GIF Task Force Response to IAEA's Comments on "GIF SFR Safety Design Criteria (SDC) Phase I Report"

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Background

- ***GIF provided "SDC Phase I Report" to IAEA for review, soon after the report approval by the GIF ca. mid-2013.***
- ***IAEA Department of Nuclear Energy provided the comments on the SDC Phase I Report, in the letter, dated 28 April 2014, to the GIF Chair. Noted on:***
  - ***IAEA had been contributed on the SDC development***
  - ***IAEA expert has been a member of GIF SDC Task Force***
  - ***Some preliminary comments on the SDC report, which had been provided in April 2013 by the IAEA experts, had been partially implemented in the SDC report.***
  - ***IAEA had suggested that the GIF Task Force would consider the implementation of the comments in the next issue of the SDC.***

Summary of IAEA Comments (1/2)

- ***IAEA commented 10 points on the SDC report:***
  - ***3 out of 10 are general comments and***
  - ***the other 7 out of 10 are comments specific to some criteria and paragraphs in the SDC report.***

- ***GIF Task Force***
  - ***had confirmed to the IAEA on the meanings of 3 general comments,***
  - ***and the IAEA replied by email on 7 Oct. 2014 to provide some examples on the 3 general comments.***

Summary of IAEA Comments (2/2)

- ***IAEA's 3 general comments on the SDC report are on:***
  - ***"Consistency of terminology with the IAEA SSR 2/1",***
  - ***"Comprehensiveness to cover different types of SFR system", and***
  - ***"Robust safety based on deterministic approach".***
- ***IAEA's the other 7 specific comments are on:***
  - ***"Passive/inherent reactor shutdown to prevent core damage",***
  - ***"Importance of primary coolant inertia on the safety of SFR",***
  - ***"Combination of events",***
  - ***"Propagations of sodium-water chemical reaction",***
  - ***"Prevention of sodium fire spread", and***
  - ***Two editorial comments and suggestions.***

Resolutions for IAEA Comments and Recommendations (1/2)

- *GIF SDC Task Force:*
  - *Deliberated the IAEA comments and recommendations in the GIF SDC Task Force 3rd meeting (June 2014) and 4th meetings (Sept. 2014), with supplemental discussions and updates via emails;*
    Totally around half-year period,
  - *Summarized the GIF Task Force's resolutions for consideration of the updates in the next issue of the SDC Phase I Report, ca. December 2014.*

Resolutions for IAEA Comments and Recommendations (2/2)

- ***The GIF Task Force's response are:***
  - ***In general, greatly appreciates IAEA's comprehensive and substantive recommendations and mostly agrees with their comments.***
  - ***Some detailed technical points will be summarized in the lower level guidance documents of the SDC which is now under development by the GIF Task Force as the "Safety Design Guidelines".***
    - *e.g. coolant inertia requirement for loss of flow accident, recommendation on measures for sodium-water reaction*
  - ***GIF Task Force adopted changes to one part in Section 2, two out of 83 criteria and one glossary in response to IAEA comments and recommendations.***

General considerations:

- ***IAEA Comment #1]***

  "The structure of the document makes reference to and is based on the IAEA SSR 2/1, which is primarily focused on water cooled reactors but "may also applied, with judgment, to other reactor types, to determine the requirements that have to be considered in developing the design". As stated in the GIF document, SFR designs have specific features which are not addressed in the existing safety standards. However, in order to avoid potential misunderstandings, it is recommended to maintain consistency with the IAEA SSR 2/1, in particular as far as terminology;"

  - *Supplement by email from IAEA, 7 Oct. 2014*

    Examples of terminology are: 'passive safety system', 'reactivity', ''fuel'', and 'robustness of safety'.

- ***Answer to IAEA comment #1]***
  - *For the terms "passive safety system", "reactivity" and "safety feature for design extension conditions", there is no contradiction between the GIF's SDC Phase I Report and IAEA's SSR 2/1 and Safety Glossary. The only one exception in the SDC report is "safety relevant system" which is used instead of "safety related system".*
  - *For the term "fuel", it includes "fissile fuel" and "blanket fuel"; although the SDC utilizes "fuel" because there is no need to distinguish the criteria between them.*
  - *For the term 'robustness of safety', the answer is described in the #4 below.*
  - *For the term "void reactivity", the answer is described in the #7 in the following page.*

- ***IAEA Comment #2]***

  "The document aims at covering different types of SFRs, i.e.: pool-type, loop-type and small modular systems. It should be recognized that some safety concepts are hardly applicable to all these types of SFRs;"

  - *Supplement by email from IAEA, 7 Oct. 2014*

    Examples of omissions and issues related to specific SFR designs are: 'decay heat', 'newly introduced criterion 42bis should be reviewed to keep it in the form of safety requirement'.

- ***Answer to IAEA comment #2]***
  - *The SDC was developed as a set of criteria for the safety approach generally applicable to the SFR (i.e. pool/loop, oxide/metal fuel), under the participation of all the SFR developing member states under the GIF. Thus, the GIF SDC TF recognizes that the SDC covers all these SFR types.*
  - *For the term "decay heat", it is a common term utilized in the nuclear field. No need to explicitly include in the glossary of the SDC.*
  - *Design options will be explained in the lower level guidance documents of "Safety Design Guidelines" that are now under developed by the GIF.*

    e.g. a "system" to transport "decay heat" from the reactor core to a final heat sink
  - *Criterion 42bis covers the requirements related to general/common concerns on SFR. The criteria after 42bis is required in combination.*

- ***IAEA Comment #3]***

  "It should be emphasized that a robust deterministic approach shall remain the sound basis of the design, even if Probabilistic Safety Assessment (PSA) is necessary."

- ***Answer to IAEA comment #3]***
  - *The SDC Phase I Report already includes the content/meaning of the IAEA's comment. The SDC forms a set of criteria for the Gen-IV SFR, which corresponds to a set of criteria for the current LWR in the IAEA SSR 2/1.*
  - *The SDC was fundamentally developed based on the deterministic approach considering the safety feature of SFR. Operational experiences of the SFR were included in the criteria and paragraphs to give indispensable attentions to the SFR designers; this serves for the robustness of the safety approach.*
  - *The PRA is referred in the identification for the postulated initiating events and a set of design extension conditions.*

Specific Comments

- ***IAEA Comment #4]***

  "Section 2.2.6, page 15: we suggest to replace the bullet "improve the robustness of the power plant safety" with the less ambiguous "increase the safety of the plant"

- ***Answer to IAEA comment #4]***

  The IAEA's proposed text "increase the safety of the plant" is fine because "robustness" is one of the important aspects to improve the safety. The update will included this point.

2.2 Fundamental Orientations on Safety

2.2.6 Provision against hazards

An exhaustive approach is expected regarding the design basis against hazards, taking into account the type of hazards, the combinations of loadings, and the design margins.

One of the main lessons learned from the TEPCO's Fukushima Dai-ichi Nuclear Power Plants accidents is to recommend considering extreme external hazards as considered for the internal events and the possible combination of external and internal hazards in order to:

- ~~improve the robustness of the power plant safety~~increase the safety of the plant,
- confirm that consequences of degraded plant situations induced by extreme hazards are acceptable,
- define equipments that need to be strengthened to resist extreme natural hazards beyond the reference used for the plant design.

- ***IAEA Comment #5]***

  "Section 2.3.3, page 21, first paragraph: in case of failure to shutdown, passive or inherent reactor shutdown capabilities may not be sufficient to prevent core damage;"

- ***Answer to IAEA comment #5]***

  "Capability to prevent core damage" is required for DEC in the SDC. If the capability is not sufficient, such design does not fit to the SDC. For AOO and DBA, two shutdown systems are required in the SDC. For DEC, passive/inherent shutdown capability is required; such capability for DEC shall have diversity to the measures for AOO and DBA (i.e. two shutdown systems). The original text sufficiently requires the capability of shutdown.

2.3.3 SFR specific safety approach in relation to the plant states

SFR design for normal operations, anticipated operational occurrences, and design basis accidents

Based on the characteristics of the SFR, the design for normal operation, anticipated operational occurrences, and design basis accidents conditions must insure that: 1) the reactor can be reliably shutdown if needed, 2) the core remains covered in the case of a leak in the primary coolant boundary ...

SFR design for design extension conditions

For the failure of reactor shutdown events, the design needs to prevent such events from damaging the core and mitigate the consequences of core damage to minimize the load on the containment function. In order to prevent core damage, the design may make use of passive or inherent reactor shutdown capabilities. Restricting generated energy and retaining/cooling of the damaged core will reduce the potential load on the containment function. ...

- ***IAEA Comment #6]***

  "There is no mention in the whole document — and in particular in section 2.3.3 - to the importance of relying on high primary pump inertia. This feature might be important to protect the core avoiding fuel/core damage in some transients like ULOF and UTOP. For instance in case of ULOF if primary pumps don't have sufficient inertia and natural circulation is not prompt, local Na boiling may occur and even additional passive or inherent reactor shutdown systems might intervene when fuel/core is already damaged;"

- ***Answer to IAEA comment #6]***
  - *Flow inertia & heat capacity of primary coolant are important parameters which affect on the transient behavior of ULOF.*
    The GIF will make further discussion on this item, and will include in the safety design guidelines (SDGs).

- ***IAEA Comment #7]***

  "The term void reactivity should be replaced with "void reactivity coefficient" or "void reactivity effect";

- ***Answer to IAEA comment #7]***
  - *The term utilization of "void reactivity" should depend on the contexts of sentences; and it will be utilized case-by-case basis.*
    - » *"Void reactivity coefficient" is given by "perturbation" when one specific parameter is changed (e.g. coolant mass in the core region) in neutronics calculation.*
    - » *"Void reactivity effect" is used to specify the effect (e.g. power increase) in comparison with the other effect (e.g. Doppler effect). Such effect is generally taken by the composition of void coefficient and change of parameter (void ratio).*
    - » *"Void reactivity" is used to generally note about the "reactivity related to void".*
  - *There are four parts where "void reactivity" is used in SDC Report. A glossary were found to be updated via "case-by-case" examinations.*

#gas entrainment

Cover gas entrainment at the free surface of sodium coolant, which is caused by, for example, surface oscillation due to earthquakes or a standing wave (seiche). An SFR shall be designed to limit the amount of gas entrainment in order to prevent void reactivity insertion and decrease in heat removal rate due to the entrained gas.

"to prevent void reactivity insertion" means "reactivity increase as an effect related to void". This "void" is not "sodium void" but "entrained-gas void". Update to avoid the confusion of "sodium void" and "entrained-gas void"

- ***IAEA Comment #8]***

  Add the underlined part: "The paragraph 5.32: …Certain events might be consequences of other events, such as a flood following an earthquake <u>or a sodium fire following a steam generator tube rupture</u>…;"

- ***Answer to IAEA comment #8]***
  - *The example in the original text is a combination with "inevitable sub-sequence", such as tsunami by earthquake. Here "inevitable" means that it cannot be mitigated by "design". The IAEA proposal to add "sodium fire after SG tube rupture" is in different situation in which the SG tube rupture is mitigated by various "design" measures. The proposal is not adequate to be added.*

Criterion 20: Design extension conditions

Combinations of events and failures

5.32. Where the results of engineering judgement, *operating experience,* deterministic safety assessments and probabilistic safety assessments indicate that combinations of events could lead to anticipated operational occurrences or to accident conditions, such combinations of events shall be considered to be design basis accidents or shall be included as part of design extension conditions, depending mainly on their likelihood of occurrence. Certain events might be consequences of other events, such as a flood following an earthquake. Such consequential effects shall be considered to be part of the original postulated initiating event.

- ***IAEA Comment #9]***

  Add the underlined part: "Paragraph 6.1 g): As sodium burns in air and intensely reacts with water, propagation of such chemical reactions <u>from one system to another and</u> to the reactor core must be prevented";

- ***Answer to IAEA comment #9]***

  The original SDC text includes the meaning of "from one system to another". The point of the IAEA's comment is that the original text of "to the reactor core" looks limited scope; because the reactor core is the object to be protected eventually. The content of the IAEA comment will be included; such that:

  – *"(g) Due to chemical risk of sodium which burns in air and intensely reacts with water, impact of such chemical reactions <u>to items important to safety</u> must be prevented."*

Criterion 42bis: Plant system performance of a sodium-cooled fast reactor

The overall plant system shall be designed considering the specific characteristics of a sodium-cooled fast reactor as described below.

(a) The reactor core is not in its most reactive configuration under normal operating conditions. This could lead to a positive reactivity insertion due to an unfavourable change in reactor

(g) ~~As sodium burns in air and intensely reacts with water, propagation of such chemical reactions to the reactor core must be prevented.~~

- ***IAEA Comment #10]***

  Criterion 74: add also a paragraph on the provisions to prevent spread of sodium fires.

- ***Answer to IAEA comment #10]***
  - *The provision related to “prevent of sodium fire spread” is important. It will be included in the update of the SDC such that:*
    - » *“6.54ter. Compartments with sodium components shall be protected from the impacts induced by sodium fire to prevent the fire spread and from water ingress to prevent sodium-water chemical reactions, especially from water used in case of fire fighting in an adjacent compartment”.*

Criterion 74: Fire protection systems

Fire protection systems, including fire detection systems and fire extinguishing systems, fire containment barriers and smoke control systems, shall be provided throughout the nuclear power plant, with due account taken of the results of the fire hazard analysis. ***Water systems shall not be used with sodium in the same compartment, except for the sodium-water heat exchanger.***

6.54ter. Compartments with sodium components shall be protected from the impacts induced by sodium fire to prevent the fire spread and from water ingress to prevent sodium-water chemical reactions, especially from water used in case of fire fighting in an adjacent compartment.

Summary

- ***IAEA review comments on "SDC Phase I Report"***
  - ***GIF SDC Task Force:***
    - » ***Applicate IAEA's comprehensive and detail review***
    - » ***Made half-year careful discussion for the resolutions to include the next update of the "SDC Phase I Report"***
    - » ***Concluded to include 4 parts:***
      - ***one part in Section 2, two out of 83 criteria and one glossary***
    - » ***Some detailed technical points will be summarized in the "Safety Design Guidelines".***