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| **From:** | Campbell, Patricia L (GE Power) |
| **To:** | AdvancedRxDCComments Resource |
| **Subject:** | [External_Sender] Comments: Solicitation of Public Comments for the Advanced Non-Light Water Reactor Design Criteria |
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| **Attachments:** | 2016-06-06 GEH Comments on Advanced Reactors GDC - Filed via e-mail.pdf |

Please see the attached comments on the NRC Solicitation of Public Comments for the Advanced Non-Light Water Reactor Design Criteria.
Please contact me if you have any questions.
Thank you,

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ADVANCED REACTOR COMMENTS

Filed Via e-Mail

In response to NRC's request for public comments, GE-Hitachi Nuclear Energy ("GEH") is pleased to provide specific comments on the proposed General Design Criteria (GDC) for Advanced Non-Light Water Reactors. These comments, provided by our GEH PRISM project team, are offered in support of the NRC's mission to protect the health and safety of the public and the environment by regulating the design, siting, construction, and operation of commercial nuclear power facilities. The PRISM team has adopted the format of the NRC's Comments Form in the comments below; however, because of the number and nature of comments provided, they have been collected into this single, comprehensive package.

Because the GDC are an important part of the NRC's regulatory framework, it is essential that the criteria reflect those design elements that are related to systems, structures and components related to safety. Therefore, both additions and deletions to the proposed criteria have been recommended for NRC's consideration. In particular, a few general observations about criteria are offered for your consideration:

1. General Design Criteria should be general. They should require few, if any, departures and then departures should only be necessary where design features that are unique to a specific design appear to conflict with the intent of an individual criterion. Throughout this initial document, design-specific or technology-specific requirements were identified that could be viewed as favoring one technology over another or were too prescriptive in general. GEH believes that the GDC should be design-neutral and should permit the development of both current known and future, unanticipated designs. Therefore, it is essential that the GDC be of a sufficient breadth to allow for innovation.
2. Along these lines, the current emergency mechanisms prevalent in light-water reactors are not necessarily needed or warranted under some of the new designs. Therefore, the criteria should be focused on the underlying safety basis of that requirement rather than the requirement itself. For example, several GDCs (34, 35, 38, and 41) identified the need for redundancy, as a secondary requirement. While in the current light-water environment, this has been necessary. The current design environment has the benefit of digital monitoring and applications that were not envisioned when the current fleet was built. Designers should be given the opportunity to at least prove a technical improvement over past designs before being required to use past fixes in their new designs.
3. The use of light-water related physics needs to be eliminated or at least minimized. References to "water" and to "pressure vessels" need to be carefully reviewed to determine if they are needed.
4. Finally, we have made a number of references to the previous NUREG reports that were referenced in the rationale sections of each of these criteria. We did not see in some cases where they were used.

On the whole, GEH believes that this was a strong initial attempt and is willing to support its current development. Our PRISM team is willing to meet with NRC to discuss any of these comments should you desire. Please contact Patricia Campbell (patricial.campbell@ge.com; 202-637-4239) if you have questions or would like to request additional information.

# GEH Comments on Advanced Non-LWR Design Criteria Table

GDC: 3
Topic: ARDC
Type of Change: Editorial

**Comment:** Recommend the rewording of the second paragraph as follows:

> "Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations ~~such as the containment and control room~~ with ~~safety-related equipment or~~ structures, systems, ~~and~~ or components important to safety."

The use of the term "safety-related equipment" is redundant when followed by the phrase "structures, systems or components important to safety." Additionally, the word "or" was added to the second paragraph of the ARDC when the word "or" did not exist in the original GDC.

GDC: 4
Topic: ARDC
Type of Change: Technical

**Comment**: Recommend revising this GDC for SFR-DC as follows:

> *Environmental and dynamic effects design bases.* Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, anticipated operational occurrences and postulated accidents, ~~including loss of coolant accidents~~ including the effects of the liquid sodium ... and aerosols and oxidation products. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping. Spontaneous and massive ruptures of sodium piping are not considered credible because the piping is in low-pressure and low stressed systems, therefore the dynamic effects of pipe rupture (i.e. pipe whip) need not be considered.

As described in NUREG-1368, the intent of this additional phrase is to require that the plant be designed and constructed with special consideration given to the effects of sodium. Because of the high chemical activity of sodium, leaks and spills can lead to chemical reactions, fires, and reaction products not possible in LWRs and, therefore, special measures need to be taken.

This criterion is written in reference to a high pressure, water coolant and includes explicit references to pipe ruptures. The words should be changed 1) to include dynamic and environmental phenomena relevant to low pressure sodium, e.g. the environmental effects of aerosols and oxidation products, 2) to delete references to dynamic and environmental accident phenomena specific to water coolant, and 3) to include references to generic design basis events, i.e. "anticipated operational occurrences."

The analysis referenced as reviewed and approved by the Commission is pipe leak before pipe break in LWRs. It is not required for SFR because the reactor coolant is a low-pressure system. Therefore, the proposed criterion is more conservative than GDC 4.

GDC: 15
Topic: SFR-DC
Type of Change: Technical

**Comment:** Revise SFR-DC as follows:

> *~~Reactor~~ Primary coolant system design.*
> The ~~reactor~~ primary coolant system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the ~~reactor~~ primary coolant ~~pressure~~ boundary and the sodium heating system for the liquid metal coolant are not exceeded during any condition of normal operation, including anticipated operational occurrences.

This criterion is written to require that the reactor coolant boundary be built to withstand design basis conditions. To be consistent with NUREG 1368, NUREG 0968, and ANSI/ANS 54, the sodium heating system should be added to the list of coolant systems subject to this requirement.

GDC: 16
Topic: SFR-DC
Type of Change: Technical

**Comment:** *Containment design.* The phrase "and its associated cooling systems," located in the first paragraph should be deleted.

The reference to the cooling system is proscriptive and presupposes a design rather than addresses the need to remove heat from the core under accident conditions. The way that this criterion is currently worded does not permit innovative designs to be developed and militates against potential designs that provide passive heat removal. If this remains unchanged, in the future such innovations will be required to demonstrate why they must be accorded a departure.

The words “high strength” and “pressure retaining” are also design-specific and should be deleted.

From a technical viewpoint, because of its relatively low melting point – 208$^{o}$F (97.8$^{o}$C), and high boiling point 1621.3$^{o}$F (882.9$^{o}$C), SFRs operate at ambient pressure. Thus, they do not require a pressure vessel for normal operations. Although temperatures may rise under some accident conditions, significant pressure build up is unlikely.

GEH is willing to share with the NRC, the results of its own probabilistic risk assessment which shows that a conventional containment has less impact to safety than other containment options.

GDC: 17
Topic: ARDC/ SFR-DC
Type of Change: Technical

**Comment:** *Electric power systems.* GEH suggests rewording this criterion to delete references to offsite power for non-LWRs, as follows:

> “Electric power systems shall be provided to permit functioning of structures, systems, and components important to safety. Quality, independence, availability, redundancy and reliability requirements of the electric power systems shall be commensurate with their importance to safety.”

The proposed criterion may be unnecessary and are likely to add significant cost to advanced reactors that are being designed to be inherently safe. Rather than speculate that these new designs will require the same emergency measures that have been provided to the existing light-water fleet, the NRC should encourage the reactor designer develop designs in which the electric power systems have a minimal importance to safety AND demonstrate that to the NRC that they will be available under all postulated accident conditions in which that power is important to safety. The arrangement and location of the electrical equipment is secondary and should not be specifically mandated as part of the GDC.

GEH is willing to share the results of its own probabilistic risk assessment which shows that the electrical system has minimal impact on safety under all currently postulated accident conditions.

GDC: 25
Topic: ARDC
Type of Change: Editorial

**Comment:** The word “any” in the inserted phrase should be deleted and replaced with “an.”

The use of this word makes the sentence all-encompassing, and the criterion should be limited to only those Anticipated Operational Occurrences (AOO) that are associated with a particular design. Unless the Standard Review Plan provides the constraints against unlimited application of the criterion, this word eliminates any constraint on the imagination of a particular staff reviewer or public intervener.

GDC: 26
Topic: ARDC
Type of Change: Technical

**Comment:** *Reactivity control system redundancy.*

The criterion as stated in the ARDC language should remain as stated in the current GDC language. The inserted words “[A]t least” added at the beginning of the GDC imply that if two are sufficient, more may be an improvement. This has no basis in the research and adds unnecessary cost to any reactor build. If at some future date a particular design requires additional reactivity control that cannot be provided by two systems, there is nothing that prevents a designer from adding them or the NRC from requiring the addition. However, these are supposed to be small, efficient designs making the need for more than two systems unlikely.

GDC: 31
Topic: SRF-DC
Type of Change: Technical

**Comment:** Consider revising the SFR-DC topic for this criterion as follows:

*Fracture prevention of reactor primary coolant ~~pressure~~ boundary*. The ~~reactor~~ primary coolant ~~pressure~~ boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a non-brittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures, service degradation of material properties, creep, fatigue, stress rupture and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation and coolant chemistry on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws.

GEH recommends adding requirements for coolant chemistry and service degradation of properties, creep, fatigue, and stress rupture to address unique concerns of CRBRP because

of the high design and operating temperatures of the primary coolant boundary and the use of sodium as the coolant under NUREG-0968.

Rapid fracture propagation is not as much of an issue for high temperature reactor compared to progressive crack growth operating at high temperature. The high temperature anneals the material. The austenitic stainless steel (SS) materials of a SFR are not susceptible to brittle fracture to the same extent that exists with LMR ferrite thick pressure vessels.

GDC: 32
Topic: SRF-DC
Type of Change: Technical

**Comment:** Revise the SFR- DC topic for this criterion as follows:

> *Inspection of reactor primary coolant ~~pressure~~ boundary.* Components which are part of the reactor primary coolant ~~pressure~~ boundary shall be designed to permit (1) periodic inspection, monitoring and testing of important areas and features to assess their structural and leak tight integrity, and (2) an appropriate material surveillance program for the reactor ~~pressure~~ vessel.

As described in the PRISM safety evaluation NUREG-1368, an alternative examination method in the applicable section of the ASME code was proposed and will include a combination of continuous monitoring and remote visual video techniques. Because the external walls of the reactor vessel and the annulus between the reactor vessel and containment vessel will be continuously monitored, they are designed with inspection access ports for remote visual inspection. The annulus space between the sodium level and reactor closure head will be continuously monitored and periodically inspected. The experience at test facilities and experimental reactors with the continuous monitoring devices indicated that the devices were sensitive to sodium leaks.

It appears that this GDC provided were based upon the correct premise that the intermediate coolant "system" has two distinct boundary requirements: one to the primary coolant (GDC 77) and one to everything else (GDC70). That said, monitoring the boundary with the primary coolant is probably impossible and an inspection program (like PWR steam generator tube inspections) would be needed (which is what the last sentence did. Perhaps better clarity between GDC 70 and 77 is needed to make one clearly applicable to the primary boundary and the other applicable to the rest of the world?

GDC: 34
Topic: ARDC
Type of Change: Technical

**Comment:** *Residual heat removal.*

The inserted second paragraph in this GDC should be rewritten to replace the phrase "to assure that the design conditions of the reactor coolant boundary are not exceeded" with "to ensure the integrity of the reactor coolant boundary." The term "design conditions" is vague as it does not address what is necessary, i.e., a demonstration that the reactor coolant will withstand the postulated accidents and continue to serve its primary function of removing decay heat from the core.

Consider removing the last paragraph, which is included in the current GCD, from the ARCD text. It is not consistent with the stated category of the GDC, *Residual Heat Removal.*

GDC: 34
Topic: SFR-DC
Type of Change: Technical

**Comment:** *Residual heat removal.* The last phrase of inserted second paragraph should be rewritten as "and the primary coolant boundary is maintained." This represents a clearer requirement.

Consider removing the last paragraph, which is included in the current GCD, from the SFR-DC text. It is not consistent with the stated category of the GDC, *Residual Heat Removal.*

Under the current wording, if a design falls outside the stated criterion, does it then have to meet the criterion in any event? How does the Designer overcome this criterion if the system is passive? The question is not rhetorical. GEH recommends that the last paragraph of the topic criterion be deleted and that the opportunity and need for redundancy be addressed on a case by case basis.

GDC: 35
Topic: ARDC
Type of Change: Editorial & Technical

**Comment:** *Emergency core cooling.* Delete this GDC, as the requirements that it embodies are inherent in GDC 34.

GEH believes this criterion is unnecessary for ARCD designs and that GDC 34 is a sufficiently robust requirement to ensure that the removal decay energy and heat from the core under accident conditions is addressed.

GDC: 36 & 37
Topic: ARDC, SFR-DC
Type of Change: Editorial

**Comment:** *Inspection of the emergency core cooling system.* Rework GDC 36 to combine this GDC system with GDC 37 the testing of the same system as they cover similar parameters. In particular

the test specifications identified in GDC 37 provide an assessment of the integrity of the system for continued operation, which is a portion of the overall inspection program.

GDC: 37
Topic: ARDC
Type of Change: Editorial

**Comment:** Revise the SFR-DC as follows:

> *Testing of residual heat removal ~~emergency core cooling~~ system*. The residual heat removal ~~emergency core cooling~~ system shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leak tight integrity of its components, (2) the operability and performance of the ~~active~~ system components ~~of the system~~, and (3) the operability of the system as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the system into operation, ~~including~~ operation of associated systems and interfaces with an ultimate heat sink including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling ~~water~~ system.

As described in INL/EXT-14-31179 Rev 1, Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors, December 2014, a pressure test is not required to demonstrate system performance for the PRISM RVACS passive system. As described in PRISM safety evaluation NUREG-1368, water systems for cooling the RCPB should be avoided. In view of the reactivity of sodium and water, other designs may have an entirely air-cooled heat sink. Therefore, references to "emergency core cooling," and in particular, to "cooling water" should be deleted.

GDC: 38
Topic: ARDC, FSR-DC
Type of Change: Technical

**Comment:** *Containment heat removal.* Delete the second paragraph of GDC 38.
In GDC 38, the reactor designer should be permitted to demonstrate that the proposed reactor design is sufficiently robust to meet the requirements of paragraph 1 without being told how to design the heat removal system in paragraph 2.

The physical and thermodynamic properties of the coolant and the use of appropriate design features can efficiently remove residual heat during an accident and should be primary before the need to introduce redundancy and other safety features, which add complexity and may introduce further accident scenarios not currently contemplated by this draft GDC.

GDC: 39 & 40
Topic: ARDC, SFR-DC
Type of Change: Editorial

**Comment:** *Inspection of containment heat removal system* and *Testing of containment heat removal system.*

GEH suggests combining these two criteria as they cover similar parameters for inspection and testing. Furthermore it is recommended that all emergency power source details be deleted as they will be design specific. For example, a design could have an entirely passive system. The details of the power system inspection and testing should be proposed by the designer and worked out in the design certification and licensing documentation.

GDC: 40
Topic: SFR-DC
Type of Change: Technical

**Comment:** *Testing of containment heat removal system.*

Recommend revising this SFR-DC as follows:

> (3) the operability of the system as a whole, and under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation, ~~including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system~~, including operation of associated systems.

The reference to emergency power source details is design specific and should be removed to be developed in future guidance documents. This criterion provides for testing of the containment heat removal system and includes specific reference to design features relevant to water -cooled systems. The criterion should be rewritten to include design characteristics relevant to sodium cooled systems.

Reference to operation of applicable portions of the protection system, cooling water systems, and power transfers is considered part of the more general "associated systems" for operability testing of the system as a whole.

GDC: 41
Topic: ARDC
Type of Change: Editorial

**Comment*:*** *Containment atmosphere cleanup.* Recommend revising ARDC by deleting the second paragraph.

GDC: 43
Topic: ARDC
Type of Change: Technical

**Comment*:*** *Testing containment atmosphere cleanup systems.* Recommend revising ARDC by deleting the clause “the transfer between normal and emergency power sources, and including the operation of associated systems.”

This wording is design-specific. If power is needed for safety functions, GDC 17 should be available to cover it.

GDC: 45 & 46
Topic: ARDC
Type of Change: Editorial & Technical

**Comment:** *Inspection of cooling ~~water~~ system and Testing of cooling ~~water~~ system.* Suggest combining these two GDCs as they cover similar parameters for inspection and testing.

Because of the chemical reactivity of sodium system with water, all references to water in the context of coolant should be deleted.

GDC: 70
Topic: SFR-DC
Type of Change: Technical

**Comment:** *Intermediate coolant system.* This GDC should be re-written as follows:

> An intermediate cooling system shall be provided. A single passive barrier shall separate intermediate coolant from primary coolant; at least a single passive barrier shall separate the energy conversion system coolant from intermediate coolant. The intermediate coolant shall be chemically nonreactive with sodium. A pressure differential shall be maintained across the primary to intermediate barrier such that any coolant barrier leakage would flow from the intermediate coolant system to the primary coolant system. ~~The intermediate coolant boundary shall be designed to permit the conduct of a surveillance program and inspection in areas where intermediate coolant leakage out of the intermediate coolant system, or energy conversion system coolant leakage into the intermediate coolant system, may hinder or prevent a structure, system or component from performing any of its intended safety functions.~~

GEH does not have an issue with the addition of separate and specific criterion for Sodium Fast Reactors, and in particular for the intermediate coolant system; however, these criteria should apply to all potential designs. There should be generic criteria applicable to all non-LWR designs.

Moreover, the distinction between this GDC 70, *Intermediate Coolant System*, and GDC 77 *Inspection of the intermediate coolant boundary,* is unclear. Based upon the premise that the intermediate coolant "system" has two distinct boundary requirements: one to the primary coolant (GDC 77) and one to everything else (GDC 70), monitoring the boundary with the primary coolant is probably impossible. Therefore, an inspection program (like PWR steam generator tube inspections) is needed, which is what the last sentence appears to do. In this case, the last sentence is necessary and should remain as part of this criterion.

However, others saw this as redundant with the requirements expressed in GDC 32, and felt that those requirements did not need to be repeated again in this criterion. See comments for intermediate circuit provided in GDC 32 for primary coolant boundary (surveillance program and inspection). Inspection of the intermediate coolant boundary is covered by the criterion GDC 77, and does not need to be repeated here. In that case, the last sentence should be deleted.

Perhaps better clarity is needed between GDC 70 and GDC 77 to make one criterion clearly applicable to the primary boundary and the other applicable to the turbine system boundary.

GDC: 74
Topic: SFR-DC
Type of Change: Technical
**Comment:** *Sodium/water/reaction prevention/mitigation.* Please revise the second paragraph of this GDC as follows:

> To prevent the loss of any plant safety function, the sodium-steam generator system shall be designed to detect and contain sodium-water reactions and limit the effects for the energy and reaction products released by such reactions ~~as well as to extinguish a fire as a result of such reactions~~.

Instead of increasing safety, the addition of such an extinguishing system could enhance the reactivity of the sodium-water reaction, which is the opposite of the safety benefit that this GDC means to achieve. For example, the current PRISM design has a glow plug in its vent line that is designed to burn any excess hydrogen that might result in the event of an unlikely sodium water reaction. The sodium-water reaction prevention should be covered by the Fire Protection GDC 3 and does not need to be repeated here.

GDC: 75
Topic: SFR-DC
Type of Change: Technical

**Comment:** *Quality of the intermediate coolant boundary.* Please delete this GDC as the requirements identified herein are covered in other criteria.

GDC: 77
Topic: SFR-DC
Type of Change: Editorial and Technical

**Comment:** *Inspection of the intermediate coolant boundary.* Please revise this GDC as follows:

> *Inspection of the intermediate coolant boundary.* Components which are part of the intermediate coolant boundary shall be designed to permit (1) periodic inspection, monitoring and testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the intermediate coolant boundary. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of coolant leakage.

As previously stated in GDC 70, we had two schools of thought about what this criterion actually meant. Presuming that GDC 77 is a requirement for inspection of the primary coolant boundary, similar to the program for PWR steam generator tube inspections, GDC 77 is reasonable as written, and without the modifications shown.

However, if this is a general inspection requirement for all of the intermediate coolant boundaries, by adding the word “monitoring” to item (1), the last sentence of this statement, which was already

included in GDC 73, may be deleted. There is no disagreement that such leaks need to be detected, but there is no need of two criteria to address this issue. In that case, the last sentence should be deleted.

Again, we believe that further clarification is needed for this criterion.