“Belgian Stress tests” specifications
Applicable to all nuclear plants, excluding power reactors
22 June 2011

Introduction

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

Considering the important work performed by the WENRA members in providing *“an independent regulatory technical definition of a “stress test” and how it should be applied to nuclear facilities across Europe.”*

Considering the political view that man-made events, f.i. terrorist attacks should be considered as triggering the loss of important systems to safety as well.

Definition of the “stress tests”

For now we define a “stress test” as a targeted reassessment of the safety margins of nuclear 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.

All nuclear class I facilities, currently in operation, will be included in the stress test. Nuclear facilities which are already in a decommissioning stage, will not be included in the stress test .

This reassessment will consist

- in an evaluation of the response of a nuclear 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. 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 plant from entering in a degraded mode 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 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 timeframe is as follows:

The national regulator will initiate the process at the latest on July 4 2011 by sending requirements to the licensees.

	Progress Report	**Final report**
Licensees report	December 15, 2011	June 30, 2012
Regulators report	February 15, 2012	October 30, 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.

Transparency

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

Technical scope of the "stress tests"

The existing safety analysis for nuclear 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, and further enlarged to take into account other events. 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 (bush or forest fires,…)
- Terrorist attacks
- Other man made events

Those initiating events conceivable at the plant are further detailed in an appendix to this document.

Loss of safety functions

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

Severe accident management issues

- Means to protect from and to manage loss of cooling function
- Means to protect from and to manage loss of cooling function in the fissile material handling or storage facilities or waste facilities
- Means to protect from and to manage the risk of
  - explosions or fire
  - criticality
- Means to protect from and to manage loss of containment integrity

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. 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….) as defined and implemented following the Fukushima event before the end of the fourth quarter of 2012.

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 nuclear facilities on the same site.

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

- location (sea, river);
- number of nuclear facilities on site ;
- license holder

In case of reactor plants, the main characteristics of each reactor unit shall be reflected, in particular:

- reactor type;
- fuel used, enrichment, cooling and moderator type

- thermal power;
- date of first criticality;
- current operational regime
- inventory, type and enrichment of new fuel in storage at plant
- inventory, type and enrichment of spent fuel in storage at plant (or shared storage).

In case of non-reactor plants, the main characteristics of the nuclear facilities on site shall be reflected, in particular:

- type and activity of the plant (nuclear, chemical, pharmaceutical,…)
- Inventory of radioactive and fissile material at plant, including risk of criticality
- Inventory of stored waste at plant, including risk of
  - Criticality
  - Explosion or fire
  - Reactivity of waste with water or in contact with air
- Date of first commercial operation

The scope and main results of Probabilistic Safety Assessments (if available) 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 September 30, 2011.

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 fissile material or waste facilities shall be supposed to be affected at the same time when it can be reasonably assumed that the initiating event or the subsequent accident could give cause to common mode failures at the other units at the same site.

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[1]) 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 downs.

To this aim, the licensee shall identify:

- the means to maintain the three fundamental safety functions (control of reactivity /prevention of criticality, 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 any nearby plant
- dependence of facilities of a plant on other facilities on the same site.

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

- the time before damage to the fuel/fissile material or release to the environment becomes unavoidable. For reactors , if the core is in the reactor vessel, indicate
  - time before water level reaches the top of the core
  - time before fuel degradation (fast cladding oxidation with hydrogen production)
  - time before risk on criticality materialises
- if the fuel is in a cooling 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;
- if the fissile material or waste is in dry storage, the effect and impact of debris on the cooling or integrity of the storage

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.

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

Specific Aspects

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 a nuclear plant 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, additional test 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 or releases becomes unavoidable.

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.

- Specify which (external) actions are foreseen to prevent damage to the fuel/fissile material or releases to the environment:
    - equipment already present on site, e.g. equipment from another facility;
    - assuming that all plants 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…).

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/fissile material or release of radioactive materials becomes unavoidable.
- Provide information on design provisions for these situations.
- Specify which external actions are foreseen to prevent degradation:
    - equipment already present on site,
    - assuming that all plants 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/fissile material or release of radioactive materials becomes unavoidable
- Specify which external actions are foreseen to prevent degradation:
    - equipment already present on site,
    - assuming that all plants on the same site are equally damaged, equipment available off site;

[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.

    - availability of competent 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…)

<u>Severe accident management</u>

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 and to reduce releases tot the environment should be assessed. Severe accident management, as forming the last line of defense-in-depth for the operator, should be consistent with the measures used for preventing 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 cooling function:
   - before occurrence of damage to plant
   - after occurrence of damage

b) Describe the accident management measures and plant design features for protecting containment integrity after occurrence of damage
   - prevention of H_2 or other explosive gas deflagration or 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 (reactors only);
   - 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 to mitigate the consequences of loss of containment integrity and to reduce releases to the environment.

d) Describe the accident management measures currently in place at the various stages of a scenario of loss of cooling function in the fuel or waste storage:
   - before/after losing adequate shielding against radiation;
   - before/after occurrence of uncover of the top of fuel in the fuel pool (reactors only);
   - before/after beginning of fuel degradation (fast cladding oxidation with hydrogen production)in the fuel pool (reactors only).

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 H_2 or other explosive gas 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 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) 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.

Attachment to Belgian Stress test specifications
List of triggering events for all nuclear plants, excluding power reactors
22 June 2011

A. Earthquake

I. Design basis

- 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.

- 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 plant from damage after the earthquake;
  - Were indirect effects of the earthquake taken into account, including:
    - 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);
    - Loss of external power supply;
    - Situation outside the plant, including preventing or delaying access of personnel and equipment to the site.

- 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

- 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 fissile material (in vessel or in storage) or waste facility 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, additional test procedures, organisational provisions…).

- 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.

- 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 structure) could have an impact on 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…)

B. <u>Flooding</u>

<u>I. Design basis</u>

- 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.

- Provisions to protect the plant against the DBF
  - Identification of the key SSCs which are needed for achieving safe state and are supposed to remain available after the flooding, including:
    - Provisions to maintain the water intake function (if applicable);
    - 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…) 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.

- 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

- 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, fissile material process facilities or waste facilities?
  - 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, additional test procedures, organisational provisions…).

C. Other extreme natural events

1. 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 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…).

2. Bush or forest fire
   - Events considered and reasons for the selection (or not) as a design basis.
   - 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,…).

D. Terrorist Attacks

- Review of maintenance of vital functions in case of an aircraft crash or a direct hit by an object
  i. Crash scenarios (aircraft type, speed; worst case location of impact zone, etc…)
  ii. Indicate if any existing provisions, layout, etc.., are available to satisfy the defence in depth principle, keeping the plant away from a SBO or the loss of UHS

- 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.

- Identification of the main provisions to protect the unit against fuel fire effects.

E. <u>Other man-made events</u>

- Site specific impacts caused by toxic and explosive gases and blast wave
    i. Events and combination of events and reasons for the selection (or not) as a design basis
    ii. Indicate if provisions exist or can be envisaged to prevent the loss of control by the operator of the plant.
- Site specific impacts caused by external attacks on computer-based controls and systems
    i. Events and combination of events and reasons for the selection (or not) as a design basis
    ii. Indicate if provisions exist or can be envisaged to prevent the loss of control by the operator of the plant.