“Stress tests” specifications
Proposal by the WENRA Task Force
21 April 2011

Introduction

Considering the accident at the Fukushima nuclear power plant in Japan, the Council of the European Union 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 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*”.

During their plenary meeting on the 22nd and 23rd of March 2011, WENRA members decided to provide “*an 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”

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 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 space starts 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 and is not re-assessed in the stress tests. 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.

Process to perform the "stress tests" and their reviews

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 potential timeframe could be as follows:

- The licensees could be given time until September 15 to carry out the work described above and to send the results and related documentation to their national regulator;
- The regulator then would perform a review of the licensees' submissions. This could take 2 months; the review report would then be published.
- This would allow ENSREG and the European Commission to prepare a report to the Council for the meeting scheduled on 9th December 2011.

To perform the reassessments, the licensees may, due to time constraints, rely on the existing safety studies and engineering judgement[1].

During the regulatory reviews, interactions between European regulators will be necessary and could be managed through WENRA or ENSREG. Results of the reviews could be discussed both in national and in European level public seminars, to which other experts (from non nuclear field, from non governmental organisations, etc) would be invited.

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 following situations will be addressed, corresponding to steps of more and more severe situations:

Initiating events conceivable at the plant site

- Earthquake
- Flooding
- Other extreme natural events

Consequential loss of safety functions

- Loss of electrical power, including station black out (SBO)
- Loss of the ultimate heat sink (UHS)
- Combination of both

[1] Due to the timeframe of the stress test process, some of the engineering studies supporting the licensee's assessment may not be available for scenarios not included in the current design.

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 spent fuel storage pool
- Means to protect from and to manage loss of containment integrity

The reassessment is not addressing other safety issues because these have already been taken into consideration by the national authorities in other reviews.

However, the considered initiating events have not been 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 by other events such as malevolent acts.

The review of the severe accident management issues focuses on the licensees 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.

It remains a national responsibility to take any appropriate measures resulting from the reassessments.

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.

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.

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 effect[2]) 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.

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.

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.

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

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;
    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.

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…);
   - Main operating provisions (including emergency operating procedure, mobile equipment…) to warn of, then to mitigate the effects of the flooding;
   - 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…).

<u>Other extreme natural events</u>

a) Very bad weather conditions (storm, heavy rainfalls…)

- Events and combination of events considered and reasons for the selection (or not) as a design basis.
- Indicate which are the weak points and specify any cliff edge effects. Identify which buildings and which equipments 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…).

b) 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) could have an impact of plant safety.
- Indicate which are the weak points and specify any cliff edge effects. Identify which buildings and which equipments 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…)

Loss of electrical power and loss of the ultimate heat sink

Electrical AC power sources are:

- off-site power sources (electrical grid);
- 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)

- 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…).

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.
- 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 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…)

c) Loss of primary ultimate heat sink (UHS)

- 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:
- Specify which external actions are foreseen to prevent fuel degradation:
  - o equipment already present on site, e.g. equipment from another reactor;
  - o assuming that all reactors on the same site are equally damaged, equipment available off-site;
  - o time necessary to have these systems operating;
  - o availability of competent human resources ;
  - o 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…).

d) Loss of the "main" 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:
  - o equipment already present on site, e.g. equipment from another reactor;
  - o assuming that all reactors on the same site are equally damaged, equipment available off site;
  - o availability of human resources;
  - o time necessary to have these systems operating;
  - o 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…)

Severe accident management

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 containment integrity after occurrence of fuel damage
   - prevention of H_2 deflagration or H_2 detonation (inerting, recombiners, or igniters), also taking into account venting processes;
   - prevention of over-pressurization of the containment;
   - prevention of re-criticality
   - prevention of basemat melt through
   - need for and supply of electrical AC and DC power to equipment used for protecting containment integrity

c) 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 severe fuel damage in the fuel pool.

For a) , b) and c), 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 availability and habitability of the control room;
     - potential H_2 accumulations in other buildings than containment;
     - .

The following aspects have to be addressed:
   - Organisation of the licensee to manage the situation, including:
     - staffing and shift management;
     - use of off-site technical support for accident 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);
   - Provisions for and management of supplies (fuel for diesel generators, water…);

- Management of radioactive releases, provisions to limit them;
- Communication and information systems (internal, external).

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) 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 and what measures could avoid such conditions to occur.

****