Summary of Revisions to GIF SFR Safety Design Criteria Based on USNRC Comments

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Background

- *On invitation of GIF chairman, USNRC Office of New Reactors (NRO) completed a review of GIF SDR SDC in January 2014*
  - *Does not constitute an endorsement of GIF SFR SDC or indicate any commitment for future use*
- *USNRC staff compared GIF SFR SDC with applicable requirements/processes in "Code of Federal Regulations (CFR)"*
  - *10 CFR 50: Domestic Licensing of Production and Utilization Facilities*
  - *Appendix A: General Design Criteria for NPPs*
  - *10 CFR 52: Licenses, Certifications, and Approvals for NPPs*
  - *NUREG-0800: Standard Review Plan for Review of SARS for NPPs*
- *Recognizing that GIF SFR SDC is based on IAEA SSR-2/1 (Safety of NPPs: Design) pertaining to LWRs, USNRC noted the*
  - *Similarities in USNRC and IAEA requirements*
  - *Differences in terminology and level of detail*

Summary of USNRC Comments

- *USNRC commented that GIF SFR SDC are comprehensive and did not identify any "insurmountable safety or regulatory issues"*
- *"Appropriate" mark given for GIF SFR SDC criteria 15, 30, 47, 48, 78, and 79 (total 6 criteria)*
- *No comments were made for GIF SFR SDC criteria 13, 17, 18, 22, 26, 27, 28, 35, 36, 39, 40, 41, 49, 51, 52, 53, 57, 59, 60, 62, 63, 64, 65, 67, 68, 69, 70, 72, 73, 74, 76, 76bis, and 77 (total 33 criteria)*
  - *Absence of comments did not imply agreement/approval*
  - *Generally, no comments were made on the criteria specific to SFR technology, introductory chapters, or appendices of SFR SDC report*
- *Bulk of USNRC comments suggested broadening the scope of GIF SFR SDC to address plant security considerations*
  - *Protection against design-basis threats such as cyber attacks and sabotage, as well as the risk of material theft and diversion*

Summary GIF TF Resolutions

- *GIF Task Force deliberated the USNRC comments during the last four meeting spanning a sixteen-month period, and planning to submit its resolutions for consideration of GIF Policy and Expert Groups in June 2015.*
- *The GIF Task Force appreciated USNRC's detailed and substantive comments/recommendations and mostly agrees with them by adopting revisions to 21 criteria and adding a new definition for confinement function in the glossary.*
- *In certain instances, USNRC comments highlight the differences between U.S. regulations and the requirements in IAEA SSR 2/1 as generic issues, not specific to SFR technology. In those instances, to stay consistent with IAEA SSR 2/1 on which GIF SFR SDC is based, original wording is retained.*
- *Since the plant security and physical protection is beyond the TF scope, USNRC recommendations on including provisions to maintain adequate security postures against design basis threats are adopted only for a select set of criteria in which plant security considerations also have an impact on safety.*

Criterion 2: Management system for the plant design

The design organization shall establish and implement a management system for ensuring that all safety requirements established for the design of the plant are considered and implemented in all phases of the design process and that they are met in the final design.

3.2. The management system shall include provision for ensuring the quality of the design of each structure, system and component, as well as of the overall design of the nuclear power plant, at all times. This includes the means for identifying and correcting design deficiencies, for checking the adequacy of the design and for controlling design changes.

Does not address a well-defined QA program to establish QA requirements for the design, manufacture, construction, and operation of SSCs including a corrective action program.

Resolution: "...through a corrective action program" is added at the end of Para 3.2.

Criterion 3: Safety of the plant design throughout the lifetime of the plant

The operating organization shall establish a formal system for ensuring the continuing safety of the plant design throughout the lifetime of the nuclear power plant.

3.5. The formal system for ensuring the continuing safety of the plant design shall include a formally designated entity responsible for the safety of the plant design within the operating organization's management system. Tasks that are assigned to external organizations (referred to as responsible designers) for the design of specific parts of the plant shall be taken into account in the arrangements.

NRC regulations emphasize that the applicant "shall retain responsibility for the quality assurance program" even though the applicant may delegate to others the work of establishing and executing the QA program activities.

Resolution: "The operating organization shall retain responsibility of the quality assurance program." is added at the end of Para 3.5

Criterion 4: Fundamental safety functions

Fulfilment of the following fundamental safety functions for a nuclear power plant shall be ensured for all plant states:

(i) control of reactivity,

(ii) removal of heat from the reactor and from the fuel storage

(iii) confinement of radioactive and toxic chemical material, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases.

Introduction of "toxic chemicals" should be tied to nuclear safety.

Resolution: Providing adequate protection against chemical risks from sodium coolant is already covered under criterion 42.bis, 47, and 74.
The reference to confinement of toxic chemicals is removed from Criterion 4.
Similar consideration is also given to criteria 7 and 34, and added text related to "chemical risks" in these criteria is also removed.

Criterion 5: Radiation protection

The design of a nuclear power plant shall be such as to ensure that radiation doses to workers at the plant and to members of the public do not exceed the dose limits; that they are kept as low as reasonably achievable in operational states for the entire lifetime of the plant, and that they remain below acceptable limits ~~and as low as reasonably achievable~~ in and following accident conditions.

Ensuring that radiation doses to the public to remain as low as reasonably achievable in and following accident conditions is generally acceptable as a design goal. However, NRC regulations at 10 CFR Part 50 and 10 CFR Part 52 do not have a regulatory requirement that the projected DBA doses as evaluated for purposes of siting and design safety assessment are as low as reasonably achievable.

Resolution: USNRC recommendation is adopted as shown

Criterion 6: Design for a nuclear power plant

The design for a nuclear power plant shall ensure that the plant and items important to safety have the appropriate characteristics to ensure that safety functions can be performed with the necessary reliability, that the plant can be operated safely within the operational limits and conditions for the full duration of its design life and can be safely decommissioned, and that ~~impacts on~~ contamination of the facility and the environment ~~are~~ is minimized.

Criterion 6, in addition to minimizing the impacts on the environment, should also stress that the plant design shall minimize contamination of the facility.

Resolution: USNRC recommendation is adopted as shown

Criterion 8: Interfaces of safety with security and safeguards

Safety measures, nuclear security measures and arrangements for the State system of accounting for, and control of, nuclear material for a nuclear power plant shall be designed and implemented in an integrated manner so that they do not compromise one another.

Criterion 8 should reflect that managing the safety-to-security interface includes establishing management systems to ensure that changes do not adversely impact either safety or security.

Resolution: GIF Task Force agrees to add the following new paragraph to Criterion 8:
4.13bis. Management system shall take into account the potential for adverse effects on safety or security when designing, and before implementing changes to, the plant configurations, facility conditions, engineering and administrative controls.

Criterion 11: Provision for construction

Items important to safety for a nuclear power plant shall be designed so that they can be manufactured, constructed, assembled, installed and erected in accordance with established processes that ensure the achievement of the design specifications and the required level of safety.

Narrowly defining "design" to not include examination and testing. Consider expanding consistent with NRC GDC 1.

Resolution: GIF TF agrees to revise the paragraph as follows:

Items important to safety for a nuclear power plant shall be designed so that they can be manufactured, constructed, assembled, installed,~~ and~~ erected, inspected and tested in accordance with established processes that ensure the achievement of the design specifications and the required level of safety.

Criterion 19: Design basis accidents

A set of accident conditions that are to be considered in the design shall be derived from postulated initiating events for the purpose of establishing the boundary conditions for the nuclear power plant to withstand, without acceptable limits for radiation protection being exceeded.

5.26. The design basis accidents shall be analysed in a conservative manner. This approach involves postulating certain failures in safety systems, specifying design criteria and using conservative assumptions, models and input parameters in the analysis. The design basis accidents could preferably be analysed in a best estimate manner, together with adequately analysed and evaluated uncertainties.

Currently no guidance in the U.S. on evaluation of DBAs using best estimate methods including uncertainty.

Resolution: Paragraph 5.26 is modified as follows:

"The design basis accidents are preferably analysed in a conservative manner. This approach involves postulating certain failures in safety systems, specifying design criteria and using conservative assumptions, models and input parameters in the analysis. The design basis accidents could also be analysed in a best estimate manner, together with adequately analysed and evaluated uncertainties."

Criterion 32: Design for optimal operator performance

5.56. The human–machine interface shall be designed to provide the operators with comprehensive but easily manageable information, in accordance with the necessary decision times and action times. The information necessary for the operator to make a decision to act shall be simply and unambiguously presented.

5.59. The need for intervention by the operator on a short time-scale shall be kept to a minimum and it shall be demonstrated that the operator has sufficient time to make a decision and sufficient time to act.

Although Criterion 7 captures, in part, the intent of Functional Allocation (FA) as it suggests that automation should be used to improve reliability of the system in the early part of abnormal operations, it is not explicitly described. Paragraphs 5.56 and 5.59 acknowledge time constraints on operators. FA uses this information to determine if automation or manual actions are appropriate for a given function.

Resolution: The following sentence is added to Para 5.59:
"The design will be capable of performing all functions necessary to bring the plant to a safe state using appropriate allocations of functions to the operator, automation, or a combination of both to minimize errors."

Criterion 37: Communication systems at the plant

Effective means of reliable communication shall be provided throughout the nuclear power plant to facilitate safe operation in all modes of normal operation and to be available for use following all postulated initiating events and in accident conditions, including applicable DBT.

5.66. Suitable alarm systems and means of communication shall be provided so that all persons present at the nuclear power plant and on the site can be given warnings and instructions, in operational states and in accident conditions, including security events.

5.67. Suitable and diverse means of communication necessary for safety and security within the nuclear power plant and in the immediate vicinity, and for communication with relevant off-site agencies, shall be provided.

Resolution: GIF TF agrees to add ", also accounting for the interface of safety with security" at the end of first sentence.

Criterion 38: Control of access to the plant

The nuclear power plant shall be isolated from its surroundings with a suitable layout of the various structural elements so that access to it can be controlled.

5.68. Provision shall be made in the design of the buildings and the layout of the site for the control of access to the nuclear power plant by operating personnel and/or for equipment, including emergency response personnel and vehicles, with particular consideration given to guarding against the unauthorized entry of persons and goods to the plant. Specific physical access control measures shall include those necessary for detecting, assessing, and delaying insider threats for systems and equipment designated as vital.

Resolution: GIF TF agrees to add "by detecting, assessing, and delaying the entry" at the end of paragraph 5.68.

Criterion 42: Safety analysis of the plant design

Deterministic approach

5.75. The deterministic safety analysis shall mainly provide:

(a)…

…

(f) Demonstration that the management of design extension conditions is possible by ~~the~~ some combination of inherent design characteristics, automatic actuation of safety systems and/or the use of safety features in combination with expected actions by the operator.

Resolution: GIF TF agrees to revise the text as follows:
(f) Demonstration that the management of design extension conditions is possible by the use of appropriate systems and the reliance on inherent and/or passive features in combination with expected actions by the operator.

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.

(e) Sodium is chemically active and opaque, and it is solid below 98 ºC.

(f) The mist and vapour of sodium are deposited on the components.

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

Includes specific criteria which address the chemical characteristics of sodium and should address chemical protection. Consider incorporation of the NRC requirement at 10 CFR 70.64(a)(5).

Resolution: GIF Task Force agrees to revise the item (g) as follows:
(g) Due to chemical risk of sodium which burns in air and reacts with water, impact of such chemical reactions to items important to safety must be prevented.

Criterion 44: Structural capability of the reactor core

The fuel elements and fuel assemblies and their supporting structures for the nuclear power plant shall be designed so that, in operational states and in accident conditions (due to both internal and external events) other than severe accidents, a geometry that allows for adequate cooling is maintained, core geometry is preserved to prevent excessive reactivity changes, and the insertion of control devices is not impeded. For the design extension conditions, provisions shall be included to avoid re-criticality resulting in potentially large mechanical energy release during a core disruptive accident.

Addresses only internal events. Fuel assemblies are considered important to safety and therefore must accomplish their safety functions, allowing reactor shutdown and maintaining a coolable geometry, under combined internal and external DBA events.

Resolution: Although "accident conditions" cover both internal and external hazards as specified in criterion 17, criterion 44 is modified as shown above.

Criterion 54: Containment system for the reactor

A containment system shall be provided to ensure or to contribute to the fulfilment of the following safety functions at the nuclear power plant: (i) confinement of radioactive substances in operational states and in accident conditions, (ii) protection of the reactor against natural external events and human induced events and (iii) radiation shielding in operational states and in accident conditions.

This criterion raises the question of “confinement” versus traditional use of “containment.” Specific criteria similar to that provided in NRC GDC would be more appropriate.

Resolution: In both GIF SFR SDC and IAEA SSR 2/1, the word “confinement” is considered as synonymous with “containment.” To address USNRC comment, a definition for "confinement function" is added to glossary as "prevention or control of releases of radioactive material to the environment in operation or in accidents" based on IAEA safety glossary.

Criterion 56: Isolation of the containment

Each line that penetrates the containment at a nuclear power plant as part of the reactor coolant boundary and the reactor cover gas boundary or that is connected directly to the containment atmosphere shall be automatically and reliably sealable in the event of an accident in which the leaktightness of the containment is essential to preventing radioactive releases to the environment that exceed acceptable limits.

6.22. Lines that penetrate the containment, as part of the reactor coolant boundary and the reactor cover gas boundary, and lines that are connected directly to the containment atmosphere shall be fitted with at least two adequate containment isolation valves ~~or check valves~~ arranged in series , and shall be provided with suitable leak detection systems for preventing the containment bypass of radioactive materials. Containment isolation valves ~~or check valves~~ shall be located as close to the containment as is practicable, and each valve shall be capable of reliable and independent actuation and of being periodically tested.

This statement is contrary to GDC 56 which states that check valves cannot be used as the automatic isolation valve outside of containment.

Resolution: Although the pipes that are part of reactor coolant or cover gas boundary are not expected to penetrate the containment in a Gen-IV SFR, TF agrees to adopt USNRC recommendation

Criterion 61: Protection system

A protection system shall be provided at the nuclear power plant that has the capability to detect unsafe plant conditions and to initiate safety actions automatically to actuate the safety systems necessary for achieving and maintaining safe plant conditions.

6.33. The design:

(a) Shall prevent operator actions that could compromise the effectiveness of the protection system in operational states and in accident conditions, but not counteract correct operator actions in accident conditions;

(b) Shall automate various safety actions to actuate safety systems so that operator action is not necessary within a justified period of time from the onset of anticipated operational occurrences or accident conditions;

(c) Shall make relevant information available to the operator for monitoring the effects of automatic actions.

No discussion of protection system independence. A protection system should consist of independent trains such that a single failure would not prevent the protective action.

Resolution: Although independence of safety-related items are covered in criteria 24 and 25, GIF TF agrees to add the following new item in criterion 61:

(d) Shall consist of independent trains such that a single failure would not disable the protective action.

Criterion 66: Supplementary control room

Instrumentation and control equipment shall be kept available, preferably at a single location (a supplementary control room) that is physically, electrically and functionally separate from the control room at the nuclear power plant. The supplementary control room shall be so equipped that the reactor can be placed and maintained in a shutdown state, decay heat can be removed, and essential plant variables can be monitored if there is a loss of ability to perform these essential safety functions in the control room.

6.41. The requirements of paragraphs 6.39 and 6.40 for taking appropriate measures and providing adequate information for the protection of occupants against hazards also apply for the supplementary control room at the nuclear power plant.

The requirements of paragraph 6.40 for paying special attention to identifying those events, both internal and external to the control room, that could challenge its continued operation, also apply to the supplementary control room at the nuclear power plant. The design of the supplementary control room shall provide for reasonably practicable measures to minimize the consequences of such events.

Resolution: Para 6.41 is modified as shown to also refer to Para 6.40 to address USNRC recommendation.

Criterion 80: Fuel handling and storage systems

Fuel handling and storage systems shall be provided at the nuclear power plant to ensure that the integrity and properties of the fuel are maintained at all times during fuel handling and storage.

The paragraphs under Criterion 80 do not address the ability of fuel storage systems to withstand external events such as earthquakes, tornados, hurricanes and floods and, additionally, consideration of externally caused rack deformation on the criticality and heat removal analyses.

Resolution: External events are addressed in Criterion 17. Nevertheless,, ”including internal and external events" is added at the end of Criterion 80 main paragraph.

Criterion 81: Design for radiation protection

Provision shall be made for ensuring that doses to operating personnel at the nuclear power plant will be maintained below the dose limits and will be kept as low as reasonably achievable, and that the relevant dose constraints will be taken into consideration.

6.73. The plant shall be divided into radiation zones that are related to their expected occupancy and to radiation levels and contamination levels in operational states (including refuelling, maintenance and inspection) and to potential radiation levels and contamination levels in accident conditions. Shielding shall be provided so that radiation exposure is prevented or reduced.

Resolution: Recommendation is adopted as shown.