Office for Nuclear Regulation

An agency of HSE

Stress tests for UK Non Nuclear Power Plants

Progress Report

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Executive Summary

Following the events at Fukushima, Japan on 11 March 2011, the nuclear industry in the UK responded quickly to review UK plants against seismic and flooding hazards. HM Chief Inspector of Nuclear Installations was requested to produce interim and final reports on the lessons to be learnt from these events for the UK nuclear industry by the Secretary of State for Energy and Climate Change. In parallel with this, the European Council (EC) requested a review of safety at European nuclear power plants (NPP) and the European Nuclear Safety Regulatory Group (ENSREG) defined criteria and a plan for this review, now known as the "stress tests". Given that the EC stress tests only focus on NPPs, HM Chief Inspector of Nuclear Installations decided to extend the stress tests process to all other licensed nuclear installations within the UK. These licensed nuclear installations are designated as non Nuclear Power Plants (non NPP). Several other countries within the European Community have also decided to apply the stress tests process to some non NPPs.

UK non NPP licensees have been advised by the Office for Nuclear Regulation (ONR) to undertake the stress tests following the specifications and guidelines provided by ENSREG as appropriate to their facilities. This report is the progress report on the stress tests as applied to UK non NPPs. It confirms that all of the UK licensees have initiated a stress tests process in line with the ENSREG specifications. ONR expects all UK licensees to be able to provide comprehensive reports by 31 December 2011 as input to the main report on the stress tests planned to be issued by ONR in spring 2012. Since the non NPPs are defined by what they are not rather than by what they are, they represent a diversity of licensees, facilities and activities, which is reflected in this progress report. Owing to the range of potential hazards and the number and size of non NPP facilities, ONR might agree in some cases that licensees provide their final reports later than expected.

To date, none of the review work by the licensees for the stress tests has indicated any fundamental weaknesses in the definition of design basis events or the safety systems to withstand them for UK non NPPs. However, lessons are being learnt about improving resilience and addressing margins.

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INTRODUCTION

1 The European Council (EC) requested a review of safety at European nuclear power plants (NPP) and the European Nuclear Safety Regulatory Group (ENSREG) defined criteria and a plan for this review, known as the "stress tests". There are overlaps between the stress tests activities and the recommendations raised in HM Chief Inspector of Nuclear Installations' Fukushima lessons learnt reports (Refs 1 and 2). Given the timescales for the stress tests and the full response to the recommendations, a further report will be produced by the Office for Nuclear Regulation (ONR) in about years time which will provide an update on progress in implementing the lessons for the UK's nuclear industry.

2 This report presents the UK progress report on the implementation of the stress tests to UK non Nuclear Power Plants (NPP).

3 Given that the EC stress tests only focus on NPPs, HM Chief Inspector of Nuclear Installations decided to extend the stress tests process to all other licensed nuclear installations within the UK. These licensed nuclear installations are designated as non NPP.

4 UK non NPP licensees have been advised by ONR to undertake the stress tests following the specifications and guidelines provided by ENSREG as appropriate to their facilities. This report is the progress report on the stress tests as applied to UK non NPPs.

5 The stress tests can be summarised as a targeted reassessment of the relevant design bases and safety margins of nuclear installations in the light of the events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident.

6 All of the UK non NPP licensees are undertaking programmes of work to complete all aspects of the stress tests with a clear intent to provide contributions to the final report of ONR on stress tests for non NPPs.

7 Overall, ONR is content with the activities planned for the stress tests programme by all the UK non NPP licensees, and expects comprehensive and timely outputs to be provided in support of the final ONR report. This final report will present the outcome of the ONR assessment of licensees' outputs and will be published. ONR also expects that a number of enhancements to strengthen resilience further may be identified and implemented which will provide a positive contribution to nuclear safety in the UK in the event of a beyond design basis event.

BACKGROUND

8 All of the UK nuclear site licensees have processes to assimilate, review and disseminate lessons learnt from significant events, both in the UK and overseas. These arrangements are part of the continuous improvement and operational experience feedback processes which are required by all licensees through Licence Conditions (LC).

9 The magnitude and scale of the events at Fukushima are such that all the licensees responded swiftly to review safety at their sites. In addition, they have been fully supportive and engaged in the wider UK and international nuclear industry responses to learn from these events.

The Fukushima Events

10 On 11 March 2011 Japan suffered its worst recorded earthquake, known as the Tohuku event. The epicentre was 110 miles east north east from the Fukushima Dai-ichi (Fukushima-1) site. Reactor Units 1, 2 and 3 on this site were operating at power before the event and, on detection of the earthquake, shut down safely. Off-site power was lost and initially emergency diesel generator power was used to provide essential post-trip cooling. Less than an hour after shutdown a massive tsunami from the earthquake inundated the site and destroyed the alternating current (AC) electrical power capability. Sometime later, alternative back-up cooling was lost. With the loss of cooling systems, Reactor Units 1, 2 and 3 overheated. The overheated zirconium cladding reacted with water and steam, generating hydrogen which resulted in several explosions causing damage to building structures. Major releases of radioactivity occurred, initially by air but later by leakage to the sea. The operator struggled to restore full control.

11 This was a major nuclear accident, with a provisional International Nuclear and Radiological Event Scale (INES) level 5, since amended to a provisional level 7 (the highest level). The Japanese authorities instigated a 20km evacuation zone, a 30km sheltering zone and other countermeasures.

UK Response

12 In response to the Fukushima accident, the UK opened the Cabinet Office Briefing Room (COBR). The Government Chief Scientific Advisor chaired a Scientific Advisory Group for Emergencies (SAGE). HM Chief Inspector of Nuclear Installations provided significant inputs to both COBR and SAGE. The Redgrave Court Incident Suite in Bootle was staffed by ONR from early in the accident and for over two weeks; it acted as a source of expert regulatory analysis, advice and briefing to central government departments and SAGE.

13 The Secretary of State for Energy and Climate Change requested HM Chief Inspector of Nuclear Installations to examine the circumstances of the Fukushima accident to see what lessons could be learnt. ONR set up a dedicated project team covering aspects of the Fukushima accident that are likely to be important in learning lessons. HM Chief Inspector of Nuclear Installations also set up a Technical Advisory Panel of external independent experts to advise him during this work.

14 HM Chief Inspector of Nuclear Installations published his Interim Report (IR) on the events at Fukushima and the implications for the UK nuclear industry, in May 2011 (Ref. 1). The IR contained 11 conclusions and 26 recommendations. HM Chief Inspector of Nuclear Installations' Final Report (FR) was published in October 2011 (Ref. 2). The FR maintained the IR conclusions and the 26 IR recommendations; it introduced 6 new conclusions and 12 new recommendations. It also provided additional further elaboration for some IR recommendations. The FR covered some additional

topics such as research, and planning controls for commercial and residential development around nuclear licensed sites.

15 HM Chief Inspector of Nuclear Installations decided to extend the stress tests required by the EC for all European NPPs to include all UK licensed nuclear installations.

16 There are several defence sites where nuclear-related activities occur which are under the control of the Crown (Ministry of Defence, MoD) and so are excluded from the need for licensing under Nuclear Installations Act 1965 (NIA65) (as amended). These sites operate under an authorisation regime regulated by the Defence Nuclear Safety Regulator (DNSR), although ONR also regulates the sites through the Health and Safety at Work etc. Act 1974 (HSWA74) and associated legislation, including the Ionising Radiations Regulations 1999 and Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR). These authorised sites are HM naval bases at Devonport and Clyde (which comprises the Faslane and Coulport sites) and the Vulcan Naval Reactor Test Establishment at Dounreay. ONR works jointly with DNSR at these sites where our responsibilities are complementary. DNSR have issued instructions to these authorised sites to carry out preliminary assessment against the stress tests to ensure MoD standards remain consistent with the civil nuclear industry where practicable and appropriate. The timescales for conducting stress tests at authorised sites are consistent with non NPP licensed sites.

EC Response

17 Following the meeting of the EC on the 24–25 March 2011, ENSREG developed the scope and modalities of the stress tests in a coordinated framework, in response to the accident in Japan at Fukushima and with the full involvement of member states, making full use of available expertise, notably from the Western European Nuclear Regulators' Association (WENRA).

18 The ENSREG members agreed on the initial independent regulatory technical definition of the stress tests and how it should be applied to NPPs across Europe at their plenary meeting on 12 – 13 May 2011.

Other International Responses

19 HM Chief Inspector of Nuclear Installations led an International Atomic Energy Agency (IAEA) high-level team of international nuclear experts to conduct a fact-finding mission to Japan in May 2011. HM Chief Inspector of Nuclear Installations reported back to a ministerial conference of the IAEA in June 2011 and the fact-finding mission team subsequently produced a report (Ref. 3).

20 The Japanese government report on the accident to the IAEA Ministerial Conference was published in June 2011 (Ref. 4).

21 An extraordinary Review Meeting of the Convention on Nuclear Safety to review contracting parties' responses to the Fukushima accident will be held in August 2012, when all participating parties have had the opportunity to complete the stress tests.

22 The UK has contributed to a significant number of other international meetings and bilateral discussions regarding the Fukushima accident since March 2011, and this is expected to continue. ONR staff play an active role in these meetings, led by HM Chief Inspector of Nuclear Installations.

OVERVIEW OF UK NON NUCLEAR POWER PLANTS AND LICENSEES

23 The locations of UK non NPPs (as defined by exclusion for the EC stress tests) are shown on the map below (Figure 1). It also shows the location of one proposed site (Hinkley Point C) for which an application for a nuclear site license has been received by ONR; authorised sites of the MoD are also shown on the map.

Figure 1: Map of Non Nuclear Power Plants

Sellafield Ltd (Sellafield and Windscale)

24 The Sellafield site in Cumbria is the location of a number of significant UK non NPP facilities. The site comprises both the Sellafield and Windscale nuclear licensed sites operated by Sellafield Ltd (the licensee) and owned by the Nuclear Decommissioning Authority (NDA).

25 Operations on the Sellafield site began in the 1940s, when the site was a Royal Ordnance factory supporting the war effort. Nuclear operations commenced on the site with initial fuel loading of the two Windscale Piles in 1950 and construction of the facilities for the separation of fissile material from the spent fuel.

26 The site later became home to the world's first commercial nuclear power station – Calder Hall, which operated four Magnox reactors successfully from 1956 to 2003. A further reactor, the Windscale Advanced Gas-cooled Reactor (WAGR) was constructed and commissioned as a prototype for the UK's second generation of reactors. WAGR ceased operating in 1981. All seven of these reactors are now in differing stages of decommissioning, with WAGR now essentially complete. The four reactors at Calder Hall have been considered within the EC stress tests as NPPs still with fuel and have been reported elsewhere (Ref. 5).

27 The facilities on the site today include several diverse operational facilities and a number of facilities undergoing decommissioning. Operations on site centre around the nuclear fuel cycle, with two spent fuel reprocessing plants, i.e. the Magnox Reprocessing Plant (MRP) and Thermal Oxide Reprocessing Plant (Thorp). The reprocessing facilities are supported by a number of waste and effluent treatment plants and associated storage facilities. Nuclear fuel manufacturing was until recently carried out on the Sellafield site at the Sellafield Mox Plant (SMP). SMP was built to return reprocessed fissile material in the form of mixed oxide fuel (MOX) to overseas customers.

28 The main focus for the Sellafield site is now reducing the radioactive hazard in a number of legacy facilities across the site and accelerated decommissioning of those facilities.

Sellafield Ltd (Capenhurst)

29 The Capenhurst site is located about 8km to the north-west of Chester city centre. The site was home to a gaseous diffusion plant for the enrichment of uranium which operated from the 1950s until 1982. The site is currently focused on decommissioning, clean-up and safe storage of uranic materials (arising from reprocessing operations at Sellafield as well as uranium hexafluoride). The majority of uranium hexafluoride currently stored on the site is depleted with respect to uranium 235; as such the predominant hazard posed by the storage and decommissioning activities on the site is dominated by the chemotoxic effect of uranium hexafluoride.

30 Urenco UK Ltd holds the licence for the facilities on the adjacent site which is subject to a separate submission and ONR assessment (provided below).

Dounreay Site Restoration Ltd

31 The ex-UK Atomic Energy Authority (UKAEA) licensed nuclear site at Dounreay on the far north coast of Scotland is operated by Dounreay Site Restoration Ltd (DSRL). The complex initially comprised the Dounreay Materials Test reactor (DMTR) followed by the Dounreay Fast Reactor (DFR). These were supported by facilities for fuel manufacture, reprocessing and storage of radioactive waste. Construction began in 1955. Criticality was first achieved in DMTR in May 1958 and in DFR in November 1959. DMTR was shut down in 1969; all of its fuel has since been removed, reprocessed and the facility is currently in a passive care and maintenance status waiting

final decommissioning. DFR ceased power generation in 1977. A second fast reactor, the Prototype Fast Reactor (PFR) became operational in 1974 and continued to generate power until 1994. Both PFR and DFR are now being decommissioned.

32 DFR and PFR have been subject to assessment in accordance with the ENSREG stress tests requirements for NPPs. DMTR and the wider facilities on the Dounreay site are subject to separate stress tests assessment for non NPP as requested by ONR.

33 A wide variety of operations within the fuel cycle area (FCA) were carried out to support reactor operations. These included reprocessing of spent fuel and the storage and treatment of radioactive waste. Reprocessing of fast reactor spent fuel ceased in October 1996 and residues were processed until January 1997.

34 The site also includes two facilities previously authorised for the disposal of intermediate and low level radioactive waste (ILW and LLW); these are, respectively the Shaft and the low level waste Pits. The consignment of radioactive waste to the Shaft ceased in 1977. Use of the LLW Pits ceased in 1997. The site also includes a facility known as the Wet Silo, in which ILW is stored underwater. Consignments to the Wet Silo ceased in 1998.

Springfields Fuels Ltd

35 Springfields licensed site near Preston, has provided nuclear fuel fabrication services since the mid-1940s. In 2005, responsibility for the assets and liabilities of the site transferred to the NDA. A new company, Springfields Fuels Ltd (SFL), was created to run the site, managed and operated by Westinghouse Electric UK Ltd on the NDA's behalf. Subsequently, Westinghouse acquired a long-term lease for the Springfields site, which transferred responsibility for the commercial fuel manufacturing business and SFL to Westinghouse.

36 The site's activities include manufacture of oxide fuels for Advanced Gas-cooled and Light Water Reactors, manufacture of uranium hexafluoride, processing of residues, decommissioning and demolition of redundant plants and buildings.

Imperial College of Science, Technology and Medicine

37 The CONSORT II Research Reactor is located on a nuclear licensed site within the Imperial College Silwood Park campus near Ascot in Berkshire. CONSORT is a low power (100kW thermal) research reactor, and first achieved criticality in 1965. The licensee, Imperial College of Science, Technology and Medicine (ICSTM) states that decommissioning plans are in an advanced state and that defuelling of all fuel elements should be complete within three years, and eventual delicensing of the site in 2023.

Urenco UK Ltd

38 Urenco UK Ltd operates a number of uranium hexafluoride gas centrifuge enrichment facilities at its Capenhurst site. The site is adjacent to the separate licensed site owned by the NDA and cooperated by Sellafield Ltd (Capenhurst).

Studsvik UK Ltd

39 The Metals Recycling Facility, located in Workington, Cumbria, is owned by Studsvik UK Ltd and was licensed in 2008 to carry out processes for decontaminating and recycling metal low-level waste as part of the UK's national LLW strategy.

Low Level Waste Repository Ltd

40 The Low Level Waste Repository (LLWR) nuclear licensed site is located about 6km to the south-east of the Sellafield site in West Cumbria. The site is owned by the NDA and operated by LLWR. The main site functions include receipt, grouting, storage and disposal of low level waste.

Research Sites Restoration Ltd

41 Research Sites Restoration Ltd (RSRL) operates the licensed facilities at Harwell (Oxfordshire) and Winfrith (Dorset) which are both owned by the NDA. Licensed facilities on these sites are undergoing decommissioning and care and maintenance activities.

GE Healthcare Ltd

42 GE Healthcare Ltd (GEHC) has three nuclear licensed sites in the UK; the Grove Centre at Amersham (Buckinghamshire); the Maynard Centre at Cardiff and a Building at Harwell. GEHC operations centre on the manufacture of radiopharmaceutical products. The Grove Centre is currently implementing its decommissioning plan whilst the Maynard Centre is also undergoing decommissioning. Grove and Maynard Centres are still being managing ILW. GEHC's former waste packaging facility and source manufacture operations at Harwell have ceased, and activities now relate to post-operational clean-out. The Building's concrete structure remains with only low level fixed contamination in some areas.

Atomic Weapons Establishment

43 The Atomic Weapons Establishment (AWE) is managed for the MoD through a contractor-operated arrangement. The AWE Aldermaston and AWE Burghfield sites and facilities remain in government ownership, but their management, day-to-day operations and maintenance are contracted to a private company. Nuclear site licences were granted to AWE plc as operator of the sites.

44 The role of AWE is to manufacture and sustain the warheads for the Trident system, ensuring optimum safety and performance, but also to maintain a capability to produce a successor system should the Government require one in the future. The work at AWE covers the entire life cycle of nuclear warheads from: initial concept; assessment and design; component manufacture; assembly; in-service support; decommissioning and disposal.

Rolls-Royce Marine Power Operations Ltd

45 Rolls-Royce Marine Power Operations Ltd (RRMPOL) operates two nuclear licensed sites at Derby in support of the MoD Naval Nuclear Propulsion Programme. RRMPOL operates the Neptune zero-energy test reactor used in the research and design of naval reactor fuels, and manufactures the nuclear fuel that powers the Royal Navy's submarines.

BAE Systems Marine Ltd

46 The Devonshire Dock Complex located at Barrow-in-Furness, is a shipbuilding facility operated by BAE Systems Marine Ltd (BAESM) as the site licence company. The complex includes the Devonshire Dock Hall, a large indoor facility that was used to construct the Vanguard Class submarines and where the Astute class submarines are being constructed. Within the complex, a ship lift facility is utilised to lower vessels into the water without reliance on tidal conditions. As well as construction, the commissioning and testing of submarines take place within the facility. New fuel for the reactor is stored on-site before it is loaded into the reactor pressure vessel prior to testing.

Devonport Royal Dockyard Ltd

47 Located at Plymouth, Devonport Royal Dockyard Ltd (DRDL) is operated by the Marine and Technology Division of Babcock International, and includes the site licence company DRDL. DRDL is contracted by MoD to refit and maintain the Royal Navy's nuclear-powered submarines. Plant and site modifications are currently being progressed by DRDL that will enable future defuelling activities to be carried out on certain classes of redundant submarines.

Rosyth Royal Dockyard Ltd

48 Rosyth Royal Dockyard is operated by the Marine and Technology Division of Babcock International and includes the site licence company Rosyth Royal Dockyard Ltd (RRDL).

49 Rosyth Royal Dockyard was used to support the refitting and maintenance of nuclear-powered submarines until such work was transferred to Devonport. The nuclear licensed site is a relatively small part of the overall dockyard and most of the nuclear-related facilities have now been decommissioned and the hazard removed. Relatively small quantities of radioactive wastes are currently stored on the site and disposal options for these wastes are currently being explored.

50 AWE, RRMPOL, BAESM, DRDL and RRDL are designated as defence licensees.

Magnox Ltd – Defuelled Reactors

51 The construction of the 26-reactor Magnox fleet started in 1953 and finished in 1971. Magnox Ltd holds nuclear site licences for a number of former reactor sites which have been defuelled and have become medium- to long-term intermediate and LLW stores. These defuelled sites were excluded from the UK national progress report on NPP stress tests for the EC (Ref. 5), and are reported here. These sites are at Hinkley Point A in Somerset, Hunterston A in Lanarkshire, Bradwell in Essex, Trawsfynydd in Wales and Berkeley in Gloucestershire.

52 Although the risks from the long-term storage of ILW and LLW at former power plant sites are low, the stores are expected to remain operational for a significant period of time. ONR therefore expects licensees to take into account the prolonged period over which benefits would be realised when considering the potential for safety improvements to further reduce risk.

Potential New Sites – Licensing and the Generic Design Assessment Process

53 There are three potential new licensees in the UK. One of these – EDF Energy NNB Generation Company (NNB GenCo) – applied for a nuclear site licence on 29 July 2011 for two Pressurised Water Reactors (PWR) (UK EPR™) at the Hinkley Point C site in Somerset. The other two potential licensees – Horizon Nuclear Power (Horizon) and NuGeneration Ltd (NUGEN) – are developing their organisational arrangements and have not yet made a choice of reactor technology. As none of the three potential licensees are currently constructing a new NPP they were excluded from the UK national report on EC stress tests for NPPs.

54 Horizon and NUGEN are also excluded from this report as they have not progressed to the point where they can undertake stress tests based on a firm design. If necessary, the stress tests process for them would take place as part of the site licensing.

55 NNB GenCo's proposed twin EPR reactor site at Hinkley Point C is included in this report because they have made a technology choice and applied for a nuclear site licence, but have not started construction. The stress tests are being applied by NNB GenCo at the design stage. This makes potential improvements both long lived and, potentially, relatively simple to introduce as the design has yet to be finalised.

56 ONR and the Environment Agency have been working together on the Generic Design Assessment (GDA) of two new reactor designs that are likely to be developed in the UK – the EDF and AREVA UK EPR™ reactor and the Westinghouse's AP1000® reactor. GDA allows the nuclear Regulators to assess new nuclear power stations before nuclear island construction begins. Identifying potential issues at the initial design stage allows any issues to be addressed more efficiently and effectively.

57 The Regulators conduct their GDA assessment using a step-wise approach, with the assessments becoming increasingly detailed at each step. At the end of each step reports are published, providing an update on the technical assessment undertaken by the nuclear assessors and highlighting any concerns or technical issues raised during the assessment (GDA publications are accessible on the ONR website at www.hse.gov.uk/newreactors/index.htm). As the Fukushima event occurred towards the end of assessment of the designs, a general issue was raised by ONR and the Environment Agency for each reactor design company to put in place plans to address any relevant recommendations from HM Chief Inspector of Nuclear Installations' final report on the Fukushima accident (Ref. 2) and any relevant findings from their own learning process. The Resolution Plans proposed by EDF and AREVA for the UK EPR™ reactor design and Westinghouse for the AP1000® reactor design are currently being assessed by ONR and the Environment Agency in order to come to a conclusion before the end of the year.

STRESS TESTS REQUIREMENTS

58 The stress tests requirements have been defined by ENSREG for NPPs (Annex 1). These requirements state that the licensees have the prime responsibility for safety so they should perform the assessments and the regulatory body should independently review them. This approach is consistent with UK legislation.

59 In order to ensure a high level of consistency, the same requirements are intended to be applied to NPPs and non NPPs in the UK. However, if any requirements are not fully applicable, they may be adapted on a case-by-case basis. During its assessment, ONR will have to ensure that any adaptations set by the licensees are adequate and relevant to each considered facility.

60 Through these requirements, national regulatory bodies have been encouraged to take due account of the principles for openness and transparency and to make their reports available to the public within the bounds of security. This accords well with ONR's openness and transparency objectives.

Initiating Events

61 The initiating events required for review under the stress tests are earthquakes, flooding and "bad weather conditions". The review considers the size and frequency of the design basis event and how it was developed, along with a review of how structures, systems and components (SSC) were designed or qualified to resist the design basis event(s).

62 The initiating event review must also consider how the margins evaluation for each facility was completed and what consequential effects should be considered. The margins evaluation includes a requirement to consider what improvements, if any, could be applied to improve margins and to remove or reduce further the probability of cliff-edge effects.

Loss of Safety Function

63 Two key loss of safety function fault sequences must be reviewed during the stress tests, these are:

- Loss of electrical power.
- Loss of ultimate heat sink.

Along with a combination of both.

64 The events which lead to a loss of safety function, such as cooling, could be as a result of seismic activity or flooding, but other external or internal hazards or faults could also be the initiator of these loss of function sequences, and this is recognised in the text of the ENSREG requirements and has been considered by the licensees.

65 For loss of electrical power, progressive loss of supplies is considered. This starts with a loss of off-site power – this is always considered as a fault scenario in UK design basis and resilience is normally provided by a range of on-site power generation and support facilities. The more severe sequence also considered for the stress tests is the loss of all off- and on-site AC power generation capacity. In common with the initiating events, a margins evaluation is requested along with a review of what improvements, if any, could be applied to improve margins and to remove or reduce further the probability of cliff-edge effects.

66 For loss of ultimate heat sink, initially the normal cooling systems are considered unavailable, and then progressive loss of alternative and backup cooling systems is reviewed.

67 For the final sequence, a loss of ultimate heat sink along with Station Blackout (SBO) event is considered. This is an extreme fault condition and the stress tests then look for information on how the fault would escalate into a severe accident and the timescales involved. A review of potential margins and of improvements, if any, which could be applied to improve margins and to remove or reduce further the probability of cliff-edge effects.

Severe Accident Management

68 The ENSREG requirements for severe accident management recognise that most severe accident management arrangements are there to mitigate the worst effects, not to prevent the effects from happening.

69 The review asks for the key management features to ensure control, cooling and containment along with instrumentation to confirm key parameters, and then the potential accident management measures which could be applied by the licensees to be considered in a systematic manner.

70 The review also builds on learning from Fukushima about damage to the local and regional infrastructure and communications and the potential for a long duration of standalone activity at the site in the face of widespread disruption in the region around the nuclear site. As before, potential cliff-edges are to be identified and any potential improvements, if any, which could be applied to improve margins and to remove or reduce the probability of cliff-edge effects are also expected to be identified.

RELEVANT ASPECTS OF UK REGULATORY REGIME

Legal Framework

71 In the UK, the legal framework for nuclear safety is established principally through two pieces of legislation, these are the:

- HSWA74.
- NIA65 (as amended).

72 Under HSWA74 employers are responsible for reducing risks, so far as is reasonably practicable, to their workers and the public. This responsibility is elaborated further in relation to nuclear sites by NIA65, which establishes a nuclear site licensing regime. The power to grant a licence to use a site to construct and operate a specified nuclear installation, and consequently for its regulation, is invested with the Health and Safety Executive (HSE), which further delegates this authority to HM Chief Inspector of Nuclear Installations. This power includes attaching conditions in the interests of safety or radioactive waste management.

73 European legislation in the form of Directives is transcribed into the UK legal framework outlined above. The most recent European legislation is the Nuclear Safety Directive, which came into force in July 2011.

74 ONR is the principal regulator of the safety and security of the nuclear industry in the UK; its independence is secured legally through HSWA74 and NIA65. ONR is mainly formed from three former bodies: Nuclear Installations Inspectorate, UK Safeguards Office and Office for Civil Nuclear Security. ONR has also taken on the nuclear regulatory functions of the Department for Transport, by incorporation of the Radioactive Materials Transport team on 24 October 2011.

Licensing

75 The regulation of safety of nuclear installations in the UK is through a system of control based on a licensing regime by which a corporate body is granted a licence to use a site for specific activities. This allows ONR to regulate the design, construction, operation and decommissioning of any nuclear installation for which a nuclear site licence is required under NIA65. Nuclear site licences are granted for an indefinite term and a single licence may cover the lifetime of an installation.

76 NIA65 allows ONR to attach to each nuclear site licence such conditions as it considers necessary or desirable in the interests of safety, or with respect to the handling, treatment or storage of nuclear materials. ONR has developed a standard set of 36 LC, which are attached to all nuclear site licences. In the main, they require the licensee to make and implement adequate arrangements to address the particular safety areas identified. The LC provide the legal basis for regulation of safety by ONR. They do not relieve the licensee of the responsibility for safety. They are non-prescriptive and set goals that the licensee is responsible for achieving.

77 One of the requirements of the LC is that the licensees produce an adequate safety case to demonstrate that facilities are safe in both normal operation and fault conditions. The safety case is a fundamental part of the licensing regime at all stages in the lifecycle of a nuclear installation. It establishes whether a licensee has demonstrated that it understands the hazards associated with its activities and has arrangements in place to control them adequately.

Design Basis

78 ONR has developed and published its own technical principles, which it uses to judge licensees' safety cases; these are set out in the Safety Assessment Principles for Nuclear Facilities (SAP) (Ref. 6). The latest version of the SAPs, published in 2006, was benchmarked against extant IAEA safety standards. In addition to the SAPs, more detailed Technical Assessment Guides (TAG, accessible at www.hse.gov.uk/nuclear/tagsrevision.htm) are available to ONR assessors to assist them in making judgements on licensees' safety submissions. In the areas relevant to the accident at the Fukushima site, the SAPs and TAGs set out regulatory expectations for protection against hazards such as extreme weather, flooding, earthquakes, fire, explosion etc, and for provision of essential services.

79 Specific SAPs and sections of the SAPs define ONR's expectations for the development of a design basis.

80 Design Basis Analysis (DBA) provides a robust demonstration of the fault tolerance of a facility and the effectiveness of its safety measures. Its principal aims are to guide the engineering requirements of the design and to determine limits to safe operation. In this approach, the risk is not quantified but the adequacy of the design and the suitability of the safety measures are assessed against deterministic targets.

Fault Analysis

81 Conservative design, good operational practice and adequate maintenance and testing should minimise the likelihood of faults. The DBA should ensure that the facility has been designed to cope with or withstand a wide range of faults without unacceptable consequences by virtue of the plant's inherent characteristics or its safety features.

82 In addition to DBA, further safety analyses are undertaken to ensure the design is optimised and to confirm that the overall risk presented by the facilities lies within target sets – generally in the SAPs (Ref. 6). These analyses can also be essential to help understand the strengths and weaknesses of the design, particularly in light of the complex designs and interdependencies.

83 DBA may also not include the full range of identified faults because it may not be reasonably practicable to make design provisions against extremely unlikely faults. It may not therefore address severe but very unlikely faults against which the design provisions may be ineffective. This is addressed by severe accident analysis.

Severe Accident Management

84 The principle of defence-in-depth requires that fault sequences leading to severe accidents are analysed and provision made to address their consequences. The analysis of severe accident events is generally performed on a best-estimate basis to give realistic guidance on the actions which should be taken in the unlikely event of such an accident occurring. Severe accident analysis may also identify that providing further plant and equipment for accident management is reasonably practicable. The stress tests process effectively undertakes a review of specific severe hazards, faults and severe accident studies in a systematic manner.

Periodic Review

85 In the UK the operator of a nuclear installation is also required by a specific LC (LC15) to periodically review its safety case for the plant. This Periodic Review (PR) usually takes place every ten years and requires the operator to demonstrate that the original design safety intent is still being met. It is then required to be assessed against the latest safety standards and technical knowledge. The operating experience of the plant is also considered in the review. If the PR identifies any reasonably practicable safety improvements, then these should be made by licensees. In addition, life-limiting factors that would preclude operation for a further ten years may also be identified in the review. The PR includes a review of the safety of the plant in response to events such as earthquakes, floods, fire and explosion. ONR independently assesses licensees' PR reports using its SAPs and TAGs.

Continuous Improvement

86 This philosophy is at the core of the UK requirements for the nuclear industry through the application of the "as low as reasonably practicable" (ALARP) principle. It is the way in which sustained high standards of nuclear safety are realised. It means that, no matter how high the standards of nuclear design and subsequent operation are, the quest for improvement must never stop. Seeking to learn from events, and from new knowledge and experience, must continue to be a fundamental feature of the safety culture of the UK nuclear industry.

87 Thus, all of the UK nuclear site licensees have processes to assimilate, review and disseminate lessons learnt from significant events both in the UK and overseas. These arrangements are part of the continuous improvement and operational experience feedback processes which are expected of all licensees.

88 Some of the licensees also participate in the continuous improvement programmes arising from their participation in the World Association of Nuclear Operators (WANO). The work of WANO and the participation of UK licensees is not a regulatory requirement, but ONR encourages this as the licensees benefit from participation in an international programme which gives them access to a wide pool of shared experiences and peer-to-peer reviews.

PROCESS FOR STRESS TESTS ACTIVITIES

89 ONR informed licensees and potential licensees about the stress tests and their requirements in June 2011.

90 The next major step was for the non NPP licensees to advise about their stress tests progress by the end of October 2011. ONR has reviewed the information supplied and produced the UK progress report, this report.

91 The licensees will continue working on preparing their main stress tests reports, one for each site, to a prescribed pro-forma with a submission date of 31 December 2011.

92 ONR will assess this information and prepare and publish the UK non NPP stress tests report in spring 2012.

93 In the UK, in line with the goal-setting non-prescriptive approach to regulation, the licensees are expected to prepare the information and the initial assessments for each non NPP site. The output will be assessed by ONR to confirm it is appropriate and that the licensees have adequately considered the margins and how they might be extended.

94 The approach adopted by many of the licensees is to apply the arrangements made under LC15 (PR) to carry out a review and reassessment of safety and submit a report to ONR. This provides a structured framework for the review activities and gives clarity of roles and functions within the licensees' arrangements for the preparation, review and reassessment of safety case information.

PROGRESS TO OCTOBER 2011

Licensee Progress

Sellafield Ltd (Sellafield and Windscale)

95 The licensee's submission (Ref. 7) indicates that Sellafield Ltd has established the Sellafield resilience programme to deliver the licensee's response to the events at Fukushima, including the delivery of the Sellafield Ltd response to the requested stress tests review. Sellafield Ltd has developed the "Stress tests" Resilience Evaluation Process (RESEP) as a structured approach for the stress tests assessment for the whole Sellafield site with its numerous and varied operational and legacy nuclear facilities. The RESEP has focused on the facilities that have a capability to generate significant off-site consequences and is designed to identity and review the impact of loss of control, shielding, containment, critical utilities services etc. and to make recommendations for improvements to enhance the resilience.

96 The licensee's progress report indicates that Sellafield Ltd has completed the initial RESEP review on the majority of the high hazard facilities on the Sellafield site and Sellafield Ltd are on course to complete the remaining initial reviews in order to compile their stress tests report by 31 December 2011.

Sellafield Ltd (Capenhurst)

97 The licensee's submission (Ref. 8) clearly defines that uranium hexafluoride storage as presenting the dominant hazard on the site, albeit dominated by its potential chemotoxic effect. Sellafield Ltd's response refers to uranium hexafluoride cylinders that have high standards of plant design, storage and procedural controls, against which the licensee's LC15 PR process has provided confidence in relation to engineering performance and seismic resilience.

98 Sellafield Ltd has included its Capenhurst site within its resilience programme.

Dounreay Site Restoration Ltd

99 DSRL submitted to ONR a progress report (Ref. 9) detailing its approach to the ENSREG stress tests requirements. In addition to the decommissioning activities of DFR and PFR to be assessed against the stress tests defined by ENSREG, DSRL committed to assess all of its facilities to a similar standard. The proposed assessment would bound offsite release severe accidents associated with FCA, nuclear material and waste storage facilities which would not strictly be required for assessment against the ENSREG's specification. DSRL's August 2011 submission therefore constitutes a progress report for the totality of NPP and non NPP aspects of site operations. Recognising the scale of facilities and operations on the site compared to other larger and more complex non NPP sites, ONR considers DSRL's approach to have been proportionate and pragmatic.

Springfields Fuels Ltd

100 SFL has submitted a brief progress report (Ref. 10) to ONR detailing its approach to stress tests currently being applied to the Springfields site. The licensee does not consider "loss of ultimate heat sink" to be relevant to its site operations, but its scope does incorporate earthquake and flooding scenarios. Reviews of the extant safety cases for assessment of reasonably beyond design basis events constitute the licensee's approach, which ONR considers proportionate for the scale of operations and hazards posed by site operations.

Imperial College of Science, Technology and Medicine

101 ICSTM has submitted a report that details progress of its assessment to date (Ref. 11), and proposed enhancements that require further consideration.

102 The CONSORT reactor was not designed with specific engineering safeguards to protect the reactor core and cooling system in the event of a design basis earthquake. However, an analysis of the potential seismic consequences to the Reactor Hall building, undertaken as part of the stress test review, assesses potential for damage to the reactor and associated equipment from building structural failure. This review has provided the licensee with confidence that such a seismic event would not credibly lead to offsite consequences whilst fuel is in containment.

103 In addition to the analysis of loss of coolant and loss of power scenarios, ICSTM has planned to consider its emergency planning and training arrangements to be well established, and has reviewed communication infrastructure.

Urenco UK Ltd

104 Urenco UK Ltd's response (Ref. 12) details the confidence derived in its stress tests assessment to date, that events in Japan could not be replicated on the site. This confidence is based upon:

- Features of facility design that revert to a fail-safe state upon loss of power.
- Criticality safe by geometry vessels and engineering defence-in-depth.
- Containment providing the basis of passive safety measures.

105 The licensee refers to work carried out to date in reviewing and challenging key safety case and emergency response assumptions. Urenco UK Ltd has liaised with counterparts on the Sellafield Ltd (Capenhurst) and SFL licensed sites which ONR considers to be pragmatic, proportionate and effective collaboration for non NPP sites with hazards of lesser but similar scale. The licensee has consolidated these interactions through engagement with its wider parent body, Urenco Group.

106 ONR is satisfied with the progress made to date, in particular the collaborative approach being taken with other licensees.

Studsvik UK Ltd

107 Studsvik's short progress response (Ref. 13) confirms that work is underway to assess the site against relevant ENSREG requirements. The licensee states that the severe accident scenarios listed in the ENSREG requirement are predominantly aligned to NPPs. Accordingly, the licensee has focused its review on resilience to flooding and severe weather events. Tsunami is specifically excluded due to the region's topography. Seismic resilience is not required by the site's safety cases by virtue of the low hazard inventory.

Low Level Waste Repository Ltd

108 LLWR's progress statement (Ref. 14) refers to the preparation and delivery of the stress tests process by an external safety consultant. LLWR has also assembled an expert panel to include representatives from emergency planning, safety case and engineering functions. ONR considers that the assessment team and specialists drawn together for the purpose of this review is appropriate.

Research Sites Restoration Ltd

109 RSRL sites do not have any operating reactors, reactors containing nuclear fuel, materials requiring cooling or significant off-site risks from other decommissioning and waste management activities. As described in their progress report (Ref. 15), RSRL has undertaken a screening exercise through engagement with a multidisciplinary team; this has identified the following main areas for consideration through a HAZOP-style approach to assessment:

- Site utilities / infrastructure.
- Safety cases.
- Emergency arrangements.

110 RSRL has not identified any severe accident management scenarios associated with the low hazards presented by extant inventories and decommissioning activities; as such this was specifically excluded from further review. To date, the review has not revealed any significant concern or shortfall to protection and arrangements available to these sites.

GE Healthcare Ltd

111 GEHC has submitted a brief progress report (Ref. 16) to ONR presenting its approach to stress tests currently being applied to the GEHC sites. The licensee considers the ENSREG requirements for Grove and Maynard Centres. Given that the radioactive source term has been removed from Building at Harwell, GEHC considers that it does not present any potential hazards to justify the application of stress tests process. ONR judges that the licensee's approach is appropriate and proportionate.

Atomic Weapons Establishment

112 AWE has confirmed its commitment to undertake the stress tests process as stated in their progress report submitted to ONR (Ref. 17).

113 AWE has established a project team to manage and undertake the work to deliver the stress tests requirements. AWE states that they have established a suitable interpretation of the stress tests requirements to make them applicable to non NPP sites while maintaining the intent.

114 Work to date includes:

- Completed planning and definition phase for project delivery.
- Internal regulatory and oversight function engaged and delivery plan accepted.
- Completed the design and preparation of stress tests methodology with dry runs.
- Workshops to review and stress existing plant and arrangements with the aim of identifying weak points and cliff-edge effects during / after extreme external events and identifying possible options to increase robustness.
- Meetings with site asset management teams to review existing safety case information and other relevant information following the learning and experience of Fukushima.
- Benchmarking meetings with other licensees to ensure a consistent, industry led approach to post-Fukushima learning, which includes participation at the Safety Directors Forum (SDF) Fukushima sub-group.

Rolls-Royce Marine Power Operations Ltd

115 RRMPOL has confirmed its commitment to undertake the stress tests process as stated in their progress report submitted to ONR (Ref. 18). They have benchmarked their approach against other naval propulsion programme licensees and the civil nuclear power sector via the SDF Fukushima sub-group.

116 RRMPOL are in the process of carrying out a PR which is a comprehensive review of safety on the site to identify any further safety improvements. The PR typically includes review of:

- Existing sites safety cases.
- Key safety functions.
- Structures, systems and components required to support key safety function.
- Internal and external hazards.
- Emergency response capability.

117 The PR covers areas relevant to the stress tests requirement, however RRMPOL have commissioned a further review to deliver the stress tests final report by 31 December 2011.

BAE Systems Marine Ltd

118 BAESM has recently implemented recommendations from a previous PR and has commenced the next planned PR.

119 BAESM has confirmed its commitment to undertake the stress tests process as stated in their progress statement submitted to ONR (Ref. 19).

120 BAESM state that they have completed an initial review of the main areas in the stress tests technical scope. They have benchmarked their approach against other naval propulsion programme licensees and the civil nuclear power sector via the SDF Fukushima sub-group.

Devonport Royal Dockyard Ltd

121 DRDL has confirmed its commitment to undertake the stress tests process as stated in their progress report submitted to ONR (Ref. 20).

122 The stress tests assessment is being undertaken jointly by DRDL and HM Naval Base Devonport. A joint project team has been established to manage and undertake the assessment and production of the final report. The project team is assisted by technical and design authorities, facility operators, the accident response organisation and other specialists as required.

123 DRDL have participated fully at the SDF Fukushima sub-group to share the learning, experience and knowledge with other UK nuclear site licensees.

124 DRDL report that the stress tests assessment is nearing completion and are presently compiling the output to populate the final report. The assessment process included the following key areas:

- Review of existing site safety cases and the substantiated design basis.
- Identification of key safety functions.
- Identification of SSC required to support key safety functions.
- Definition of the approach for considering increasing hazard magnitudes.

- Understanding of SSC behaviour in the event of extreme natural hazards and other identified events.
- Understanding of plant behaviour in the event of extreme natural hazards and other identified events.
- Identification of available or potential resilience measures in the event of extreme natural hazards and other identified events.
- Identification of the response to extreme natural hazards required both from the plant, facility and organisation.
- Consideration of the available and required severe accident responses to the scenarios identified.
- Collation and management of the information gathered during assessment for further consideration and development.

Rosyth Royal Dockyard Ltd

125 RRDL has confirmed its commitment to undertake the stress tests process as stated in their progress report submitted to ONR (Ref. 21).

126 RRDL state that, to date, the review has not identified any "cliff-edge" effect in the failure modes of the nuclear facility.

Magnox Ltd

127 Magnox confirmed their commitment to undertake the stress tests process by letter in June 2011 and issued their progress report in August 2011 (Ref. 22).

128 Magnox set up a project team to deliver the stress tests work in a timely and consistent manner across its various sites. The organisation initiated a Project Implementation Board to oversee the work and a small central project team to ensure timely and consistent delivery of information and assessment from the site-based teams. Each site has a core team including a member from the site-based safety case development team, along with mechanical and control and instrumentation engineers and a member of the operations team.

129 The process for the stress tests is aligned with the LC15 arrangements for a periodic review of safety. This enables the inclusion of the normal internal regulatory and oversight processes including the Nuclear Safety Committee (NSC) and the environmental, health, safety, security and quality function.

130 Workshops to review the options to improve resilience have been held starting with the highest hazard sites – the operating reactors (the subject of the separate NPP report) – then moving on to fuel storage in ponds and other defuelling facilities, before finishing on the defuelled sites.

131 Magnox has recognised the interaction between the stress tests and HM Chief Inspector of Nuclear Installations' report recommendation activities and has developed a series of workstreams to deliver useful outputs for both. Key workstreams set up to help deliver the stress tests assessment include:

- Seismic qualification.
- Impact of natural hazards.
- Fuel pond design.

- Off-site electrical supplies.
- On-site electrical supplies.
- Cooling supplies – to reactors.
- Cooling supplies and pondwater make-up.
- Combustible gases.
- Off-site infrastructure resilience.
- Emergency control centres and available control and instrumentation.
- Human capacities and capabilities.

132 Magnox is working with Sellafield Ltd and with EDF Energy Nuclear Generation Ltd (EDF NGL); it has also extended local working arrangements at sites which they share with EDF NGL, such as Sizewell, Dungeness, Hunterston and Hinkley Point. A particular focus has been provided by the SDF, a cross-nuclear industry group.

133 Magnox completed their initial stress tests activities with the issue of reports on the 31 October 2011. These included the reports for the defuelled sites as well as the operating and defuelling sites.

NNB GenCo

134 NNB GenCo confirmed their commitment to undertake the stress tests process by letter in June 2011 and issued their progress report in August 2011 (Ref. 23).

135 NNB GenCo is not required to fully respond to the stress tests programme at this stage as they have only recently submitted a licence application and their proposed plant at Hinkley Point C is not yet under construction. Nevertheless, they have chosen to provide a full submission. This is in order to introduce lessons from the Fukushima events as early as possible into the design stage.

136 NNB GenCo set up a project team to review the lessons. This includes input from the architect engineer and from EDF and AREVA, who as the reactor vendor and Requesting Parties will also perform post-Fukushima reviews as part of the GDA. NNB GenCo is also working closely with EDF NGL to ensure they learn from the wider group and to ensure consistency with submissions from the adjacent site (Hinkley Point B) and from the UK's operating PWR at Sizewell B.

137 The NNB GenCo team is directed by a steering committee, and led by a project manager from the NNB GenCo organisation. There is input from the EDF architect engineering function, with a review and approval system developed which incorporates the UK Design Authority, the Design Assurance Co-ordination Committee, the Operational Control Committee and the NSC.

138 NNB GenCo reports they have held a series of design review meetings for Hinkley Point C – building on those held for the Flamanville 3 design in France. The design review process forms the principal work activity.

ONR Progress

139 ONR has engaged with the licensees as they have developed their response to HM Chief Inspector of Nuclear Installations' interim and final reports and to the stress tests for NPPs. The main licensees' responses to the IR recommendations have been reviewed and assessed by ONR specialists through desk based assessment and technical meetings with licensees.

140 ONR is monitoring progress with the work for HM Chief Inspector of Nuclear Installations' reports and stress tests, via a series of weekly teleconferences and several larger technical meetings. The industry's responses to HM Chief Inspector of Nuclear Installations' report have been led to a large extent by the SDF in the UK. ONR attendees at that forum have reported a positive commitment from all licensees to respond to HM Chief Inspector of Nuclear Installations' report and to the stress tests requirements.

141 ONR is aware of the resources committed by the civil non NPP sites in responding to the events of Fukushima and consider the responses to date have been appropriate and well considered, as well as timely. The resources applied appear to be sufficient and of a suitable standard using recognised specialists where and when appropriate.

142 ONR has engaged with the defence licensees during routine regulatory business at both the corporate and local level to derive sufficient confidence that their approach to stress tests is appropriate and proportionate.

143 The engagement with Magnox during the period when the station-specific reports for EC stress tests were in preparation included a series of technical exchange meetings to review the planned work and likely outcomes, to ensure Magnox was progressing in an appropriate manner and to reduce the risk of the submitted reports reflecting insufficient work on specific topics.

144 ONR also undertook some specific additional inspections of the Magnox site-based activities, including seismic walkdowns and reviews of potential improvements and modifications to ensure their routes and layouts are secure and diverse. ONR also inspected some of the optioneering meetings to review the process for developing options to improve resilience and defence-in-depth.

PLANNED WORK TO COMPLETE FINAL NATIONAL REPORT

Licensees' Planned Work

145 In their submissions for the stress tests progress report, all of the UK non NPP licensees have provided an indication of their plans for future work to complete the stress tests review of each site and to identify potential improvements which could arise.

Sellafield Ltd (Sellafield and Windscale)

146 Sellafield Ltd will continue to progress its programme of RESEP reviews and plans to complete their programme of reviews prior to the submission of their next report by 31 December 2011. It is envisaged that Sellafield will produce a further progress / final report during summer 2012.

Sellafield Ltd (Capenhurst)

147 Sellafield Ltd details the corporate resilience programme initiated following events in Japan and co-ordinated by the management team at the Sellafield site. The licensee has provided a clearly defined work breakdown structure that, while aimed at reviewing the much more significant hazard posed by inventories and operations at Sellafield, accommodates the envelope of Sellafield Capenhurst.

148 ONR is satisfied that Sellafield Ltd's inclusion of Capenhurst within its corporate resilience programme is appropriate, and is further satisfied that sufficient progress is being made towards delivery of a final submission by 31 December 2011.

Dounreay Site Restoration Ltd

149 DSRL has submitted to ONR its final stress tests report (Ref. 24) pursuant to meeting the requirements of ENSREG for NPPs on 31 October 2011. DSRL has embodied the assessment of aspects of site operations and facilities that do not meet ENSREG definition for NPPs within its final report, focusing on REPPIR significant events; these non NPP facilities comprise the FCA and other facilities that treat or store nuclear material and waste. ONR's national progress report published on 15 September 2011 considered DSRL's progress report to be positive and proportionate to the level of risks posed by remaining inventories and decommissioning activities.

Springfields Fuels Ltd

150 ONR has engaged with the licensee during routine regulatory business to derive sufficient confidence that SFL's approach to stress tests is appropriate and proportionate. ONR inspectors continue to monitor SFL's progress through such interactions.

Imperial College of Science, Technology and Medicine

151 ICSTM notes its intention to review arrangements for provision of back-up equipment. ONR considers this approach to be proportionate and appropriate. ICSTM further notes a review being undertaken against capability to sustain response to a prolonged incident.

Urenco UK Ltd

152 Urenco UK Ltd's response details the scope of further work needed to complete the stress tests by 31 December 2011. The licensee continues to liaise with other licensees to ensure a consistent but proportionate response to ENSREG requirements. The licensee notes its intention to develop its initial reviews to date to specifically challenge assumptions for cliff-edge effects associated with seismic, flooding, loss of power and severe accident management scenarios. ONR is satisfied with the licensee's proposed plan and is confident, based on routine engagements to date, that a final report will be delivered before 31 December 2011.

Studsvik UK Ltd

153 Studsvik's metal recycling facility does not have, nor does it require off-site emergency arrangements, but ONR welcomes the licensee's ongoing review of arrangements for on-site emergency conditions. ONR is satisfied with the approach taken to date and has no concerns in regard to delivery of a final report before 31 December 2011.

Low Level Waste Repository Ltd

154 At the time of writing, LLWR has submitted its final stress tests report (Ref. 25) in response to ENSREG's specifications. ONR will assess this submission formally as part of the wider assessment of non NPP final submissions. Nevertheless, initial examination of the response provides ONR with confidence that the licensee has undertaken an appropriate review of proportionate scope that meets the expectations of ENSREG.

Research Sites Restoration Ltd

155 RSRL has commissioned a study group to address recommendations for further action derived from the HAZOP review. These will be considered within an ALARP review, and where necessary incorporated into an implementation plan. The outcome of the study will be provided by the licensee in its final report in December 2011. ONR is satisfied with the review undertaken to date and the proposed way forward to implement improvements.

GE Healthcare Ltd

156 ONR inspectors continue to monitor GEHC's progress to its final stress tests report via technical meetings to derive sufficient confidence that GEHC's stress tests process is applied in accordance with the licensee's proposal and reported in a comprehensive manner. ONR has no concerns in regard to delivery of a final report by 31 December 2011.

Atomic Weapons Establishment

157 AWE has confirmed its commitment to complete the stress tests process by the 31 December 2011 as stated in their progress report submitted to ONR (Ref. 17).

158 To complete the stress tests AWE plan to:

- Continue to complete planned workshops and meetings with site asset management teams. Following this, analysis of the findings will be conducted comparing the findings with expectations with the stress tests specification. Any possible options for improvement will be carried forward to a later decision-making process and appropriate actions taken.

- Produce a single internally verified stress tests report by the project team for both licensed sites.

Rolls-Royce Marine Power Operations Ltd

159 RRMPOL has confirmed its commitment to complete the stress tests process by 31 December 2011 as stated in their progress report submitted to ONR (Ref. 18).

160 The PR being conducted by RRMPOL covers areas relevant to the stress tests requirements. However RRMPOL has commissioned a further review to deliver the stress tests final report by 31 December 2011.

BAE Systems Marine Ltd

161 BAESM has confirmed its commitment to undertake the stress tests process as stated in their progress statement (Ref. 19).

162 Preliminary analysis has been undertaken on four key scenarios, which will be concluded through more detailed studies for the stress tests final report.

Devonport Royal Dockyard Ltd

163 DRDL has confirmed its commitment to complete the stress tests process by 31 December 2011 as stated in their progress report submitted to ONR (Ref. 20).

164 As stated earlier, DRDL report that the stress tests assessment is nearing completion and they are presently compiling the output to populate the final stress tests report.

Rosyth Royal Dockyard Ltd

165 RRDL has confirmed its commitment to complete the stress tests process by 31 December 2011 as stated in their progress report submitted to ONR (Ref. 21).

166 The scope of the remaining planned work includes:

- A reassessment of the safety margins of the nuclear facility and its resilience to withstand all extreme hazardous events beyond the design basis, but particularly earthquake and tsunami as these are considered to be bounding hazards for the site at Rosyth.
- An assessment of the worst case radiological consequences arising from the release of radioactive material from its containment in the event of an extreme accident.
- A reassessment of the viability of the emergency plan to respond to such an accident in the event that the emergency facilities and services were similarly disrupted by common cause.

167 RRDL intend to identify, where practical, improvements to current arrangements to curtail the radiological consequences if events described above occur.

Magnox Ltd

168 As noted in earlier, Magnox completed their initial stress tests activities with the issue of reports on 31 October 2011. These included the reports for the defuelled sites as well as the operating and defuelling sites.

NNB GenCo

169 NNB GenCo have completed their initial stress tests planned activities and have prepared a draft report which is currently being reviewed and approved prior to issue to ONR.

170 NNB GenCo were originally planning to submit their report at the same time as the EDF NGL reports for operating sites in the UK. With ONR's agreement, this plan was held back for a month to allow further consideration of the NNB GenCo response in line with the wider EDF group (Ref. 26).

ONR Planned Work

171 Monthly progress review meetings are being held between ONR and Sellafield Ltd. In addition, ONR specialist inspectors are engaged with Sellafield Ltd to discuss the emerging findings of the RESEP reviews.

172 ONR has engaged with Sellafield Ltd and Urenco UK Ltd about their Capenhurst sites during routine regulatory business to derive sufficient confidence that its approach to stress tests is appropriate and proportionate. ONR site inspectors for the Sellafield and Capenhurst sites continue to monitor progress both at the corporate level and locally at Capenhurst.

173 ONR's review of DSRL's assessment for NPP and non NPP facilities will be provided within the separate EC stress tests and non NPP national reports respectively. Inspectors continue to engage with the licensee during routine site inspections to secure confidence that sufficient but proportionate progress is being made. This is supported by inspections of higher hazard facilities across the site.

174 ONR has engaged with SFL during routine regulatory business to derive sufficient confidence that its approach to stress tests is appropriate and proportionate. ONR inspectors continue to monitor SFL's progress through such interactions.

175 ONR continues to monitor progress being made by defence licensees, Studsvik UK Ltd, RSRL sites, ICSTM and GEHC as part of routine regulatory business ahead of delivery of a final submission from each licensee.

176 ONR assessment resource has been assigned to align with the delivery of the licensees submissions and assessment will commence in January 2012.

177 ONR has weekly progress meetings via teleconference with Magnox Ltd. Additional reviews take place via senior level interactions between the licensees and ONR staff.

178 ONR has weekly progress meetings via teleconference with EDF NGL and NNB GenCo. Additional reviews take place via senior level interactions between the licensees and ONR staff.

EXPECTED OUTCOMES AND SAFETY IMPROVEMENTS

Sellafield Ltd (Sellafield and Windscale)

179 The licensee anticipates that potential enhancements will be identified from the RESEP review process and other workstreams currently being undertaken by the Sellafield Ltd resilience project team. The identified enhancements will be reviewed by the Sellafield Ltd NSC through established processes, and the enhancements considered reasonably practicable will be implemented as part of the next phase of the Sellafield site resilience programme which will commence in 2012.

Sellafield Ltd (Capenhurst)

180 Sellafield Ltd's response states that the Capenhurst site currently presents a low hazard and therefore the scope for enhancements will potentially be limited. ONR agrees with Sellafield's proposal that only those enhancements that are considered reasonably practicable should be implemented, and welcomes the licensee's pragmatic interaction with Urenco UK Ltd on this matter.

Dounreay Site Restoration Ltd

181 A number of opportunities for resilience enhancements to improve the overall robustness of the DSRL's capability to withstand flooding events have been identified. DSRL has committed to undertake a full ALARP review prior to implementation.

Springfields Fuels Ltd

182 SFL has yet to identify the extent of any safety improvements at the time of writing, subject to its ongoing assessment process.

Imperial College of Science, Technology and Medicine

183 ICSTM notes its intention to review arrangements for provision of diesel-powered portable power supplies to better manage a loss of power supply lasting more than 24 hours. ONR considers this approach to be proportionate and positive, demonstrating the importance of sustained monitoring and surveillance capability in the event of a severe accident. ICSTM review being undertaken against capability to sustain a response to a prolonged incident could provide some other potential enhancements.

184 ONR considers ICSTM's progress towards an assessment pursuant to ENSREG's specifications to be appropriate. Further clarification is expected from the licensee regarding seismic resilience to beyond design basis / domino effects ahead of submission of a final report.

Urenco UK Ltd

185 Urenco UK has yet to identify the extent of any safety improvements at the time of writing, subject to its ongoing assessment process. The licensee has, however, clarified that a major component of its focus is on the management of severe accidents, in which the licensee intends to review the potential effect of widespread disruption, as well as the need for additional training or greater redundancy of resources to ensure continuity of response. ONR considers that severe accident

management and associated preparedness is the more significant area of focus for Urenco UK Ltd in recognising the lesser magnitude and scale of hazards associated with its operations.

Studsvik UK Ltd

186 Studsvik's review to date has not revealed any requirements for changes to plant design, layout, operational or management requirements.

Low Level Waste Repository Ltd

187 Initial examination of the licensee's final submission provides ONR with confidence that the licensee has undertaken an appropriate review of proportionate scope that meets the expectations of ENSREG. ONR has yet to examine or discuss with the licensee any planned improvements or changes to the site emanating from this review.

Research Sites Restoration Ltd

188 RSRL has not specified in its progress report any individual improvements. ONR is nonetheless satisfied with the progress made to date and is encouraged that the licensee is in a relatively advanced stage in its stress tests process.

GE Healthcare Ltd

189 The progress report transmitted by the licensee indicates that the stress tests process may not identify many safety improvements due to the geographic location of the centres, reducing the impact of flooding and the nature of the radioactive matters in place which does not need any active cooling.

Defence Licensees

190 The defence licensees, AWE, RRMPOL, BAESM DRDL and RRDL, at the time of writing, continue with the stress tests process in order to identify potential safety improvements.

Magnox Ltd

191 The exact nature of modifications and additional equipment to further improve resilience where reasonably practicable has not yet been fully developed for any of the sites.

192 Simple improvements being considered by Magnox include increasing the dispersal and number of storage locations for essential drawings and information. Magnox is also reviewing the location and contents of its emergency control centres, and the resilience of off-site communications.

193 Magnox also intends to review its site-based vehicles such as mobile cranes, telehandlers, access vehicles etc. to ensure its equipment is suitable to support and provide access to the site following a variety of challenging natural hazards.

NNB GenCo

194 The exact nature of modifications and additional equipment to further improve resilience where reasonably practicable has not yet been fully developed.

195 NNB GenCo has indicated that reviews of resilience of strategic stocks, such as diesel fuel, the life of battery-backed uninterruptible power supplies and coolant supplies are in hand. They note that key items of work to review alternative means of water injection and the potential provision of a containment venting system are also ongoing. Site-specific plant design and layout changes are also being considered to improve potential resilience and give room for future design evolution should these be needed.

SUMMARY AND CONCLUSIONS

196 The damage from the Tohuku earthquake and tsunami has been extremely challenging for the people of Japan. The subsequent damage to the reactors at Fukushima-1 created further difficulties. Much has been learnt from the events at Fukushima already; more will come in the future. A wide variety of international and national responses have resulted in ensuring nuclear installations have been reviewed in the light of these events and have improved their resilience as appropriate.

197 HM Chief Inspector of Nuclear Installations requested that the stress tests process be applied to all nuclear licensed installations in the UK which are not in the EC stress tests scope. This progress report confirms that the UK nuclear site licensees have all initiated programmes of work to address the stress tests topics and have made satisfactory progress to date.

198 Non NPPs represent a significant diversity of licensees, facilities and activities, which is reflected in this progress report. Due to the diverse nature of potential hazards and the number and size of facilities, ONR might agree on a case-by-case basis that some licensees complete and provide their final reports later than expected.

199 To date, none of the review work by the licensees for the stress tests – or from earlier national reviews – has indicated any fundamental weaknesses in the definition of design basis events, or the safety systems to withstand them for UK non NPPs. However, lessons are being learnt about improving resilience for beyond design basis events and removing or reducing cliff-edge effects – and these will be applied in a timely manner where reasonably practicable.

ANNEX 1: FULL ENSREG REQUIREMENTS

Reproduced verbatim of the specification document.

EU "Stress tests" Specifications

Introduction

Considering the accident at the Fukushima nuclear power plant in Japan, the EC of March 24th and 25th declared that "the safety of all EU nuclear plants should be *reviewed, on the basis of a comprehensive and transparent risk assessment ("stress tests"); the European Nuclear Safety Regulatory Group (ENSREG) and the Commission are invited to develop as soon as possible the scope and modalities of these tests in a coordinated framework in the light of the lessons learned from the accident in Japan and with the full involvement of Member States, making full use of available expertise (notably from the Western European Nuclear Regulators Association); the assessments will be conducted by independent national authorities and through peer review; their outcome and any necessary subsequent measures that will be taken should be shared with the Commission and within ENSREG and should be made public; the European Council will assess initial findings by the end of 2011, on the basis of a report from the Commission*".

On the basis of the proposals made by WENRA at their plenary meeting on the 12-13 of May, the European Commission and ENSREG members decided to agree upon "an initial independent regulatory technical definition of a "stress tests" and how it should be applied to nuclear facilities across Europe". This is the purpose of this document.

Definition of the "stress tests"

For now we define a "stress tests" as a targeted reassessment of the safety margins of nuclear power plants in the light of the events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident.

This reassessment will consist:

– In an evaluation of the response of a nuclear power plant when facing a set of extreme situations envisaged under the following section "technical scope" and

– In a verification of the preventive and mitigative measures chosen following a defence-in-depth logic: initiating events, consequential loss of safety functions, severe accident management.

In these extreme situations, sequential loss of the lines of defence is assumed, in a deterministic approach, irrespective of the probability of this loss. In particular, it has to be kept in mind that loss of safety functions and severe accident situations can occur only when several design provisions have failed. In addition, measures to manage these situations will be supposed to be progressively defeated.

For a given plant, the reassessment will report on the response of the plant and on the effectiveness of the preventive measures, noting any potential weak point and cliff-edge effect, for each of the considered extreme situations. A cliff-edge effect could be, for instance, exceeding a point where significant flooding of plant area starts after water overtopping a protection dike or exhaustion of the capacity of the batteries in the event of a station blackout. This is to evaluate the robustness of the defence-in-depth approach, the adequacy of current accident management measures and to identify the potential for safety improvements,

both technical and organisational (such as procedures, human resources, emergency response organisation or use of external resources).

By their nature, the stress tests will tend to focus on measures that could be taken after a postulated loss of the safety systems that are installed to provide protection against accidents considered in the design. Adequate performance of those systems has been assessed in connection with plant licensing. Assumptions concerning their performance are re-assessed in the stress tests and they should be shown as provisions in place. It is recognised that all measures taken to protect reactor core or spent fuel integrity or to protect the reactor containment integrity constitute an essential part of the defence-in-depth, as it is always better to prevent accidents from happening than to deal with the consequences of an occurred accident.

Process to perform the "stress tests" and their dissemination

The licensees have the prime responsibility for safety. Hence, it is up to the licensees to perform the reassessments, and to the regulatory bodies to independently review them.

The timeframe is as follows:

The national regulator will initiate the process at the latest on June 1 by sending requirements to the licensees.

	Progress report	**Final report**
Licensee report	August 15	October 31
National report	September 15	December 31

– The final national reports will be subjected to the peer review process described below.

– The European Commission, with the support of ENSREG, will present a progress report to the EU Council for the meeting scheduled on 9th December 2011 and a consolidated report to the EU Council for the meeting scheduled for June 2012.

Due to the timeframe of the stress tests process, some of the engineering studies supporting the licensees' assessment may not be available for scenarios not included in the current design. In such cases engineering judgment is used.

During the regulatory reviews, interactions between European regulators will be necessary and could be managed through ENSREG. Regulatory reviews should be peer reviewed by other regulators. ENSREG will put at the disposal of all peer reviews the expertise necessary to ensure consistency of peer reviews across the EU and its neighbours.

Peer review process

In order to enhance credibility and accountability of the process the EU Council asked that the national reports should be subjected to a peer review process. The main purpose of the national reports will be to draw conclusions from the licensees' assessment using the agreed methodology. The peer teams will review the fourteen national reports of Member States that presently operate nuclear power plants and of those neighbouring countries that accept to be part of the process.

– **Team composition.** ENSREG and the Commission shall agree on team composition. The team should be kept to a working size of seven people, one of whom should act as a chairperson and a

second one as rapporteur. Two members of each team will be permanent members with the task to ensure overall consistency. The Commission will be part of the team. Members of the team whose national facilities are under review will not be part of that specific review. The country subject to review has to agree on the team composition. The team may be extended to experts from third countries.

- **Methodology.** In order to guarantee the rigor and the objectivity of any peer review, the national regulator under review should give the peer review team access to all necessary information, subject to the required security clearance procedures, staff and facilities to enable the team, within the limited time available.
- **Timing.** Reviews should start immediately when final national reports become available. The peer reviews shall be completed by the end of April 2012.

Transparency

National regulatory authorities shall be guided by the "principles for openness and transparency" as adopted by ENSREG in February 2011. These principles shall also apply to the EU "stress tests".

The reports should be made available to the public in accordance with national legislation and international obligations, provided that this does not jeopardize other interests such as, inter alia, security, recognized in national legislation or international obligations.

The peer will review the conclusions of each national report and its compliance with the methodology agreed. Results of peer reviews will be made public.

Results of the reviews should be discussed both in national and European public seminars, to which other stakeholders (from non nuclear field, from non governmental organizations, etc) would be invited.

Full transparency but also an opportunity for public involvement will contribute to the EU "stress tests" being acknowledged by European citizens.

Technical scope of the “stress tests”

The existing safety analysis for nuclear power plants in European countries covers a large variety of situations. The technical scope of the stress tests has been defined considering the issues that have been highlighted by the events that occurred at Fukushima, including combination of initiating events and failures. The focus will be placed on the following issues:

a) Initiating events

- Earthquake
- Flooding

b) Consequence of loss of safety functions from any initiating event conceivable at the plant site

- Loss of electrical power, including Station Blackout (SBO)
- Loss of the ultimate heat sink (UHS)
- Combination of both

c) Severe accident management issues

- Means to protect from and to manage loss of core cooling function
- Means to protect from and to manage loss of cooling function in the fuel storage pool
- Means to protect from and to manage loss of containment integrity

b) and c) are not limited to earthquake and tsunami as in Fukushima: flooding will be included regardless of its origin. Furthermore, bad weather conditions will be added.

Furthermore, the assessment of consequences of loss of safety functions is relevant also if the situation is provoked by indirect initiating events, for instance large disturbance from the electrical power grid impacting AC power distribution systems or forest fire, airplane crash.

The review of the severe accident management issues focuses on the licensee's provisions but it may also comprise relevant planned off-site support for maintaining the safety functions of the plant. Although the experience feedback from the Fukushima accident may include the emergency preparedness measures managed by the relevant off-site services for public protection (fire-fighters, police, health services….), this topic is out of the scope of these stress tests.

The next sections of this document set out:

- General information required from the licensees;
- Issues to be considered by the licensees for each considered extreme situation.

General aspects

Format of the report

The licensee shall provide one document for each site, even if there are several units on the same site. Sites where all NPPs are definitively shutdown but where spent fuel storages are still in operation shall also be considered.

In a first part, the site characteristics shall be briefly described:

- location (sea, river);
- number of units;
- license holder

The main characteristics of each unit shall be reflected, in particular:

- reactor type;
- thermal power;
- date of first criticality;
- presence of spent fuel storage (or shared storage).

Safety significant differences between units shall be highlighted.

The scope and main results of Probabilistic Safety Assessments shall be provided.

In a second part, each extreme situation shall be assessed following the indications given below.

Hypothesis

For existing plants, the reassessments shall refer to the plant as it is currently built and operated on June 30, 2011. For plants under construction, the reassessments shall refer to the licensed design.

The approach should be essentially deterministic: when analysing an extreme scenario, a progressive approach shall be followed, in which protective measures are sequentially assumed to be defeated.

The plant conditions should represent the most unfavourable operational states that are permitted under plant technical specifications (limited conditions for operations). All operational states should be considered. For severe accident scenarios, consideration of non-classified equipment as well as realistic assessment is possible.

All reactors and spent fuel storages shall be supposed to be affected at the same time.

Possibility of degraded conditions of the site surrounding area shall be taken into account.

Consideration should be given to:

- automatic actions;
- operators actions specified in emergency operating procedures;
- any other planned measures of prevention, recovery and mitigation of accidents;

Information to be included

Three main aspects need to be reported:

- Provisions taken in the design basis of the plant and plant conformance to its design requirements.
- Robustness of the plant beyond its design basis. For this purpose, the robustness (available design margins, diversity, redundancy, structural protection, physical separation, etc) of the safety-relevant systems, structures and components and the effectiveness of the defence-in-depth concept have to be assessed. Regarding the robustness of the installations and measures, one focus of the review is on identification of a step change in the event sequence (cliff-edge effect1) and, if necessary, consideration of measures for its avoidance.

Any potential for modifications likely to improve the considered level of defence-in-depth, in terms of improving the resistance of components or of strengthening the independence with other levels of defence.

In addition, the licensee may wish to describe protective measures aimed at avoiding the extreme scenarios that are envisaged in the stress tests in order to provide context for the stress tests. The analysis should be complemented, where necessary, by results of dedicated plant walk down.

To this aim, the licensee shall identify:

- The means to maintain the three fundamental safety functions (control of reactivity, fuel cooling, confinement of radioactivity) and support functions (power supply, cooling through ultimate heat sink), taking into account the probable damage done by the initiating event and any means not credited in the safety demonstration for plant licensing.
- Possibility of mobile external means and the conditions of their use.

[1] Example : exhaustion of the capacity of the batteries in the event of a station blackout

- Any existing procedure to use means from one reactor to help another reactor.
- Dependence of one reactor on the functions of other reactors on the same site.

As for severe accident management, the licensee shall identify, where relevant:

- The time before damage to the fuel becomes unavoidable. For PWR and BWR, if the core is in the reactor vessel, indicate time before water level reaches the top of the core, and time before fuel degradation (fast cladding oxidation with hydrogen production)
- If the fuel is in the spent fuel pool, the time before pool boiling, time up to when adequate shielding against radiation is maintained, time before water level reaches the top of the fuel elements, time before fuel degradation starts;

Supporting documentation

Documents referenced by the licensee shall be characterised either as:

- Validated in the licensing process.
- Not validated in the licensing process but gone through licensee's quality assurance program.
- Not one of the above.

Earthquake

I. Design basis

a) Earthquake against which the plant is designed:

- Level of the design basis earthquake (DBE) expressed in terms of peak ground acceleration (PGA) and reasons for the choice. Also indicate the DBE taken into account in the original licensing basis if different.
- Methodology to evaluate the DBE (return period, past events considered and reasons for choice, margins added…), validity of data in time.
- Conclusion on the adequacy of the design basis.

b) Provisions to protect the plant against the DBE

- Identification of the key structures, systems and components (SSCs) which are needed for achieving safe shutdown state and are supposed to remain available after the earthquake.
- Main operating provisions (including emergency operating procedure, mobile equipment…) to prevent reactor core or spent fuel damage after the earthquake.
- Were indirect effects of the earthquake taken into account, including:

  1. Failure of SSCs that are not designed to withstand the DBE and that, in loosing their integrity could cause a consequential damage of SSCs that need to remain available (e.g. leaks or ruptures of non seismic pipework on the site or in the buildings as sources of flooding and their potential consequences);
  2. Loss of external power supply;
  3. Situation outside the plant, including preventing or delaying access of personnel and equipment to the site.

c) Plant compliance with its current licensing basis:

- Licensee's general process to ensure compliance (e.g. , periodic maintenance, inspections, testing).

- Licensee' process to ensure that off-site mobile equipment/supplies considered in emergency procedures are available and remain fit for duty.
- Any known deviation, and consequences of these deviations in terms of safety; planning of remediation actions.
- Specific compliance check already initiated by the licensee following Fukushima NPP accident.

II. Evaluation of the margins

d) Based on available information (which could include seismic PSA, seismic margin assessment or other seismic engineering studies to support engineering judgement), give an evaluation of the range of earthquake severity above which loss of fundamental safety functions or severe damage to the fuel (in vessel or in fuel storage) becomes unavoidable.
   - Indicate which are the weak points and specify any cliff edge effects according to earthquake severity.
   - Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

e) Based on available information (which could include seismic PSA, seismic margin assessment or other seismic engineering studies to support engineering judgement), what is the range of earthquake severity the plant can withstand without losing confinement integrity.

f) Earthquake exceeding DBE and consequent flooding exceeding DBF
   - Indicate whether, taking into account plant location and plant design, such situation can be physically possible. To this aim, identify in particular if severe damages to structures that are outside or inside the plant (such as dams, dikes, plant buildings and structures) could have an impact of plant safety.
   - Indicate which are the weak points and failure modes leading to unsafe plant conditions and specify any cliff edge effects. Identify which buildings and equipment will be impacted.
   - Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

Flooding

I. Design basis

a) Flooding against which the plant is designed:
   - Level of the design basis flood (DBF) and reasons for choice. Also indicate the DBF taken into account in the original licensing basis if different;
   - Methodology to evaluate the DBF (return period, past events considered and reasons for choice, margins added…). Sources of flooding (tsunami, tidal, storm surge, breaking of dam…), validity of data in time;
   - Conclusion on the adequacy of the design basis.

b) Provisions to protect the plant against the DBF
   - Identification of the key SSCs which are needed for achieving safe shutdown state and are supposed to remain available after the flooding, including:

- Provisions to maintain the water intake function.
- Provisions to maintain emergency electrical power supply.

– Identification of the main design provisions to protect the site against flooding (platform level, dike…) and the associated surveillance programme if any.
– Main operating provisions (including emergency operating procedure, mobile equipment, flood monitoring, alerting systems…) to warn of, then to mitigate the effects of the flooding, and the associated surveillance programme if any.
– Were other effects linked to the flooding itself or to the phenomena that originated the flooding (such as very bad weather conditions) taken into account, including:
  - Loss of external power supply.
  - Situation outside the plant, including preventing or delaying access of personnel and equipment to the site.

c) Plant compliance with its current licensing basis:
– Licensee's general process to ensure compliance (e.g., periodic maintenance, inspections, testing).
– Licensee's process to ensure that off-site mobile equipment/supplies considered in emergency procedures are available and remain fit for duty.
– Any known deviation and consequences of these deviations in terms of safety; planning of remediation actions.
– Specific compliance check already initiated by the licensee following Fukushima NPP accident.

II. Evaluation of the margins

d) Based on available information (including engineering studies to support engineering judgement), what is the level of flooding that the plant can withstand without severe damage to the fuel (core or fuel storage)?
– Depending on the time between warning and flooding, indicate whether additional protective measures can be envisaged / implemented.
– Indicate which are the weak points and specify any cliff edge effects. Identify which buildings and which equipment will be flooded first.
– Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

Loss of electrical power and loss of the ultimate heat sink

Electrical AC power sources are:

- off-site power sources (electrical grid);
- plant generator;
- ordinary back-up generators (diesel generator, gas turbine…);
- in some cases other diverse back-up sources.

Sequential loss of these sources has to be considered (see a) and b) below).

The ultimate heat sink (UHS) is a medium to which the residual heat from the reactor is transferred. In some cases, the plant has the primary UHS, such as the sea or a river, which is supplemented by an alternate UHS, for example a lake, a water table or the atmosphere. Sequential loss of these sinks has to be considered (see c) below).

a) Loss of off-site power (LOOP[2])
   - Describe how this situation is taken into account in the design and describe which internal backup power sources are designed to cope with this situation.
   - Indicate for how long the on-site power sources can operate without any external support.
   - Specify which provisions are needed to prolong the time of on-site power supply (refuelling of diesel generators…).
   - Indicate any envisaged provisions to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

For clarity, systems such as steam driven pumps, systems with stored energy in gas tanks etc. are considered to function as long as they are not dependent of the electric power sources assumed to be lost and if they are designed to withstand the initiating event (e.g. earthquake).

b) Loss of off-site power and of on-site backup power sources (SBO). Two situations have to be considered:
   - LOOP + Loss of the ordinary back-up source;
   - LOOP + Loss of the ordinary back-up sources + loss of any other diverse back- up sources.

For each of these situations:

- Provide information on the battery capacity and duration.
- Provide information on design provisions for these situations.
- Indicate for how long the site can withstand a SBO without any external support before severe damage to the fuel becomes unavoidable.
- Specify which (external) actions are foreseen to prevent fuel degradation:
  - equipment already present on site, e.g. equipment from another reactor;
  - assuming that all reactors on the same site are equally damaged, equipment
  - available off-site;
  - near-by power stations (e.g. hydropower, gas turbine) that can be aligned to provide power via a dedicated direct connection;
  - time necessary to have each of the above systems operating;
  - availability of competent human resources to make the exceptional connections;
  - identification of cliff edge effects and when they occur.
- Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

[2] All offsite electric power supply to the site is lost. The offsite power should be assumed to be lost for several days. The site is isolated from delivery of heavy material for 72 hours by road, rail or waterways. Portable light equipment can arrive to the site from other locations after the first 24 hours.

c) Loss of primary ultimate heat sink (UHS[3])
   - Provide a description of design provisions to prevent the loss of the UHS (e.g. various water intakes for primary UHS at different locations, use of alternative UHS, …)

Two situations have to be considered:
   - Loss of primary ultimate heat sink (UHS), i.e. access to water from the river or the sea;
   - Loss of primary ultimate heat sink (UHS) and the alternate UHS.

For each of these situations:
   - Indicate for how long the site can withstand the situation without any external support before damage to the fuel becomes unavoidable:
   - Provide information on design provisions for these situations.
   - Specify which external actions are foreseen to prevent fuel degradation:
      - equipment already present on site, e.g. equipment from another reactor;
      - assuming that all reactors on the same site are equally damaged, equipment available off-site;
      - time necessary to have these systems operating;
      - availability of competent human resources;
      - identification of cliff edge effects and when they occur.
   - Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

d) Loss of the primary UHS with SBO
   - Indicate for how long the site can withstand a loss of "main" UHS + SBO without any external support before severe damage to the fuel becomes unavoidable
   - Specify which external actions are foreseen to prevent fuel degradation:
      - equipment already present on site, e.g. equipment from another reactor;
      - assuming that all reactors on the same site are equally damaged, equipment available off site;
      - availability of human resources;
      - time necessary to have these systems operating;
      - identification of when the main cliff edge effects occur.
   - Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions…).

[3] The connection with the primary ultimate heat sink for all safety and non safety functions is lost. The site is isolated from delivery of heavy material for 72 hours by road, rail or waterways. Portable light equipment can arrive to the site from other locations after the first 24 hours.

Severe accident management

This chapter deals mostly with mitigation issues. Even if the probability of the event is very low, the means to protect containment from loads that could threaten its integrity should be assessed. Severe accident management, as forming the last line of defence-in-depth for the operator, should be consistent with the measures used for preventing the core damage and with the overall safety approach of the plant.

a) Describe the accident management measures currently in place at the various stages of a scenario of loss of the core cooling function:

- before occurrence of fuel damage in the reactor pressure vessel/a number of pressure tubes;
  - last resorts to prevent fuel damage
  - elimination of possibility for fuel damage in high pressure
- after occurrence of fuel damage in the reactor pressure vessel/a number of pressure tubes;
- after failure of the reactor pressure vessel/a number of pressure tubes.

b) Describe the accident management measures and plant design features for protecting integrity of the containment function after occurrence of fuel damage:

- prevention of H2 deflagration or H2 detonation (inerting, recombiners, or igniters), also taking into account venting processes;
- prevention of over-pressurization of the containment; if for the protection of the containment a release to the environment is needed, it should be assessed, whether this release needs to be filtered. In this case, availability of the means for estimation of the amount of radioactive material released into the environment should also be described;
- prevention of re-criticality;
- prevention of basemat melt through;
- need for and supply of electrical AC and DC power and compressed air to equipment used for protecting containment integrity.

c) Describe the accident management measures currently in place to mitigate the consequences of loss of containment integrity.

d) Describe the accident management measures currently in place at the various stages of a scenario of loss of cooling function in the fuel storage (the following indications relate to a fuel pool):

- before/after losing adequate shielding against radiation;
- before/after occurrence of uncover of the top of fuel in the fuel pool;
- before/after occurrence of fuel degradation (fast cladding oxidation with hydrogen production) in the fuel pool.

For a) b) c) and d), at each stage:

- identify any cliff edge effect and evaluate the time before it;
- assess the adequacy of the existing management measures, including the procedural guidance to cope with a severe accident, and evaluate the potential for additional measures. In particular, the licensee is asked to consider:
  - the suitability and availability of the required instrumentation;
  - the habitability and accessibility of the vital areas of the plant (the control room, emergency response facilities, local control and sampling points, repair possibilities);

- potential H2 accumulations in other buildings than containment ;

The following aspects have to be addressed:

- Organisation of the licensee to manage the situation, including:
  - staffing, resources and shift management;
  - use of off-site technical support for accident and protection management (and contingencies if this becomes unavailable);
  - procedures, training and exercises;
- Possibility to use existing equipment;
- Provisions to use mobile devices (availability of such devices, time to bring them on site and put them in operation, accessibility to site);
- Provisions for and management of supplies (fuel for diesel generators, water…);
- Management of radioactive releases, provisions to limit them;
  Management of workers' doses, provisions to limit them;
- Communication and information systems (internal, external).
  Long-term post-accident activities.

The envisaged accident management measures shall be evaluated considering what the situation could be on a site:

- Extensive destruction of infrastructure around the plant including the communication;
- Facilities (making technical and personnel support from outside more difficult);
- Impairment of work performance (including impact on the accessibility and habitability of the main and secondary control rooms, and the plant emergency/crisis centre) due to high local dose rates, radioactive;
- Contamination and destruction of some facilities on site;
- Feasibility and effectiveness of accident management measures under the conditions of external hazards (earthquakes, floods);
- Unavailability of power supply;
- Potential failure of instrumentation;
- Potential effects from the other neighbouring plants at site.

The licensee shall identify which conditions would prevent staff from working in the main or secondary control room as well as in the plant emergency/crisis centre and what measures could avoid such conditions to occur.

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While every effort has been made to ensure the accuracy of the references listed in this report, their future availability cannot be guaranteed.

GLOSSARY AND ABBREVIATIONS

AC	Alternating current
ALARP	As low as reasonably practicable
AREVA	AREVA NP SAS
AWE	Atomic Weapons Establishment
BAESM	BAE Systems Marine Ltd
Beyond design basis	In a beyond design basis event, the conditions are more severe than in a design basis event
Cliff-edge	A cliff-edge effect is a small change in a parameter that leads to a disproportionate increase in consequences
COBR	Cabinet Office Briefing Room
DBA	Design Basis Analysis
DBE	Design Basis Earthquake
DBF	Design Basis Flood
Design basis	The range of conditions and events that should be explicitly taken into account in the design of the facility, according to established criteria, such that the facility can withstand them without exceeding authorised limits by the planned operation of safety system.
DFR	Dounreay fast reactor
DMTR	Dounreay materials test reactor
DNSR	Defence Nuclear Safety Regulator
DRDL	Devonport Royal Dockyard Ltd
DSRL	Dounreay Site Restoration Ltd
EC	European Council
EDF NGL	EDF Energy Nuclear Generation Ltd
ENSREG	European Nuclear Safety Regulatory Group
FCA	Fuel cycle area
FR	Fukushima final report
GDA	Generic Design Assessment
GEHC	GE Healthcare Ltd
HAZOP	A hazard and operability analysis: it uses a method based on a structured and systematic examination of operations or of a process, in order to identify and evaluate potential problems
Horizon	Horizon Nuclear Power
HSE	Health and Safety Executive
HSWA74	Health and Safety at Work etc. Act 1974

GLOSSARY AND ABBREVIATIONS

IAEA	International Atomic Energy Agency
ICSTM	Imperial College of Science, Technology and Medicine
ILW	Intermediate level radioactive waste
INES	International Nuclear and Radiological Event Scale
IR	Fukushima interim report
LLW	Low level radioactive waste
LLWR	Low Level Waste Repository Ltd
LC	Licence Condition
Magnox	Magnox NPPs are a gas-cooled reactor design where the natural uranium (or slightly enriched in some cases) fuel is clad in magnesium.
MoD	Ministry of Defence
MOX	Mixed oxide fuel
MRP	Magnox reprocessing plant
NDA	Nuclear Decommissioning Authority
NIA65	Nuclear Installations Act 1965
NNB GenCo	EDF Energy NNB Generation Company Ltd
non NPP	A non NPP is a generic term to designate any licensed nuclear installation different than an operating or a defuelling nuclear power reactor. Defuelled reactors are included in the set of non NPPs
NPP	Nuclear power plant
NSC	Nuclear Safety Committee
NUGEN	NuGeneration Ltd
ONR	Office for Nuclear Regulation (formerly the Nuclear Directorate of the HSE)
PFR	Prototype fast reactor
PGA	Peak ground acceleration
PSA	Probabilistic safety analysis
PR	Periodic review of safety
PWR	Pressurised water reactor
REPPIR	Radiation Emergency Preparedness and Public Information Regulations
RESEP	Resilience evaluation process
RRDL	Rosyth Royal Dockyard Ltd
RRMPOL	Rolls-Royce Marine Power Operations Ltd
RSRL	Research Sites Restoration Ltd
SAGE	Scientific Advisory Group for Emergencies
Safety margins	Safety margins identify the gap between a considered situation and the threshold situation beyond which the probability of accident is not tolerable.

GLOSSARY AND ABBREVIATIONS

SAP	Safety assessment principle(s) (HSE)
SBO	Station blackout
SDF	Safety Directors Forum
SFL	Springfields Fuels Ltd
SMP	Sellafield Mox Plant
SSC	Structure, system and component important for safety
Stress tests	The stress tests are summarised as a targeted reassessment of the relevant safety margins of NPPs in the light of events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident
TAG	Technical Assessment Guide(s) (HSE)
THORP	Thermal oxide reprocessing plant
UKAEA	United Kingdom Atomic Energy Authority (split in the 1990s)
WAGR	Windscale advanced gas-cooled reactor
Walkdown	An on-site systematic review of a structure, system or components (SSC) by a small team of SQEPs to review the SSC capability to withstand defined hazards
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association

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