IRSN
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ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

IRSN comments on the document Safety Design Criteria for Generation IV Sodium-cooled Fast Reactors (Reference SDC-TF/2013/01) issued in May 2013

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SAFETY OF SODIUM-COOLED FAST REACTORS

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Context

- In July 2013, the vice-Chairman of the GIF asked the French Safety Authority (ASN) to provide comments on the document "Safety Design Criteria for Generation IV Sodium cooled Fast Reactor System" (reference SDC-TF/2013/01) issued in May 2013 by the GIF Safety Design Criteria Task Force (SDC-TF)

- As technical support of French Safety Authority, IRSN provided its comments to ASN in August 2014

- But ASN has not forwarded up to now these comments to the GIF but recently agreed that IRSN sends them directly to the GIF in the framework of the present meeting

- These comments have been already sent to GIF SFR SDC TF leader on June 1st 2015

Overall comments (1/2)

- The SDC for SFR document does not provide really " Safety Design Criteria" but corresponds rather to safety requirements that remain quite qualitative as those given in the SSR-2/1

- Moreover, IRSN considers that the implementation of SDC does not guarantee the achievement of a high level of safety equivalent or higher than that one specified for the Generation-III systems under construction in the world even if in the Chapter 2.2.32 it is written: "*Generation-IV reactor systems aim at achieving a higher safety level than that of Generation-III systems. In order to realise this, a highly reliable system with very low probability of accidents and with enhanced measures against severe accidents has to be achieved, in addition to improved well-balanced safety throughout the whole range of accident conditions .*"

- Nevertheless, IRSN notes that GIF wants to complete the SDC for SFR document with more quantitative criteria defining more precisely what the level of safety to be considered.

Overall comments (2/2)

- The characteristics of SFRs may be very different from one project to another (electrical power range from 50 MW to 2000 MW, “loop” or “pool” concepts, fuel types, etc.) and the safety issues are quite dependent from these characteristics

  - IRSN suggests to add a section dealing with these design differences

- IRSN believes also that “Safety Design Criteria" should be completed, by a document identifying the target safety goals for the SFR presently considered and that could prefigure those of Generation IV. The safety goals of the Generation IV reactors should take into account the experience gained from design, construction and operation of these “prefiguring“ SFRs

Comments on specific points (1/14)

IRSN provided also about comments on specific points: these comments are given afterwards with the page and paragraph numbers corresponding to the SDC-TF/2013/01 document

- p 11 – Defence-in-Depth and plant status

IRSN considers, as European regulatory authorities and TSOs, that the multiple failure events should be addressed in the level 3 of the defence-in-depth with consequences limited to those of category 4 of design basis accidents, not to those of severe accidents. This may have a direct impact on plant safety systems architecture when looking for independence between levels 3 and 4.

Comments on specific points (2/14)

- p 15 – 2.2.4 Prevention of cliff-edge effect

It is written that « *The severe accidents that are determined to be practically eliminated should be restricted to those that are not deemed physically impossible as determined by deterministic and probabilistic considerations* ».

It is not the usual practice (WENRA for example) : situations deemed physically impossible are included in the list of « practically eliminated » situations.

Moreover, this sentence is in contradiction with the appendix (C): « *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 level of confidence to be extremely unlikely to arise* » [that is the WENRA definition]

Comments on specific points (3/14)

- p 17-19 2.3.2 : Approach based on basic characteristics of the SFR – Physical and Chemical Properties Sodium coolant

1. It is suggested to add, at the end of the first paragraph, that sodium physical properties have drawbacks regarding structures robustness in case of accident (the sodium may reach temperatures that may affect mechanical structures and equipment).

2. "Supporting and Auxiliary Systems; Fuel Handling & Storage"
   A list of SSCs specific to SFRs is given and is reflected in the document. IRSN mentions that 2 SSCs should be added:

   - the clad rupture detection and localization systems (very important in case of MOX fuel)

   - the sodium cleaning system (to remove the residual sodium for assemblies before their storage in a water pool)

Comments on specific points (4/14)

p 17-18: Leak Before Break

It is mentioned that « *As sodium allows the use of low pressure coolant systems, application of the Leak Before Break concept is feasible and would enable continuous leakage-monitoring as an inspection method for the coolant boundary. Application of Leak Before Break concept could also help in the determination of design basis leaks* ».

IRSN does not share this statement for the two following main reasons:

1. Mechanical loadings considered to design mechanical structures correspond to the situation the structures have to face, i.e. low pressure does not mean lower stresses on structures and equipment.
2. Applying the LBB concept assumes that cracking phenomenon is modeled correctly and thus known in advance. Experience feedback shows that it is not the case. IRSN considers that the LBB concept is contrary to the approach that should prevail to ensure a high safety level: provisions should be taken to cover as far as possible all possible causes of damage that could occur, including phenomenona that are not known. In-service inspection cannot be only based on leakage detection. It should aim to detect degradation before leak occurrence (loss of integrity starts before leak).

Moreover, LBB concept is a method and not a « safety criteria »; it does not seem appropriate to introduce this concept in this type of document.

Comments on specific points (5/14)

p 19 to 21 : SFR safety approach in relation with the plant states

- This part gives insights to design basis accident (DBA) on one hand, design extension conditions (DEC) on the other hand.

- It is not possible to give insights on the type of conditions considered in each category independently from a reactor design

- Single events sequences are generally part of the design basis accident but, it is written on the page 21 that the situations of « *potential significant sodium chemical reactions (e.g. combustion resulting from leakage, sodium-water reactor resulting for steam generator tube rupture…* » are part of design extension conditions.

- IRSN suggests to review this part of the report being more cautious about the classification of the different situations. However, the report should insist on the justification that should be provided by the licensee to support its proposition of situations classification (on the basis of events or situations frequencies in particular).

Comments on specific points (6/14)

- p 26 - Criterion 4: Fundamental safety functions

This criterion includes the confinement of radioactive and chemical material (good point) but mentions only the limitation of accidental radioactive releases. IRSN thinks that limitation of accidental radioactive releases have also to be sought for.

- p 27– Criterion 7: Application of the defence-in-depth

It is written "*The design of a nuclear power plant shall be such that level 4 of the defence in depth and the associated safety design for prevention and/or mitigation of severe accident conditions shall be incorporated, in order to practically eliminate significant radioactive release* »

IRSN suggests replacing the underlined text by: *in order that significant radioactive release can be considered as belonging to the residual risk*. This sentence may induce some confusion. The same comment applies to the criterion 20 in page 37 which repeats the same sentence.

Comments on specific points (7/14)

- p 35: Criterion 17: Internal and external hazards

In 5.16, IRSN proposes the following text : *sodium chemical reaction…associated pressure wave, temperature increase and product releases…*

- p 37 - Criterion 19: Design basis conditions – 5.26

The possibility to study « *in a best estimate manner, together with adequately analysed and evaluated uncertainties* » has been added to the SSR2/1 original text (« *The design basis accidents shall be analysed in a conservative manner. This approach involved postulating certain failures in safety systems, specifying design criteria and using conservative assumptions, models and input parameters in the analysis* »). The two proposed approaches are contradictory. Sole the conservative approach, mentioned in the SSR-2/1, is acceptable. Therefore, IRSN suggests suppressing the text in italics. Moreover, it should be emphasized that a robust deterministic approach shall remain the sound basis for the design, even if PSA are necessary to confirm design options.

Comments on specific points (8/14)

- p 46 Criterion 34 : Systems containing fissile material or radioactive material

At the end of the criterion definition, IRSN suggests to write: *and to facilitate mitigation of radiological and toxic releases*

- p 54 - Criterion 47: Design of reactor coolant system 6.16ter

IRSN proposes to add the following point between (a) and (b) of 6.16 ter: *The mitigation of a sodium-water reaction occurring in a heat exchanger should be achieved automatically by draining the water side. This action should be fast enough to prevent further damages to secondary sodium circuit (risk of sodium-water-air reaction).*

Comments on specific points (9/14)

p 60- Criterion 61: Protection system

A first list of trip parameters mandatory for SFRs safety be proposed such as:

- Clad rupture detection (for MOX fuel)
- Sodium/water reaction (if the tertiary circuit uses water)
- Fuel assembly blockage

A link should be made with the criterion 46 (Reactor shutdown). IRSN proposes to add the following point 6.34.
(6.34): *Each event identified in the point 5.1 (p. 32) should be detected by a sufficient number of trip parameters according to the event classification (NO, AOO, DBA or DEC).*

Comments on specific points (10/14)

- p 65 - Criterion 69: Performance of supporting systems and auxiliary systems

A sentence may be added to point out that the design of supporting systems should not, as far as possible, question the principle of independence of levels of defence-in-depth.

- p 68: Criterion 76bis: Sodium heating systems

IRSN proposes to modify the first sentence by including the following underlined text: *Heating systems shall be provided for components containing sodium to prevent both loss of fundamental safety functions (decay heat removal) and sodium/water leak extension (in case of impossibility to drain sodium) by sodium freezing.*

Comments on specific points (11/14)

- p 69 to 71 - Criterion 80: Fuel handling and storage systems

- In 6.66 (e) and 6.67(b) IRSN proposes "*To prevent the dropping and blockage on fuel in transit*"

- Cooling of non-irradiated fuel using plutonium has to be considered (this point is emphasized when the fuel contains MAs)

- A topic 6.68 ter should be added for the case of spent fuel storage in the reactor vessel (so-called internal vessel storage)

Comments on specific points (12/14)

APPENDIX B : Guide to Design Extension Conditions

p 91: §2.2.1 Loss of Reactor Level (LORL)

IRSN does not consider that the « *conditions to clarify « practical elimination* »» of a double leakage from the RV and the GV (guard vessel) mentioned in the appendix are sufficient.
Conditions rely to the design and manufacturing. At least two crucial elements are missing:

- the licensee should be able to justify a positive feedback on the type of steels the RV and GV are made of,
- a complete program of in-service inspection at least of the GV should be set up to ensure that there is no pre-existing loss of integrity of the GV in case of RV leakage.

Moreover, it could be added that « *the design of the two vessels should comply with the principle of diversity.* »

Comments on specific points (13/14)

APPENDIX C: Guide to “practical elimination” of accident situations

p 96: Principles for setting up a demonstration of Practical Elimination

The document says“ *Deterministic demonstrations are organized by lines of defense”*

IRSN considers that there is no reason to enforce the use of the methodology of lines of defense. It may help defining the provisions to be set up to prevent situations but the demonstration should rely on the robustness and the reliability of the provisions added, not on a number of lines of defence

Moreover the use of this methodology requires fulfilling some requirements in terms of independence of the different lines, reliability of each line, etc. which are not defined. IRSN suggests suppressing the sentence.

Comments on specific points (14/14)

APPENDX E: Approach to Extreme External Events

The way to design SSC against design extension conditions for external hazards is explained.

IRSN considers that there is no reason to design these SSC with different methods than the ones used to design SSC against design basis accidents for external hazards.

The main difficulty is to define the beyond design hazards to be taken into account (type of hazards and characteristics). Some discussions are held in WENRA on this topic.

Conclusions should be taken into account in this document (in terms of probability of level or intensity exceeding the beyond design level or intensity).

Thank you for you attention