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New guidelines on safety demonstration and specific external hazards

Overview

- Introduction and background
- Guideline on the safety demonstration
- Guidelines on specific external hazards:
 - Unintentional aircraft crashes, seismic hazard and external flooding
- Conclusion and Outlook

Introduction and background

- The Belgian Nuclear Research Centre SCK·CEN aims to develop a LBE cooled research reactor (ADS) through the MYRRHA project.
- Due to this project, and others that have been initiated since then, the need arose to develop expectations by the nuclear regulator with respect to the safety demonstration and specific external hazards
- The guidelines have a non-binding nature, but serve as a reference for the review by the Belgian nuclear regulator of the safety demonstration for new nuclear installations of class I (NPPs, research reactors, storage, ...)
- All guidelines were extensively discussed with stakeholders and were finally published early 2015.

Guideline on the safety demonstration

- Scope: new “class I” nuclear installations except waste disposal installations.
- Contents:
 - Defence in depth and design basis categories
 - Quantified safety objectives
 - General approach to external hazards including a graded approach
- Main sources of inspiration:
 - WENRA RHWG documentation notably the report on “safety of new NPP designs” of March 2013
 - Euratom council directive 2014/87/Euratom
 - Practices by other regulators

SD Guideline: Defence in Depth

DiD Level	Objective	Qualitative safety objective (Off-site radiological consequences)
Level 1	Prevention of abnormal operation and failures	No off-site radiological impact (bounded by regulatory operating limits for discharge)
Level 2	Control of abnormal operation and detection of failures	
Level 3.a	Control of accident to limit radiological releases and prevent escalation to severe accidents	No off-site radiological impact or only minor radiological impact (part of WENRA Objective O2)
Level 3.b		
Level 4	Control of severe accidents to limit off-site releases	Off-site radiological impact may imply limited protective measures in area and time (part of WENRA Objective O3)
		Reduce the risk further
Level 5 (out of scope)	Mitigation of radiological consequences of significant releases of radioactive material	-

SD Guideline: DiD and design basis categories

DiD Level	Associated Design Basis Categories	
	Definition	Radiological Safety Objective
Level 1	C1 “Normal operation”	GRR-2001
Level 2	C2 “Anticipated operational Occurrences”	SO1
Level 3.a	C3a “Postulated single initiating events”	SO2
Level 3.b	C3b “Postulated multiple failure events”	SO2
Level 4	C4a “Severe Accidents not practically eliminated”	SO3
	C4b “Severe Accidents practically eliminated”	Not applicable
Level 5	(out of scope)	(out of scope)

Nb. probabilistic arguments for classification of initiating events are allowed (and sometimes required)

SD Guideline: Quantified safety objectives

<p>SO1:</p>	<p>For events at least as frequent as once in a year:</p> <ul style="list-style-type: none"> • Effective dose/event < 0,1 mSv/event; • Equivalent thyroid dose/event for the infant, child or adolescent < 0,3 mSv/event; <p>For events less frequent than once in a year:</p> <ul style="list-style-type: none"> • Effective dose/event < 0,5 mSv/event; • Equivalent thyroid dose/event for the infant, child or adolescent < 1,5 mSv/event;
<p>SO2:</p>	<ul style="list-style-type: none"> • Effective dose/event < 5 mSv/event; • Equivalent thyroid dose/event for the infant, child or adolescent < 10 mSv/event; • Lifetime effective dose/event < 1 Sv /event, beyond the site limits (all paths); • Agricultural products should be consumable one year after the accident, beyond the site limits.
<p>SO3:</p>	<ul style="list-style-type: none"> • Effective dose/event < 50 mSv/event beyond the evacuation zone. The dose should be integrated over 7 days; • Effective dose/event < 5 mSv/event, beyond the sheltering zone. The dose should be integrated over 24 hours; • Equivalent thyroid dose/event for the infant, child or adolescent < 10 mSv/event during cloud passage, beyond the sheltering zone; • Lifetime effective dose/event < 1 Sv/event, beyond the site limits (all paths); • Agricultural products should be consumable one year after the accident, beyond the sheltering zone.

Nb. For SO3, If the whole released source term is released in a period of time exceeding the relevant integration time (i.e. 24 hours or 7 days), then an equivalent release rate and release time should be defined.

SD Guideline: External hazards

- For each type of external hazard, two hazard levels are to be defined, HL1 and HL2, and a margin assessment should be carried out.
- HL1: defined under C3a - SO₂ should be met. The annual *exceedance frequency* should not be higher than 10⁻⁴/y for natural hazards and 10⁻⁶/y for unintentional man-made hazards.
- HL2: defined under C3b or C4a - SO₂ resp. SO₃ should be met. More severe and less frequent than HL1.
- Margin assessment to demonstrate the sufficiency of conservatism in reference to the HL1 and defined as the gap between the 'HL1' hazard, and a hazard for which the radiological safety objective SO₂ can still be ensured.

SD Guideline: Graded approach for external hazards

- Graded approach based on the potential worst-case radiological consequences. It defines how the scope of the safety demonstration for external hazards may be reduced if these consequences are sufficiently low.
- The general steps in this process are the following:
 - Characterize the potential worst-case radiological consequences related to the new installation and, when necessary, in relation to a specific external hazard;
 - Categorize this potential worst-case radiological consequence in relation to the safety objectives SO2 and SO3;
 - Determine the scope of the safety analysis in function of the categorization of the potential worst-case consequences

SD Guideline: Graded approach for external hazards

- The hazard-specific worst-case radiological consequences will fall into one of the following graded approach categories:
 - Radiological consequences on-site and off-site below the SO₂ limits;
 - Radiological consequences on-site larger than SO₂ but radiological consequences off-site below the SO₂ limits;
 - Radiological consequences off-site larger than SO₂ but not larger than SO₃ limits;
 - Radiological consequences off-site larger than SO₃ limits.

Graded approach category	Include in safety demonstration?		
	HL1	Margin assessment	HL2
4	yes	yes	yes
3	yes	yes	no
2	yes	no	no
1	yes ^{*1}	no	no

^{*1}. Reduced scope – see specific hazard guides for examples

Guidelines on specific external hazards

- Three external hazards: unintentional aircraft crashes, seismic hazard and external flooding
- These guidelines closely align with the guideline on the safety demonstration and provide additional expectations on how a hazard level (HL1, HL2) can be derived and, in some case, how the margin assessment can be carried out.
- Unintentional aircraft crashes:
 - HL based on crash probability: HL1 ($>10^{-6}/y$) or HL2 ($<10^{-6}/y$)
 - Define representative aircraft crash (type, flight path, impact speed, location and weight are suggested)

Guidelines on specific external hazards

- Seismic hazard:
 - HL1: site-specific Uniform Hazard Response Spectrum (UHRS) for the 10^{-4} mean annual hazard exceedance frequency
 - HL2: maximum credible earthquake affecting the site derived from a Deterministic Seismic Hazard Analysis (DSHA)
- External flooding:
 - Suggests sources, phenomena and combinations
 - HL1: not higher than 10^{-4} /y exceedance frequency
 - HL2: aim at 10^{-6} /y exceedance frequency
 - Extra consideration needed for non-stationary effects (e.g. climate change)

Conclusion and outlook

- The Belgian nuclear regulator has clearly defined its expectations regarding relevant topics through the development of the guidelines on safety demonstration and specific external hazards,
- The Belgian nuclear regulator continues its work on:
 - refining the current guidelines (e.g. on-site objectives),
 - drafting of complementary guidelines (e.g. radiological impact calculations).