Office for Nuclear Regulation

An agency of HSE

European Council "Stress Tests" for UK Nuclear Power Plants

National Progress Report

15 September 2011

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 tsunami external hazards. The 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. Subsequently, the European Council (EC) requested a review of safety at European nuclear power plants and the European Commission, supported by the European Nuclear Safety Regulatory Group (ENSREG) produced criteria and a plan for this review, now known as the "stress tests".

The UK lessons learnt and EC stress tests assessments share common themes and the UK licensees and the Office for Nuclear Regulation (ONR) are using the same or similar teams to ensure the reviews are completed efficiently and effectively. This report is the UK progress report to the European Commission on the stress tests as applied to UK nuclear power plants.

This report confirms that all of the UK licensees have initiated a stress tests process in line with the ENSREG specification. As a result of our inspections and technical exchange meetings with the licensees along with a review of the licensees' submissions, ONR has confirmed that the UK licensees are making good progress with the stress tests reviews. We expect UK licensees to be able to provide comprehensive reports as input to the main UK national report on the stress tests due at the end of December 2011.

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 nuclear power plants. However, lessons are being learnt about improving resilience and addressing cliff-edge effects.

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INTRODUCTION

1 This report presents the UK national progress report to the European Commission on the implementation of the stress tests to UK Nuclear Power Plants (NPP).

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

3 All of the UK licensees of operating and defuelling NPPs have responded to the request for a progress report in a timely manner. They are all undertaking programmes of work to complete all aspects of the stress tests with a clear intent to provide contributions to the UK national report by the required timescales.

4 In the UK, the licensees responded to initial requests for reviews of design basis and beyond design basis events by ONR and by the World Association of Nuclear Operators (WANO) shortly after the start of the sequence of events at Fukushima. They have also supported and provided information for the HM Chief Inspector of Nuclear Installations' report on the implications of the Japanese earthquake and tsunami for the UK nuclear industry. These activities and the work for the EC stress tests have strong synergies and overlaps. UK licensees have taken account of these when possible, and have worked together to provide a consistent UK nuclear industry response when appropriate.

5 Overall, ONR is content with the activities planned for the EC stress tests programme by all the UK nuclear power plant licensees, and expects comprehensive and timely outputs to be provided in support of the UK national report. ONR also expects that a number of enhancements to strengthen resilience further will be identified and implemented which will provide a positive contribution to nuclear safety in the UK in the event of a significant beyond design basis event.

BACKGROUND

6 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.

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

The Fukushima Events

8 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, shutdown safely. Off-site power was lost and initially on-site 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 to 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 sea. The operator struggled to restore full control.

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

10 The Japanese Government report on the accident to the International Atomic Energy Agency (IAEA) Ministerial Conference was published in June 2011 (Ref. 1).

UK Response

11 In response to the Fukushima accident, the UK established the Cabinet Office Briefing Room (COBR). The Government Chief Scientific Advisor chaired a Scientific Advisory Group for Emergencies (SAGE). The 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 the first day of the accident for over two weeks; it acted as a source of expert regulatory analysis, advice and briefing to central government departments and SAGE.

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

13 The HM Chief Inspector of Nuclear Installations published his Interim report on the events at Fukushima and the implications for the UK nuclear industry, on 18 May 2011 (Ref. 2). This report

contained 11 conclusions and 26 recommendations. Many of the recommendations covered topics similar to those in the stress tests and the UK licensees were reminded of the potential synergies in the work for the recommendations and for the stress tests in the letters which requested them to undertake stress tests.

14 The HM Chief Inspector of Nuclear Installations' final report has been prepared to a timescale very similar to that for this stress tests progress report, although the timing of its publication will depend upon parliamentary process.

EC Response

15 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 ENSREG and the European Commission are invited to develop, as soon as possible, the scope and modalities of these tests in a coordinated framework, in light of the lessons learnt 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 (WENRA). 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 EC will assess initial findings by the end of 2011, on the basis of a report from the Commission".

16 The European Commission and ENSREG members agreed on the initial independent regulatory technical definition of the stress tests and how it should be applied to nuclear facilities across Europe at their plenary meeting on the 12-13 May 2011.

17 Progress on the stress tests process will be reported by the Commission to the EC on 9 December 2011.

Other International Responses

18 The HM Chief Inspector of Nuclear Installations led an IAEA high level team of international nuclear experts to conduct a fact finding mission to Japan in May 2011. The 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).

19 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.

20 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 the HM Chief Inspector of Nuclear Installations.

OVERVIEW OF UK NUCLEAR POWER PLANTS AND LICENSEES

21 The operating and defuelling UK nuclear power plants are all located on or close to the coast, their locations are shown on the map below (Figure 1). The former NPPs mentioned in this report as defuelled sites are also shown on the map.

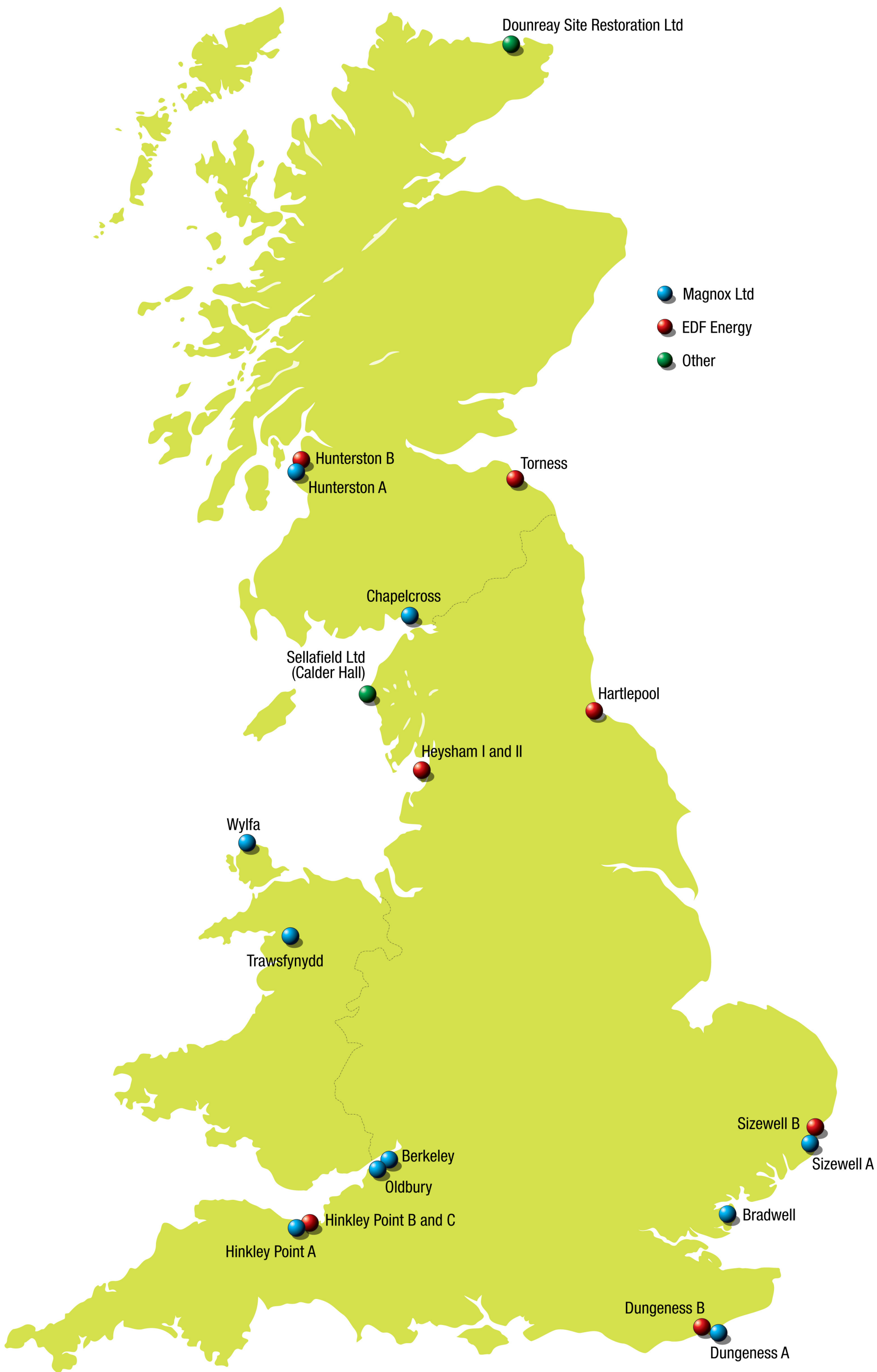

Figure 1: Map of operating, defuelling and defuelled NPPs

EDF Energy – Nuclear Generation Ltd

22 EDF Energy – Nuclear Generation Ltd (EDF Energy NG) operates a fleet of 15 reactors in the UK. Fourteen of these reactors are twin unit Advanced Gas-cooled Reactor (AGR) designs at seven NPPs on six sites. The other operating reactor is Sizewell B, a Pressurised Water reactor (PWR) in Suffolk. The AGRs are at Hunterston B and Torness in Scotland, Hartlepool on Teesside, Heysham 1 and Heysham 2 in Lancashire, Hinkley Point B in Somerset and Dungeness B in Kent.

23 The PWR at Sizewell B was commissioned in 1995: the AGR sites were commissioned over the period 1976 to 1988, giving current lives of 23 to 35 years. All of the NPPs have been subject to a plant lifetime extension review by the licensee with the exception of Sizewell B, Torness and Heysham 2. Current plans indicate that the stations will continue operation through a range of dates from 2023 to 2045, subject to periodic formal reviews of their safety cases and the consent of ONR, as appropriate.

24 The requirements for seismic analysis, design and qualification of NPPs were developed during the design and construction of the early AGRs, and only Heysham 2, Torness and Sizewell B were fully designed from the outset to resist earthquakes. The Periodic Safety Review (PSR) process allowed the earlier designs to be re-evaluated against seismic and other hazards, and all NPPs in the UK have had their design basis event defined and analysis and qualification activities completed to demonstrate that the plants will be resilient against modern design basis external hazards in a controlled manner. Modern standards reviews - as part of the PSR process - have since been completed at all sites, including the more recent AGRs and Sizewell B, to ensure their design or re-evaluation remains valid.

25 With a large operating fleet and long predicted lifetimes, the scope and extent of potential improvements in light of the stress tests and the HM Chief Inspector of Nuclear Installations' reports are significant for EDF Energy NG. An extensive programme of work has been initiated to respond to the events at Fukushima.

26 The EDF Energy NG group is engaged with the wider EDF group to ensure reviews and options for improvement are consistent (where appropriate) in both France and the UK and to share information and maximise the potential for learning.

Magnox Ltd – Operating Reactors

27 The construction of the 26-reactor Magnox fleet started in 1953 and finished in 1971. Nowadays, Magnox Ltd operates two twin gas cooled Magnox reactor power stations in the UK. These are the last of the operating Magnox fleet. The two sites are at Oldbury on the Severn estuary and Wylfa on Anglesey. One Oldbury reactor ceased generation in June 2011: the last remaining Oldbury reactor is scheduled to cease generation in 2012. The reactors at Wylfa are expected to cease generation by 2014. After this remaining period of operation, there will be a short period of defuelling of approximately two years before the sites prepare to enter a care and maintenance period.

28 The short remaining periods for both operation and subsequent defuelling act as a constraint on potential improvements resulting from the stress tests reviews. Magnox has recognised this and has initiated reviews and optioneering studies to determine if enhancements can be implemented in a timely manner in order that a real safety benefit is realised.

Magnox Ltd – Defuelling Reactors

29 Magnox Ltd is in the process of defuelling three shutdown Magnox reactors in the UK. These are at Sizewell A in Suffolk, Dungeness A in Kent, and Chapelcross in Dumfries and Galloway. The Magnox fuel is exported from the sites in flasks by rail for reprocessing at Sellafield. The actual export rate is typically controlled by the throughput of the Sellafield facilities. All of the defuelling Magnox sites expect to be free from fuel in the next few years, and all sites, including those generating electricity, plan to be free from fuel by 2016.

30 The fuel at these sites is typically stored in both the reactor pressure vessels in carbon dioxide or air, and in ponds under water, and the export routes are from the pond storage to flasks. The exception to this is at Chapelcross where the fuel is stored in the reactors only and the export route is direct from the reactors to a flask without intermediate pond storage.

31 The short remaining periods for defuelling act as a constraint on potential improvements resulting from the stress tests reviews. Magnox has recognised this and has initiated reviews and optioneering studies to determine if enhancements can be implemented as soon as practicable in order that a real safety benefit is realised.

Magnox Ltd – Defuelled Reactors

32 Magnox also holds nuclear site licences for a number of other former reactor sites which have been defuelled and have become medium to long term intermediate level waste stores. These sites are excluded from the UK national report on stress tests for the EC, but will be reported separately (see Section Process for Stress Tests Activities).

33 These sites are at Hinkley Point A in Somerset, Hunterston A in Lanarkshire, Bradwell in Essex, Trawsfynydd in Wales and Berkeley in Gloucestershire.

Sellafield Ltd – Defuelling Reactors

34 Four Magnox reactors are located at Calder Hall on the Sellafield site in Cumbria. The reactors have been shutdown for over eight years and the fuel in the reactor cores at the time of shutdown remains in passive storage within the reactors. Defuelling operations are planned to commence soon and defuelling to be completed by 2016.

35 There are no spent fuel ponds at Calder Hall and fuel removed from the reactors has and will be transported in flasks directly to the adjacent fuel storage and reprocessing facilities on the Sellafield site. Core cooling relies only on natural convection of air. Although electric power is used to generate a dry air feed this is to prevent long term deterioration of the fuel and reactor internals. Loss of the dry air would have no significant consequences in the short and medium term.

Dounreay Site Restoration Ltd

36 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). Construction of the Dounreay Fast Reactor (DFR) started in 1955, followed by construction of the 250MWe Prototype Fast Reactor (PFR) which achieved criticality in 1974. DFR was shutdown in 1977 and PFR in 1994. PFR has been de-fuelled and its liquid metal removed, with fuel currently stored within the PFR complex pending treatment. DFR retains one fuel element and a large number of breeder elements, with its liquid

metal coolant currently being removed prior to removal of all fuel elements. Decommissioning of the reactors is due to continue to the 'Interim End State' currently scheduled for 2025-2032.

Potential New Sites – Licensing and the Generic Design Assessment Process

37 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 PWRs (UK EPR™) at the Hinkley Point C site in Somerset. The other two potential licensees, Horizon and 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 are excluded from the UK national report on the stress tests.

38 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 – EDF and AREVA's UK EPR™ and Westinghouse's AP1000®.

39 GDA allows the nuclear regulators to assess new nuclear power stations before construction begins. Identifying potential issues at the initial design stage allows any issues to be addressed more efficiently and effectively.

40 The regulators conduct their assessments 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 for the reactor design companies to put in place plans to address any relevant recommendations from the HM Chief Inspector of Nuclear Installations' final report on the Fukushima accident. This GDA issue is currently being considered by the designers.

ENSREG REQUIREMENTS

41 The ENSREG requirements are detailed in Annex 1.

42 ENSREG notes that the licensees have the prime responsibility for safety so they should perform the assessments and the regulatory body should independently review them.

43 The 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 and international obligations. This accords well with ONR's openness and transparency objectives. ENSREG also notes that the reports from the peer review process will be made public.

Initiating Events

44 The initiating events required for review under the stress tests are earthquakes and tsunamis. 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).

45 In the UK, the licensees reviewed compliance with their safety cases in the first few days following the Fukushima event following a request from ONR and WANO for the licensees to undertake such a review. ONR monitored this work undertaken by the licensees and the findings, which were generally positive, although a few minor issues were raised, which were quickly resolved by the licensees.

46 The initiating event review must also consider how the margins evaluation for each NPP or SSC was completed and what consequential effects should be considered. The margins evaluation also asks the licensees to consider what improvements, if any, could be applied to improve margins and to remove or extend cliff-edge effects.

Loss of Safety Function

47 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.

48 These events which lead to a loss of safety function, such as cooling, could be as a result of seismic or tsunami activity, but other external or internal hazards 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.

49 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 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, this is generally known as Station Blackout (SBO). 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.

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

51 For the final sequence, a loss of ultimate heat sink along with station blackout 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 further cliff-edge effects is required.

Severe Accident Management

52 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.

53 The review asks for the key management features to ensure criticality control, cooling, and containment along with control and 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.

54 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 stand alone 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

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

- Health and Safety at Work etc. Act 1974 (HSWA74).
- Nuclear Installations Act 1965 (NIA65) (as amended).

56 Under HSWA74 employers are responsible for ensuring, so far as is reasonably practicable, the safety of 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 ONR and in particular to the HM Chief Inspector of Nuclear Installations.

57 European legislation in the form of EC 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.

58 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 the Nuclear Installations Inspectorate, UK Safeguards Office and the former Office for Civil Nuclear Security. In addition, ONR expects to take on the nuclear regulatory functions of the Department for Transport (DfT) shortly, by incorporation into ONR of the DfT Radioactive Materials Transport team.

Licensing

59 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 for the regulation by ONR of 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.

60 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 disposal of nuclear materials. ONR has developed a standard set of 36 Licence Conditions (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 provides 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.

61 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 to control them adequately.

Design Basis

62 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. 4). 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.

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

64 Design Basis Analysis (DBA) provides a robust demonstration of the fault tolerance of a facility and of 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 risk is not quantified but the adequacy of the design and the suitability of the safety measures are assessed against deterministic targets.

Fault Analysis

65 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 plants' inherent characteristics or its safety features.

66 In addition to DBA, Probabilistic Safety Analysis (PSA) is also generally used for NPPs to confirm the overall risk presented by the NPP lies within targets set – generally in the SAPs (Ref. 4). PSA can also be essential to help understand the strengths and weaknesses of the design, particularly in light of the complex designs and interdependencies.

67 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

68 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.

69 All of the UK NPPs had design basis analysis, PSA and severe accident analysis undertaken during their design or in subsequent Periodic Safety Review (PSR). The stress tests process effectively undertakes a review of specific hazards, faults and severe accident studies in a systematic manner.

Periodic Safety Review

70 In the UK the operator of a nuclear installation is also required by a specific Licence Condition (LC15) to periodically review its safety case for the plant. This PSR 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 PSR 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 PSR includes a review of the safety of the plant in response to events such as earthquakes, floods, fire and explosion. ONR independently assesses licensees' PSR reports using its SAPs and TAGs.

71 All of the UK nuclear power plants were designed and built to standards relevant at the time. For all of the UK fleet of reactors this involved flooding studies, but for most, this did not include seismic design. The initial round of PSR identified the absence of a seismic safety case and a re-evaluation process was completed to confirm the adequacy of the relevant SSCs and to make necessary modifications to improve seismic resistance.

72 The PSRs for each site take account of modern standards and recent research findings. Over the last two decades, a number of tsunami studies have been completed by the UK nuclear industry or been commissioned by Government. The outputs from these studies have been considered in the subsequent PSRs.

Continuous Improvement

73 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.

74 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.

75 The licensees also participate in the continuous improvement programmes arising from their participation in 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 this international programme which gives them access to a wide pool of shared experiences and peer to peer reviews.

76 In normal circumstances, feedback from WANO peer reviews and evaluations required by WANO are not made available to ONR. In light of the extraordinary circumstances of the Fukushima event, the output from the WANO sponsored evaluations from the major NPP licensees was made available to ONR.

PROCESS FOR STRESS TESTS ACTIVITIES

77 The assessment process was required to commence by 1 June 2011 and the major UK NPP licensees, and the potential licensees were informed of this by letter in advance.

78 The major UK licensees were requested to respond by 10 June 2011 confirming that they were aware of, and would act on, the stress tests programme of work and to provide a lead contact to engage with the team in ONR. This was completed in a timely manner.

79 The next major step was for the NPP licensees to submit their stress tests progress reports by 15 August 2011 – this was also completed in a timely manner. ONR has reviewed the information supplied and produced the UK Progress Report – this report – by 15 September 2011.

80 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 October 2011.

81 ONR will assess this information and submit the UK national report to the European Commission by 31 December 2011.

82 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 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.

83 The approach adopted by the licensees is to apply the arrangements made under LC15 (Periodic Review) 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.

84 The licensees have used their internal oversight and challenge groups to carry out inspection and assessment of the work performed under the stress tests. They have reported this work and its findings to their Nuclear Safety Committees (NSC) and set up other oversight arrangements to ensure the work is comprehensive, accurate and evidence based, as well as timely.

85 In order to enhance credibility and accountability of the process, the EC asked that the national reports should be subject to a peer review process. The peer reviews will be undertaken by teams which include relevant specialists. They will have access to all supporting information, subject to security clearances. The peer reviews will start once the national reports become available and will be completed by the end of April 2012. The exact composition, extent and reporting of the peer reviews is being developed.

PROGRESS TO AUGUST 2011

Licensee Progress

EDF Energy - NG

86 EDF Energy NG confirmed their commitment to undertake the stress tests process by letter on 10th June and issued their progress report on 12 August 2011 (Ref. 5).

87 EDF Energy NG has set up a major project team to manage and undertake the work associated with the various post-Fukushima activities. The team is managing the work arising from the HM Chief Inspector of Nuclear Installations' interim and final reports, the IAEA reports, the various mandatory evaluations initiated by WANO and the EC stress tests, and from other sources including the wider EDF group.

88 The team includes a significant central resource mainly supplied by suitably qualified and experienced contractors from the supply chain, led and managed by a team of EDF Energy NG personnel. The decision to use contractors has been deliberate to ensure a continued focus on the delivery of existing programmes of work and to maintain the necessary operational focus in a time of change. The work produced by the central team for each site will be reviewed and assessed by site based teams to validate the summaries and conclusions.

89 EDF Energy NG has adopted an approach based on the nuclear site LC15 arrangements as this standardizes the way work is initiated, undertaken, reviewed and approved. In particular, the internal regulatory and oversight functions are fully engaged with this process, including the independent nuclear safety assessment and nuclear inspection and oversight functional groups, the NSC and Executive Board oversight and review.

90 The work to date, and the forward work is planned around three key workstreams with a total of 14 supporting work areas, these are summarised below:

- Review and Challenge:

  This is principally a review of the existing safety case information and other relevant information in the light of the experience and learning from Fukushima

  - Plant Information.
  - Hazard magnitude.
  - Impact on the site.
  - Impact on the locality.
  - Impact on the plant systems.
  - Plant response to SBO (and loss of heat sink).
  - Operational procedures.

- Emergency Arrangements:

  This is an assessment of the current procedures and emergency arrangements including extendibility options in light of the learning from Fukushima

  - Company emergency arrangements.
  - Regional emergency arrangements.

- National emergency arrangements.

- Response:

  This work stream provides a focus on delivery of improvements to on- and off-site resilience equipment and arrangements and the associated training and infrastructure.

  - Modifications to existing equipment.
  - Back up equipment.
  - Back up services.
  - Training.

91 EDF Energy NG is working with Magnox and Sellafield sites to ensure a consistent, industry-led approach is taken to post-Fukushima learning. A particular focus has been provided by the Safety Directors Forum (SDF), a cross nuclear industry group. EDF Energy NG is also taking advantage of its links with the wider EDF group including the new build organisation in the UK, NNB GenCo. EDF Energy NG has also been represented on international working groups helping set the direction of current and future post-Fukushima work across the industry.

Magnox Reactors (including Calder Hall)

92 Magnox confirmed their commitment to undertake the stress tests process by letter on 6 June 2011 and issued their progress report on 12 August 2011 (Ref. 6).

93 Magnox has set up a project team to deliver the stress tests work in a timely and consistent manner. The organisation has initiated a Project Implementation Board (PIB) 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.

94 The process for the stress tests is aligned with the LC15 arrangements for a review of safety. This allows the inclusion of the normal internal regulatory and oversight processes including the NSC and the Environmental, Health, Safety, Security and Quality function.

95 Workshops to review the options to improve resilience have been held starting with the highest hazard sites – the operating reactors – then moving on to fuel storage in ponds and other defuelling facilities, before finishing on the defuelled sites.

96 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 pond water make up.
- Combustible gases.
- Off-site infrastructure resilience.
- Emergency control centres and available control and instrumentation.
- Human capacities and capabilities.

97 Magnox is working with Sellafield Ltd, particularly on the Calder Hall reactor stress tests assessment, but also in a joint working group for all post-Fukushima activities jointly with Sellafield Ltd and with EDF Energy NG. It has also extended local working arrangements at sites which they share with EDF Energy NG, such as Sizewell, Dungeness, Hunterston, etc.

98 Sellafield Ltd has confirmed its commitment to ONR to undertake the stress tests process and issued their progress report on 15 August 2011 (Ref. 7).

99 Sellafield Ltd has also established a Resilience Programme Team (RPT) to deliver the totality of the Sellafield response to the events at the Fukushima NPP in Japan, including the requested responses to both the EC stress tests and the HM Chief Inspector of Nuclear Installations' interim report recommendations. The RPT continues to work closely with the teams carrying out the EC stress tests review work within the Magnox Ltd and EDF Energy NG, particularly with the Magnox Ltd team, which is carrying out the review at the 'sister' station at Chapelcross Dumfries. This has reactors of a similar design and operational status to the Calder Hall reactors.

Dounreay Site Restoration Ltd

100 DSRL confirmed its commitment to undertake the stress tests process by letter on 17 June 2011 (Ref. 8), and issued a progress report on 15 August 2011 (Ref. 9). DSRL has recognised that DFR and PFR meet the criteria of being a 'shutdown NPP where spent fuel storage is still in operation'. However, as described earlier, DSRL's reactors have been de-fuelled and spent fuel storage is being carried out, and does not therefore require active cooling. Nonetheless, DSRL has confirmed its intention to carry out a thorough but proportionate response to the ENSREG tests.

101 To that end, DSRL is reviewing the decommissioning activities of DFR and PFR against the stress tests identified by ENSREG, to ascertain if any additional measures need to be taken to enhance the safety of reactor defuelling operations and associated spent fuel storage.

102 ONR continues to engage with DSRL to verify satisfactory progress through routine regulatory business. ONR considers DSRL's responses and progress to date to be positive and proportionate to the level of risks posed by remaining inventories and decommissioning activities.

ONR Progress

103 ONR has engaged with the licensees as they have developed their response to the HM Chief Inspector of Nuclear Installations' interim report and the stress tests. The main licensees' responses to the recommendations have been reviewed and assessed by ONR specialists both when received and by a series of technical meetings.

104 ONR has also monitored progress with the work for the HM Chief Inspector of Nuclear Installations' report and stress tests via a series of weekly teleconferences and several larger technical meetings. The industry based responses to the HM Chief Inspector of Nuclear Installations' report have been led to some extent by the SDF in the UK. ONR attendees at that forum have reported a positive

commitment from all licensees to respond to the HM Chief Inspector of Nuclear Installations' report and to the stress tests reports.

105 We are aware of the resources committed by EDF Energy NG, Magnox and from DSRL 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.

106 ONR is aware of, and fully supports, the industry-wide approaches being adopted by the major NPP licensees. Although there will be site and technology specific aspects to the reviews and potential improvements, there are also strong synergies with opportunities to share learning and potentially procure equipment that can be used across a variety of sites, but stored in different locations, further strengthening resilience.

PLANNED WORK TO COMPLETE FINAL NATIONAL REPORT

Licensees Planned Work

107 In their submissions for the UK stress tests progress report, all of the UK 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 result.

EDF Energy - NG

108 EDF Energy NG will continue the work of the three main workstreams and the 14 key work areas. Options for improvement will be developed and decision making processes applied to determine those which will be carried forward.

109 The process for delivery of the site based reports has been developed with a centrally based standardised and modular approach for all stations to ensure consistency, along with a station based review by suitable SQEPs as part of the validation process.

110 EDF Energy NG has recognised that the timescales for production of the site based reports will not allow them to have fully developed and sanctioned the list of modifications planned. It is partly because of the likely extent, (from minor document changes to major equipment procurement) but more importantly because of the need to apply the full modification process (LC11, 22 and 24 are applicable), to ensure potential improvements are fully thought through and implemented in a controlled manner.

111 ONR expect that EDF Energy NG will be able to give a clear indication of which work is likely to proceed and the basis for decision making on the rest of the potential modifications, by the time the national report is published.

112 EDF Energy NG expect to continue engagement with the industry groups and ONR to ensure all parties have an early view of the planned work and its outcomes, and to ensure the stress tests reports' content meet the regulatory expectations.

Magnox Reactors (including Calder Hall)

113 Magnox will continue with the remaining workshops to review the safety case claims and beyond design basis fault sequences. From those workshops options for improvements will be carried forward into a decision making process and the appropriate options carried forward.

114 Progress will continue with the workstreams and meetings with the other major NPP licensees will continue to ensure consistency. Where possible potential improvements will be made such that contingency equipment can be used on a variety of sites, including those of EDF and Magnox, to allow fast sharing of equipment if required.

115 Each site will prepare the main stress tests report and the central team will review these to ensure consistency of approach and standards. When appropriate, the central engineering function SQEPs will prepare information for all of the site stress tests reports.

116 The site stress tests reports will be assessed by the internal regulator and considered by the PIB before submission to ONR. The PIB includes a sub-set of members of the Magnox NSC, the full NSC will review the station reports following submission.

117 Sellafield Ltd is continuing with its review of the resilience of the Calder Hall reactors with respect to the EC stress tests aspects to identify sensitivities to loss of shielding, containment, cooling and

utility systems and any cliff-edge effects. The progress made by Sellafield Ltd and any emerging findings are being discussed in regular ONR / Sellafield Ltd progress review meetings. The Sellafield Ltd final report for the Calder Hall reactors will be reviewed by the Sellafield Ltd internal independent peer review teams and considered by the relevant Sellafield safety committee before its issue, planned for 31 October 2011.

Dounreay Site Restoration Ltd

118 DSRL intends to produce a top-tier summary report. It is DSRL's intention to review the Dounreay beyond design basis events against the requirements of the EC stress tests, to ascertain if there are any reasonably practicable safety improvements that could be identified.

ONR Planned Work

119 The planned engagement with EDF Energy NG during the period when the station specific reports are being written will be via each of the three main workstreams. ONR plan to have technical exchange meetings with relevant licensee technical experts and ONR's specialist inspectors; inspections of a sample of site based stress tests activities will be carried out; and, reviews of some of the modular report chapters are also planned.

120 The planned engagement with Magnox during the period when the station specific reports are in preparation includes a series of technical exchange meetings to review the planned work and likely outcomes, to ensure Magnox is progressing in an appropriate manner and to reduce the risk of the submitted reports reflecting insufficient work on specific topics.

121 ONR also plan to undertake some specific additional inspections of the Magnox site based activities which could look at: seismic walkdowns; walkdowns for other hazards; or, reviews of potential improvements and modifications to ensure their routes and layouts are secure and diverse.

122 ONR also has weekly progress meetings via teleconference with each of the major NPP licensees. Additional reviews take place via senior level interactions between the licensees and ONR staff.

EXPECTED OUTCOMES AND SAFETY IMPROVEMENTS

123 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 licensees or sites. Some simple improvements to housekeeping to reduce the potential for seismic interactions (where non-safety related equipment could impact or fall onto seismically qualified equipment) have already been completed at several NPPs following the WANO instigated reviews.

124 EDF Energy NG has indicated that resilience enhancements under consideration include the provision of additional local flood protection to key equipment and the provision of further emergency back-up equipment to provide cooling and power.

125 Additional studies are being prepared by EDF Energy NG and its supply chain to re-consider flood modelling for specific sites and to review recent climate change information that arrived subsequent to the recent routine ten yearly PSR. EDF Energy NG will also be involved in the grid resilience workshops planned with the UK National Grid.

126 For the Magnox reactors, the main focus of improvements is to improve the reliability of cooling systems in the face of a variety of beyond design basis faults to reduce or minimise the potential for cliff-edges.

127 Other simple solutions 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.

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

129 For all of the operating NPPs, a review of the number, contents and locations of the resilience trailers to provide more equipment, closer to site, and more relevant equipment to respond to a variety of challenges should offer a significant improvement to post accident responses.

130 NNB GenCo has indicated that reviews of resilience of strategic stocks, such as diesel fuel and carbon dioxide, and usage, 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.

131 The four Calder Hall Magnox reactors located on the Sellafield site have been shut down for a number of years and the fuel stored within the reactors will be removed over the next few years. Because of the operational status of the facilities, it is anticipated that few significant enhancements to the Calder Hall facilities will be considered necessary and justifiable and Sellafield Ltd will focus on the defuelling operations programme. However, Sellafield Ltd remains committed to completing the resilience reviews to determine if enhancements can be implemented in a timely manner, such that a real safety benefit is realised. Furthermore, as part of the Sellafield site, the Calder Hall facilities will benefit from any site wide enhancements to infrastructure and emergency arrangements, etc. that may be identified as part of the parallel reviews that are being carried on the other non-NPP facilities located on the Sellafield site.

132 DSRL has proposed to review the resilience of facilities on the Dounreay site to beyond design basis events in the context of onsite and externally available infrastructure.

Summary and Conclusions

133 The damage from the Tohuku earthquake and tsunami have 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 to ensure NPPs have been reviewed in the light of these events and to improve their resilience.

134 The EC and ENSREG requested all European Union member states with a nuclear power programme enter into the stress tests process and provide a progress report by mid-September 2011. This UK national 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.

135 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 nuclear power plants. However, lessons are being learnt about improving resilience for beyond design basis events and removing or reducing cliff-edges – these will be applied in a timely manner.

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 test” 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 test” 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 test 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.
- Any existing procedure to use means from one reactor to help another reactor.

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

- 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

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.
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.
Magnox	Magnox NPPs are a gas cooled reactor design where the natural uranium (or slightly enriched in some cases) fuel is clad in Magnesium.
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.
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.

ABBREVIATIONS

AC	Alternating Current
AGR	Advanced Gas-cooled Reactor
ALARP	As Low As Reasonably Practicable
AREVA	AREVA NP SAS
COBR	Cabinet Office Briefing Room
DBA	Design Basis Analysis
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DFR	Dounreay Fast reactor
DfT	Department for Transport
DSRL	Dounreay Site Restoration Ltd
EC	European Council
EDF	EDF SA
EDF Energy NG	EDF Energy Nuclear Generation Ltd
ENSREG	European Nuclear Safety Regulatory Group
GDA	Generic Design Assessment
HSE	Health and Safety Executive
HSWA74	Health and Safety at Work etc. Act 1974
IAEA	International Atomic Energy Agency
INES	International Nuclear and Radiological Event Scale
LC	Licence Condition
NIA65	Nuclear Installations Act 1965
NNB GenCo	EDF Energy NNB Generation Company Ltd
NSC	Nuclear Safety Committee
NPP	Nuclear Power Plant
ONR	Office for Nuclear Regulation (formerly the Nuclear Directorate of the HSE)
PFR	Prototype Fast Reactor
PIB	Project Implementation Board
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor

ABBREVIATIONS

RCIS	Redgrave Court Incident Suite
RPT	Resilience Programme Team
SAG	Severe Accident Guidelines
SAGE	Scientific Advisory Group for Emergencies
SAP	Safety Assessment Principle(s) (HSE)
SBERG	System Based Emergency Response Guidelines
SBO	Station Blackout
SDF	Safety Directors' Forum
SQEP	Suitably Qualified and Experienced Persons
SSC	Structure, System and Component important for safety
TAG	Technical Assessment Guide(s) (HSE)
UKAEA	United Kingdom Atomic Energy Authority (split in the 1990s)
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association

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