WENRA and its expectations on the safety of new NPP

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Basic facts

• Association of the Heads of nuclear regulatory authorities of the EU countries with NPP and Switzerland

• Original Terms of Reference signed on 4 February 1999 (10 countries)
  • Revised on 14 March 2003 => (17 countries)
  • Revised on 26 March 2010

• Independent from politics

• European centre of competence for Nuclear Safety

www.wenra.org
01 WENRA
Basic facts

- 17 Members
- 9 Observers
01 WENRA
Policy Statements

• Develop common approach to nuclear safety
• Commitment to continuous improvement of nuclear safety
• Nuclear safety and radiation protection are the prime responsibility of the operator

• In WENRA MS are 137 NPP in operation, 5 types of NPP
01 WENRA
Working Groups

RHWG  Reactor Harmonization Working Group

WGWD  Working Group on Waste and Decommissioning

Ad-hoc Working Groups (post Fukushima):

• Natural hazards
• Containment integrity
• Accident management
• Periodic safety review
• Mutual assistance
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RHWG task

• Work on safety of new NPP designs initiated in 2008

• Development of WENRA Safety Objectives for new NPP
  ➢ WENRA Statement (November 2010)
    http://www.wenra.org/media/filer_public/2012/11/05/wenra_statementonsafetyobjectivesfornewnuclearpowerplants_nov2010.pdf

• Selection of key safety issues for new reactors
  ➢ WENRA Statement and WENRA Report on Safety of new NPP designs (March 2013)
    http://www.wenra.org/media/filer_public/2013/04/05/wenra_statement_newdesigns2.pdf

  ➢ Lessons from the Fukushima accident have been included
02 WENRA and the safety of new NPP

WENRA Safety Objectives for new NPPs

- Review of the national and international documentation showed consistency on the main lines of expected safety improvements:
  - Reinforce the defence-in-depth (each level and their independence)
  - Extend the design (include severe accidents as a new level of defence)
  - Reduce the necessity of off-site measures in case of accident
  - Consider safety issues in existing plants
  - Increase components and systems diversity
  - Increase protection against hazards
  - Pay more attention to security and safety/security interface
  - Better consider management of safety
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WENRA Safety Objectives for new NPPs

O1. Normal operation, abnormal events and prevention of accidents
O2. Accidents without core melt
O3. Accidents with core melt
O4. Independence of the levels of Defence-in-Depth (DiD)
O5. Safety and security interfaces
O6. Radiation protection and waste management
O7. Leadership and management for safety
02 WENRA and the safety of new NPP
Strengthening the DiD concept

“The primary means of preventing accidents in a nuclear power plant and mitigating the consequences of accidents is the application of the concept of Defence-in-Depth (DiD). This concept should be applied to all safety related activities, whether organizational, behavioural or design related, and whether in full power, low power or various shutdown states. This is to ensure that all safety related activities are subject to independent layers of provisions, [...]”

WENRA RHWG Report, Safety of new NPP designs, March 2013
“Therefore, Defence-in-Depth is a key concept of the safety objectives established by WENRA for new nuclear power plants. In particular, these safety objectives call for an extension of the safety demonstration for new plants, in consistence with the reinforcement of the Defence-in-Depth approach. Thus the DiD concept should be strengthened in all its relevant principles.”

WENRA RHWG Report, Safety of new NPP designs, March 2013
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Strengthening the DiD concept

WENRA aims for strengthening the Defence-in-Depth concept by

• Reinforcing each DiD level
• Improving the independence between levels of DiD

Safety Objective O4:

“WENRA expects new NPP to be designed, sited, constructed, commissioned and operated with the objective of enhancing the effectiveness of the independence between all levels of DiD, in particular through diversity provisions, to provide an overall reinforcement of DiD.”
WENRA and the safety of new NPP
Selected key safety issues

Position 1: Defence-in-Depth approach for new nuclear power plants (related to O4)
Position 2: Independence of the levels of Defence-in-Depth (related to O4)
Position 3: Multiple failure events (related to O4)
Position 4: Provisions to mitigate core melt and radiological consequences (related to O3)
Position 5: Practical elimination (related to O3)
Position 6: External Hazards (related to O2)
Position 7: Intentional crash of a commercial airplane (related to O5)
02 WENRA and the safety of new NPP
Multiple failure events

Refined structure of the DiD levels

Level 3:
“Control of accident to limit radiological releases and prevent escalation to core melt conditions“
is now split up into:

3.a Postulated single initiating events

3.b Postulated multiple failure events
(previously “beyond design”, now in the design, e.g. station black-out or loss of ultimate heat sink)
## WENRA and the safety of new NPP

### Multiple failure events

Examples of postulated common cause failures of safety systems needed to fulfill a safety function necessary to cope with an AOO or a single PIE

<table>
<thead>
<tr>
<th>Denotation</th>
<th>Postulated Initiating Event</th>
<th>Loss of a safety system</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCA</td>
<td>Small LOCA</td>
<td>Medium head safety injection</td>
</tr>
<tr>
<td></td>
<td>Small LOCA</td>
<td>Low head safety injection</td>
</tr>
<tr>
<td>Station blackout</td>
<td>Loss of off-site power</td>
<td>Emergency power supply</td>
</tr>
<tr>
<td>Total loss of feed water</td>
<td>Loss of main feed water</td>
<td>Emergency feed water supply</td>
</tr>
<tr>
<td>ATWS</td>
<td>Anticipated Transient</td>
<td>Fast shutdown</td>
</tr>
</tbody>
</table>

Examples of postulated common cause failures of safety systems needed to fulfill the fundamental safety functions in normal operation

<table>
<thead>
<tr>
<th>Denotation</th>
<th>Initiating condition</th>
<th>Loss of a system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of RHR</td>
<td>normal operation</td>
<td>Residual heat removal</td>
</tr>
<tr>
<td>Loss of UHS</td>
<td>normal operation</td>
<td>Ultimate heat sink</td>
</tr>
<tr>
<td>Loss of CCW/ECW</td>
<td>normal operation</td>
<td>Component cooling water / essential cooling water</td>
</tr>
<tr>
<td>Loss of spent fuel pool cooling</td>
<td>normal operation</td>
<td>Spent fuel pool cooling</td>
</tr>
</tbody>
</table>
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Accidents with core melt

Accidents with core melt (Level 4), safety objective O3:

- Accidents with core melt leading to early or large releases have to be practically eliminated.
- For accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public (...) and that sufficient time is available to implement these measures.

Core melt accidents are included in the design of new NPPs.
## WENRA and the safety of new NPP
### Defence-in-Depth for new NPP designs

<table>
<thead>
<tr>
<th>Levels of defence in depth</th>
<th>Associated plant condition categories</th>
<th>Objective</th>
<th>Essential means</th>
<th>Radiological consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Normal operation</td>
<td>Prevention of abnormal operation and failures</td>
<td>Conservative design and high quality in construction and operation, control of main plant parameters inside defined limits</td>
<td>Regulatory operating limits for discharge</td>
</tr>
<tr>
<td>Level 2</td>
<td>Anticipated operational occurrences</td>
<td>Control of abnormal operation and failures</td>
<td>Control and limiting systems and other surveillance features</td>
<td></td>
</tr>
<tr>
<td>Level 3 (1)</td>
<td>DiD Level 3.a</td>
<td>Control of abnormal operation and failures</td>
<td>Reactor protection system, safety systems, accident procedures</td>
<td>No off-site radiological impact or only minor radiological impact</td>
</tr>
<tr>
<td></td>
<td>Postulated single initiating events</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DiD Level 3.b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Postulated multiple failure events</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 4</td>
<td>Postulated core melt accidents</td>
<td>Control of accidents with core melt to limit off-site releases</td>
<td>Complementary safety features³ to mitigate core melt, Management of accidents with core melt (severe accidents)</td>
<td>Limited protective measures in area and time</td>
</tr>
<tr>
<td>Level 5</td>
<td>-</td>
<td>Mitigation of radiological consequences of significant releases of radioactive material</td>
<td>Off-site emergency response Intervention levels</td>
<td>Off site radiological impact necessitating protective measures</td>
</tr>
</tbody>
</table>

Notes:
1. DiD Level 3.a
2. Postulated single initiating events: Control of accident to limit radiological releases and prevent escalation to core melt conditions.
3. Additional safety features.
4. Postulated multiple failure events: Additional safety features³, accident procedures.
5. Postulated core melt accidents: Control of accidents with core melt to limit off-site releases.
6. Level 5: Mitigation of radiological consequences of significant releases of radioactive material.
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Independence of DiD Levels

• There shall be independence to the extent reasonably practicable between different levels of DiD

• The means to achieve independence between levels are:
  – diversity provisions
  – physical separation, structural or by distance
  – functional isolation

• Attention shall be paid to the design of I&C and of the reactor auxiliary and support systems (e.g. electrical power supply, cooling systems)
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Independence of DiD Levels

In particular, and to the extent reasonably practicable,

• DiD level 3 should be independent from levels 1 and 2,
• DiD sub-levels 3.a and 3.b should be independent from each other,
• DiD level 4 should be independent from all the other levels.
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Practical elimination

• According to WENRA safety objective O3, accident sequences with core melt which may lead to early or large radioactive releases must be practically eliminated.

• Accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public.

• Accident sequences can be considered to be practically eliminated
  – if it is physically impossible for the accident sequence to occur or
  – if the accident sequence can be considered with a high degree of confidence to be extremely unlikely to arise.
02 WENRA and the safety of new NPP
Practical elimination

SAFETY DEMONSTRATION

Events considered to occur and consequences considered in the design

- Single postulated initiating events DiD level 3a
- Multiple failure events DiD level 3b
- Confined fuel melt DiD level 4

Design basis*

Design extension*

Events which have to be practically eliminated, as would lead to large or early radioactive release

- Initiators (reactor vessel rupture...)
- Consequential faults (severe reactivity increases accidents...)
- Fuel melt sequences challenging the confinement

Practical elimination

* Comparable to IAEA SSR 2.1
Conclusions
Conclusions

Expectations on safety of new NPP

WENRA RHWG completed its task to elaborate safety objectives for new reactors, including a reinforced Defence-in-Depth concept.

The improved DiD approach will be used for new reactors in all WENRA member countries.

An appropriate adaptation to the safety related aspects of SMR designs might be necessary.
Thank you.

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ANNEX

WENRA safety objectives for new reactors

• **O1. Normal operation, abnormal events and prevention of accidents**
  – reducing the frequencies of abnormal events by enhancing plant capability to stay within normal operation.
  – reducing the potential for escalation to accident situations by enhancing plant capability to control abnormal events.

• **O2. Accidents without core melt**
  – ensuring that accidents without core melt induce\(^1\) no off-site radiological impact or only minor radiological impact (in particular, no necessity of iodine prophylaxis, sheltering nor evacuation\(^2\)).
  – reducing, as far as reasonably achievable,
    • the core damage frequency taking into account all types of credible hazards and failures and credible combinations of events;
    • the releases of radioactive material from all sources.
  – providing due consideration to siting and design to reduce the impact of external hazards and malevolent acts.

\(^1\) In a deterministic and conservative approach with respect to the evaluation of radiological consequences.

\(^2\) However, restriction of food consumption could be needed in some scenarios.
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WENRA safety objectives for new reactors

• O3. Accidents with core melt
  – reducing potential radioactive releases to the environment from accidents with core melt\(^1\), also in the long term\(^2\), by following the qualitative criteria below:
    • accidents with core melt which would lead to early\(^3\) or large\(^4\) releases have to be practically eliminated\(^5\);
    • for accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public (no permanent relocation, no need for emergency evacuation outside the immediate vicinity of the plant, limited sheltering, no long term restrictions in food consumption) and that sufficient time is available to implement these measures.

\[^1\] For new reactors, the scope of the safety demonstration has to cover all risks induced by the nuclear fuel, even when stored in the fuel pool. Hence, core melt accidents (severe accidents) have to be considered when the core is in the reactor, but also when the whole core or a large part of the core is unloaded and stored in the fuel pool. It has to be shown that such accident scenarios are either practically eliminated or prevented and mitigated.

\[^2\] Long term: considering the time over which the safety functions need to be maintained. It could be months or years, depending on the accident scenario.

\[^3\] Early releases: situations that would require off-site emergency measures but with insufficient time to implement them.

\[^4\] Large releases: situations that would require protective measures for the public that could not be limited in area or time.

\[^5\] In this context, the possibility of certain conditions occurring is considered to have been practically eliminated if it is physically impossible for the conditions to occur or if the conditions can be considered with a high degree of confidence to be extremely unlikely to arise (from IAEA NSG1.10).
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WENRA safety objectives for new reactors

• **O4. Independence between all levels of defence-in-depth**
  – enhancing the effectiveness of the independence between all levels of defence-in-depth, in particular through diversity provisions (in addition to the strengthening of each of these levels separately as addressed in the previous three objectives), to provide as far as reasonably achievable an overall reinforcement of defence-in-depth.

• **O5. Safety and security interfaces**
  – ensuring that safety measures and security measures are designed and implemented in an integrated manner. Synergies between safety and security enhancements should be sought.

• **O6. Radiation protection and waste management**
  – reducing as far as reasonably achievable by design provisions, for all operating states, decommissioning and dismantling activities:
    • individual and collective doses for workers;
    • radioactive discharges to the environment;
    • quantity and activity of radioactive waste.
ANNEX

WENRA safety objectives for new reactors

• O7. Leadership and management for safety
  – ensuring effective management for safety from the design stage. This implies that the licensee:
    • establishes effective leadership and management for safety over the entire new plant project and has sufficient in house technical and financial resources to fulfil its prime responsibility in safety;
    • ensures that all other organizations involved in siting, design, construction, commissioning, operation and decommissioning of new plants demonstrate awareness among the staff of the nuclear safety issues associated with their work and their role in ensuring safety.
Seven safety objectives are derived from the IAEA Safety Fundamentals document (SF-1) which establishes ten safety principles (SP)

SP1: Responsibility for safety  
SP2: Role of government  
SP3: Leadership and management for safety  
SP4: Justification of facilities and activities  
SP5: ...  
SP 6, 7, 8: ...  
SP9: Emergency preparedness and response  
SP 10: Protective actions to reduce existing or unregulated radiation risks

<table>
<thead>
<tr>
<th>IAEA SF-1 safety principles</th>
<th>WENRA safety objectives</th>
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<tbody>
<tr>
<td></td>
<td>O1</td>
</tr>
<tr>
<td>SP 3 Leadership and management for safety</td>
<td>✓</td>
</tr>
<tr>
<td>SP 5 Optimization of protection</td>
<td>✓</td>
</tr>
<tr>
<td>SP 6 Limitation of risks to individuals</td>
<td>✓</td>
</tr>
<tr>
<td>SP 7 Protection of present and future generations</td>
<td>✓</td>
</tr>
<tr>
<td>SP 8 Prevention of accidents</td>
<td>✓</td>
</tr>
</tbody>
</table>