for post-Fukushima assessment of seismically-induced fire hazards at US nuclear power plants, and other experience data on seismically-induced fire at power plant and industrial facilities.

Only in one instance did the assessment highlight an area where it is considered that fire could develop with moderate potential consequences for safety-related plant within the scope. Wylfa site has taken action to address the identified moderate fire risk. In all other areas the seismically-induced fire risk was determined to be low such that it is unlikely that fire will start or there would be little consequence for safety-related plant within the scope if fire was to ignite. No areas were identified with a high risk of seismically-induced fire.

Although the risks from seismically-induced fire are much lower, all other Magnox Limited sites have reviewed the fire risks to safety-significant facilities to address actions arising from the site resilience workshops described in Section 3.3.1. Typically sites have reviewed current procedures relating to control of fires and have carried out walkdowns to identify areas that contain superfluous combustible materials. Where opportunities have been identified to further reduce already low risks the sites have completed appropriate improvement measures.

Conclusion

A further systematic review of the potential for seismically-induced fire at Wylfa has been completed and actions to reduce the single area of moderate risk identified have been implemented. All other Magnox Limited sites have reviewed potential fire hazards and, where appropriate, have taken actions to reduce the already low risks.

STF-5 Licensees should further review the margins for all safety-significant structures, systems and components (SSC), including cooling ponds, in a structured systematic and comprehensive manner to understand the beyond design basis sequence of failure and any cliff-edges that apply for all external hazards.

Magnox Limited Response to STF-5

Wylfa is the only Magnox Limited site where there is significant safety-related dependence on the integrity of the reactor pressure boundary and provision of active cooling of nuclear fuel in the short to medium term following an event that may challenge normal plant integrity or functionality (see Section 2). For this reason the Magnox Limited response to Stress Test Finding STF-5 has concentrated primarily on Wylfa.

The margin to failure of a structure or component is, in principle, a measure of the strength of the structure or component relative to the magnitude of the load to which the structure or component is subjected. To quantify such a margin necessitates a prediction of the load at which the structure or component will fail. Failure prediction for even the simplest of engineering components under the most well-defined loading conditions is generally impossible except in a statistical manner. Such statistical characterisations of failure margin cannot be used reliably to predict the sequence of failure for complex structures, systems and components (see also the discussion of Seismic Margins below).

Furthermore, most engineering loading conditions, and those associated with external hazards in particular, are not well defined. Events with notionally similar "magnitude" can be manifest in an infinite number of different load geometries and distributions, each nuance of which will influence the response of the structure, system or component and, thus, its disposition to failure under the loading condition.

Moreover, the evident difficulties in estimating failure are exacerbated by the fact that failure is inherently a non-linear phenomenon, occurring by definition in a response region where linear scaling between load magnitude and response has broken down.

Further difficulties arise in comparing notional margins to failure for disparate structures, systems and components where for each such entity failure is inevitably characterised in a different manner. This is further aggravated when trying to quantify a margin for a compound system whose integrity depends in a complex manner on that of its individual components.

For these reasons, and many others, the use of margins analysis to predict failure sequences is apt to be misleading and may lead to erroneous conclusions that result in inappropriate and possibly hazardous actions being taken unnecessarily.

The safety justifications for Magnox Limited plant do not, therefore, rely on failure prediction or on specific margins assessment of the kind discussed above. Rather, those justifications depend on the principles of failure avoidance and defence in depth.

While it is not possible to predict failure it is possible to define limits within which a structure, system or component is unlikely to fail and hence to define, conservatively, a safe operating envelope. This does not mean, however, that failure will occur if the limits that define that conservatively safe operating envelope are exceeded.

The way in which Magnox Limited achieves failure avoidance and defence in depth is briefly outlined below.

Firstly, Magnox Limited safety principles require, where possible, that measures be put in place to prevent initiating conditions that could lead to plant failure. Such measures include:

- having operating rules and limits that define the conservative envelope within which the plant may be safely operated, including defining minimum safety-related plant availability, operating procedures that implement these rules, and continual monitoring to ensure that such rules are observed;
- having engineered interlocks and administrative processes that actively prevent operation outside of the conservative safe operating envelope;
- carrying out rigorous inspections, maintenance and testing of the plant;
- undertaking periodic reviews of the plant safety case to ensure that modern standards are met as far as is reasonably practicable.

Clearly it is not, in general, possible to prevent the occurrence of external hazards. Nonetheless, ensuring that the plant is operated and maintained well within the known safe operating envelope makes a significant contribution to the resilience of the plant against such events.

Secondly, protection is provided against loss of essential safety functions from events that cannot be reasonably prevented, including external hazards. The requirements for such protection include:

- Demonstration of sufficient diversity and redundancy in systems claimed to support essential safety functions during and following events, including: avoidance of potential common-mode failure conditions, resilience against random component failures, and recognition and avoidance of disproportionate increases in consequences for events beyond the plant design basis;
- Demonstration that the claimed systems are functionally capable of achieving the desired support to essential safety functions, employing conservative engineering design principles and rigorous assessment methodologies to assure integrity of the claimed protection including the associated structures, systems and components by segregation from, or qualification against, the hazard;
- Consideration of the potential for human factors, including operator error, to impact the effectiveness of the protection provided and provision of appropriate mitigation measures.

Meeting these requirements contributes further to the margins, albeit largely unquantifiable, against failure of protection measures under external hazard loading conditions.

Finally, it is recognised that, despite all of the above measures, prevention and protection could prove inadequate, or fail to operate as intended. For this reason emergency procedures and accident management guidance, supported by emergency equipment, are provided to mitigate the consequences that may ensue under such circumstances. These include Symptom-Based Emergency Response Guidelines (SBERGs) which provide advice leading to the restoration of essential safety functions with the aim of preventing damage to the reactor core. The SBERGs are backed-up by Severe Accident Guidelines (SAGs) that provide advice on pre-planned or ad hoc measures that can be deployed to mitigate the consequences in the event of severe damage to the reactor core and/or containment. The SBERGs and SAGs and other accident management guidance are discussed further within the response to Stress Test Finding STF-16.

The three stages of prevention, protection and mitigation and the requirements that underpin each stage, all contribute in robust and defined ways to failure avoidance and to assuring defence in depth against conditions that could lead to a significant radiological release from the plant. The effectiveness of these contributors is further underpinned by probabilistic safety analysis (see also the response to Recommendation FR-4).

Rigorous application of the above failure avoidance and defence in depth measures ensures that the probability of safety-significant plant failures is as low as reasonably practicable.

Magnox Limited has approached Stress Test Finding STF-5 within the context outlined above and in accordance with the overarching aim of identifying reasonably practicable and proportionate enhancements that can deliver tangible safety benefits within the short remaining operational timescales at Wylfa.

Wylfa is currently also undergoing a ten-yearly Periodic Safety Review. Some of the outcomes from that review, which has been concurrent with the reviews carried out to address implications of the Japanese earthquake and tsunami, are also relevant to this Stress Test Finding and are outlined below.

Seismic Margins

Magnox Limited commissioned a seismic margins study for plant at Wylfa that contributes to protection against loss of post-trip reactor cooling (including components of the reactor pressure boundary) and reactor monitoring. The aim was to quantify the margin available to accommodate seismic events more severe, and hence less frequent, than events bounded by the site's seismic design basis definition and, thereby, to identify any items that could be considered particularly limiting to the overall ability to withstand beyond design basis earthquakes. Source data to inform this margins study were gathered during the confirmatory seismic walkdowns of that plant described in Section 3.3.2.

The margin estimation was restricted to consideration of the intrinsic capacity (or "strength") of the selected systems and components together with local interaction and secondary damage threats from adjacent plant and equipment.

Civil structures (including non-structural items such as masonry walls) have been addressed extensively during past Periodic Safety Reviews with appropriate strengthening measures having been implemented. The possibility of identifying further reasonably practicable enhancements to civil structures that could be implemented and provide tangible safety benefit within the remainder of the station life was judged to be very remote. The capacity of the civil structures was, therefore, excluded from the scope of the margins study.

The seismic margins study was carried out in accordance with a standard methodology developed by the United States Electric Power Research Institute.

The outcome of the seismic walkdowns was used to categorise items of equipment in terms of their level of "ruggedness" and, hence, into common fragility groups for the purpose of assigning median capacities characterised by spectral acceleration limits following Electric Power Research Institute guidelines. A bounding approach was taken to assigning equipment capacity (or "strength") based on consideration of structure-mounted items (rather than ground-mounted items that are typically less heavily loaded during a seismic event). As noted in the introductory comments in this response, it is not possible to define the capacity of an equipment item precisely. Rather the capacity is quantified statistically as a family of fragility curves that relate the probability of failure of the item to the magnitude of the applied loading. That family of fragility curves is determined by the assigned median capacity together with parameters representing log-normal capacity variability associated with randomness and uncertainty. A typical range of values for these variability parameters has been investigated within this study.

The design basis seismic demand on equipment was determined from in-structure response spectra calculated previously from detailed dynamic models of the Wylfa buildings. The most onerous in-structure response spectrum was used to define a bounding demand for use in estimating margins.

There is no single definition of seismic margin primarily because the capacity is only defined statistically. Thus the margin will depend on the desired statistical confidence level and acceptable probability of failure.

It is common in studies such as this to consider the "High Confidence of Low Probability of Failure" (HCLPF) capacity which is the capacity at which there is 95% confidence that the probability of failure is less than 5%. Comparing a minimum HCLPF capacity (derived using bounding fragility variability parameters) with the most onerous in-structure demand, the study estimates a lower bound for the minimum seismic margin approaching 20% to accommodate seismic demands more severe than the design basis level for the structures, systems and components considered within the scope.

Calculating the margin on a "best-estimate" basis (median confidence of 50% probability of failure) yields a minimum margin, for the equipment within the scope of this study, in excess of 150%. The Wylfa response to the European Council Stress Tests (Ref. 11) judged that a best-estimate margin of at least 50% existed against loss of essential safety functions. In the light of the results of this margins study that judgement is revealed to be very conservative, at least for the structures, systems and components within the study scope.

The estimated margins presented above contain a number of conservatisms associated with technical aspects of the derivation of capacity and demand. As a consequence the margin estimates presented above are considered to be absolute minimum values for all structures, systems and components within the scope of the study. Thus, it is concluded that substantial margins exist within the Wylfa plant to accommodate earthquake loadings that are more severe than the design basis without loss of essential safety functions.

In addition to formal margins estimation, a further aim of this study was to identify plant items that are likely to be limiting in terms of beyond design basis capability with a view to considering the reasonable practicability of enhancing the seismic capacity of those items and thereby increasing the overall plant resilience in a risk-informed manner. In practice the methodology employed in this study proved to be insufficiently discriminating to identify such limiting items with any confidence. Nonetheless, this aim has been met to some extent by the seismic walkdowns (Section 3.3.2) that provided input into the margins study and identified a number of areas in which the ruggedness of particular components could be enhanced. Those potential enhancements have been addressed as described in Section 3.3.2. Furthermore, enhancements to seismic resilience have also been achieved through the general enhancements implemented at Wylfa outlined in Section 3.3.1. Of particular note is the new emergency equipment compound provisioned with back-up equipment to facilitate restoration of essential safety functions following a design basis event. The compound storage facilities have been designed to be lightweight such that potential collapse in an extreme seismic event will not prevent use of the stored equipment.

A similar seismic margins analysis to that discussed above was also completed for Oldbury as part of the same study. However, both reactors at Oldbury are now permanently shut down and the dependence on safety systems is much reduced (see Section 2.3) rendering the results of that margins analysis redundant. Nevertheless, substantial resilience enhancements have been delivered at Oldbury (and other sites) as described in Section 3.3.1.

Coastal Flooding Margins

As a consequence of its coastal location on the northern edge of the island of Anglesey, Wylfa could, in principle, be susceptible to flooding from the sea. The design basis for coastal flooding at Wylfa has been reviewed as part of the detailed review of flooding hazards for all Magnox sites discussed within the response to Recommendation IR-10. That review concluded that the characterisation of the 10^{-4} per annum exceedance frequency extreme sea state affecting the Wylfa site is consistent with that which would be predicted in accordance with modern standards. The extreme 10^{-4} per annum exceedance frequency water level (combined high tide, storm surge, swell and wind waves) is predicted via a joint probability analysis to be 9.41m above ordnance datum (AOD) including allowance for a rise in sea levels resulting from climate change.

Wylfa is built on a rocky headland with a ground level of approximately 12.5m AOD. Flood levels would need to exceed this ground level before damage to safety-significant plant or equipment could occur.

As part of the Wylfa response to WANO SOER 2011-2 (see Section 3.3.4) a comprehensive site walkdown was carried out to identify items of plant and equipment that could be vulnerable in the unlikely event that the Wylfa site was to flood. The margin between the most onerous predicted design basis sea state and the flood level that could credibly damage each safety-significant plant item was evaluated. It was concluded that there is more than 3m margin between the design basis extreme wave crest level and a flood level that could threaten safety-related plant.

The 10^{-4} per annum exceedance frequency extreme still water level (excluding swell and wind waves but including tide and storm surge) is predicted to be 5.2m AOD. The margin against this extreme still water level exceeds 7m.

Given the size of these margins, the likelihood of coastal flooding affecting safety-related plant at Wylfa is considered to be very low. Nevertheless, as part of the response to the Japanese earthquake and tsunami consideration has been given to enhancing the resilience of the plant against flooding still further. As discussed in Section 3.3.1 substantial enhancements have been delivered, of particular note in the present context are:

- construction of a new emergency equipment compound some 5m higher than the main site ground level and 8m above the predicted extreme wave crest level;
- provision of additional pumps (stored within the new emergency equipment compound) capable of meeting the reactor heat removal requirements following a flooding event;
- provision of an alternative reactor monitoring system independent of site electrical supplies with wireless data transmission to the emergency equipment compound;
- provision of two submersible pumps for flood alleviation, particularly for restoring cooling to the primary dry store cells;
- provision of a range of mobile and portable generators, and supporting services, for restoring electrical supplies thereby aiding recovery from a flooding event.

Thus the aim of identifying and implementing reasonably practicable enhancements to resilience against flooding events has been met.

Resilience enhancements have been implemented at all Magnox Limited sites consistent with the site risk as described in Section 3.3.1. Particular consideration has been given to Oldbury; a more complete discussion is given in the response to Recommendation IR-10.

Extreme Weather Margins

The design basis safety case for Wylfa considers the potential adverse effects resulting from high winds, extreme ambient temperatures and heavy rainfall or snowfall. For this purpose the design basis is defined as events that could occur with an exceedance frequency of 10^{-4} per annum. The effects, including those from combinations of coincident meteorological events, have been evaluated during Periodic Safety Reviews and specific safety reviews to address operating experience.

Considerable enhancements to the resilience against extreme weather events have been delivered over recent years as a consequence of such evaluations. Examples include strengthening of building envelopes to improve resistance to wind loading including the potential for dominant openings, and overhaul of the storm water drainage system to enhance the ability to cope with extreme rainfall events. Such measures have been implemented in accordance with modern standards and therefore provide inherent margins beyond the design basis. The safety case for extreme low ambient temperatures has recently been updated to modern standards and enhancements have been implemented to further enhance resilience against extreme low temperatures.

Further support for plant resilience against the effects of extreme weather is provided by comprehensive instructions that operators must follow when such conditions are forecast. Such measures include surveillance of potentially vulnerable plant areas and implementation of preparatory measures.

A further layer of resilience has been provided by the enhancements that have been specifically implemented following the Japanese earthquake and tsunami (see Section 3.3.1). Of particular note is the new emergency equipment compound provisioned with back-up equipment to facilitate restoration of essential safety functions following a design basis event. The compound storage facilities have been designed to be lightweight such that potential collapse in an extreme weather event will not prevent use of the stored equipment. A further measure that has been implemented is the inclusion within the newly-developed Fuel Route Accident Management Guidelines (see the response to Stress Test Finding STF 16) of guidance on actions to be taken in the unlikely event that the Primary Dry Store Cell air inlet ducts become blocked as a result of flooding or extreme weather for example.

These measures collectively provide assurance that substantial margins exist to accommodate beyond design basis weather events without significant adverse effects on safety-related plant. Given the range and potential complexity of such events it is not possible to quantify such margins in a straightforward manner.

The most recent Wylfa Periodic Safety Review, carried out during 2012-13 to underpin site operation beyond September 2014, has recognised the benefit of providing a consolidated safety case for extreme weather that meets modern standards. A Periodic Safety Review finding has been raised, therefore, whose resolution is to produce a consolidated extreme weather safety case. This provides an opportunity to draw together all existing strands of the site safety case relating to meteorological events, facilitating updating of assessments where necessary and systematic review of potential consequences, including beyond design basis cliff-edges, and protection requirements. That consolidated safety case will be delivered under established arrangements for closing-out the Periodic Safety Review under normal business arrangements.

Conclusion

Magnox Limited has reviewed the resilience of safety-significant structures, systems and components against external hazards in structured manner. Primary emphasis has been placed in reviewing the resilience of Wylfa, the single remaining Magnox Limited site with an operating nuclear reactor. In some cases it has been possible to quantify margins, albeit in a generalised statistical manner. However, such quantification has not proven useful in identifying failure sequences, particularly for complex hazards, or in identifying potential cliff-edges that were not already recognised. Nevertheless, substantive enhancements have been implemented as a consequence of these reviews providing an extra layer of resilience over and above the “defence in depth” that already existed.

STF-6 Licensees should review further the margin to failure of the containment boundary and the point at which containment pressure boundary integrity is lost should be clearly established for the advanced gas-cooled reactors (AGR) and Magnox stations.

Magnox Limited Response to STF-6

The only Magnox Limited site for which integrity of the reactor pressure boundary is relevant is Wylfa which has a single operating reactor (Reactor 1). There is no longer a necessity to maintain the integrity of the pressure boundary on the shutdown Wylfa reactor (Reactor 2) or at Oldbury or Sizewell A; these reactors are now air-filled and at atmospheric pressure.

Stress Test Finding STF-6 is a special case of Stress Test Finding STF-5. The structures, systems and components considered in responding to STF-5 included those forming the reactor pressure boundary of Wylfa Reactor 1. The discussion of margins assessment within the STF-5 response applies equally to STF-6 and will not be repeated here.

The reactor pressure boundary for Wylfa Reactor 1 comprises a massive pre-stressed concrete pressure vessel with a large number of engineered penetrations for the gas circulators, boiler inlets and outlets, refuelling, coolant gas conditioning, reactor blowdown, monitoring etc. These structures have been subject to considerable assessment against external and internal hazards during Periodic Safety Reviews. Very substantial strengthening and modification of these structures, systems and components has been undertaken to ensure that the reactor pressure boundary is well-protected from hazards and to minimise the consequences in the unlikely event that the pressure boundary is breached. It has also been established that reactor cooling remains secure in the event that small breaches of the pressure boundary occur, even under an extreme assumption that forced coolant gas circulation within the reactor is lost. Thus some loss of reactor pressure boundary integrity can be tolerated.

Being wholly contained within the envelope of a substantial reinforced concrete building structure, the reactor pressure boundary is unlikely to be threatened by most external hazards.

The limiting feature in terms of pressure boundary integrity is likely to be small bore pipework associated primarily with instrumentation, gas conditioning and the refuelling system. The most significant challenge to this small-bore pipework, given its relatively protected position within the building envelope, is secondary damage from collapse of adjacent structures or equipment or from movement of large equipment items to which the pipework is attached. Such potential vulnerabilities have been exhaustively assessed during Periodic Safety Reviews. Adjacent structures (masonry walls, for example) have been strengthened and adjacent or attached plant items have been secured. Similarly, pipework support systems have been examined and enhanced to ensure that the pipework is both well-supported and not vulnerable to differential movement between anchor points. Measures have also been implemented to ensure that the extent of pressurised pipework is minimised during operation as far as reasonably practicable and to control the status of valves that determine the pressure boundary extent.

This small bore pipework was reviewed further as part of the confirmatory seismic walkdowns carried out following the Japanese earthquake and tsunami (described in Section 3.3.2). No immediate threats to pressure boundary integrity were identified but a number of opportunities to improve the ruggedness of the small bore pipework were identified including reinstatement of missing or defective pipework supports, and removal or restraint of mobile items adjacent to pressure boundary pipework. These recommendations have been implemented.

The seismic margins analysis described within the response to Stress Test Finding STF-5 included small bore reactor pressure boundary pipework. It is concluded from that analysis that substantial margins exist within the Wylfa plant to accommodate earthquake loadings that are more severe than the design basis without loss of reactor pressure boundary integrity.

Notwithstanding the robust and protected nature of the reactor pressure boundary against external or internal hazards, it is recognised that should an event occur that challenges reactor cooling, temperatures and pressures within the pressure boundary could ultimately challenge pressure boundary integrity. The potential for this to occur as a result of beyond design basis accident progression has been considered within the review of Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs) (see the response to Stress Test Finding STF-16) and within the associated limited-scope Level 2 probabilistic safety analysis described in the response to Recommendation FR-4. In particular, the revised SBERGs contain updated advice on controlling reactor temperatures and pressures under beyond design basis accident conditions to mitigate the possibility of pressure boundary failure. Furthermore, as a result of reviews initiated by the resilience enhancement workshops described in Section 3.3.1 Wylfa has procured additional equipment for pressure boundary pipework sealing which has been stored in diverse resilient locations. These measures, implemented in response to lessons learned from the Japanese events, have enhanced the capability to maintain or restore reactor pressure boundary integrity following beyond design basis faults.

Conclusion

Magnox Limited has undertaken further reviews of the vulnerability of the reactor pressure boundary for Wylfa Reactor 1, the only remaining Magnox Limited reactor for which pressure boundary integrity is of safety significance. The limiting feature of the pressure boundary is considered to be small bore pipework. The vulnerability of that pipework has been further assessed and it is concluded that substantial margins exist against pressure boundary failure in beyond design basis earthquakes that are likely to present the most significant challenge. Some quantification of those margins is provided in the response to Stress Test Finding STF-5. Measures to improve the ruggedness of the pressure boundary pipework identified by confirmatory seismic walkdowns have been implemented. Further measures have been implemented to enhance the capability to maintain or restore pressure boundary integrity following beyond design basis faults.

STF-7 Licensees should undertake a more structured and systematic study of the potential for floodwater entry to buildings containing safety-significant structures, systems and components (SSC) from extreme rainfall and / or overtopping of sea defences.

Magnox Limited Response to STF-7

Magnox Limited has completed a comprehensive critical review of the design basis flooding hazard assessments for all ten sites. Further details are provided in the response to Recommendation IR-10.

Although all sites have reviewed their resilience against flooding, Stress Test Finding STF-7 applies specifically to sites with remaining nuclear fuel: Wylfa, Oldbury and Sizewell A.

Wylfa

The vulnerability of safety-significant structures, systems and components at Wylfa to flooding has been systematically assessed. More details of the outcome of that assessment are provided in the response to Stress Test Finding STF-5. The assessment demonstrates large margins between extreme 10^{-4} per annum exceedance frequency sea conditions and levels that could lead to site flooding of an extent that could credibly threaten reactor safety. It is concluded that flooding does not pose a significant threat to reactor safety at Wylfa.

Nevertheless, flood resilience has been taken into account when implementing enhancements to overall site resilience against external hazards following the Japanese events. In particular:

- The new beyond design basis emergency equipment compound has been located on ground some 5m higher than the operational site ground level and sheltered from the sea.
- Within that compound additional pumps and generators, together with the necessary hoses and connectors, have been provided that would aid restoration of necessary reactor post-trip cooling functions in the highly unlikely event that normal back-up systems were to succumb to flooding.
- A totally diverse monitoring system for a limited set of reactor parameters has been installed that is independent of site electrical supplies and not vulnerable to flooding. That system transmits monitoring information wirelessly to the beyond design basis emergency equipment compound.

Other enhancements that also improve flood resilience are outlined in Section 3.3.1 and in the response to other recommendations and findings, particularly Recommendations IR-8, IR-13 and FR-3.

Thus, despite the very low flooding risk, substantial enhancements have been implemented at Wylfa that reduce the risks to reactor safety that may result from site flooding still further.

Oldbury

The flooding hazards review (Recommendation IR-10) identified that the combined height of extreme tide plus storm surge events affecting the Severn Estuary at an exceedance frequency greater than 10^{-4} per annum could be sufficient for water levels to rise to the Oldbury site level around the peak of the tidal cycle. As a consequence of that review finding, a flooding hazard reassessment has been completed for Oldbury including re-evaluations of the likelihood of site flooding and detailed systematic consideration of potential consequences of flooding, supported by comprehensive site walkdowns. Following this re-assessment a revised external flooding safety case has been developed.

The general site level at Oldbury was raised significantly above the level of the surrounding agricultural land during construction. Flood defences along the estuary upstream and downstream of the site are lower than the site. Thus the surrounding land would flood before the Oldbury site. The duration of high water levels in the estuary even under extreme conditions would be limited because of the very high tidal range within the estuary at Oldbury. Thresholds to the main site buildings are higher than the general site roadway levels. It is, therefore unlikely that significant flooding of buildings on the Oldbury site would occur. Notwithstanding this conclusion the revised flooding safety case for the Oldbury site assumes that water will enter the buildings.

On this basis, following systematic reviews of potential flooding consequences, further proportionate enhancements to site flooding resilience have been implemented to reduce the risks, including:

- provision of an additional back-up boiler feed pump for each reactor, located higher than credible flood levels, together with other suitable pumps stored in containers located at the highest point of the site;
- provision of means to isolate and re-power electrical systems above the flood level;
- provision of enhanced instructions for actions to be taken by site operations staff in the event that flood warnings are received;
- procurement of dam boards and sand bags to assist with reducing water ingress into buildings, together with a deployment plan.

Sizewell A

Sizewell A occupies an elevated position with respect to surrounding ground and the sea. Significant flooding from any source is, therefore, considered highly unlikely. Nevertheless, the potential consequences of credible flooding events have been reviewed. It has been identified that an extreme rainfall event could, for a short time, overwhelm run-off capacity of the site leading to water ingress into building basements. Theoretically this could lead to release from waste tanks in the basements but this is considered highly unlikely as it would require the entire basement to fill with water. No practical enhancements to the flood resilience of waste or fuel storage facilities have been identified.

Conclusion

Magnox Limited has completed systematic and comprehensive reviews of flooding hazards and potential consequences at all ten sites. The specific response to Stress Test Finding STF-7 has concentrated on Wylfa, Oldbury and Sizewell A, the sites with remaining nuclear fuel. Proportionate resilience enhancements have been implemented to reduce the already low risks posed by site flooding.

The removal and passivation of the remaining radioactive material on the sites will steadily diminish the residual risks from beyond design basis flood events as the sites progress towards their planned care and maintenance condition.

Further reviews of the flooding safety cases will continue to be undertaken as part of the normal Periodic Safety Review process. Similarly, reviews are undertaken when the site safety cases are re-baselined at key change points within the site lifecycle such as transition from generation to defuelling and defuelling to decommissioning. These will continue to be carried out by Magnox Limited under normal business arrangements.

STF-8 Licensees should further investigate the provision of suitable event-qualified connection points to facilitate the reconnection of supplies to essential equipment for beyond design basis events.

Magnox Limited Response to STF-8

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined possible hazards, safety requirements and plant, people and processes needed to meet these requirements. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of the actions placed at those workshops, site-specific reviews of the resilience of safety-related systems and their essential supplies have been completed. These site-specific reviews have identified opportunities for enhancing resilience by providing additional standby plant for connection into the main site systems and/or providing or identifying additional means of making connections to existing plant.

The response to Recommendation IR-18 describes the provision of additional equipment to enhance resilience of on-site electrical supplies. The responses to Recommendations IR-19 and IR-20 describe the provision of additional supplies of boiler feed water and water for spent fuel ponds. The present response considers the provision of connection points to facilitate the reconnection of supplies to essential equipment. Examples of resilience enhancements that have been implemented relevant to the provision of suitable connection points are summarised below.

Wylfa

For the operating reactor, the provision of an adequate supply of clean feed water to the boilers is the most important requirement. It is not necessary, however, to restore feed to the boilers immediately; a period of several hours is available to initiate feed in order to maintain adequate reactor cooling.

In order to reinforce the existing arrangements six new pumps have been provided, any one of which is sufficient to provide the feed requirements of the one operating reactor. Alternative boiler connection points have been identified and the necessary flanges and fittings to make these connections have been procured and are stored in dedicated boxes located near to where the connections would need to be made. Procedures for making these connections in an emergency have been produced. In order to reinforce the availability of stocks of water on the site, a “bonded store” has been provided for the storage of hoses required for an alternative supply of water from the reserve feedwater tanks to the back-up feed systems.

In the absence of forced gas circulation for the reactor it is beneficial to apply static gas circulator seals to prevent the loss of reactor coolant from a pressurised reactor or to prevent air ingress into the gas circuit of a depressurised reactor. One of the ways the seal can be applied is by means of a motor supplied by a diesel generator. A connection point for the diesel generator is supplied external to the reactor building adjacent to each gas circulator motor room. Two 100m extension leads have been procured to allow the generator to operate more remotely from the area if local conditions would prevent generator operation. These leads are stored in separate locations.

The provision of additional diverse means of providing independent long term electrical supplies on Wylfa site is discussed in the response to Recommendation IR-18. Enhancements to increase the resilience of the necessary diesel fuel supply are described in the response to Recommendation IR-8.

The requirements for residual cooling of the shutdown reactor at Wylfa are much more limited than those outlined above for the operating reactor, with longer timescales for re-establishing cooling following an event. Nevertheless, the enhancements implemented to improve the resilience of cooling for the operating reactor, particularly those associated with provision of boiler feed, would also be of benefit to maintaining adequate cooling of the shutdown reactor.

Oldbury

The two reactors at Oldbury are permanently shut down, depressurised and air filled, and are being defuelled. Forced gas circulation is no longer required and the static seals on the gas circulators are permanently in place. Reactor temperatures are kept well below 100°C. Feed water is supplied to the boilers intermittently to assist with removal of residual decay heat from the fuel remaining within the reactor pressure vessel. In an emergency, water from the back-up feed system tanks could be supplied to the boilers either via the back-up feed system pumps or other alternative pumps.

Although the water contained in a back-up feed system tank would last for a considerable period of time, to increase resilience, enhancements have been made to allow the tanks to be refilled from the two reserve feed water tanks or from the towns water reservoir. Suitable hoses have been procured for either of these options and plant operators have undergone appropriate training to enable them to make these connections if required. As a further enhancement, additional pumps have been installed in elevated locations to provide additional resilience against potential flooding events. Additional general purpose portable pumps have also been procured and are stored within emergency equipment containers.

Irradiated fuel elements discharged from the reactors are stored in ponds filled with water which provides cooling and radiation shielding. To improve resilience against a significant loss of water from the ponds, an emergency pond water filling line has been installed to allow water to be pumped directly into the ponds from outside the building.

As part of the update of the site external flooding safety case (for more details see the responses to Recommendation IR-10 and Stress Test Finding STF-7) a procedure has been developed for isolating electrical circuits that could be rendered unavailable by flooding of building basement locations and then re-powering circuits above the flood level using identified connection points and alternative supply sources.

The provision of additional diverse means of providing independent long term electrical supplies on Oldbury site is discussed in the response to Recommendation IR-18. Enhancements to increase the resilience of the necessary diesel fuel supply are described in the response to Recommendation IR-8.

Sizewell A

The reactors at Sizewell A have been shut down longer than those at Oldbury. The reactors are in the process of being defuelled and the decay heat of the remaining fuel is such that the cooling of the reactors and the spent fuel pond is achieved passively without the use of powered systems. The pond is not now required to cool the fuel elements but is required to provide shielding. To enhance resilience against a significant loss of pond water, additional pumps have been procured and an emergency pond filling line accessible from outside the building has been installed. Since fuel element cooling is not an issue at Sizewell A, the provision of a covering material to provide airborne contamination control could be appropriate. Suitable foam has been procured and suitable pumps and connections have been provided.

The provision of means of providing long-term electrical supplies on the Sizewell A site is discussed in the response to Recommendation IR-18.

Decommissioning Sites

At all of the other Magnox sites, the reactors have been defuelled and the fuel has been sent off-site for reprocessing. There is no requirement to cool the reactors. At sites where the spent fuel ponds remain, they are no longer required to provide cooling or shielding for irradiated fuel elements. In the event of a loss of pond cooling water from a breached pond, there would be no requirement to replace the water within a particular time period.

Limited resilience enhancements have been implemented following site resilience reviews. For example, at Hinkley Point A a connection point has been identified for a back-up generator to supply the waste vault ventilation systems. Similarly at Hunterston A, a procedure has been developed for connecting a portable generator to the waste bunker hydrogen monitoring system.

Conclusion

Magnox Limited has reviewed the provision of suitable connection points to facilitate the reconnection of supplies to essential equipment following beyond design basis events. Proportionate enhancements have been implemented across the Magnox Limited fleet.

STF-9 Licensees should further investigate the enhancement of stocks of essential supplies (cooling water, fuel, carbon dioxide, etc.) and extending the autonomy time of support systems (e.g. battery systems) that either provide essential safety functions or support emergency arrangements.

Magnox Limited Response to STF-9

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined possible hazards, safety requirements and plant, people and processes needed to meet these requirements. Stocks of essential supplies have been a key issue addressed at the workshops and significant enhancements have been made. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of the actions placed at those workshops, site-specific reviews of the resilience of safety-related systems and their essential supplies have been completed. These site-specific reviews have identified opportunities to enhance stocks of essential consumable supplies and to extend the autonomy time of safety-related systems. Examples of resilience enhancements that have been implemented are summarised below.

Wylfa

Wylfa is still a generating site and therefore has the greatest need of provisions and services in the short term following an event.

Fuel

The site has numerous diesel fuel storage tanks associated with the various gas turbines and diesel engines. The fuel is cross-compatible for use in any of the safety-related plant. Two additional bowsers have been procured for moving fuel around site should the need arise. The opportunity has also been taken to increase the diesel fuel storage capacity. The resulting increased fuel stocks will enhance resilience against loss of off-site or on-site electrical supplies and improve operational flexibility, particularly under emergency conditions. It is also noteworthy that the requirements for fuel to support operation of systems associated with the permanently shut down reactor at Wylfa are now substantially lower than those to support systems associated with the operating reactor. Thus a greater proportion of the fuel stocks held on site will be available to support the operating reactor.

Water

To increase the availability of water for reactor cooling the site initially purchased one road tanker and hired a second to aid transportation of additional water stocks to site if necessary. Possible sources of treated water and lake water that could be used following a serious event have been identified. The number of tankers has now been reduced to one following shutdown of Reactor 2.

Carbon Dioxide

Stocks of carbon dioxide available on site have been reviewed. The site holds in excess of four times the minimum operating requirement for two operating reactors. Only one reactor is now operating and potentially requiring carbon dioxide. Therefore, ample stocks of carbon dioxide to maintain control of reactor gas composition under emergency conditions already exist on site. Procurement of additional carbon dioxide stocks is not warranted.

Electrical Supplies

To supplement normal sources of emergency electrical supply from installed systems two new large transportable diesel generators have been provided which are stored in a resilient location. In an emergency situation these could be connected to any suitable switchboard. To allow the Emergency Controller flexibility to choose where the supplies are most needed, a list of suitable switchboards has been produced along with a basic procedure for connecting to any switchboard. These generators could be used for restoring lighting, or running ancillary plant. Although not large enough to run a gas circulator DC pony motor directly, one of these generators could be connected to charge the guaranteed supplies batteries which could then run a gas circulator pony motor for a limited length of time thereby providing limited forced cooling should this be advantageous.

The site has also procured four small diesel driven generators to power hand tools, portable lighting, monitoring equipment etc.

Oldbury

Oldbury was still a generating site for approximately one year following the Japanese earthquake and tsunami. Both reactors are now permanently shut down.

Fuel

As a prudent measure, during that generating period Oldbury increased the minimum stock holding of kerosene fuel for the gas turbines and diesel for other pumps and generators. Both Oldbury reactors are now permanently shut down and have minimal active cooling requirements with long timescales for restoring cooling should it be lost. The kerosene minimum stock level has been reduced back to its previous value. This measure minimises holdings of potentially hazardous substances on site while maintaining adequate kerosene stocks to meet normal and emergency requirements.

Water

While generating, in addition to that specifically stored for post-trip cooling in the Back-Up Feed System (BUFS) tanks, boiler quality water was potentially available in the reserve feed water tanks, the deaerator or the turbine condenser. Previous plant modifications and equipment purchases had been made to enable recovery of this water for use via the BUFS if needed post event. Refresher training on deployment of the BUFS system specifically including recovery of water from these diverse locations was delivered to all appropriate operations staff. Following permanent shutdown of both reactors the decision was taken not to use the deaerator or condenser as potential water sources due to building loadings and the possibility of water contamination.

With both reactors shut down the normal cooling requirement has reduced to intermittent circulation of water through the boilers only, with no external cooling applied and no boiling taking place. Supplies remain available from the reserve feed water tanks and the BUFS tanks with the option of taking supplies from a large towns water tank or re-commissioning a bore hole on site if other water sources are rendered unserviceable. The current availability of water stocks is considered adequate given the current and reducing demand.

Carbon Dioxide

As a prudent measure, during the generating period Oldbury increased the minimum stock holding of carbon dioxide for reactor cooling. With both reactors now permanently shut down and air-filled, all bulk carbon dioxide has been removed from site to minimise holdings of potentially hazardous substances.

Electrical Supplies

Oldbury has obtained a number of general purpose portable generators and pumps that could be deployed to support the limited remaining essential safety functions on site. To enhance resilience of electrical supplies in the unlikely event of site flooding, the means to segregate flooded parts of safety-related electrical systems have been identified together with points for connecting portable generators to re-power the remaining serviceable parts of the systems. Instructions for achieving this re-powering have been provided.

Sizewell A

Both reactors at Sizewell A were permanently shut down more than four years before the Japanese earthquake and tsunami. Cooling of the reactors is achieved passively without the use of powered systems (or boiler feed water). Furthermore, there is no requirement for active cooling of the spent fuel pond.

Fuel

Existing fuel stocks are considered ample to meet the requirements for the few remaining active systems that maintain site safety. In any case, these systems have long timescales for restoration should they be lost. No requirement to increase fuel stocks at Sizewell A has been identified.

Water

Cooling of the reactors is achieved passively without the use of boiler feed water. There is, therefore, no longer any requirement for cooling water stocks.

Carbon Dioxide

Carbon dioxide is no longer required as the reactors are permanently shut down and air-filled. All bulk carbon dioxide has been removed from site to minimise holdings of potentially hazardous substances.

Electrical Supplies

There is no dependence on electrical supplies to maintain radiological safety at Sizewell A. Nevertheless, to assist with post-event recovery operations the site has a number of portable generators that can be used for a variety of emergency duties, in particular to power pumps to recycle leaked pond water from various sumps should the pond primary containment be breached.

Decommissioning Sites

All other Magnox Limited sites have been fully defuelled and do not depend on off-site supplies to ensure safety in the short to medium term following an event. No specific opportunities to enhance consumable stocks were identified for these sites.

All sites

All sites have been supplied with a dedicated beyond design basis emergency equipment container which provides equipment specifically to facilitate recovery from an extreme event where circumstances might involve isolation of the site from external supplies for a limited period.

Conclusion

Magnox Limited has investigated the enhancement of stocks of essential supplies and extending the autonomy time of support systems that either provide essential safety functions or support emergency arrangements. Proportionate enhancements have been implemented across the Magnox Limited fleet.

STF-10 Licensees should identify safety-significant prime mover-driven generators and pumps that use shared support systems (including batteries, fuel, water and oil) and should consider modifying those prime movers systems to ensure they are capable of being self-sufficient.

Magnox Limited Response to STF-10

Magnox Limited has conducted a number of hazard-based workshops specifically looking at resilience of sites to beyond design basis events. Section 3.3.1 provides further details of these workshops. The workshops examined possible hazards, safety requirements and plant, people and processes needed to meet these requirements. Following the workshops, actions were placed on all sites to undertake further resilience reviews of specific areas of potential risk consistent with the lifecycle position of the site (generating, defuelling or decommissioning) and the particular plant design.

As a result of actions placed at the resilience workshops, sites have reviewed the dependence on safety-significant prime mover-driven generators and pumps that use shared support systems.

No safety-significant prime mover-driven generators or pumps that use shared support systems have been identified at Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A, Trawsfynydd or Sizewell A sites.

Some prime mover-driven generators and pumps with shared supporting systems exist at Wylfa and Oldbury, although it is noted that it is planned shortly to remove from service the only such system remaining at Oldbury. Within these systems a substantial degree of diversity, redundancy and segregation is provided. It is recognised, however, that each system is not fully segregated.

Consideration has been given to providing a greater degree of segregation within these systems. However, modifications to operational plant are not without risks if inadequately conceived or executed and are not reasonably practicable on timescales consistent with the remaining period of operation at Magnox Limited sites as discussed within Sections 2 and 3.

Therefore, in accord with the overall aims of the Magnox Limited response to the Japanese events (Section 3.1), the approach adopted to address resilience of safety-significant prime mover-driven generators and pumps that use shared support systems (including batteries, fuel, water and oil) has been to augment these systems where reasonably practicable rather than to attempt to upgrade the resilience of primary plant.

Examples of resilience enhancements that have been implemented are summarised below.

Wylfa

- Provision of six new diesel-driven fire pumps, any one of which would meet the boiler feed requirements for the operating reactor;
- Procurement of one road tanker and hire of a second until final shutdown of Reactor 2 to facilitate transport of additional water supplies to site if required;
- Procurement of two large mobile diesel generators complete with connection cables and bowsers with fuel for about 72 hours and procedures for connecting to station switchboards;
- Procurement of four small generators with emergency lighting sets, leads and connectors;
- Work is in progress to increase diesel fuel oil stocks held on site, suitable for the gas turbine generators and all diesel generators and pumps on site;
- Procurement of two submersible sump pumps for flood alleviation;
- Procurement of a new fire tender to supplement existing fire-fighting provisions.

Oldbury

- Provision of two additional back-up boiler feed pumps together with hoses and couplings, elevated above ground level;
- Provision of further pumps, stored within equipment containers located at the highest point of the site, that will be adequate to provide boiler feed;
- Provision of additional generators stored in a resilient location;

- Minimum fuel stocks for the gas turbines that provide back-up electrical supplies were increased before permanent reactor shutdown, but have since been reduced again;
- Provision of diesel fuel into three storage tanks that the site had previously purchased; these tanks have now reverted to operational use.

Sizewell A

- Procurement of two containers of site-specific emergency equipment containing, inter alia, additional pumps and generators.

Decommissioning sites

- Provision of additional portable generators and pumps, stored in resilient locations.

Conclusion

Magnox Limited has completed a review of safety-significant prime mover-driven generators and pumps that use shared support systems. The approach adopted to address resilience of safety-significant prime mover-driven generators and pumps that use shared support systems has been to augment these systems where reasonably practicable rather than to attempt to upgrade the resilience of primary plant. Many enhancements to site resilience have been implemented, mainly in the form of extra pumps, generators and fuel stocks.

STF-11 Licensees should further consider resilience improvements to equipment associated with the connection of the transmission system to the essential electrical systems (EES) for severe events

Magnox Limited Response to STF-11

Magnox Limited has considered the resilience of on-site and off-site electrical supplies in responding to Recommendations IR-8, IR-17 and IR-18.

The one remaining generating Magnox Limited site, Wylfa, and the two remaining fuelled sites, Oldbury and Sizewell A, make no safety case claims on off-site electrical supplies to support essential safety functions. Loss of off-site electrical supplies is considered a frequent fault and safety cases and protection measures have been developed such that a prolonged period without off-site electrical supplies can be tolerated. Following a loss of off-site electrical supplies, there are diverse back-up systems available to support plant that provides essential safety functions. As part of the Magnox Limited response to the Japanese events the resilience of the on-site electrical systems has been comprehensively reviewed and enhanced as outlined in the response to Recommendation IR-18.

Given that no claims are made on the availability of off-site electrical supplies to provide essential safety functions following an extreme event, the approach of enhancing resilience by increasing site autonomy is considered more beneficial than improving the resilience of equipment associated with the transmission system connection. It is noted, however, that there is redundancy of equipment associated with connection of the transmission system to the site essential electrical supply systems. The robustness of the transmission (grid) systems and connections to the transmission system was also considered as part of the response to Recommendation IR-17.

Conclusion

Magnox Limited recognises the need for robust connections to the transmission system. However, the three remaining generating or fuelled sites do not rely on off-site electrical supplies to support their essential safety functions. Therefore Magnox Limited has concentrated on increasing the resilience of on-site supply sources whilst acknowledging the need to pursue the reconnection of off-site electrical supplies following an event.

STF-12 Magnox Ltd should assess the progressive loss of electrical systems on all aspects of the fuel route and address any implications.

Magnox Limited Response to STF-12

Stress Test Finding STF-12 is only relevant to Magnox Limited sites where nuclear fuel remains on site: Wylfa, Oldbury and Sizewell A.

Nuclear fuel is removed from an operating or shutdown reactor using a fuelling machine that is connected to the reactor vessel. Fuel elements are removed individually from a fuel channel (typically 8 per channel) using a grab on a cable. For an operating reactor (now only applicable to Reactor 1 at Wylfa) new fuel is loaded into the reactor also using the fuelling machine. Spent fuel elements are transferred to ponds at Oldbury and Sizewell A and dry storage tubes at Wylfa. From these storage locations spent fuel is transferred into fuel transport flasks and then off-site for reprocessing. The structures, systems and components involved in all of these fuel handling operations are collectively known as the fuel route.

Loss of power is a fault that is already addressed by the safety case for fuel handling. Nevertheless, in response to Stress Test Finding STF-12 Magnox Limited commissioned a further assessment to reconsider the effects of loss of electrical supplies to the fuel routes at each relevant site.

The assessment considered the effects of a sudden and extended loss of electrical power when fuel is being:

- loaded into or discharged from the reactor by the fuelling machine;
- transported within the fuelling machine;
- loaded into ponds or dry stores;
- handled within ponds or dry stores;
- stored in ponds or dry stores;
- transferred from ponds or dry stores to transport flasks.

The assessment identified no consequences of an extended loss of power affecting the fuel route at any of the relevant sites that would lead to a significant increase in the risk of an off-site radiological release.

Key conclusions from the assessment are:

- The fuel handling process at all sites would stop and remain in a safe state in the event of a loss of power, with fuel remaining adequately cooled and shielded.
- Loss of electrical supplies will not cause a fuel fire and there is, therefore, no initiator for a significant off-site radiological release.
- The major loads associated with the fuel routes are fuelling machines and flasks. In some instances loss of electrical supplies could result in a suspended or, at worst, gradually descending load with no significant consequences.
- The spent fuel dry stores at Wylfa are passively cooled and would not be affected by loss of power;
- Loss of power to spent fuel pond facilities, including pond water conditioning plants, at Oldbury and Sizewell A will neither lead to fuel overheating nor any significant increase in fuel corrosion.
- Loss of electrical supplies would interrupt the function of active ventilation systems which are designed to prevent localised contamination spread in non-sealed areas. However, it is considered that there is no consequential risk of an off-site release.

Conclusion

Magnox Limited has completed a comprehensive reassessment of the effects of extended loss of electrical systems affecting the fuel routes at Wylfa, Oldbury and Sizewell A, the only sites at which nuclear fuel remains. No consequences of an extended loss of power affecting the fuel routes have been identified that would lead to a significant increase in the risk of an off-site radiological release at any of these sites.

STF-13 Magnox Ltd should demonstrate that all reasonably practical means have been taken to ensure integrity of the fuel within the dry fuel stores in the extremely unlikely event of the natural draft air ducting becoming blocked.

Magnox Limited Response to STF-13

Stress Test Finding STF-13 applies only to Wylfa. Following discharge from a reactor, spent fuel is stored in a carbon dioxide atmosphere in one of three primary dry store cells. The primary dry store cells are totally passive with no requirement for electrical supplies or water supplies for cooling of the irradiated fuel elements. Each dry store cell contains many storage tubes for irradiated fuel elements. Heat is removed from the spent fuel elements by heat transfer to the storage tube wall. The outside of each storage tube is cooled by a natural thermal siphon air circulation system, driven by the heat of the contained fuel, to a high level ventilation stack. Air enters at the lower end through three massive underground ducts (one to each cell). There are two inlet vents that extend from ground level to a height of three to four metres above ground level: one north facing and the other south facing with a substantial separation between the two vents.

If the cooling air flow were to become 100% blocked it has been assessed, based on pessimistic assumptions, that newly discharged fuel in a dry store cell would take approximately 58 hours to reach a temperature where the fuel cladding could melt. The cells are sealed and there would, therefore, be no immediate off-site radiological consequences even if fuel damage occurred.

It would be physically impossible to block a dry store cell cooling air inlet duct with any form of solid debris to a degree that would prevent adequate cooling. Flooding of the underground ducts could potentially achieve complete blockage (see below).

Resilience of the primary dry store cells at Wylfa to beyond design basis events was addressed at a specific Magnox Limited resilience workshop as described in Section 3.3.1. The outcome of actions arising from that workshop is outlined below:

- It has been confirmed that the ground slopes away from the cooling air inlet ducts in the vicinity of the air intakes which make water ingress into the ducts during a beyond design basis flooding event less likely.
- Two sump pumps have been provided to facilitate draining of the cooling air inlet ducts in the unlikely event that they fill with water; there is ample time following such an event for the ducts to be pumped out and passive cooling to be restored.
- Mechanical jack-hammers have been provided to allow clearance of blockages or opening-up of alternative air inlet routes; again there would be time to complete such operations if the need arose.
- Blockage of the primary dry store cell cooling air inlet ducts has been included as one of the scenarios covered by the new fuel route accident management guidelines that have been developed for Wylfa in response to actions from the site resilience workshops (Section 3.3.1) and covered in more detail in the response to Stress Test Finding STF-16.
- If the cooling air inlet ducts completely filled with water then water would cover the bottom of the fuel storage tubes. Although water would not contact the fuel elements directly the possibility of a local criticality of the fuel as a result of the moderating effect of the water has been assessed and ruled out.

A specific concern that was raised during the review is the potential for drifting snow to block the dry store air inlet vents. Given the size of each vent (see above) it is unlikely that complete blockage of a single vent would occur, particularly with the degree of sheltering from surrounding structures. Furthermore, because the two vents are separated and face in opposite directions it is even less likely that both vents would become blocked. Nevertheless, if both vents did become blocked the cooling requirements are so modest that there would be ample time (see above) for the blockage to be relieved by operator action or by snow melt or drift consolidation.

With respect to flooding of the cooling air inlet ducts it is noted that the air inlets are located 3m above the predicted 10^{-4} per annum exceedance frequency extreme sea level at Wylfa (see also the responses to Stress Test Findings STF-5 and STF-7). Thus there is already substantial margin above the design basis flood levels before flooding of the ducts becomes a possibility. Furthermore, there is no credible way that the ducts could continue to be supplied by flood water as any extreme storm surge, sea level or tsunami would have receded well within the available time for restoring cooling.

Conclusion

Any event that could lead to blockage of the Wylfa primary dry store cell cooling air inlet ducts would be very much more severe than the current plant design basis. Nevertheless, the potential for such blockage and the timescales for restoring cooling have been comprehensively reviewed. Significant resilience enhancements have been implemented to ensure integrity of the fuel in the dry store cells in the extremely unlikely event that the cooling air inlet ducts were to become blocked.

STF-14 Licensees should confirm the extent to which resilience enhancements are to be made to existing equipment and systems that are currently installed at nuclear power plants. Information should be provided on the equipment and systems that may be affected and the nature of the resilience enhancements, including interconnectivity with mobile back-up equipment.

Magnox Limited Response to STF-14

Magnox Limited has implemented a considerable number of resilience enhancements across its sites. The extent of enhancements relevant to particular areas of resilience is confirmed within responses to other recommendations and findings. For example:

- IR-8 and STF-9: enhancements implemented to improve site autonomy;
- IR-13: enhancements implemented to improve resilience to extreme events;
- IR-17, IR-18 and STF-11: enhancements implemented to improve the robustness of off-site and on-site electrical supplies;
- IR-19 and STF-9: enhancements implemented to improve the resilience of coolant supplies at Wylfa and Oldbury;
- IR-20: enhancements implemented to improve the resilience of provision of make-up water to spent fuel ponds at Oldbury and Sizewell A;
- IR-22 and IR-23: enhancements implemented to improve the resilience of on-site and off-site emergency control, instrumentation and communications;
- FR-2 and FR-3: enhancements implemented to improve the resilience of structures, systems and components needed for managing and controlling actions in response to an accident;
- STF-4: enhancements implemented to improve the resilience against seismically-induced fire at Wylfa;
- IR-10, STF-5 and STF-7: enhancements implemented to improve the resilience of safety-significant structures, systems and components against external hazards;
- STF-8: enhancements implemented to improve the provision of connection points to facilitate re-connection of supplies to essential equipment following a beyond design basis event;
- STF-10: enhancements implemented to increase the provision of back-up plant for prime mover-driven generators and pumps.

A summary of enhancements that have been implemented on Magnox Limited sites is provided in Section 3.3.1.

Conclusion

The extent to which resilience enhancements have been implemented on Magnox Limited sites has been confirmed in responses to other recommendations and findings with further details having been provided to the ONR.

STF-15 Licensees should complete the various reviews that they have highlighted so that ONR can assess their proposals and associated timescales. These reviews should look in detail at on-site emergency facilities and arrangements, off-site facilities, facilities for remote indication of plant status, communication systems, contents and location of beyond design basis containers and the adequacy of any arrangements necessary to get people and equipment on to and around site under severe accident conditions. Any changes to arrangements and equipment will require appropriate training and exercising.

Magnox Limited Response to STF-15

The Magnox Limited site responses to the European Council Stress Tests (Refs. 2 to 11, see Section 3.3.3 for more details) identified a number of "Stress Test Considerations" which encapsulated the programme of further work to be undertaken by each site in response to the resilience reviews discussed in Section 3.3.1. The Stress Test Considerations are the basis for reviews that are the subject of Stress Test Finding STF-15.

Details of the way in which applicable Stress Test Considerations have been taken forward for each site have been provided to the ONR and in most cases are addressed by the responses to other recommendations and findings as indicated below.

1. Consideration will be given to enhancing the methods and equipment for primary pressure circuit sealing (Wylfa only): Wylfa site enhancements; also covered by the responses to Recommendation IR-13 and Stress Test Finding STF-17.
2. Consideration will be given to increasing the resilience of the back-up feed system (Oldbury only): Oldbury site enhancements; also covered by responses to IR-13, IR-19, STF-9 and STF-10.
3. Consideration will be given to increasing the resilience of the back-up feed systems and tertiary feed systems (Wylfa only): Wylfa site enhancements; also covered by responses to IR-13, IR-19, STF-9 and STF-10.
4. Consideration will be given to increasing the resilience of the on-site electrical system (Oldbury and Wylfa only): Oldbury and Wylfa site enhancements; also covered by responses to IR-8, IR-17, IR-18, STF-8 and STF-11.
5. Consideration will be given to providing a facility for the injection of nitrogen to support reactor hold-down; Wylfa site enhancements.
6. Consideration will be given to enhancing the resilience of plant monitoring systems (Oldbury and Wylfa only): Oldbury and Wylfa site enhancements; also covered by responses to IR 13 and IR 22.
7. Consideration will be given to enhancing the availability of beyond design basis equipment (all sites): enhancements at all sites; also addressed in the responses to IR-8, IR-13 and IR-25.
8. Consideration will be given to providing further equipment to facilitate operator access around the site (all sites): enhancements at all sites; also covered by response to IR-13.
9. Consideration will be given to reinforcing the training for staff who may be required to respond to extreme events (Oldbury and Wylfa only): Oldbury and Wylfa enhancements; also covered by responses to IR-22, IR-23, IR-24, STF-3, STF-16 and STF-83.
10. Consideration will be given to enhancing on site arrangements for command, control and communications (all sites): enhancements at all sites; also covered by responses to IR-22 and IR-23.
11. Consideration will be given to providing additional stocks of consumables for plant and personnel (Oldbury and Wylfa only): Oldbury and Wylfa site enhancements; also covered by responses to IR-8, IR-13, IR-19 and STF-9.
12. Consideration will be given to updating and enhancing severe accident management guidance (all sites but addressed centrally): addressed in full by the response to STF-16.
13. Consideration will be given to enhancing the resilience of spent fuel pond equipment to severe events (Oldbury and Sizewell A only): Oldbury and Sizewell A enhancements; also covered by responses to IR-13, IR-14 and IR-20.
14. Consideration will be given to enhancing the resilience of spent fuel equipment to severe events (Chapelcross and Dungeness A only): Chapelcross and Dungeness A site enhancements. At the time of the Stress Tests Chapelcross and Dungeness A were in the process of defuelling their reactors; this has since been completed.
15. Consideration will be given to enhancing the resilience of the primary dry cells to severe events (Wylfa only); Wylfa site enhancements; also covered by responses to IR-13 and STF-13.
16. Consideration will be given to the fire safety case for ILW storage facilities to identify any appropriate enhancements to the level of resilience (Berkeley, Bradwell, Dungeness A, Hinkley Point A, Hunterston A, Sizewell A and Trawsfynydd only): enhancements at all relevant sites and also at Oldbury; also covered by the responses to IR-13 and STF-83.

Conclusion

Magnox Limited has completed the reviews highlighted by its Stress Test Considerations and has provided details of the reviews and their outcome to the ONR.

STF-16 Licensees should review the symptom-based emergency response guidelines (SBERG) and severe accident guidelines (SAG) taking into account improvements to the understanding of severe accident progression, phenomena and the equipment available to mitigate severe accident. This review should also take into account the fuel route. Once completed, appropriate training and exercising should be arranged.

Magnox Limited Response to STF-16

Magnox Limited Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs) in their pre-existing form are now only applicable to the operating reactor at Wylfa. The reactors at Oldbury and Sizewell A have been shut down for a considerable period of time and are being defuelled (see Section 2.3). Accidents of the severity addressed by the SBERGs and SAGs are no longer credible at these sites. All other reactors within the Magnox fleet are completely defuelled and passively safe.

SBERGs provide advice to the operator on the best course of action to take in beyond design basis accidents or situations that are outside the scope of standard operating instructions. The SBERGs are focussed on maintaining four critical safety functions:

- Control of reactivity;
- Maintenance of pressure circuit integrity;
- Control of reactor heat removal;
- Control of radiological release.

The SBERGs are intentionally not event-specific and do not depend on fault diagnosis. Rather, the SBERGs address challenges to the critical safety functions indicated by the monitoring of key plant parameters. The aim of the SBERGs is to prevent fault escalation and the risk of uncontrolled radiological release. Unlike operating instructions, which are mandatory, SBERGs are advisory and applied with discretion depending on the prevailing situation.

Severe Accident Guidelines (SAGs) provide advice to the operator on actions to be taken to mitigate the consequences following beyond design basis accidents where it has either not been possible to implement the SBERGs or implementation of the SBERGs has failed to maintain the critical safety functions and core damage has occurred or is imminent. The fundamental aim of the SAGs is to limit the escape of radioactive material to the environment. It is not practicable to anticipate the detailed plant conditions that might exist during such accidents. The advice, which is addressed to the emergency controller and his supporting team, is therefore broadly based. As with the SBERGs the suggested courses of action are not mandatory and the decision on which, if any, of the advice to follow will be made by the emergency controller taking into account all of the information available at the time of the accident.

In response to Stress Test Finding STF-16 Magnox Limited has completed comprehensive reviews and revision of the Wylfa SBERGs and SAGs. The SBERGs and SAGs are concerned entirely with reactor safety and do not address potential accidents affecting the equipment and facilities for dealing with nuclear fuel (new or spent) outside the reactor (the "fuel route"). The fuel routes on Magnox Limited sites are relatively benign with limited fuel cooling requirements (see also the responses to Stress Test Findings STF-12 and STF-13). Nevertheless, as part of the response to this stress test finding, new Fuel Route Accident Management Guidelines have been developed to provide advice on mitigating actions that may be taken in the event of an incident within the fuel route having the potential to cause significant off-site radiological release. This is relevant to those sites with remaining nuclear fuel: Wylfa, Oldbury and Sizewell A. More detail of these response activities is provided below.

Also of relevance to this stress test finding is the development of guidance for mitigating accidents affecting intermediate and low level radioactive waste materials. This has been undertaken specifically to address Stress Test Finding STF-83 and details are provided in the response to that finding.

Review of the Wylfa SBERGs and SAGs

Prior to undertaking formal document reviews, a programme of refresher training in the use of the SBERGs and SAGs was completed. Training packages were presented to emergency controllers and assistant emergency controllers to improve awareness of the advice contained in the SBERGs and SAGs and their intended use in managing beyond design basis accidents. Further training was provided to scientific and engineering personnel that staff the off-site Central Emergency

Support Centre, to enhance and refresh understanding of the technical basis for advice contained within the SBERGs and SAGs. This training provided a rapid enhancement of the capability to successfully manage beyond design basis accidents at Wylfa.

Magnox Limited commissioned detailed reviews of the Wylfa SBERGs and SAGs documents from a specialist contractor.

The scope of the SBERGs review was to:

- establish whether the critical safety functions remain valid and complete;
- establish whether the indicators have been correctly identified and are sufficiently complete;
- review whether the limiting plant constraints remain valid;
- establish whether understanding of transient behaviour has led to a change in failure timescales;
- establish whether any change to plant or understanding of its behaviour alters the recovery advice given;
- establish whether the format of guidance is fit for purpose.

This review was carried out by consultation with Magnox Limited technical staff and via a detailed line-by-line evaluation of the existing SBERGs advice at a workshop involving a broad range of Wylfa engineering, safety case, operations and emergency response staff, Magnox Limited human performance and hazards specialists, and external emergency response specialists.

The review identified opportunities for improving the existing documents. These opportunities were assessed and sentenced by Magnox Limited specialists for carrying forward into revision of the SBERGs.

The SAGs were reviewed in parallel with the SBERGs. The SAGs review was wide-ranging, including:

- Independent expert review of the SAGs content;
- Review against International Atomic Energy Agency guidance on severe accident management programmes, summarising international best-practice;
- A workshop attended by personnel involved with preparing the Wylfa SAGs customisation documents, engineering, safety case, operations and emergency response staff, and Magnox Limited human performance and hazards specialists to consider:
    - » the clarity of the high level guidance to be used by the emergency controller and his team to develop a strategy to respond to the event;
    - » the practicability of the mitigation approaches proposed;
    - » the human factors involved in developing the response and implementing the strategy;
    - » current views on the long-term performance of the containment, including methods to enhance its performance;
    - » the adequacy of existing training and exercising arrangements for accident management guidance.

The SAGs review identified opportunities for improving the existing guidance. These opportunities were assessed and sentenced by Magnox Limited specialists for carrying forward into revision of the SBERGs and SAGs.

Recognising the importance of human response and performance to successful accident management, a specialist human factors review of the usability of the SBERGs and SAGs was commissioned. This part of the review included:

- presentation, content and format;
- user feedback;
- lessons from wider operational experience feedback;
- consideration of accident management guidance developments in other licensees.

Human factors specialist input has been an integral part of the programme of review and revision of the SBERGs and SAGs. The findings from the review of human factors aspects have been carried forward into the revision of the SBERGs and SAGs.

A further input into the overall SAGs review process has been provided by the limited-scope Level 2 probabilistic safety analysis completed in response to Recommendation FR-4. The goal of that analysis was to apply Level 2 probabilistic safety analysis techniques to extend the understanding of credible accident progression for Wylfa Reactor 1 in a way that informs improved severe accident management measures. The output from that analysis is a series of detailed observations that identify potential enhancements to the existing guidance (both SBERGs and SAGs). These observations were evaluated by Magnox Limited specialists and carried forward into revision of the SBERGs and SAGs. The analysis is described in more detail in the response to Recommendation FR-4.

Following this thorough and rigorous programme of reviews the Wylfa SBERGs and SAGs have been comprehensively revised and re-issued taking account of the enhancement opportunities identified by the various strands of the review process. The end-users for the SBERGs and SAGs have been instrumental in this revision, bringing a wealth of detailed plant knowledge into the process. Improvements that have been achieved include:

- making the advice fully consistent with current technical understanding and plant configuration;
- simplifying the format and structure to improve clarity and usability, following international best-practice;
- enhancing support for effective decision-making and prioritisation in accident response;
- removal (or down-grading) of less practical advice while improving the practicability of the remaining guidance;
- providing clarity of scope between SBERGs and SAGs and ensuring that the transition between actions to prevent reactor core damage (SBERGs) and actions to mitigate the consequences of core damage (SAGs) is well-defined.

The revised SBERGs, supported by a suite of new Emergency Operating Procedures, and SAGs have been issued. Familiarisation training for emergency response personnel in the use of the draft revised SBERGs and SAGs has been completed including use of the plant computer simulators to simulate response to beyond design basis accident conditions. Feedback from that training has been incorporated into the issued documents.

Use of the revised guidance will be exercised as part of the continuing programme of emergency exercises at Wylfa.

Development of Fuel Route Accident Management Guidelines

As has been noted above, a further element of the programme to enhance accident management guidance has been the development of guidance to address potential fuel route accidents. This has been undertaken for each Magnox Limited site at which nuclear fuel remains: Wylfa, Oldbury and Sizewell A.

Although there is much overall commonality, the fuel routes are different in the detail of plant and equipment at each site; for example Wylfa has dry storage for spent fuel whereas Oldbury and Sizewell A store spent fuel in water-filled ponds. Furthermore, the current state of the fuel differs between sites. Wylfa still discharges high decay heat fuel from the operating reactor but all fuel at Sizewell A is now long-cooled with low decay heat, the decay heat of Oldbury fuel lying somewhere between that of those two sites. For these reasons site-specific fuel route accident management guidelines have been developed for each site.

Fuel route accidents are most likely to occur as a result of a plant or operating fault that results in loss of containment and/or shielding for spent fuel elements or possibly as a consequence of a conventional industrial incident, fire for example, affecting facilities in which fuel is stored. This is unlike reactor accidents that would most probably be preceded by a significant period of accident escalation even where the initiating event is an extreme external hazard. Hence it was considered that a scenario-based approach would be more appropriate than the symptom-based approach inherent in the reactor SBERGs and SAGs.

Broadly-based candidate scenarios for which accident management guidance might be useful were proposed by examining the fuel route for each site in detail to identify ways in which the safety of fuel within the fuel route could be challenged in a manner that could have significant radiological consequences. Scenarios already adequately addressed by existing operating instructions were excluded. Workshops were held at each site to refine, and augment where necessary, the list of candidate scenarios and agree those for which accident management guidance would be developed. Those workshops were attended by site and central engineering staff with specialist knowledge of the fuel routes, fuel behaviour and associated safety cases. A human factors specialist was also present.

Following the site workshops, accident management guidance has been developed for each agreed scenario based on the best available technical knowledge. For each scenario the guidelines define:

- entry points;
- materials and resources required to manage the accident;
- cautions, warnings, consequences and timescales to facilitate decision-making and prioritisation;
- accident management advice;
- exit points.

The guidance is presented in the form of concise advice statements, one for each scenario. The way in which the advice is presented in terms of organisation and flow of information has been developed by a human factors specialist in consultation with end-users.

Fuel route accident management guidelines for Wylfa, Oldbury and Sizewell A have been issued, and familiarisation training for emergency response personnel has been completed.

Exercising of the fuel route accident management guidelines will take place, as appropriate, on the applicable sites as part of the normal programme of site emergency exercises.

Conclusion

Magnox Limited has completed a comprehensive programme of review and revision of the SBERGs and SAGs for Wylfa. Fuel route accident management guidelines for Wylfa, Oldbury and Sizewell A have been developed and issued. Familiarisation training has been completed. Appropriate exercising of the revised accident management guidelines will take place as part of the normal programme of site emergency exercises.

STF-17 Licensees should further review the systems required to support long-term claims on the pre-stressed concrete pressure vessel containment capability in severe accident conditions.

Magnox Limited Response to STF-17

Magnox Limited has one remaining operating reactor, Wylfa Reactor 1, which can credibly give rise to an accident with consequences sufficiently severe to challenge the pre-stressed concrete pressure vessel containment capability. Stress Test Finding STF-17 therefore only applies to that reactor.

Maintenance of the pressure vessel containment under accident conditions has been reviewed as part of the overall review of the Severe Accident Guidelines (SAGs) more fully described within the response to Stress Test Finding STF-16.

The SAGs review concluded that the primary method to support long-term claims on the reactor containment under severe accident conditions is provision of sufficient heat removal from the reactor and preventing additional sources of heat by controlling criticality and coolant composition. Successful operation of the installed pressure vessel cooling system would guarantee that the concrete containment remains at low temperature and so within design capabilities. Based on a review of Wylfa-specific modelling, even without the pressure vessel cooling system no action would be required to protect the concrete containment vessel for a period of approximately two months. Under unmitigated severe accident conditions, however, the reactor containment critical safety function could be threatened on a timescale of a few days by excessive heating of steel penetrations that pass through the concrete pressure vessel.

Emergency actions to protect reactor containment including the concrete pressure vessel and penetrations were reviewed further as part of the limited-scope Level 2 probabilistic safety analysis described within the response to Recommendation FR-4. That analysis raised an observation highlighting the potential to improve guidance on maintaining the containment boundary under severe accident conditions. That observation was carried forward for consideration within the programme of work to revise the Symptom Based Emergency Response Guidelines (SBERGs) and SAGs (see the response to Stress Test Finding STF-16).

The revised SBERGs contain updated advice on controlling reactor temperatures and pressures under beyond design basis accident conditions to mitigate the possibility of pressure boundary failure. Additionally, the updated SAGs incorporate revised advice on actions that will assist in preventing, delaying and mitigating containment boundary failures in the event that the reactor core becomes degraded. These measures implemented in response to lessons learned from the Japanese events have enhanced the capability to maintain or restore reactor pressure boundary integrity following beyond design basis faults leading to severe accident conditions.

The revised SBERGs, supported by a suite of new Emergency Operating Procedures, and SAGs have been issued. Familiarisation training for emergency response personnel in the use of the revised SBERGs and SAGs has been completed including use of the plant computer simulators to simulate response to beyond design basis accident conditions. Feedback from that training has been incorporated into the issued documents.

Conclusion

Magnox Limited has conducted further reviews of the systems required to support long-term claims on the pre-stressed concrete pressure vessel containment capability in severe accident conditions for Wylfa Reactor 1. These reviews have resulted in enhanced guidance being provided in the revised SBERGs and SAGs.

STF-19 Reports on the progress made in addressing the conclusions of the licensees Considerations and the ONR findings should be made available to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented.

Magnox Limited Response to STF-19

On 26th June 2012 Magnox Limited provided to the ONR a comprehensive report on progress made with addressing the Magnox Limited Stress Test Considerations (see Section 3.3.3) and ONR stress test findings together with the recommendations from HM Chief Inspector's Interim and Final Reports. That progress report included the status of plans and details of improvements that had been implemented.

Conclusion

Stress Test Finding STF-19 was fully discharged by the submission made by Magnox Limited to the ONR in June 2012.

4.4 Stress Tests for UK Non-Power Generating Nuclear Facilities Final Report Findings

STF-20 Sellafield Ltd, AWE, RRMPOL, BAESM, DRDL, RRDL, Magnox Ltd and NNB GenCo should provide ONR with the decision-making process to be applied to their Considerations along with a report which describes the sentencing of all their Considerations. The report will need to demonstrate to ONR that the conclusions reached are appropriate.

Magnox Limited Response to STF-20

All Magnox Limited Stress Test Considerations (see Section 3.3.3) were carried forward for further assessment and development by the relevant sites. The submission made by Magnox Limited to the ONR in June 2012 provided a matrix that cross-referenced each Stress Test Consideration to work programmes under which the Considerations were being addressed.

The outcome of each site's work programme including the way in which the Stress Test Considerations have been addressed and enhancements that have been delivered in response to the Stress Test Considerations is summarised in Section 3.3.1 of the present report and the response to Stress Test Finding STF-15.

Appropriate and reasonably practicable enhancements have been made to address all Magnox Limited Stress Test Considerations.

Conclusion

All Magnox Limited Stress Test Considerations have been addressed and appropriate enhancements have been implemented across the Magnox Limited fleet. Details of how individual sites have developed and addressed potential enhancements implied by the Stress Test Considerations have been provided to the ONR.

STF-47 Magnox Ltd should carry out a review of the design basis and margins available against external hazards at each decommissioning site to ensure adequate provisions are in place throughout the decommissioning process commensurate with the remaining radiological hazard potential.

Magnox Limited Response to STF-47

Following discussions with the Office for Nuclear Regulation, the intent of Stress Test Finding STF-47 has been clarified as described below.

As sites have progressed from generation, through defuelling to care and maintenance preparations, the site safety cases have historically not been consistently updated to take specific account of the diminishing radiological consequences and risks arising from certain faults that may result from external hazards. In some instances safety case claims on the qualification of structures, systems and components are much greater than is now warranted by the much reduced radiological risk with the plant in its current and future states. This is particularly prevalent for legacy structures such as reactor buildings. During the generating phase, when the reactors were operational, such structures required high levels of integrity to prevent the possibility of significant radiological releases. Now that the reactors have been defuelled, the reactor buildings and other interior structures can accommodate substantial damage without there being any significant radiological consequence. Thus it is not appropriate to maintain the operational design basis integrity requirements during the care and maintenance preparations phase. The end result is that the protection requirements in some external hazards safety cases for the decommissioning sites are more onerous than necessary and less focussed than might be desirable.

The intent of Stress Test Finding STF-47, as clarified by the Office for Nuclear Regulation, is to encourage Magnox Limited to ensure that the design basis for structures, systems and components reflected in the safety case is consistent with the potential radiological consequences. The expectation is that the design basis requirements will reduce as the remaining radiological inventory on decommissioning sites is removed or passivated (see Section 2.3).

The intent of this finding reflects precisely Magnox Limited's company standard on the assessment of external hazards within safety cases for decommissioning sites. That standard explicitly requires protection requirements to be consistent with the radiological consequences of a fault or hazard. In particular, for external hazards the standard requires a graded approach to qualification of structures, systems and components depending on the potential radiological dose that could result from failure.

For specific operations undertaken on decommissioning sites (radioactive waste retrieval, processing or storage, for example) safety cases are routinely produced in accordance with the company standard. Such safety cases meet the intent of Stress Test Finding STF-47.

By contrast, external hazards safety cases for legacy reactor structures, for example, that will remain essentially in their present, largely quiescent, state into site care and maintenance (see Section 2) are typically reviewed as part of the Periodic Safety Review process. As a result, for some sites these safety cases are not yet fully consistent with the company standard. There is, however, a rolling programme of such reviews and the plan is to update all safety cases in accordance with the company standard requirements at the earliest available opportunity as part of that programme. This has already been implemented for the Hinkley Point A site as part of the recent Periodic Safety Review and is also being addressed for the Bradwell site in the care and maintenance entry safety case. The process will be completed for all sites within the declared Periodic Safety Review programme.

It is stressed that maintaining more onerous protection requirements from earlier safety cases relating to operational phases in which potential radiological consequences were greater errs on the side of pessimism and is, therefore, safe.

Conclusion

The intent of Stress Test Finding STF-47, as clarified by the Office for Nuclear Regulation, is fully consistent with the Magnox Limited company standard on the assessment of external hazards within the safety cases for decommissioning sites. The safety cases for specific decommissioning operations already meet the intent of this finding. Magnox Limited will address this finding for legacy structures in the course of updating relevant safety assessments within the declared Periodic Safety Review programme as part of normal business.

STF-83 Magnox Ltd should review, update and issue revised severe accident guidelines in the light of changing hazard at decommissioning sites; the guidelines should include human performance / welfare issues and availability of equipment located in beyond design basis containers.

Magnox Limited Response to STF-83

The reactors at the decommissioning Magnox Limited sites (Berkeley, Bradwell, Chapelcross, Dungeness A, Hinkley Point A, Hunterston A and Trawsfynydd) are defuelled. There is, therefore, no possibility of a severe accident involving nuclear material occurring at those sites. Nonetheless, radioactive waste material is still present on these sites. It is recognised that accidents affecting these waste materials could occur which might lead to relatively small off-site radiological releases.

For this reason Magnox Limited has developed new accident management guidelines to address accident scenarios involving intermediate and low level waste materials.

There are substantial differences in the detail of waste inventories and storage facilities across the Magnox Limited fleet. However, following consideration of this variety during a series of workshops supported by site-specific information gathering, a small set of common broadly-based accident scenarios has been identified that encompasses potential accident scenarios that might cause off-site radiological releases and for which accident management guidance would be helpful. The guidance that has been developed is, therefore, generic and has been made available to all sites: the decommissioning sites and Wylfa, Oldbury and Sizewell A.

The process for developing this guidance has been identical to that followed in developing the fuel route accident management guidelines detailed in the response to Stress Test Finding STF-16. That process involved the development of candidate scenarios for which accident management guidance might be useful by examination of the waste inventories and facilities across the fleet to identify ways in which the safety of waste material could be challenged in a manner that could lead to radiological consequences. Workshops have been held involving all sites to refine, and augment where necessary, the list of candidate scenarios and agree those for which accident management guidance would be developed. Those workshops were attended by site and central engineering staff with specialist knowledge of waste facilities, waste behaviour and associated safety cases. A human factors specialist was also present.

During and following the site workshops, accident management guidance has been developed for each agreed scenario based on the best available technical knowledge. For each scenario the guidelines define:

- entry points;
- materials and resources required to manage the accident;
- cautions, warnings, consequences and timescales to facilitate decision-making and prioritisation;
- accident management advice;
- exit points.

The guidance is presented in the form of concise advice statements, one for each scenario. The way in which the advice is presented in terms of organisation and flow of information has been developed by a human factors specialist in consultation with end-users.

Development of the generic accident management guidelines has been completed and appropriately customised versions of the guidelines have been issued by each site. Familiarisation training for emergency response personnel has been completed.

The radioactive waste accident management guidelines will be exercised as part of the normal programme of site emergency exercises.

Conclusion

Magnox Limited has developed new generic accident management guidelines for accident scenarios involving intermediate and low level radioactive wastes. Familiarisation training for emergency response personnel has been completed. Exercising will take place as part of the normal programme of emergency exercises.

STF-94 Reports on the progress made in addressing the conclusions of the licensees Considerations and the ONR findings should be made available to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented.

Magnox Limited Response to STF-94

On 26th June 2012 Magnox Limited provided to the ONR a comprehensive report on progress made with addressing the Magnox Limited Stress Test Considerations (see Section 3.3.3) and ONR stress test findings together with the recommendations from HM Chief Inspector's Interim and Final Reports. That report included the status of plans and details of improvements that had been implemented.

Conclusion

Stress Test Finding STF-94 was fully discharged by the submission made by Magnox Limited to the ONR in June 2012.

5. Further Work

All resilience reviews associated with lessons learned to date from the Japanese earthquake and tsunami have been completed. The vast majority of identified site enhancements have also been completed.

An enhancement to enable an increase in diesel fuel stocks at Wylfa is on-going and will be completed shortly.

A small number of specific resilience reviews have only very recently been finalised and the resulting enhancement opportunities will be pursued expeditiously under normal business arrangements. Examples include on-site emergency communications enhancements and improvements to the availability and operability of equipment or facilities associated with the revised accident management guidance at Wylfa.

Exercising of the revised accident management guidance will be carried out as part of the normal programme of site emergency exercises.

Some longer-term work items have been identified associated with assimilating emerging information from Japan and maintaining safety cases as sites progress through their lifecycle. These longer term items are being progressed under normal business arrangements.

On-going work items that are to be progressed under normal business arrangements following closure of the specific Magnox Limited response programme will continue to be monitored by the Chief Nuclear Officer.

6. Concluding Remarks

Magnox Limited is a learning organisation that seeks continual improvement particularly in matters affecting nuclear, radiological, environmental and industrial safety. The events surrounding the March 2011 Japanese earthquake and tsunami, and the consequential effects on nuclear facilities, present many learning opportunities.

Accordingly, Magnox Limited has sought to learn lessons from the events in Japan, a purpose shared with nuclear operators, regulators and governments worldwide; the collective aim being to further diminish the likelihood of nuclear accidents, from whatever cause, occurring in future. Recognising that the likelihood of such accidents, although considered to be already very low, can never be reduced to zero, a further objective has been to ensure that utilities and supporting agencies become even better prepared to mitigate accident consequences and lessen any societal and environmental impacts.

There remains only one operating nuclear reactor within the Magnox Limited fleet: Reactor 1 at Wylfa, for which for final shutdown is planned in 2015 subject to regulatory approval. Two other sites, Oldbury and Sizewell A, are presently undergoing defuelling. The remaining seven sites are already defuelled and in various stages of decommissioning, progressing towards a care and maintenance phase in which all remaining radioactive material is either removed or held in a passively safe state.

The overarching aim of the Magnox Limited response to lessons learned from the Japanese events has, therefore, been to implement reasonably practicable and proportionate enhancements that deliver tangible safety improvements swiftly and pragmatically across the ten sites and support functions.

Magnox Limited has conducted wide-ranging reviews of the resilience of its sites and operations, particularly against extreme events that lie outside the plant design basis, as well as questioning whether the design basis for extreme events remains valid. These reviews have generally shown that the existing position for Magnox Limited sites is robust. This is in large part a testament to the rigorous UK nuclear regulatory regime. In particular, the drive for timely completion of ten-yearly Periodic Safety Reviews (including compliance with modern engineering design standards and good engineering practice), and the adoption of 10^{-4} per annum exceedance frequency (1 in 10,000 year) events as the plant design basis, has put UK nuclear plants in a strong position. As an example, more than £100million has been spent assessing and upgrading the Wylfa plant during past Periodic Safety Reviews.

Nevertheless, the reviews carried out following the Japanese earthquake and tsunami have identified opportunities for further enhancing resilience across the Magnox Limited fleet. Consequently, many physical and procedural enhancements have been implemented. As would be expected, more substantial and wider-ranging enhancements have been implemented at Wylfa, the only site with an operating reactor. The scope of enhancements implemented across the sites has been proportionate with the remaining nuclear, radiological and environmental safety risks posed by each site in its current and projected future states.

A significant source of lessons learned has been the series of reports produced by the Office for Nuclear Regulation, including those arising from the European Council Stress Tests. Magnox Limited has responded to all applicable recommendations and findings contained within those reports. In accord with its overarching aim, Magnox Limited has sought to interpret these recommendations and findings in very tangible and practical ways with a focus on converting the recommendations and findings into improvements that can be delivered in a timely manner so as to maximise the safety benefits given the limited period of high hazard operations remaining.

This programme of review and enhancement has continued within Magnox Limited for a period of three years as additional lessons from the Japanese events have emerged. The specific Magnox Limited programme responding to lessons learned is now drawing to a conclusion.

All resilience reviews associated with lessons learned to date from the Japanese earthquake and tsunami have been completed. The vast majority of identified site enhancements have also been completed. Some short-term and longer-term on-going work items have been identified. These items will be pursued under specified normal business arrangements following closure of the specific response programme. On-going work items that are to be progressed under normal business arrangements will continue to be monitored by the Chief Nuclear Officer.

The Japanese events will have an enduring impact within Magnox Limited. The company will continue to maintain the highest standards of nuclear, radiological, environmental and industrial safety, learning from experience and identifying opportunities to improve. In so doing, Magnox Limited will seek to protect the public, its workers and the environment from potentially harmful effects should extreme events impact on our sites in the future.

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9. Tables

Site	Location	Electricity Generation Commenced	Electricity Generation Ceased	Current Site Lifecycle Phase	Planned Entry to Care & Maintenance
Berkeley	Gloucestershire	1962	1989	C&M Preparations	2021
Bradwell	Essex	1962	2002	C&M Preparations	2015
Chapelcross	Dumfries & Galloway	1959	2004	C&M Preparations	2028
Dungeness A	Kent	1965	2006	C&M Preparations	2027
Hinkley Point A	Somerset	1965	1999	C&M Preparations	2025
Hunterston A	Ayrshire	1964	1990	C&M Preparations	2022
Oldbury	South Gloucestershire	1967	2012	Defuelling	2027
Sizewell A	Suffolk	1966	2006	Defuelling	2027
Trawsfynydd	Gwynedd	1965	1991	C&M Preparations	2016
Wylfa	Ynys Môn (Anglesey)	1971	Expected 2015	Generating (1 reactor)	2025

Table 1: Summary of the Status of the Magnox Limited Nuclear Sites

10. Figures

Figure 1: Location of Magnox Limited Sites

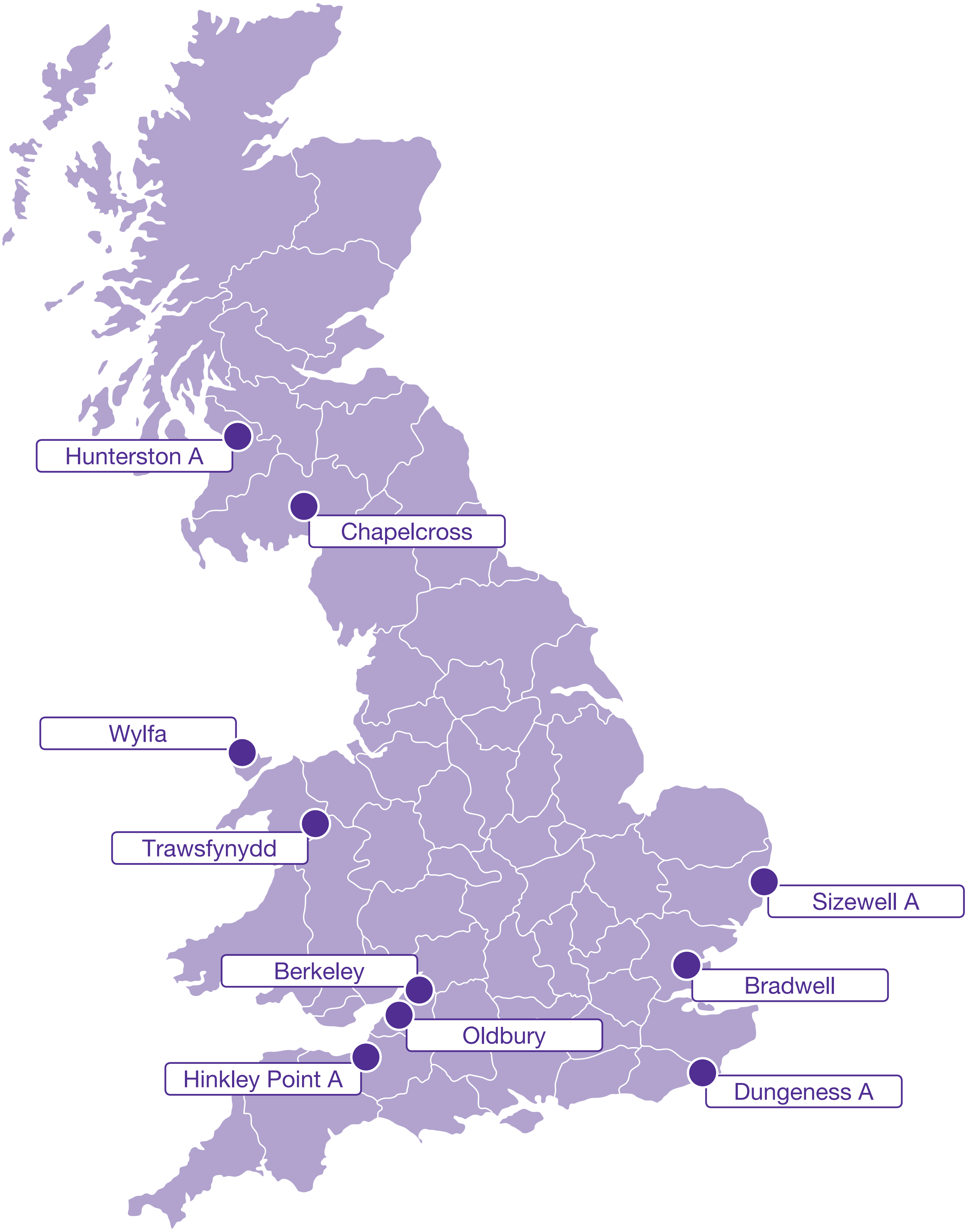

Figure 2: Beyond Design Basis Emergency Equipment Compound at Wylfa

Figure 3: Diesel Driven Fire Pumps at Wylfa

Figure 4: Road Tanker for Emergency Water Transportation at Wylfa

Figure 5: Emergency Diesel Generators at Wylfa

Figure 6: Alternative Emergency Reactor Monitoring System at Wylfa

Figure 7: Submersible Pumps at Wylfa

Figure 8: New Fire Tender at Wylfa (below)

Figure 9: Emergency Debris and Access Clearance Earthmover at Wylfa

Figure 10: Diverse Flood Resilient Boiler Feed Pump at Oldbury

Figure 11: Emergency Pond Water Filling Line at Oldbury

Figure 12: Emergency Debris and Access Clearance Equipment at Oldbury

Figure 13: Beyond Design Basis Emergency Equipment Containers at Oldbury

Figure 14: Enhanced Stocks of Staff Welfare Supplies at Oldbury

Figure 15: Emergency Spent Fuel Pond Filling Line at Sizewell A

Figure 16: Beyond Design Basis Emergency Equipment Containers at Sizewell A

Figure 17: Satellite Telephones Supplied to All Sites

Figure 18: Beyond Design Basis Emergency Equipment Containers Supplied to All Sites

11. List of Abbreviations

AC	Alternating Current
AOD	Above Ordnance Datum
BUFS	Back-Up Feed System
C&M	Care and Maintenance
CO_2	Carbon Dioxide
DC	Direct Current
EDF	Électricité de France Energy Nuclear Generation Limited
EES	Essential Electrical Supplies
ENSREG	European Nuclear Safety Regulators Group
EOPs	Emergency Operating Procedures
FR	ONR Final Report Recommendation
GPS	Global Positioning System
HCLPF	High Confidence of Low Probability of Failure
HM	Her Majesty's
IAEA	International Atomic Energy Agency
IR	ONR Interim Report Recommendation
kV	Kilovolt (1000 volts)
Mw	Moment Magnitude
NGET	National Grid Electricity Transmission
ONR	Office for Nuclear Regulation
RIMNET	Radioactive Incident Monitoring Network
SAGs	Severe Accident Guidelines
SBERGs	Symptom Based Emergency Response Guidelines
SHWP	Seismic Hazard Working Party
SOER	Significant Operating Experience Report
SPEN	Scottish Power Electricity Networks
SSC	Structures, Systems and Components
SSHAC	Senior Seismic Hazard Analysis Committee
STF	Stress Test Finding
UK	United Kingdom
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association