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## Submitter Information

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**Name:** Anonymous Anonymous
**Submitter's Representative:** Mark Holbrook
**Organization:** Idaho National Laboratory
**Government Agency Type:** Federal
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## General Comment

See attached file(s)

## Attachments

DOE-National Lab Team Comments on NRC Draft Reg Guide DG-1330

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**Add=** M. Orr (MPO2)

# DOE/National Laboratory Team Comments on Draft Regulatory Guide DG-1330

## Docket ID NRC–2017–0016

## Positive Comments

| Section | Page | Regulatory Guide Text | Positive Team Comments |
|---|---|---|---|
| Appendix A<br>Appendix B<br>Appendix C | A-7<br>B-9<br>C-11 | ARDC 26: *Reactivity control systems.*<br>Reactivity control systems shall include the following capabilities:<br><br>(1) A means of shutting down the reactor shall be provided to ensure that, under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions, design limits for fission product barriers are not exceeded.<br><br>(2) A means of shutting down the reactor and maintaining a safe shutdown under design-basis event conditions, with appropriate margin for malfunctions, shall be provided. A second means of reactivity control shall be provided that is independent, diverse, and capable of achieving and maintaining safe shutdown under design-basis event conditions.<br><br>(3) A system for holding the reactor subcritical under cold conditions shall be provided. | The original GDC 26 language was unnecessarily confusing and the staff's proposed revision of ARDC 26-27 offers greater clarity of underlying safety intent. Generally speaking, the team agrees that the revised structure of ARDC 26 is a significant improvement.<br><br>This positive comment also applies to the corresponding SFR-DC 26 and mHTGR-DC 26. |
| Appendix A | | ARDC 17: *Electric power systems.*<br>Electric power systems shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for the systems shall be to provide sufficient capacity, capability, and reliability to ensure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant boundary are not exceeded as a result of anticipated operational occurrences and (2) vital functions that rely on electric power are maintained in the event of postulated accidents.<br><br>The onsite electric power systems shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure. | The team commends the NRC for this criterion adaptation. The adaptation provides increased flexibility for designers and license applicants as they pursue enhanced margins of safety and the use of simplified, inherent, passive, or other innovative means to accomplish safety and security functions, consistent with the Commission's policy on advanced reactors.<br><br>This positive comment also applies to the corresponding SFR-DC-17 and modular HTGR-DC-17. |
| Appendix C | C-3 | mHTGR-DC-10 *Reactor design* | The NRC staff's incorporation of the SARRDL as a replacement for the SAFDL is a very important step forward in the development of the modular HTGR design criteria. |

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| Appendix C | C-5 | mHTGR-DC 14 *Reactor helium pressure boundary* Rationale: For consistency, a specific requirement is appended to mHTGR DC 30 for a means of detecting ingress of moisture, air, secondary coolant, or other fluids. Although "other fluids" could be interpreted as including water and steam, for emphasis, the word "moisture" is included in the list of contaminants in both mHTGR DC 14 and mHTGR DC 30. | The addition of the reference to modular HTGR DC 30, and the associated changes to modular HTGR Criteria 14 and 30, are both excellent improvements. |
| Appendix C | C-6 | mHTGR-DC-15 *Reactor helium pressure boundary design* | The changes to the text in the body of this criterion made by the NRC staff relative to the proposed text in the DOE/INL report are an improvement. |
| Appendix C | C-14 | mHTGR-DC 28 *Reactivity limits* Rationale: The list of "postulated reactivity accidents" has been deleted. Each design will have to determine its postulated reactivity accidents based on the specific design and associated risk evaluation. | The deletion of the list of postulated reactivity accidents, leaving each design to determine its list of postulated reactivity accidents, is a very good change. |
| Appendix C | C-15 | mHTGR-DC 30 *Quality of reactor helium pressure boundary*: Means shall be provided for detecting ingress of moisture, air, secondary coolant, or other fluids to within the reactor helium pressure boundary. | The NRC staff's addition of the last sentence to this criterion is an excellent improvement. |

# General Comments on the Report Section of Draft Regulatory Guide DG-1330

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| Related Guidance, Communications, and Policy Statements | 3 | The draft regulatory guide includes the following citation in its "Related Guidance, Communications, and Policy Statements" listing: *NRC, "Next Generation Nuclear Plant - Assessment of Key Licensing Issues," dated July 17, 2014, provides the NRC staff's review and insights on the Next Generation Nuclear Plant mHTGR design (Ref. 11).* | The NGNP interactions did not include NRC review of a specific modular HTGR "*design*", but rather a series of proposals to address policy and key technical issues associated with mHTGR technology. The word "*design*" should be deleted and replaced with "*proposed licensing approach.*" |
| Role of GDC in Regulatory Framework | 6 | The draft regulatory guide states: *"The GDC are also intended to provide guidance in establishing the PDC for non-LWRs. The GDC serve as the fundamental criteria for the NRC staff when reviewing the SSCs that make up a nuclear power plant design particularly when assessing the performance of their safety functions in design basis events postulated to occur during normal operations, anticipated operational occurrences (AOOs), and postulated accidents."* | Our understanding is that SSC safety functions are only relied on during plant response to postulated accidents. This sentence, which also refers to normal operations and AOOs, should be revised to more clearly reflect this. A suggested revision is to change "safety functions" to "intended functions". |
| Role of GDC for Non-LWRs | 7 | The draft regulatory guide states: *"Together, these requirements recognize that different requirements may be necessary for non-LWR designs."* | Based on the "generally applicable" statement from Appendix A in the previous paragraph, "requirements" should be revised to "adapted requirements". |
| Role of GDC for Non-LWRs | 7 | The draft regulatory guide states: *"The non-LWR design criteria developed by the NRC staff and included in Appendices A to C of this regulatory guide, are intended to provide stakeholders with insight into the staff's views on how the GDC could be interpreted to address non-LWR design features; however, these are not considered to be final or binding regarding what may eventually be required from a non-LWR applicant."* | This statement is not adequately clear and predictable for industry. The staff appears to be saying that the guidance in this draft regulatory guide may not be the complete list of design requirements that apply. However, the last phrase of the cited text implies that the items being addressed in the draft regulatory guide may be incomplete and not a fully acceptable approach for developing the associated principal design criteria. It is recommended that the phrase "*however, these are not considered to be final or binding regarding what may eventually be required from a non-LWR applicant*" be deleted. |
| Role of GDC for Non-LWRs | 7 | The draft regulatory guide states: *"The NRC recognizes the benefits to risk informing the non LWR design criteria to the extent possible, depending on the design information and data available."* | Suggest changing "benefits" to "future benefits" to make it clear that this initial set has not been risk-informed beyond the general consideration of risk consistent with the LWR-based GDCs in Appendix A. |
| DOE-NRC Initiative Phase 1 | 8 | The draft regulatory guide states: *"The ARDC are intended to be technology neutral and, therefore, could apply to any type of non LWR design."* | A better term would be "technology inclusive" to align with the list of six technologies above, and to exclude LWRs. The DOE proposal was based on the six advanced reactor technologies summarized in the previous paragraph, and not "any type". |
| Key Assumptions | 9 | The draft regulatory guide states: *"It is the responsibility of the applicant to demonstrate compliance with applicable severe accident and BDBE regulations and orders, demonstrate why any that are not* | Since ARDC/SFR-DC/mHTGR-DC apply to normal, AOOs, and design-basis events, and do not pertain to BDBE regulations, this sentence is outside the scope of this report.<br>It is recommended that this key assumption be deleted. |

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| | | *applicable do not apply, and demonstrate why other design specific severe accidents or BDBE that can occur will be mitigated."* | |
| Key Assumptions | 9 | The draft regulatory guide states: *"While developing the non-LWR design criteria, the staff assumed that a core disruptive accident will be demonstrated to be a severe accident or a BDBE by the applicant."* | This text implies that non-LWR designs must designed for a core disruptive accident that is a deterministic holdover from the past that current risk-informed design approaches will likely eliminate from consideration. For some technologies, the terms "severe accident" or "core disruptive accident" are not technically meaningful. A goal of non-LWR designs would be to eliminate core disruptive accidents from consideration by reducing their likelihood to less than the lower frequency threshold for beyond design basis events.<br><br>It is recommended that this key assumption be deleted. |
| Key Assumptions | 9 | The draft regulatory guide states: *"Safety design objectives for non-LWRs can differ substantially from those associated with LWRs."* | The statement is correct (replace "objectives" with "approach") but it's not clear why it is listed as an "assumption". |
| Key Assumptions | 9 | The draft regulatory guide states: *"Proposed GDC adaptations were focused on those needed for improved regulatory certainty and clarity."* | This is the better choice of language – NRC should use "adaptation" throughout. |
| Key Assumptions | 9 | Currently, the following items are located in the text of the NRC rationales:<br>• Prior to issuing this regulatory guide as final, it appears that Commission agreement will be needed on the "functional containment" performance requirements for the mHTGR.<br>• In addition, staff acceptance of the "SARRDL" will also be needed. | It seems reasonable to state these in the assumptions to highlight that there are key policy items discussed in the regulatory guide that are still unresolved. |
| Harmonization with International Standards | 10 | The draft regulatory guide states: *"The NRC will continue to monitor and collaborate on these documents and consider using them to the extent practical in developing SFR design criteria."* | The last sentence states that NRC will consider use of international standards. Will the US industry get to review and comment on these international standards-based criteria? |
| Harmonization with International Standards | 10 | *"Harmonization with International Standards"* | It's not clear why this section is included, and if it's retained, why it doesn't include other international efforts, such as the IAEA CRP on safety design criteria for mHTGRs. |
| Harmonization with International Standards | 10 | The draft regulatory guide states: *"The International Atomic Energy Agency (IAEA), in collaboration with the International Project on Innovative Nuclear Reactors and Fuel Cycles and the Generation IV International Forum, established the Sodium-Cooled Fast Reactor Task Force."* | This last paragraph focuses solely on the SFR. There is a similar activity underway for modular HTGRs that should be cited. |
| Intended Use | 11 | The draft regulatory guide states: *"For example, FHRs are liquid-metal reactors that use tristructural isotropic (TRISO) fuel, which is the same fuel used for mHTGR technologies."* | FHRs are not liquid-metal reactors. FHRs are a type of molten-salt-cooled high-temperature reactors that use a fixed core rather than liquid fuel. |
| Intended Use of this Regulatory Guide | 11 | The draft regulatory guide states: *"Applicants may use this RG to develop all or part of the PDC and are free to choose among the ARDC, SFR-DC, or mHTGR-DC to develop each PDC."* | Should add something like "after considering the underlying safety basis for the criterion and evaluating the rationale for the adaptation described in this Reg. Guide" to the end of this sentence. |

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| Intended Use of this Regulatory Guide | 11 | The draft regulatory guide states: *"Finally, the non-LWR design criteria as developed by the NRC staff are intended to provide stakeholders with insights into the staff's views on how the GDC could be interpreted to address non-LWR design features; however, these are not considered to be final or binding on what may eventually be required from a non-LWR applicant."* | Should add something like "after considering the underlying safety basis for the criteria and evaluating the rationale for the adaptation described in this Reg. Guide" to the end of this sentence. |
| Table 1, Multiple Barriers | 14 | The draft regulatory guide states: mHTGR-DC 18 - *"Same as GDC"* | Should say "Same as ARDC" |
| Acronyms | 22 | The draft regulatory guide states: *"SARRDL - specified acceptable system radionuclide release design limit"* | Not what was proposed; should be "specified acceptable core radionuclide release design limit". The detailed basis for this comment is provided with comments on modular HTGR-DC 10. |
| References | 25 | The draft regulatory guide states: *32. "DOE, Tanju Sofu, Argonne National Laboratory, "Sodium-cooled Fast reactor (SFR) Technology Overview..."* | The NGNP – modular HTGR training material also should be referenced. |
| Appendix A | A-1 | The draft regulatory guide states: *"The NRC staff then determined what if any adaptation was appropriate for non-LWRs."* | The "if any" part should be separated from the rest of the sentence with commas: "The NRC staff then determined what, **if any,** adaptation was appropriate for non-LWRs." |
| Appendix C | C-1 | Introduction | Reference is made to the "Glossary" section of the guide for a definition of the modular HTGR, but no Glossary section is provided in the draft. |

# DOE/National Laboratory Team Comments on Appendix A – ARDC

## Docket ID NRC–2017–0016

**Note: Criterion are not included the table if the team had no related comments on the criterion or rationale language.**

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
|---|---|---|---|
| **10** | *Reactor design.*<br>Same as GDC | (No rationale provided) | **Flexibility to Apply SARRDL**<br>Some fast reactor designs utilize vented fuel concept that release the fission gas to the primary coolant during normal operation. SARRDL concept may be more applicable than SAFDL for such designs. SARDDL would also apply more readily to liquid fueled molten salt reactor concepts. It would be very useful if the ARDC-10 rationale offered the flexibility to adopt the mHTGR-DC 10 approach in such cases. |
| **16** | *Containment design.*<br>Same as GDC | For non-LWR technologies other than SFRs and mHTGRs, designers may use the current GDC to develop applicable principal design criteria. However, it is also recognized that characteristics of the coolants, fuels, and containments to be used in non-LWR designs could share common features with SFRs and mHTGRs. Hence designers may propose using the SFR-DC-16 or mHTGR-DC 16 as appropriate. Use of the mHTGR-DC 16 will be subject to a policy decision by the Commission. See rationale for mHTGR-DC 16 for further information on the policy decision. | **Add Functional Containment Language**<br>ARDC 16 language should include technology neutral containment requirements which can be subsequently applied to a specific technology. The original DOE/INL language for ARDC 16, which was written with the objective of being technology neutral, is provided below.<br>*"Containment design.*<br>*A reactor functional containment consisting of a structure surrounding the reactor and its cooling system or* multiple *barriers internal and/or external to the reactor and its cooling system, shall be provided to control the release of radioactivity to the environment and to assure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require."*<br>The concept of a functional containment would be of interest for application to other technologies. Applying this recommendation would provide a high-level technology-neutral ARDC which could be used to obtain Commission approval of containment performance criteria. SFR and mHTGR DC 16 would then serve to illustrate how technology-specific design criteria can be derived from ARDC 16. |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
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| | | | **Functional Containment Policy Issue**<br>Discussions of Commission policy decisions on functional containment need to be worded carefully. For the modular HTGR, a policy decision is not needed regarding the general acceptability of applying a functional containment (radionuclide retention) approach that differs from a conventional LWR high-pressure, low-leakage structure. However, based on the SRM to SECY-03-0047, a policy decision is needed regarding the performance criteria to be applied to a functional containment. The information located in the mHTGR-DC 16 rationale correctly states that a policy decision regarding functional containment performance requirements and criteria will be needed. It's noted that containment performance criteria for LWRs are provided in 10 CFR 50 Appendix J, rather than in the GDC of Appendix A. The last two sentences in the rationale for ARDC 16 should be deleted. |
| 17 | *Electric power systems.*<br>Electric power systems shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for the systems shall be to provide sufficient capacity, capability, and reliability to ensure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant boundary are not exceeded as a result of anticipated operational occurrences and (2) vital functions that rely on electric power are maintained in the event of postulated accidents.<br><br>The onsite electric power systems shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure. | A reliable power system is required for SSCs during postulated accident conditions. Power systems shall be sufficient in capacity, capability, and reliability to ensure vital safety functions are maintained. The emphasis is placed on requiring reliability of power sources rather than prescribing how such reliability can be attained. Reference to onsite vs. offsite electric power systems was deleted to provide for those reactor designs that do not depend on offsite power for the functioning of SSCs important to safety.<br><br>Text related to "…supplies, including batteries, and the onsite distribution system," was deleted to allow increased flexibility in the design of offsite power systems for advanced reactor designs. However, it is still expected that such onsite systems must remain capable of performing assigned safety functions during accidents as a condition of requisite reliability.<br>The existing single switchyard allowance remains available under ARDC 17. If a particular advanced design requires the use of GDC single switchyard allowance wording, the designer should look to GDC 17 for guidance when developing PDC.<br><br>If electrical power is not required to permit functioning of SSCs important to safety, the requirements in the ARDC are not applicable to the design. In this case, the functionality of | See positive comment table. |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
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| | | SSCs important to safety must be fully evaluated and documented in the design bases.<br><br>"Reactor coolant pressure boundary" has been relabeled as "reactor coolant boundary" to create a more broadly applicable non-LWR term that defines the boundary without giving any implication of system operating pressure. As such, the term "reactor coolant boundary" is applicable to non-LWRs that operate at either low or high pressure. | |
| **26** | *Reactivity control systems.*<br>Reactivity control systems shall include the following capabilities:<br><br>(1) A means of shutting down the reactor shall be provided to ensure that, under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions, design limits for fission product barriers are not exceeded.<br><br>(2) A means of shutting down the reactor and maintaining a safe shutdown under design-basis event conditions, with appropriate margin for malfunctions, shall be provided. A second means of reactivity control shall be provided that is independent, diverse, and capable of achieving and maintaining safe shutdown under design-basis event conditions.<br><br>(3) A system for holding the reactor subcritical under cold conditions shall be provided. | Recent licensing activity associated with the application of GDC 26 and GDC 27 to new reactor designs "Response to Gap Analysis Summary Report for Reactor System Issues," (Ref. 26) and "Response to NuScale Gap Analysis Summary Report for Reactivity Control Systems, Addressing Gap 11, General Design Criteria 26," (Ref. 27), revealed that additional clarity could be provided in the area of reactivity control requirements. ARDC 26 combines the scope of GDC 26 and GDC 27. The development of ARDC 26 is informed by the proposed General Design Criteria of 1965, AEC-R 2/49 and November 5, 1967 (32 FR 10216) (Ref. 28); the current GDC 26 and 27; the definition of safety-related SSC in 10 CFR 50.2; and SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs" (Ref. 29); and the prior application of reactivity control requirements.<br><br>Current GDC 26, first sentence, states that two reactivity control systems of different design principles shall be provided. In addition, the NRC has not licensed a power reactor that did not provide two independent means of shutting down the reactor.<br><br>(1) Current GDC 26, second sentence, states that one of the reactivity control systems shall use control rods and shall be capable of reliably controlling reactivity changes to ensure that, under conditions of normal operation, including AOOs, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The staff recognizes that specifying control rods may not be suitable for advanced reactors. Additionally, reliably controlling reactivity, as required by GDC 26, has been | **Important to Safety**<br>The term "important to safety" is almost universally understood to mean safety-related in the context of the GDC and ARDC. ARDC 1-5, referenced in the phrase *"...highly reliable and robust (e.g., meet ARDC 1-5)"* most often refer to "safety functions," strongly implying safety systems. The DOE/INL ARDC report (December 2014) defined "important to safety" as follows:<br><br>*"Based on existing 10 CFR 50 Appendix A language, this designation refers to structures, systems, and components (SSCs) that provide reasonable assurance the facility can be operated without undue risk to the health and safety of the public. SSCs with this designation are safety related and are relied upon to remain functional during design basis accidents.*<br><br>*Undue risk is associated with the inability to ensure the capability to prevent or mitigate the consequences of accidents which could result in offsite radiological consequences exceeding the limits set forth in 10 CFR 50.34 (or 10 CFR 52.79)."*<br><br>Within the scope and context of the GDC, "important to safety" is equivalent to safety related. Therefore, it is recommended that the subject paragraph in the rationale be reworded to avoid potential contradiction with the common usage of the term throughout the GDC and ARDC.<br><br>**ARDC Scope Changes**<br>Item (1) seems to have a narrower focus than the GDC, focusing more on shutdown capability than on reactivity |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
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| | | interpreted as ensuring the control rods are capable of rapidly (i.e., within a few seconds) shutting down the reactor (Ref. 27).<br><br>The staff changed control rods to "means" in recognition that advanced reactor designs may not rely on control rods to rapidly shut down the reactor (e.g., alternative system designs or inherent feedback mechanisms may be relied upon to perform this function). Additionally, "specified acceptable fuel design limits" is replaced with "design limits for fission product barriers" to be consistent with the AOO acceptance criteria. ARDC 10 and ARDC 15 provide the appropriate design limits for the fuel and reactor coolant boundary, respectively. A non-LWR may not necessarily shut down rapidly (within seconds) but the shutdown should occur in a time frame such that the fission product barrier design limits are not exceeded. In regards to safety class, the capability to shut down the reactor is identified as a function performed by safety-related SSCs in the 10 CFR 50.2 definition of safety-related SSCs.<br><br>(2) Current GDC 27 states that the reactivity control systems shall be designed to have a combined capability of reliably controlling reactivity changes to assure that, under postulated accident conditions and with appropriate margin for stuck rods, the capability to cool the core is maintained. Reliably controlling reactivity, as required by GDC 27, requires that the reactor achieve and maintain safe, stable conditions, including subcriticality, using only safety related equipment with margin for stuck rods (Ref. 26). The first sentence of ARDC 26 (2) refers to the safety-related means (systems and/or mechanisms) to achieve and maintain safe shutdown. "Maintain safe shutdown" indicates subcriticality in the long term or an equilibrium condition naturally achieved by the design.<br>The staff changed "reactivity control systems" to "means" in recognition that advanced reactor designs may rely on a system, inherent feedback mechanism, or some combination thereof to shut down the reactor and maintain a safe shutdown under design-basis event conditions. SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs" (Ref. 29), describes the characteristics of a safe shutdown condition as reactor subcriticality, decay heat removal, and | control and does not appear to reflect the requirement of GDC 26 to have two reactivity control systems for controlling reactivity for normal operations and AOOs. In addition, Item (2) of this combined design criteria requires two independent and diverse means of achieving and maintaining safe shutdown under design-basis conditions whereas GDC 27 seems to allow a collective and combined capability.<br><br>The existing rationale does not explicitly explain the apparent scope changes that occurred in the transition from the original GDC language to the current ARDC 26 language. The rationale should be revised to include an explanation for the apparent scope changes. In addition, a change in the title, such as *Reactivity Control System Shutdown Capability*, would better align the ARDC and its title.<br><br>ARDC 26 Item (1) also included the replacement of "*specified acceptable fuel design limits*" with "*design limits for fission product barriers.*" The discussion in the rationale and the NRC staff presentation of February 22, 2017, indicate that the focus of this change is on both the fuel and the reactor coolant boundary. Addition of the reactor coolant boundary is an increase in scope from GDC 26 relative to what needs to be protected from failure during normal operation and AOOs. This change is inconsistent with the fact that some AOOs could involve failure of fission product barriers (e.g., failure of instrumentation lines, sample lines, etc.). Furthermore, nothing is provided in the rationale to prevent future interpretations of the language as also encompassing the reactor containment for those designs that use a traditional approach to containment. All of these points need clarification.<br><br>**ARDC Development References**<br>The first paragraph of the rationale notes that the development of ARDC 26 was informed by a number of references. Most of these references preceded the current version of the GDC. An explanation of how these older |

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| | | radioactive materials containment. The staff replaced "postulated accident conditions" with "design-basis event conditions," to emphasize that plants are required to maintain a safe shutdown following AOOs as well as postulated accidents.<br><br>The second sentence of ARDC 26(2) refers to a means of achieving and maintaining shutdown that is important to safety but not necessarily safety related. The second means of reactivity control serves as a backup to the safety-related means and, as such, margins for malfunctions are not required but the second means shall be highly reliable and robust (e.g., meet ARDC 1 -5). "Independent" indicates no shared systems or components with the safety-related means and "diverse" indicates a different design than the safety-related means. The purpose of an independent and diverse means of controlling reactivity is to preclude a potential common cause failure affecting both means of reactivity control, which would lead to the inability to shut down the reactor. The second means of reactivity control does not have to demonstrate that design limits for fission product barriers are met.<br><br>Additionally, the current GDC 26, third sentence, states that the second reactivity control system shall be capable of reliably controlling the rate of changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. Staff has identified this as an operational requirement that is not necessary to ensure reactor safety provided a design complies with ARDC 26(1). Therefore, this sentence is not retained in ARDC 26. | references supported the changes from the current GDC would be helpful.<br><br>**Use of "Design-Basis Event" Language**<br>It is not clear why the wording *"design-basis event conditions"* is used explicitly in item (2) whereas *"postulated accidents"* is used consistently for the rest of the ARDC/SFR-DC/mHTGR-DC sets.<br><br>**Common Cause Failures**<br>Suggest changing the Rationale discussion regarding "diverse" from *"...different design than the safety-related means"* to *"different design not subject to common cause failures."*<br><br>**Definition of Cold Shutdown**<br>Item (2) specifies *"safe shutdown"* whereas item 3 specifies *"reactor being subcritical under cold conditions."* Safe shutdown state is defined in the rationale but a definition of "cold shutdown" is also needed (confusion might arise for some systems if the coolant is frozen at room temperature). Suggest including a sentence in the rationale that "cold conditions" imply temperatures at which refueling, inspections, and repair functions can be performed.<br><br>**Achieving Cold Shutdown**<br>It is not clear if item (3) calls for a third system/mechanism to render the reactor subcritical. A paragraph should be added in the rationale to clarify that the safety-related shutdown system is expected to achieve safe shutdown; but "cold shutdown" can be achieved by either a safety or non-safety shutdown system.<br><br>**Basis for Operational Requirement**<br>The reference should be provided where the staff identified the requirement that the third sentence of GDC 26 is considered to be an operational requirement and not relevant as a DC. |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
|---|---|---|---|
| 31 | *Fracture prevention of reactor coolant boundary.*<br>The reactor coolant boundary shall be designed with sufficient margin to ensure that when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect 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. | "Reactor coolant pressure boundary" has been relabeled as "reactor coolant boundary" to create a more broadly applicable non-LWR term that defines the boundary without giving any implication of system operating pressure. As such, the term "reactor coolant boundary" is applicable to non-LWRs that operate at either low or high pressure.<br><br>Specific examples are added to the ARDC to account for the high design and operating temperatures and unique potential coolants. | **Concern Regarding "Coolant Chemistry"**<br>Item (2) adds *"...and coolant chemistry"* to material property considerations. This creates a degree of uncertainty. The justification identifies *"unique potential coolants"* as a concern but "chemistry" infers a reactive property. Does this include secondary/tertiary reaction product interactions decedent from some initial "coolant chemistry"? Are coolant contaminants considered in the criterion? "Coolant chemistry" could be interpreted as a scope expansion and is unnecessary given ARDC-14 requirements.<br><br>**Missing Words**<br>Proposed ARDC language seems to accidentally drop the highlighted words in item (2): *"The design shall reflect **consideration of** service temperatures, service degradation of material properties..."* These words properly appear in SFR-DC 31 and GDC 31. |
| 32 | *Inspection of reactor coolant boundary.*<br>Components that are part of the reactor coolant boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor vessel. | "Reactor coolant pressure boundary" has been relabeled as "reactor coolant boundary" to create a more broadly applicable non-LWR term that defines the boundary without giving any implication of system operating pressure. As such, the term "reactor coolant boundary" is applicable to non-LWRs that operate at either low or high pressure.<br><br>The staff modified the LWR GDC by replacing the term "reactor pressure vessel" with "reactor vessel," which the staff believes is a more generically applicable term. | **Addition of the Word "Functional"**<br>For the replacement of *"testing" with "functional testing"*; information should be added to the rationale to explain the intent behind the addition of the word "functional." The word is not included in GDC 32. What kind of functional testing is intended? What is the rationale for the addition of this word? |
| 35 | *Emergency core cooling.*<br>A system to provide sufficient emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core such that effective core cooling is maintained and fuel damage is limited.<br><br>Suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure. | In most advanced reactor designs, a single system (i.e., the residual heat removal system) is provided to perform both the residual heat removal and emergency core cooling functions. In this case, the single system would be designed to meet the requirements of ARDC 34 and ARDC 35 (for more discussion see NUREG-0968 (Ref. 5) and NUREG-1368 (Ref. 4)). However, the staff acknowledges that this may not be the case for every advanced reactor design. Therefore, to allow current and future non-LWR designers the flexibility to provide a single system or multiple systems to perform residual heat removal and emergency core cooling, the staff decided to keep the ARDC 34 and ARDC 35 separate in lieu of combining them into a single criterion. Effective core cooling may include | **Reference to Fuel Damage**<br>Regarding the addition of the words *"and fuel damage is limited"* to the first paragraph of the criterion, the rationale does not provide guidance for how these new words (which reflect an expansion in scope relative to GDC 35) should be interpreted or why they have been added.<br><br>The added words are ambiguous when considering (1) to what level should fuel damage be limited? (2) What are the appropriate measures of fuel damage? (3) How would fuel damage be interpreted for a molten salt reactor or for a modular HTGR? |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
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| | | maintaining the primary coolant boundary in a condition necessary for adequate postulated accident heat removal. The staff's approach to provide two separate criteria is consistent with the approach taken in the LWR GDCs.<br><br>This change removes the light-water reactor emphasis on loss of coolant accidents that may not apply to every design. Loss of coolant accidents may still require analysis in conjunction with postulated accidents if they are relevant to the design.<br><br>The GDC reference to electric power was removed. Refer to ARDC 17 concerning those systems that require electric power. | It appears that the cited ARDC 35 text expands the scope of the existing GDC, and is therefore outside of the scope of this ARDC effort. Absent further information regarding the intent of these words, it is recommended that they be deleted from the criterion.<br><br>**ARDC Missing Words**<br>Proposed ARDC language seems to accidentally drop the following highlighted words: "The system safety function shall be to transfer heat from the reactor core **at a rate** such that effective core cooling is maintained." |
| **37** | *Testing of residual heat removal system.*<br>A system that provides emergency core cooling shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the system components, 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 any associated systems and interfaces necessary to transfer decay heat to the ultimate heat sink. | In most advanced reactor designs, a single system (i.e., the residual heat removal system) is provided to perform both the residual heat removal and emergency core cooling functions. In this case, the single system would be designed to meet the requirements of ARDC 34 and ARDC 35. (for more discussion see NUREG-0968 (Ref. 5) and NUREG-1368 (Ref. 4)) However, the staff acknowledges that this may not be the case for every advanced reactor design. Therefore, to allow current and future non-LWR designers the flexibility to provide a single system or multiple systems to perform residual heat removal and emergency core cooling, the staff decided to keep the ARDC 34 and ARDC 35 separate in lieu of combining them into a single criterion. The staff's approach to provide two separate criteria is consistent with the approach taken in the LWR GDCs.<br><br>The ARDC has slightly different wording than the GDC to clarify the scope of the criterion. Any system, or portions of a system, credited with an emergency core cooling function during postulated accidents (for example, a system that performs both the residual heat removal function and the emergency core cooling function) would need to meet ARDC 37.<br><br>Specific mention of "pressure" testing has been removed yet remains a potential requirement should it be necessary as a component of "...appropriate periodic functional testing..." of cooling systems. | **Use of the Word "Leaktight"**<br>"Leaktight" standards may not be necessary for certain advanced reactor SSCs, but keeping this word in the criterion infers expectation of leaktight capability. Determination of the degree to which a system is "leaktight" should be subject to acceptance criteria that are appropriate for each reactor technology. The words "*and leaktight*" should be deleted.<br><br>**Title Change**<br>Title should read "*Testing of ~~residual heat removal~~* ***emergency core cooling*** *system.*"<br><br>**Connection Between Defense in Depth and System Leakage**<br>Additional clarification is needed in the rationale to explain the criterion that a non-leaktight system may be acceptable if "*defense in depth is not impacted by system leakage.*" This clarification applies to other criteria (e.g., ARDC 40, 43, and 46) that address defense in depth. |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
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| | | A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br><br>"Active" has been deleted in item (2) as appropriate operability and performance system component testing are required, regardless of an active or passive nature.<br><br>Reference to the operation of applicable portions of the protection system, cooling water system, and power transfers is considered part of the more general "associated systems." Together with the ultimate heat sink, they are part of the operability testing of the system as a whole.<br><br>The GDC reference to electric power was removed. Refer to ARDC 17 concerning those systems that require electric power. | |
| **40** | *Testing of containment heat removal system.*<br>The containment heat removal system shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the system components, and (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 the operation of associated systems. | Specific mention of "pressure" testing has been removed yet remains a potential requirement should it be necessary as a component of "…appropriate periodic functional testing..." of containment heat removal.<br><br>A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br>Reference to the operation of applicable portions of the protection system, structural and equipment cooling , and power transfers is considered part of the more general "associated systems" for operability testing of the system as a whole.<br><br>The GDC reference to electric power was removed. Refer to ARDC 17 concerning those systems that require electric power. | **Use of the Word "Leaktight"**<br>"Leaktight" standards may not be necessary for certain advanced reactor SSCs but keeping it in the criterion infers expectation of leaktight capability. Leaktight should be interpreted as a structural integrity element and subject to functional testing in that capacity. Determination of the degree to which a system is "leaktight" should be subject to acceptance criteria that are appropriate for each reactor technology. The words "*and leaktight*" should be deleted |
| **43** | *Testing of containment atmosphere cleanup systems.*<br>The containment atmosphere cleanup systems shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the | "Active" has been deleted in item (2), as appropriate operability and performance testing of system components is required regardless of an active or passive nature, as are cited examples of active system components. | **Use of the Word "Leaktight"**<br>"Leaktight" standards may not be necessary for certain advanced reactor SSCs but keeping it in the criterion infers expectation of leaktight capability. Leaktight should be interpreted as a structural integrity element |

| Criterion | 2017 – NRC ARDC Title and Content | 2017 – NRC Rationales | Team Comments |
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| | system components, and (3) the operability of the systems as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the systems into operation, including the operation of associated systems. | Examples of active systems under item (2) have been deleted, both to conform to similar wording in ARDC 37 and 40 and ensure that passive as well as active system components are considered.<br><br>Specific mention of "pressure" testing has been removed yet remains a potential requirement should it be necessary as a component of "...appropriate periodic functional testing..." of cooling systems. A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br><br>The GDC reference to electric power was removed. Refer to ARDC 17 concerning those systems that require electric power. | and subject to functional testing in that capacity. Determination of the degree to which a system is "leaktight" should be subject to acceptance criteria that are appropriate for each reactor technology The words "*and leaktight*" should be deleted |
| 46 | *Testing of structural and equipment cooling systems.* The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of their components, (2) the operability and performance of the system components, and (3) the operability of the systems as a whole and, under conditions as close to design as practical, the performance of the full operational sequences that bring the systems into operation for reactor shutdown and postulated accidents, including the operation of associated systems. | This renamed ARDC accounts for advanced reactor system design differences to include possible cooling requirements for SSCs important to safety. Specific mention of "pressure" testing has been removed yet remains a potential requirement should it be necessary as a component of "...appropriate periodic functional testing..." of cooling systems. A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br><br>"Active" has been deleted in item (2) because appropriate operability and performance tests of system components are required regardless of their active or passive nature. The LOCA reference has been removed to provide for any postulated accident that might affect subject SSCs.<br><br>The GDC reference to electric power was removed. Refer to ARDC 17 concerning those systems that require electric power. | **Use of the Word "Leaktight"**<br>"Leaktight" standards may not be necessary for certain advanced reactor SSCs but keeping it in the criterion infers expectation of leaktight capability. Leaktight should be interpreted as a structural integrity element and subject to functional testing in that capacity. Determination of the degree to which a system is "leaktight" should be subject to acceptance criteria that are appropriate for each reactor technology. The words "*and leaktight*" should be deleted |

# DOE/National Laboratory Team Comments on Appendix B – SFR Design Criteria

## Docket ID NRC–2017–0016

**Note: Criterion are not included the table if the team had no related comments on the criterion or rationale language.**

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
|---|---|---|---|
| **10** | *Reactor design.*<br>Same as GDC | (No rationale provided) | **Flexibility to Apply SARRDL**<br>Some fast reactor designs utilize vented fuel concept that release the fission gas to the primary coolant during normal operation. SARRDL concept may be more applicable than SAFDL for such designs. It would be convenient to offer in SFR-DC 10 rationale the flexibility to adopt mHTGR-DC 10 approach in such cases. |
| **26** | *Reactivity control systems.*<br>Same as ARDC<br>Reactivity control systems shall include the following capabilities:<br>(1) A means of shutting down the reactor shall be provided to ensure that, under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions, design limits for fission product barriers are not exceeded.<br>(2) A means of shutting down the reactor and maintaining a safe shutdown under design-basis event conditions, with appropriate margin for malfunctions, shall be provided. A second means of reactivity control shall be provided that is independent, diverse, and capable of achieving and maintaining safe shutdown under design-basis event conditions.<br>(3) A system for holding the reactor subcritical under cold conditions shall be provided. | Recent licensing activity associated with the application of GDC 26 and GDC 27 to new reactor designs "Response to Gap Analysis Summary Report for Reactor System Issues," (Ref. 26) and "Response to NuScale Gap Analysis Summary Report for Reactivity Control Systems, Addressing Gap 11, General Design Criteria 26," (Ref. 27), revealed that additional clarity could be provided in the area of reactivity control requirements. ARDC 26 combines the scope of GDC 26 and GDC 27. The development of ARDC 26 is informed by the proposed General Design Criteria of 1965, AEC-R 2/49 and November 5, 1967 (32 FR 10216) (Ref. 28); the current GDC 26 and 27; the definition of safety-related SSC in 10 CFR 50.2; and SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs" (Ref. 29); and the prior application of reactivity control requirements.<br>Current GDC 26, first sentence, states that two reactivity control systems of different design principles shall be provided. In addition, the NRC has not licensed a power reactor that did not provide two independent means of shutting down the reactor.<br>(1) Current GDC 26, second sentence, states that one of the reactivity control systems shall use control rods and shall be capable of reliably controlling reactivity changes to | **Important to Safety**<br>The term "important to safety" is almost universally understood to mean safety-related in the context of the GDC and ARDC. ARDC 1-5, referenced in the phrase *"...highly reliable and robust (e.g., meet ARDC 1-5)"* most often refer to "safety functions," strongly implying safety systems. The DOE/INL ARDC report (December 2014) defined "important to safety" as follows:<br>*"Based on existing 10 CFR 50 Appendix A language, this designation refers to structures, systems, and components (SSCs) that provide reasonable assurance the facility can be operated without undue risk to the health and safety of the public. SSCs with this designation are safety related and are relied upon to remain functional during design basis accidents.*<br>*Undue risk is associated with the inability to ensure the capability to prevent or mitigate the consequences of accidents which could result in offsite radiological consequences exceeding the limits set forth in 10 CFR 50.34 (or 10 CFR 52.79)."*<br>Within the scope and context of the GDC, "important to safety" is equivalent to safety related. Therefore, it is recommended that the subject paragraph in the rationale be reworded to avoid potential contradiction with the |

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
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| | | ensure that, under conditions of normal operation, including AOOs, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The staff recognizes that specifying control rods may not be suitable for advanced reactors. Additionally, reliably controlling reactivity, as required by GDC 26, has been interpreted as ensuring the control rods are capable of rapidly (i.e., within a few seconds) shutting down the reactor (Ref. 27).<br><br>The staff changed control rods to "means" in recognition that advanced reactor designs may not rely on control rods to rapidly shut down the reactor (e.g., alternative system designs or inherent feedback mechanisms may be relied upon to perform this function). Additionally, "specified acceptable fuel design limits" is replaced with "design limits for fission product barriers" to be consistent with the AOO acceptance criteria. ARDC 10 and ARDC 15 provide the appropriate design limits for the fuel and reactor coolant boundary, respectively. A non-LWR may not necessarily shut down rapidly (within seconds) but the shutdown should occur in a time frame such that the fission product barrier design limits are not exceeded. In regards to safety class, the capability to shut down the reactor is identified as a function performed by safety-related SSCs in the 10 CFR 50.2 definition of safety-related SSCs.<br><br>(2) Current GDC 27 states that the reactivity control systems shall be designed to have a combined capability of reliably controlling reactivity changes to assure that, under postulated accident conditions and with appropriate margin for stuck rods, the capability to cool the core is maintained. Reliably controlling reactivity, as required by GDC 27, requires that the reactor achieve and maintain safe, stable conditions, including subcriticality, using only safety related equipment with margin for stuck rods (Ref. 26). The first sentence of ARDC 26 (2) refers to the safety-related means (systems and/or mechanisms) to achieve and maintain safe shutdown. "Maintain safe shutdown" indicates subcriticality in the long term or an equilibrium condition naturally achieved by the design. | common usage of the term throughout the GDC and ARDC.<br><br>**ARDC Scope Changes**<br>Item (1) seems to have a narrower focus than the GDC, focusing more on shutdown capability than on reactivity control and does not appear to reflect the requirement of GDC 26 to have two reactivity control systems for controlling reactivity for normal operations and AOOs.<br><br>In addition, Item (2) of this combined design criteria requires two independent and diverse means of achieving and maintaining safe shutdown under design-basis conditions whereas GDC 27 seems to allow a collective and combined capability.<br><br>The existing rationale does not explicitly explain the apparent scope changes that occurred in the transition from the original GDC language to the current ARDC 26 language. The rationale should be revised to include an explanation for the apparent scope changes. In addition, a change in the title, such as *Reactivity Control System Shutdown Capability*, would better align the ARDC and its title.<br><br>ARDC 26 Item (1) also included the replacement of *"specified acceptable fuel design limits"* with *"design limits for fission product barriers."* The discussion in the rationale and the NRC staff presentation of February 22, 2017, indicate that the focus of this change is on both the fuel and the reactor coolant boundary. Addition of the reactor coolant boundary is an increase in scope from GDC 26 relative to what needs to be protected from failure during normal operation and AOOs. This change is inconsistent with the fact that some AOOs could involve failure of fission product barriers (e.g., failure of instrumentation lines, sample lines, etc.). Furthermore, nothing is provided in the rationale to prevent future interpretations of the language as also encompassing the reactor containment for those designs that use a traditional approach to containment. All these points need clarification. |

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
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| | | The staff changed “reactivity control systems” to “means” in recognition that advanced reactor designs may rely on a system, inherent feedback mechanism, or some combination thereof to shut down the reactor and maintain a safe shutdown under design-basis event conditions. SECY-94-084, “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs” (Ref. 29), describes the characteristics of a safe shutdown condition as reactor subcriticality, decay heat removal, and radioactive materials containment. The staff replaced “postulated accident conditions” with “design-basis event conditions,” to emphasize that plants are required to maintain a safe shutdown following AOOs as well as postulated accidents.<br><br>The second sentence of ARDC 26(2) refers to a means of achieving and maintaining shutdown that is important to safety but not necessarily safety related. The second means of reactivity control serves as a backup to the safety-related means and, as such, margins for malfunctions are not required but the second means shall be highly reliable and robust (e.g., meet ARDC 1 -5). “Independent” indicates no shared systems or components with the safety-related means and “diverse” indicates a different design than the safety-related means. The purpose of an independent and diverse means of controlling reactivity is to preclude a potential common cause failure affecting both means of reactivity control, which would lead to the inability to shut down the reactor. The second means of reactivity control does not have to demonstrate that design limits for fission product barriers are met.<br><br>Additionally, the current GDC 26, third sentence, states that the second reactivity control system shall be capable of reliably controlling the rate of changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. Staff has identified this as an operational requirement that is not necessary to ensure reactor safety provided a design complies with ARDC 26(1). Therefore, this sentence is not retained in ARDC 26. | **Safe Shutdown, Cold Conditions Terminology**<br>Suggested alternative to cold conditions for SFR DC 26. Use the definition of subcritical under cold conditions comes from the work on GIF SFR design criteria.<br><br>*Subcritical under cold conditions is defined as the state with the reactivity of the reactor kept to a margin below criticality under a prescribed coolant temperature condition in which interventions such as fuel reloading, periodic inspection and repair work in the reactor can be achievable.*<br><br>This is very similar to cold conditions for LWRs if the prescribed temperature condition is < boiling at atmospheric pressure. This might work for the mHTGR; if so, it could be used in ARDC since it will work for fluid fueled MSRs as well. It would avoid the confusion of “cold” for these high temperature systems.<br><br>**ARDC Development References**<br>The first paragraph of the rationale notes that the development of ARDC 26 was informed by a number of references. Most of these references preceded the current version of the GDC. An explanation of how these older references supported the changes from the present GDC, and why the present GDC is considered not appropriate, would be helpful.<br><br>**Use of “Design-Basis Event” Language**<br>It is not clear why the wording “design-basis event” is used explicitly in Item (2) when the term “postulated accidents” is used consistently for the rest of the ARDC/SFR-DC/mHTGR-DC sets?<br><br>**Common Cause Failures**<br>Suggest changing the Rationale discussion regarding “diverse” from “*...different design than the safety-related means*” to *“different design not subject to common cause failures.”* |

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
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| | | | **Achieving Cold Shutdown**<br>It is not clear if item (3) calls for a third system/mechanism to render the reactor subcritical. A paragraph should be added in the rationale to clarify that the safety-related shutdown system is expected to achieve safe shutdown; but "cold shutdown" can be achieved by either a safety or non-safety shutdown system.<br><br>**Basis for Operational Requirement**<br>The reference should be provided where the staff identified the requirement that the third sentence of GDC 26 is considered to be an operational requirement and not relevant as a DC. |
| 32 | *Inspection of primary coolant boundary.*<br>Components that are part of the primary coolant boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor vessel. | "Reactor coolant pressure boundary" has been relabeled as "primary coolant boundary" to conform to standard terms used in the LMR industry.<br><br>The use of the term "primary" indicates that the SFR-DC are applicable only to the primary cooling system, not the intermediate cooling system.<br><br>The cover gas boundary is included as part of the reactor primary coolant boundary (referred to as RCPB by PRISM) per NUREG-1368 (page 3-38) (Ref.4).<br><br>The staff modified the LWR GDC by replacing the term "reactor pressure vessel" with "reactor vessel," which the staff believes is a more generically applicable term. | **Addition of the Word "Functional"**<br>Replacement of *"testing" with "functional testing";* information should be added to the rationale to explain the intent behind the addition of the word "functional." The word is not included in GDC 32. What kind of functional testing is intended? What is the rationale for the addition of this word? |
| 35 | *Emergency core cooling.*<br>Same as ARDC<br>A system to provide sufficient emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core such that effective core cooling is maintained and fuel damage is limited.<br><br>Suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure. | In most advanced reactor designs, a single system (i.e., the residual heat removal system) is provided to perform both the residual heat removal and emergency core cooling functions. In this case, the single system would be designed to meet the requirements of SFR-DC 34 and SFR-DC 35. (for more discussion see NUREG-0968 (Ref. 5) and NUREG-1368 (Ref. 4)) However, the staff acknowledges that this may not be the case for every advanced reactor design. Therefore, to allow current and future non-LWR designers the flexibility to provide a single system or multiple systems to perform residual heat removal and emergency core cooling, the staff decided to | **Textual Reference to Fuel Damage**<br>Regarding the addition of the words *"and fuel damage is limited"* to the first paragraph of the criterion, the rationale does not provide guidance for how these new words (which reflect an expansion relative to GDC 35) should be interpreted or why they have been added.<br><br>The added words are ambiguous when considering (1) to what level should fuel damage be limited? (2) What are the appropriate measures of fuel damage?<br><br>It is suggested to replace the words "fuel damage is limited" with "fuel and clad damage that could interfere |

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
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| | | keep the SFR-DC 34 and SFR-DC 35 separate in lieu of combining them into a single criterion. Effective core cooling may include maintaining the primary coolant boundary in a condition necessary for adequate postulated accident heat removal. The staff's approach to provide two separate criteria is consistent with the approach taken in the LWR GDCs.<br><br>This change removes the light-water reactor emphasis on loss of coolant accidents that may not apply to every design. Loss of coolant accidents may still require analysis in conjunction with postulated accidents if they are relevant to the design.<br><br>The discussion related to sodium leakage and required barriers was moved to a new SFR-DC 78.<br><br>The GDC reference to electric power was removed. Refer to SFR-DC17 concerning those systems that require electric power. | with continued effective core cooling is prevented" also consistent with the GDC wording.<br><br>**ARDC Missing Words**<br>Proposed ARDC language seems to accidentally drop the highlighted words: "The system safety function shall be to transfer heat from the reactor core **at a rate** such that effective core cooling is maintained." |
| **36** | *Inspection of residual heat removal system.*<br>Same as ARDC<br>A system that provides emergency core cooling shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system. | In most advanced reactor designs, a single system (i.e., the residual heat removal system) is provided to perform both the residual heat removal and emergency core cooling functions. In this case, the single system would be designed to meet the requirements of SFR-DC 34 and SFR-DC 35. (for more discussion see NUREG-0968 (Ref. 5) and NUREG-1368 (Ref. 4)) However, the staff acknowledges that this may not be the case for every advanced reactor design. Therefore, to allow current and future non-LWR designers the flexibility to provide a single system or multiple systems to perform residual heat removal and emergency core cooling, the staff decided to keep the SFR-DC 34 and SFR-DC 35 separate in lieu of combining them into a single criterion. The staff's approach to provide two separate criteria is consistent with the approach taken in the LWR GDCs.<br><br>The SFR-DC has slightly different wording than the GDC to clarify the scope of the criteria. Any system, or portions of a system, credited with an emergency core cooling function during postulated accidents (for example, a system that performs both the residual heat removal | **Title Change**<br>Title should be *"Inspection of **emergency core cooling** system."* |

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
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| | | function and the emergency core cooling function) would need to meet SFR-DC 36.<br><br>The list of examples has been deleted because it applies to LWR designs, and each specific design will have different important components associated with residual heat removal. This revision allows for a technology-neutral SFR-DC.<br><br>Review of the proposed DOE SFR and HTGR DC found that only SFR provided specific examples of important components but were generic in nature and did not include any significant additional guidance. | |
| 37 | *Testing of residual heat removal system.*<br>Same as ARDC<br>A system that provides emergency core cooling shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the system components, 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 any associated systems and interfaces necessary to transfer decay heat to the ultimate heat sink. | In most advanced reactor designs, a single system (i.e., the residual heat removal system) is provided to perform both the residual heat removal and emergency core cooling functions. In this case, the single system would be designed to meet the requirements of SFR-DC 34 and SFR-DC 35. (for more discussion see NUREG-0968 (Ref. 5) and NUREG-1368 (Ref. 4)) However, the staff acknowledges that this may not be the case for every advanced reactor design. Therefore, to allow current and future non-LWR designers the flexibility to provide a single system or multiple systems to perform residual heat removal and emergency core cooling, the staff decided to keep the SFR-DC 34 and SFR-DC 35 separate in lieu of combining them into a single criterion. The staff's approach to provide two separate criteria is consistent with the approach taken in the LWR GDCs.<br><br>The SFR-DC has slightly different wording than the GDC to clarify the scope of the criteria. Any system, or portions of a system, credited with an emergency core cooling function during postulated accidents (for example, a system that performs both the residual heat removal function and the emergency core cooling function) would need to meet SFR-DC 37.<br><br>Specific mention of "pressure" testing has been removed yet remains a potential requirement should it be necessary as a component of "...appropriate periodic functional testing..." of cooling systems. | **Title Change**<br>Title should be *"Testing of **emergency core cooling** system."* |

| Criterion | 2017 NRC SFR-DC Title and Content | 2017 NRC Rationales | Team Comments |
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| | | A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br><br>"Active" has been deleted in item (2) as appropriate operability and performance system component testing are required, regardless of an active or passive nature.<br><br>Reference to the operation of applicable portions of the protection system, cooling water system, and power transfers is considered part of the more general "associated systems." Together with the ultimate heat sink, they are part of the operability testing of the system as a whole.<br><br>The GDC reference to electric power was removed. Refer to SFR-DC17 concerning those systems that require electric power. | |
| **41** | *Containment atmosphere cleanup.*<br>Same as ARDC<br>Systems to control fission products and other substances that may be released into the reactor containment shall be provided as necessary to reduce, consistent with the functioning of other associated systems, the concentration and quality of fission products released to the environment following postulated accidents and to control the concentration of other substances in the containment atmosphere following postulated accidents to ensure that containment integrity is maintained.<br><br>Each system shall have suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities to ensure that its safety function can be accomplished, assuming a single failure. | Advanced reactors offer potential for reaction product generation that is different from that associated with clad metal-water interactions. Therefore, the terms "hydrogen" and "oxygen" are removed while "other substances" is retained to allow for exceptions.<br><br>The GDC reference to electric power was removed. Refer to SFR-DC17 concerning those systems that require electric power. | **Additional Wording**<br>First paragraph should end as "... to ensure that containment integrity **and other safety functions are** maintained". If the intent is to exempt SFR-DC 41 from the requirement for "other safety functions," then "Same as ARDC" phrase should be removed. |
| **61** | *Fuel storage and handling and radioactivity control.*<br>Same as ARDC<br>The fuel storage and handling, radioactive waste, and other systems that may contain radioactivity shall be designed to ensure adequate safety under normal and postulated accident conditions. These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of | The underlying concept of establishing functional requirements for radioactivity control in fuel storage and fuel handling systems is independent of the design of non-LWR reactors. However, some advanced designs may use dry fuel storage that incorporates cooling jackets that can be liquid cooled or air cooled to remove heat. This | **Missing Wording**<br>Following passage seems accidentally dropped from the end: "**...confinement, and filtering systems, (4) with a residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal, and** |

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| | components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, | modification to this GDC allows for both liquid and air cooling of the dry fuel storage containers. | **(5) to prevent significant reduction in fuel storage cooling under accident conditions."** |
| **75** | *Quality of the intermediate coolant boundary.*<br>Components that are part of the intermediate coolant boundary shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. | This criterion is similar to GDC 30 in 10 CFR Part 50, Appendix A, and is intended to ensure that, similar to the reactor coolant pressure boundary, the intermediate coolant boundary is designed, fabricated, and tested using quality standards and controls sufficient to ensure that failure of the intermediate system would be unlikely. | **Remove SFR-DC 75, 76, and 77**<br>SFR-DC 75, 76, and 77 are superfluous when evaluated in combination with the cited text from SFR-DC 70. SFR-DC 75, 76, and 77 appear to be applicable when the role of the intermediate coolant system is commensurate with a safety function. However, other than the case when it could serve as a path for decay heat removal, the intermediate coolant system does not have any safety function.<br><br>If the intermediate cooling system provides a safety-related heat removal capability, then SFR-DC 34-37 and SFR-DC 78 specify its requirements. The quality and fracture prevention requirements specified in SFR-DC 75 and 76 are supplementary requirements that are not consistent with the requirements for the decay heat removal and emergency core cooling systems specified in SFR-DC 34 and 35. Likewise, the inspection and testing requirements specified in SFR-DC 77 for the intermediate cooling system are contained in SFR-DC 36 and 37. Therefore, for the case where the intermediate cooling system provides safety-related heat removal capability, SFR-DC 75, 76, and 77 are redundant and unnecessary.<br><br>If the intermediate cooling system does not provide safety-related heat removal capability, then only the requirements of SFR-DC 70 are necessary to specify the system design with appropriate margin to assure the design conditions of its boundary and the integrity of the primary coolant boundary. Therefore, for the case where the intermediate cooling system does not provide safety-related heat removal capability, SFR-DC 75, 76, and 77 are also redundant and unnecessary. |
| **76** | *Fracture prevention of the intermediate coolant boundary.*<br>The intermediate coolant boundary shall be designed with sufficient margin to ensure that, when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the | This criterion is similar to GDC 31 in 10 CFR Part 50, Appendix A, and is intended to ensure that, similar to the reactor coolant pressure boundary, the intermediate coolant boundary is designed to avoid brittle and rapidly propagating facture modes. | See SFR-DC 75 comment. |

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| | boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. | The second sentence related to required analyses is removed to make the criteria more generic. In this manner, the design considerations may include, but are not limited to, those previously stated in the design criteria. | |
| 77 | *Inspection of the intermediate coolant boundary.*<br>Components that are part of the intermediate coolant boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leaktight integrity commensurate with the system's importance to safety, 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. | This criterion is similar to GDC 32 in 10 CFR Part 50, Appendix A, and is intended to ensure that, similar to the reactor coolant pressure boundary, the intermediate coolant boundary is designed to avoid brittle and rapidly propagating fracture modes.<br>A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br><br>The staff added "commensurate with the system's importance to safety." If leakage of the intermediate system constitutes a significant risk to the plant, then the appropriate inspection of the intermediate coolant boundary is necessary to ensure that the structural integrity of the boundary is maintained.<br><br>The requirement for an appropriate surveillance program is maintained to ensure that such a program is provided, as needed, to ensure that the integrity of the intermediate boundary is maintained. At this time, the staff generally does not expect that the projected fluence on the intermediate boundary will be at levels that would necessitate a materials surveillance program that focuses on the impacts of irradiation embrittlement. However, the staff recognizes that this may not be the case for every design. In addition, a materials surveillance program may be used to monitor the effect of other environmental conditions on the boundary materials. | See SFR-DC 75 comment. |

# DOE/National Laboratory Team Comments on Appendix C – Modular HTGR Design Criteria

## Docket ID NRC–2017–0016

**Note: Criterion are not included the table if the team had no related comments on the criterion or rationale language.**

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| **10** | *Reactor design.*<br>The reactor system and associated heat removal, control, and protection systems shall be designed with appropriate margin to ensure that specified acceptable system radionuclide release design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. | The concept of specified acceptable fuel design limits, which prevent additional fuel failures during anticipated operational occurrences (AOOs), has been replaced with that of the specified acceptable system radionuclide release design limits (SARRDL), which limits the amount of radionuclide inventory that is released by the fuel and surfaces within the helium coolant boundary under normal and AOO conditions. The "system" refers to the components and internals of the mHTGR helium pressure boundary. Design features within the reactor system must ensure that the SARRDLs are not exceeded during normal operations and AOOs.<br><br>The tristructural isotropic (TRISO) fuel used in the mHTGR design is the primary fission product barrier and is expected to have a very low incremental fission product release during AOOs.<br><br>As noted in NUREG-1338 (Ref. 3) and in the NRC staff's feedback on the Next Generation Nuclear Plant (NGNP) project white paper, "Next-Generation Nuclear Plant – Assessment of Key Licensing Issues" (Ref. 11) the TRISO fuel fission product transport and retention behavior under all expected operating conditions is the key to meeting dose limits, as a different approach to defense in depth is employed in an mHTGR. The SARRDL concept allows for some small increase in circulating radionuclide inventory during an AOO. To ensure the SARRDL is not violated during an AOO, a normal operation radionuclide inventory limit must also be established (i.e., appropriate margin). The radionuclide activity circulating within the helium coolant boundary is continuously monitored such that the normal operation limits and SARRDLs are not exceeded.<br><br>The SARRDLs will be established so that the most limiting license-basis event does not exceed the siting regulatory dose | **SARRDL Definition**<br>The NRC staff's incorporation of the SARRDL as a replacement for the SAFDL is a very important step forward in the development of the modular HTGR design criteria. However, the change in the definition of the SARRDL, replacing "core" with "system," is problematic. The NRC apparently expanded SARRDL applicability to the entire reactor helium pressure boundary rather just applying it as a measure of particle fuel coating effectiveness. In addition to the concerns expressed below, use of "system" could be misinterpreted in the future to include systems such as the helium purification system.<br><br>The rationale for this criterion, and the NRC staff presentation of 02/22/17 to the ACRS Subcommittee, indicates that this change is intended to capture the idea that radionuclides that deposit, or plate out, on the internal surfaces of the reactor helium pressure boundary can be re-entrained during normal operations or AOOs, and that such re-entrainment needs to be taken into account in assessing whether the SARRDL is exceeded.<br><br>While this is conceptually true, in fact the amount of re-entrainment that occurs during an AOO is negligible. Experiments to measure re-entrainment under depressurization conditions have shown that re-entrainment is a function of shear ratio. Shear ratio is the ratio of the maximum helium shear force during a transient event to the shear force of the flowing helium at any given location during normal, full power operation. As described in the NGNP Mechanistic Source Terms White Paper, which is listed as a reference in the draft regulatory guide, in-situ measurements of re-entrainment vs. shear ratio indicate that re-entrainment |

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| | | limits criteria at the exclusion area boundary (EAB) and low-population zone (LPZ), and also so that the 10 CFR 20.1301 annualized dose limits to the public are not exceeded at the EAB for normal operation and AOOs.<br><br>The NRC has not approved the concept of replacing specified acceptable fuel design limits with SARRDLs. The concept of the TRISO fuel being the primary fission product barrier is intertwined with the concept of a functional containment for mHTGR technologies. See the rationale for mHTGR-DC 16 for further information on the Commission's current position.<br><br>The word "coolant" has been replaced with "heat removal," as helium coolant inventory control for normal operation and AOOs is not necessary to meet the SARRDLs, due to the reactor system design. | of radionuclides greater than 1% does not occur until the shear ratio reaches 5.<br><br>As discussed in the Preliminary Safety Information Document (PSID) for the General Atomics MHTGR, the peak shear ratio expected for the design basis depressurization event is 1.15. This design basis event entails a breach of the reactor vessel pressure relief line, resulting in an opening of 13 $in^2$ and a depressurization in a period of minutes.<br><br>For the largest breach in the helium pressure boundary that would be expected to fall within the spectrum of the AOOs (failure of an instrumentation line equivalent to a breach of less than one square inch, resulting in depressurization over a period of hours), the changes in helium flow velocity and in the shear forces on the reactor helium pressure boundary surfaces result in shear ratios less than one.<br><br>When the reactor is started up from cold shutdown, the shear forces around the helium pressure boundary are lower than those during normal, full power operation, so the shear ratios in this case are also less than one. Insignificant re-entrainment is expected to occur when shear ratios are less than one.<br><br>It should be noted that essentially all fission product radionuclides on the reactor helium pressure boundary surfaces are originally released from the core. The release of activation products from reactor helium pressure boundary surfaces is expected to be minimal compared to release from the core. Core radionuclide release values are measured by grab samples (plateout activity) and plateout probes (condensed activity) for comparison with the SARRDL. Gross circulating activity is also monitored continuously. It is not possible to distinguish radionuclides that have been re-entrained from other circulating activity that is monitored or collected in a grab sample. The SARRDL value is set taking into account the amount of re-entrainment that can occur during AOOs or postulated accidents. The |

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| | | | value is also set taking into account the fact that the plateout inventory of long-lived radionuclides will increase over time to an end of life maximum.<br><br>Due to all of the above considerations, the definition of the SARRDL should be that which was proposed by DOE/INL: Specified Acceptable **Core** Radionuclide Release Design Limit.<br><br>**SARRDL Approval**<br>The Rationale states that the NRC has not yet approved the SARRDL concept for replacement of the SAFDL and refers to the rationale for modular HTGR DC 16 for information. However, the DC 16 rationale has no link back to DC 10 and the SARRDL, so it is not clear what this means. This paragraph should be revised so that the relationship between the referenced DC 16 discussion and this issue is clarified. Clarification is also needed regarding whether release of the Regulatory Guide will constitute approval of the SARRDL, and if release does not constitute approval, what further steps would be needed to obtain approval. |
| **12** | *Suppression of reactor power oscillations.*<br>The reactor core and associated control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable system radionuclide release design limits are not possible or can be reliably and readily detected and suppressed. | Helium in the mHTGR does not affect reactor core susceptibility to coolant-induced power oscillations; therefore, a separate mHTGR-specific DC is appropriate. The word "coolant" was deleted and the specified acceptable fuel design limits were replaced by SARRDLs. The discussion on the SARRDL is given in mHTGR-DC 10. | See SARRDL comment on mHTGR-DC 10. |
| **14** | *Reactor helium pressure boundary.*<br>The reactor helium pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, of gross rupture, and of unacceptable ingress of moisture, air, secondary coolant, or other fluids. | "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br><br>The mHTGR-DC 14 addresses the need to consider leakage of contaminants into the helium used to transport heat from the reactor to the heat exchangers for power production, residual heat removal, and process heat. The phrase "reactor helium pressure boundary" encompasses the entire volume containing helium used to cool the reactor, not just the volume within the reactor vessel. For consistency, a specific requirement is appended to mHTGR-DC 30 for a means of detecting ingress of moisture, air, secondary coolant, or other | See positive comment table. |

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| | | fluids. Although "other fluids" could be interpreted as including water and steam, for emphasis, the word "moisture" is included in the list of contaminants in both mHTGR-DC 14 and mHTGR-DC 30. | |
| **15** | *Reactor helium pressure boundary system design.*<br>All systems that are part of the reactor helium pressure boundary, such as the reactor system, vessel system, and heat removal systems, and the associated auxiliary, control, and protection systems, shall be designed with sufficient margin to ensure that the design conditions of the reactor helium pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. | "Reactor coolant system" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs. | **Removal of the Word "System"**<br>The changes to the text in the body of this criterion made by the NRC staff relative to the proposed text in the DOE/INL report are an improvement. However, the word "System" should be removed from the title of the criterion. The reactor helium pressure boundary is not an individual system, but rather is constituted from parts of several systems, which are listed and referred to in the body of the criterion. Removal of the word "System" from the title will make the title consistent with modular HTGR terminology. |
| **16** | *Containment design.*<br>A reactor functional containment, consisting of multiple barriers internal and/or external to the reactor and its cooling system, shall be provided to control the release of radioactivity to the environment and to ensure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require. | The term "functional containment" is applicable to advanced non-LWRs without a pressure retaining containment structure.<br><br>A functional containment can be defined as "a barrier, or set of barriers taken together, that effectively limit the physical transport and release of radionuclides to the environment across a full range of normal operating conditions, AOOs, and accident conditions."<br><br>Functional containment is relied upon to ensure that dose at the site boundary as a consequence of postulated accidents meets regulatory limits. Traditional containment structures also provide the reactor and SSCs important to safety inside the containment structure protection against accidents related to external hazards (e.g., turbine missiles, flooding, aircraft).<br><br>The mHTGR functional containment safety design objective is to meet 10 CFR 50.34, 52.79, 52.137, or 52.157 offsite dose requirements at the plant's exclusion area boundary (EAB) with margins.<br><br>The NRC staff has brought the issue of functional containment to the Commission, and the Commission has found it generally acceptable, as indicated in the staff requirements memoranda (SRM) to SECY-93-092 (Ref. 8) | **Functional Containment Policy Issue**<br>Discussions of Commission policy decisions on functional containment need to be worded carefully. For the modular HTGR, a policy decision is not needed regarding the general acceptability of applying a functional containment (radionuclide retention) approach that differs from a conventional LWR high-pressure, low-leakage structure. However, based on the SRM to SECY-03-0047, a policy decision is needed regarding the performance criteria to be applied to a functional containment. The information located in the mHTGR-DC 16 rationale correctly states that a policy decision regarding functional containment performance requirements and criteria will be needed. It's noted that containment performance criteria for LWRs are provided in 10 CFR 50 Appendix J, rather than in the GDC of Appendix A. The last two sentences in the rationale for ARDC 16 should be deleted.<br><br>**Functional Containment Language**<br>ARDC 16 should discuss "functional containment" with the mHTGR-DC referring to the ARDC. See ARDC 16 team comment. |

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| | | and SECY-03-0047 (Ref. 9). In the SRM to SECY-03-0047 (Ref. 10), the Commission instructed the staff to "...develop performance requirements and criteria working closely with industry experts (e.g., designers, EPRI, etc.) and other stakeholders regarding options in this area, taking into account such features as core, fuel, and cooling systems design," and directed the staff to submit options and recommendations to the Commission for a policy decision.<br><br>The NRC staff also provided feedback to the DOE on this issue as part of the NGNP project. In the NRC staff's "Summary Feedback on Four Licensing Issues NGNP" (Ref. 11), the area on functional containment and fuel development and qualification noted that "...approval of the proposed approach to functional containment for the mHTGR concept, with its emphasis on passive safety features and radionuclide retention within the fuel over a broad spectrum of off-normal conditions, would necessitate that the required fuel particle performance capabilities be demonstrated with a high degree of certainty."<br><br>GDC 38, 39, 40, 41, 42, 43, 50, 51, 52, 53, 54, 55, 56, and 57 are not applicable to the mHTGR design, since they address design criteria for pressure-retaining containments in the traditional LWR sense. Requirements for the performance of the mHTGR reactor building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for periodic testing and inspection). | **Functional Containment Performance Standard**<br>The NRC staff notes in the next-to-last rationale paragraph that the staff has provided feedback to DOE on the use of a functional containment as part of its review of the NGNP. The rationale should also note that the NRC staff also stated in its assessment report that it finds the DOE proposed performance standard for the modular HTGR functional containment to be reasonable. This performance standard ensures the integrity of the fuel particle barriers rather than to allow significant fuel particle failures and then to rely extensively on other mechanistic barriers. |
| 17 | *Electric power systems.*<br>Electric power systems shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for the systems shall be to provide sufficient capacity, capability, and reliability to ensure that (1) specified acceptable system radionuclide release design limits and design conditions of the reactor helium pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) vital functions that rely on electric power are maintained in the event of postulated accidents.<br>The onsite electric power systems shall have sufficient independence, redundancy, and testability to perform their safety functions, assuming a single failure. | A reliable power system is required for SSCs during postulated accident conditions. Power systems shall be sufficient in capacity, capability, and reliability to ensure vital safety functions are maintained. The emphasis is placed on requiring reliability of power sources rather than prescribing how such reliability can be attained. The reference to onsite vs. offsite electric power systems was deleted to provide for those reactor designs that do not depend on offsite power for the functioning of SSCs important to safety.<br><br>The text related to "...supplies, including batteries, and the onsite distribution system," was deleted to allow increased flexibility in the design of offsite power systems for | **Use of the Word "Systems"**<br>Based on the ACRS discussion of 02/22/17, we might wish to request increased clarity on what is intended when the plural "**systems**" is used with respect to duplicate and independent power supply. As written now, multiple independent systems are more implied rather than explicitly stated in the DC. |

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| | | advanced reactor designs. However, such onsite systems are still expected to remain capable of performing assigned safety functions during accidents as a condition of requisite reliability. "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br>The specified acceptable fuel design limit has been replaced with the SARRDL. The discussion on the change to SARRDL is given in mHTGR-DC 10.<br><br>The existing single switchyard allowance remains available under ARDC 17. If a particular advanced design requires the use of GDC single switchyard allowance wording, the designer should look to GDC 17 for guidance when developing PDC.<br>If electrical power is not required to permit the functioning of SSCs important to safety, the requirements in the mHTGR-DC are not applicable to the design. In this case, the functionality of SSCs important to safety must be fully evaluated and documented in the design bases. | |
| **18** | *Inspection and testing of electric power systems.*<br>Same as ARDC<br>Electric power systems important to safety shall be designed to permit appropriate periodic inspection and testing of important areas and features, such as wiring, insulation, connections, and switchboards, to assess the continuity of the systems and the condition of their components. The systems shall be designed with a capability to test periodically (1) the operability and functional performance of the components of the systems, such as onsite power sources, relays, switches, and buses, and (2) the operability of the systems as a whole and, under conditions as close to design as practical, the full operation sequence that brings the systems into operation, including operation of applicable portions of the protection system, and the transfer of power among systems. | GDC 18 is a design-independent companion criterion to GDC 17.<br><br>Wording pertaining to additional system examples has been deleted to allow increased flexibility associated with various designs.<br><br>The text related to the nuclear power unit, offsite power system, and onsite power system was deleted to be consistent with mHTGR-DC 17. | **Rationale Wording Inconsistency**<br>Paragraph two of the rationale refers to the deletion of words pertaining to additional system examples, but there do not appear to be any such deletions from the text of the criterion. |
| **26** | *Reactivity control systems.*<br>Same as ARDC<br>Reactivity control systems shall include the following capabilities: | Recent licensing activity associated with the application of GDC 26 and GDC 27 to new reactor designs "Response to Gap Analysis Summary Report for Reactor System Issues," (Ref. 26) and "Response to NuScale Gap Analysis Summary Report for Reactivity Control Systems, Addressing Gap 11, General Design Criteria 26," (Ref. 27), revealed that | **ARDC Scope Changes**<br>Item (1) seems to have a narrower focus than the GDC, focusing more on shutdown capability than on reactivity control and does not appear to reflect the requirement of GDC 26 to have two reactivity control systems for controlling reactivity for normal operations and AOOs. |

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| | (1) A means of shutting down the reactor shall be provided to ensure that, under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions, design limits for fission product barriers are not exceeded.<br><br>(2) A means of shutting down the reactor and maintaining a safe shutdown under design-basis event conditions, with appropriate margin for malfunctions, shall be provided. A second means of reactivity control shall be provided that is independent, diverse, and capable of achieving and maintaining safe shutdown under design-basis event conditions.<br><br>(3) A system for holding the reactor subcritical under cold conditions shall be provided. | additional clarity could be provided in the area of reactivity control requirements. ARDC 26 combines the scope of GDC 26 and GDC 27. The development of ARDC 26 is informed by the proposed General Design Criteria of 1965, AEC-R 2/49 and November 5, 1967 (32 FR 10216) (Ref. 28); the current GDC 26 and 27; the definition of safety-related SSC in 10 CFR 50.2; and SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs" (Ref. 29); and the prior application of reactivity control requirements.<br><br>Current GDC 26, first sentence, states that two reactivity control systems of different design principles shall be provided. In addition, the NRC has not licensed a power reactor that did not provide two independent means of shutting down the reactor.<br><br>(1) Current GDC 26, second sentence, states that one of the reactivity control systems shall use control rods and shall be capable of reliably controlling reactivity changes to ensure that, under conditions of normal operation, including AOOs, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The staff recognizes that specifying control rods may not be suitable for advanced reactors. Additionally, reliably controlling reactivity, as required by GDC 26, has been interpreted as ensuring the control rods are capable of rapidly (i.e., within a few seconds) shutting down the reactor (Ref. 27).<br><br>The staff changed control rods to "means" in recognition that advanced reactor designs may not rely on control rods to rapidly shut down the reactor (e.g., alternative system designs or inherent feedback mechanisms may be relied upon to perform this function). Additionally, "specified acceptable fuel design limits" is replaced with "design limits for fission product barriers" to be consistent with the AOO acceptance criteria. ARDC 10 and ARDC 15 provide the appropriate design limits for the fuel and reactor coolant boundary, respectively. A non-LWR may not necessarily shut down rapidly (within seconds) but the shutdown should occur in a time frame such that the fission product barrier design limits | In addition, Item (2) of this combined design criteria requires two independent and diverse means of achieving and maintaining safe shutdown under design-basis conditions whereas GDC 27 seems to allow a collective and combined capability.<br><br>The existing rationale does not explicitly explain the apparent scope changes that occurred in the transition from the original GDC language to the current ARDC 26 language. The rationale should be revised to include an explanation for the apparent scope changes. In addition, a change in the title, such as *Reactivity Control System Shutdown Capability*, would better align the ARDC and its title.<br><br>ARDC 26 Item (1) also included the replacement of "*specified acceptable fuel design limits*" with "*design limits for fission product barriers.*" The discussion in the rationale and the NRC staff presentation of February 22, 2017, indicate that the focus of this change is on both the fuel and the reactor coolant boundary. Addition of the reactor coolant boundary is an increase in scope from GDC 26 relative to what needs to be protected from failure during normal operation and AOOs. This change is inconsistent with the fact that some AOOs could involve failure of fission product barriers (e.g., failure of instrumentation lines, sample lines, etc.). Furthermore, nothing is provided in the rationale to prevent future interpretations of the language as also encompassing the reactor containment for those designs that use a traditional approach to containment. All of these points need clarification.<br><br>**ARDC Development References**<br>The first paragraph of the rationale notes that the development of ARDC 26 was informed by a number of references. Most of these references preceded the current version of the GDC. An explanation of how these older references supported the changes from the current GDC would be helpful. |

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| | | are not exceeded. In regards to safety class, the capability to shut down the reactor is identified as a function performed by safety-related SSCs in the 10 CFR 50.2 definition of safety-related SSCs.<br><br>(2) Current GDC 27 states that the reactivity control systems shall be designed to have a combined capability of reliably controlling reactivity changes to assure that, under postulated accident conditions and with appropriate margin for stuck rods, the capability to cool the core is maintained. Reliably controlling reactivity, as required by GDC 27, requires that the reactor achieve and maintain safe, stable conditions, including subcriticality, using only safety related equipment with margin for stuck rods (Ref. 26). The first sentence of ARDC 26 (2) refers to the safety-related means (systems and/or mechanisms) to achieve and maintain safe shutdown. "Maintain safe shutdown" indicates subcriticality in the long term or an equilibrium condition naturally achieved by the design.<br><br>The staff changed "reactivity control systems" to "means" in recognition that advanced reactor designs may rely on a system, inherent feedback mechanism, or some combination thereof to shut down the reactor and maintain a safe shutdown under design-basis event conditions. SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs" (Ref. 29), describes the characteristics of a safe shutdown condition as reactor subcriticality, decay heat removal, and radioactive materials containment. The staff replaced "postulated accident conditions" with "design-basis event conditions," to emphasize that plants are required to maintain a safe shutdown following AOOs as well as postulated accidents.<br><br>The second sentence of ARDC 26(2) refers to a means of achieving and maintaining shutdown that is important to safety but not necessarily safety related. The second means of reactivity control serves as a backup to the safety-related means and, as such, margins for malfunctions are not required but the second means shall be highly reliable and robust (e.g., meet ARDC 1 -5). "Independent" indicates no | **Use of "Design-Basis Event" Language**<br>It is not clear why the wording "design-basis event conditions" is used explicitly in Item (2) whereas "postulated accidents" is used consistently for the rest of the ARDC/SFR-DC/mHTGR-DC sets.<br><br>**Basis for Operational Requirement**<br>The reference should be provided where the staff identified the requirement that the third sentence of GDC 26 is considered to be an operational requirement and not relevant as a DC. |

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| | | shared systems or components with the safety-related means and "diverse" indicates a different design than the safety-related means. The purpose of an independent and diverse means of controlling reactivity is to preclude a potential common cause failure affecting both means of reactivity control, which would lead to the inability to shut down the reactor. The second means of reactivity control does not have to demonstrate that design limits for fission product barriers are met.<br><br>Additionally, the current GDC 26, third sentence, states that the second reactivity control system shall be capable of reliably controlling the rate of changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. Staff has identified this as an operational requirement that is not necessary to ensure reactor safety provided a design complies with ARDC 26(1). Therefore, this sentence is not retained in ARDC 26. | |
| **28** | *Reactivity limits.*<br>The reactor core, including the reactivity control systems, shall be designed with appropriate limits on the potential amount and rate of reactivity increase to ensure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor helium pressure boundary greater than limited local yielding, nor (2) sufficiently disturb the core, its support structures, or other reactor vessel internals to impair significantly the capability to cool the core. | "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br><br>The list of "postulated reactivity accidents" has been deleted. Each design will have to determine its postulated reactivity accidents based on the specific design and associated risk evaluation. | See positive comment table. |
| **30** | *Quality of reactor helium pressure boundary.*<br>Components that are part of the reactor helium pressure boundary shall be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor helium leakage. Means shall be provided for detecting ingress of moisture, air, secondary coolant, or other fluids to within the reactor helium pressure boundary. | "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br><br>The mHTGR-DC 14 addresses the need to consider leakage of contaminants into the helium used to transport heat from the reactor to the heat exchangers for power production, residual heat removal, and process heat. The phrase "reactor helium pressure boundary" encompasses the entire volume containing helium used to cool the reactor, not just the volume within the reactor vessel. For consistency, a specific requirement is appended to mHTGR-DC 30 for a means of detecting ingress of moisture, air, secondary coolant, or other | See positive comment table. |

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| | | fluids. Although "other fluids" could be interpreted as including water and steam, for emphasis, the word "moisture" is included in the list of contaminants in both mHTGR-DC 14 and mHTGR-DC 30. | |
| **31** | *Fracture prevention of reactor helium pressure boundary.*<br>The reactor helium pressure boundary shall be designed with sufficient margin to ensure that, when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle 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. | "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br><br>Specific examples are added to the mHTGR-DC to account for the high design and operating temperatures and unique potential coolants. | **Coolant Chemistry**<br>The staff has added "coolant chemistry" to item (2) in the criterion, and the second paragraph of the rationale refers to "unique potential coolants." The working fluid in the modular HTGR is helium, which is chemically inert. Concerns regarding "coolant chemistry" in HTGRs pertain to the effects of contaminants on material properties.<br><br>Item (2) in the criterion should be changed to, "(2) the effects of irradiation and helium contaminants on material properties,".<br><br>The last three words of the rationale should be replaced with, "potential helium contaminants". |
| **32** | *Inspection of reactor helium pressure boundary.*<br>Components that are part of the reactor helium pressure boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor vessel. | "Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br><br>The staff modified the LWR GDC by replacing the term "reactor pressure vessel" with "reactor vessel," which the staff believes is a more generically applicable term.<br><br>A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) leakage is consistent with SARRDL. | **Addition of the Word "Functional"**<br>Replacement of *"testing" with "functional testing";* information should be added to the rationale to explain the intent behind the addition of the word *"functional."* The word is not included in GDC 32. The rationale for the criterion (and for the ARDC and SFR criteria) does not address this change in wording and does not explain what is intended by *"functional testing."* Either an explanation should be provided in the three rationales or, preferably, the word *"functional"* should be deleted.<br><br>**"Leaktight" vs. Allowable Leakage**<br>The inclusion of the words *"and leaktight"* in the criterion is not necessary when *"structural integrity"* is sufficient to describe the requirement. The allowable leak rate for a given design should be one of the acceptance criteria for the test for *"structural integrity."* The words *"and leaktight"* should be deleted here and in the ARDC and the SFR versions of this criterion. |
| **34** | *Passive residual heat removal.*<br>A passive system to remove residual heat shall be provided. For normal operations and anticipated operational occurrences, | The word "passive" was added, based on the definition of a mHTGR. In definitions Section 3.1 of the DOE report titled "Guidance for Developing Principal Design Criteria for | **Passive vs. Active Residual Heat Removal**<br>To ensure that the first line of the criterion is not interpreted as requiring that the residual heat removal |

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| | the system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core to an ultimate heat sink at a rate such that specified acceptable system radionuclide release design limits and the design conditions of the reactor helium pressure boundary are not exceeded.<br><br>During postulated accidents, the system safety function shall provide effective core cooling.<br><br>Suitable redundancy in components and features and suitable interconnections, leak detection, and isolation capabilities shall be provided to ensure the system safety function can be accomplished, assuming a single failure. | Advanced (Non-Light-Water) Reactors" (Ref. 17), the mHTGR design has a low power density and hence residual heat is removed by a passive system.<br><br>"Ultimate heat sink" has been added to explain that, if mHTGR-DC 44 is deemed not applicable to the design, the residual heat removal system is then required to provide the heat removal path to the ultimate heat sink.<br><br>"Reactor coolant pressure boundary" has been relabeled as "reactor helium pressure boundary" to conform to standard terms used for mHTGRs.<br><br>The SARRDL replaces the ARDC specified acceptable fuel design limits as described in the rationale to mHTGR-DC 10.<br><br>The mHTGR-DC 34 incorporates the postulated accident residual heat removal requirements contained in GDC 35.<br><br>Effective core cooling under postulated accident conditions is defined as maintaining fuel temperature limits below design values to help ensure the siting regulatory dose limits criteria at the exclusion area boundary (EAB) and low-population zone (LPZ) are not exceeded and a geometry is preserved which supports residual heat removal.<br><br>The GDC reference to electric power was removed. Refer to the rationale for ARDC 17 on electric power systems. | system operate passively during normal operations and AOOs, the first paragraph of the rationale should note that the system may operate actively for heat removal during normal operations/AOOs, but that it shall operate passively during postulated accidents.<br><br>**Effective Core Cooling**<br>In the second paragraph of this criterion, NRC staff has changed the words "*effective cooling*" submitted by DOE/INL to "*effective core cooling.*" DOE/INL used the words "*effective cooling*" because it is not just the core that needs to be effectively cooled during postulated accidents, but also structural components such as the core barrel and the reactor vessel. Effective cooling for these components is needed to ensure that a passively coolable geometry is maintained. The word "*core*" should be deleted from the criterion.<br><br>To explain the basis for changing "effective core cooling" to effective cooling, the following paragraph should be added to the rationale:<br><br>*The modular HTGR residual heat removal system protects the integrity of the core, the core structural components, and the reactor vessel when needed under postulated accident conditions, thereby helping to ensure that the geometry required for passive heat removal is maintained. Therefore, "core cooling" was replaced with "cooling" to reflect the broader range of necessary cooling provided by the system during postulated accidents.*<br><br>**Rationale for Ultimate Heat Sink**<br>The second paragraph of the rationale, which explains the basis for adding the words "*ultimate heat sink*" to the criterion, is taken from the rationale for ARDC 34 that was provided in the original DOE/INL submittal. As it is written here, the second paragraph is tied to the possible need for a system like that addressed in GDC 44.<br>In the case of the modular HTGR version of the criterion, "*ultimate heat sink*" was added to the criterion by DOE/INL only for consistency with the ARDC and |

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| | | | completeness, and the second paragraph was intentionally not included by DOE/INL in the modular HTGR DC 34 rationale. The paragraph was not included because modular HTGRs, unlike LWRs, SFRs, and possibly other advanced non-LWRs, do not have or need a system that corresponds to the Cooling Water System that is required by GDC 44. The staff seems to have incorrectly assumed that the paragraph was omitted in error by DOE/INL and that the paragraph needs to be added to tie into a system like that addressed in GDC 44.<br><br>The paragraph should be deleted from the modular HTGR rationale, and Criterion 44 and its associated criterion for inspection, etc. should be listed as "*Not Applicable to the modular HTGR.*"<br><br>**Definition of Effective Core Cooling**<br>The next to last paragraph of the rationale provides a definition of "effective core cooling under postulated accident conditions." It is not clear why the staff has added this paragraph here but not done so in the ARDC or in the SFR DC. For the modular HTGR, effective cooling is not just a matter of fuel temperature, but also of time at temperature. As it is written, this paragraph could be interpreted by future regulators as requiring a specific temperature limit, or a "design value," under accident conditions. Such a requirement <u>would not</u> be an accurate reflection of the effects of fuel temperature on coated particle fuel performance. Either this section of the rationale should be deleted (preferred), or effective cooling should be defined in the ARDC and SFR DC versions of Criterion 34. |
| **35** | *Emergency core cooling.*<br>Not applicable to mHTGR. | In the mHTGR design the power density and large length to diameter ratio are such that maintaining the helium coolant inventory is not necessary to maintain effective core cooling. Postulated accident heat removal is accomplished by the residual heat removal system described in mHTGR DC 34. | **Suggested Rationale Wording Change**<br>The decision to classify Criterion 35 as not applicable to the modular HTGR is correct. However, the rationale cites the reactor power density and the core length-to-diameter ratio as the reasons that maintaining helium inventory is not needed. The power density and core geometry are only two of the reasons that might be listed. Others include, but are not limited to, high graphite heat capacity and the high temperature capability of the fuel and the graphite. Rather than trying |

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| | | | to list all of the factors that apply, it would be better to revise the first sentence of the rationale as follows: "*In the mHTGR design maintaining the helium inventory is not necessary to maintain effective cooling.*" Note that this suggested wording also deletes the word "*core,*" consistent with the comment on the rationale for modular HTGR DC 34. |
| **36** | *Inspection of passive residual heat removal system.*<br><br>The passive residual heat removal shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system. | The word "passive" was added, based on the definition of a mHTGR. In definitions Section 3.1 of DOE report titled "Guidance for Developing Principal Design Criteria for Advanced (Non-Light-Water) Reactors" (Ref. 17), the mHTGR design has a low power density and hence residual heat is removed by a passive system.<br><br>The GDC 36 system is renamed and revised to provide for inspection of the residual heat removal systems as required for mHTGR-DC 34.<br><br>The list of examples was deleted, as they apply to LWR designs and each specific design will have different important components associated with residual heat removal. | **Editorial Comment**<br>In the first line of the criterion, the word "system" should be inserted between the words "removal" and "shall". |
| **37** | *Testing of passive residual heat removal system.*<br><br>The passive residual heat removal system shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the system components, 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 and the transition from the active normal operation mode to the passive operation mode relied upon during postulated accidents, including the operation of applicable portions of the protection system and the operation of the associated structural and equipment cooling water system. | Criterion 37 has been renamed and revised for testing the passive residual heat removal system required by mHTGR-DC 34.<br><br>Section 2.3.4 of INL/EXT-10-17997, "Mechanistic Source Terms White Paper," (Ref. 33) notes that the passive reactor cavity cooling system (RCCS) (using either air or water as heat transfer fluid) contributes to the mHTGR safety basis and is subject to component integrity testing. However, Section 6.1 of INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach," (Ref. 34), indicates that RCCS performance does not require "leaktight" conditions. For an RCCS which is an "open system", the normal and expected loss of RCCS coolant through the exhaust structure would not be considered leakage. Abnormal leakage of RCCS coolant to locations other than the exhaust structure may be acceptable provided that (1) the RCCS leakage does not impact safety functions under all conditions, and (2) functional containment is not impacted by RCCS leakage. | **Leaktight vs. Allowable Leakage**<br>As in mHTGR-DC 32, the inclusion of the word "*leaktight*" in the criterion is not necessary when "*structural integrity*" is sufficient to describe the requirement. The allowable leak rate for a given design should be one of the acceptance criteria for the test for "*structural integrity.*" In particular, for the air-cooled variant of the RCCS, the system is open and not leaktight at all. The words "*and leaktight*" should be deleted here and in the ARDC and the SFR versions of this criterion.<br><br>**Air-Cooled vs. Water-Cooled RCCS**<br>Item (3) of the criterion addresses the full operational sequence that brings the RCCS into operation, which is intended to include the transition from the normal active operating mode to the passive operating mode. The DOE/INL suggested text for this criterion included the words "*if applicable*" with this part of the criterion, but those words were omitted by the NRC staff. The words |

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| | | Some mHTGR RCCS designs will provide continuous passive operation without need for a requirement to test the operation sequence that brings the system into operation; "if applicable" is included to recognize this contingency.<br><br>Reference to the operation of applicable portions of the protection system, structural and equipment cooling water systems, and power transfers is considered part of the more general "associated systems" for operability testing of the system as a whole.<br><br>The criterion was modified to reflect the passive nature of the mHTGR RCCS and the need to verify the ability to transition the RCCS from active mode (if present) to passive mode during postulated accidents. | were proposed because there are two possible designs of the RCCS. The air-cooled design operates passively both during normal operating conditions and during postulated accident conditions. There is no transition such as that intended to be described under Item (3) of the criterion. The water-cooled design variant, on the other hand, operates actively during normal operation and AOOS and operates passively during postulated accident conditions, so a transition such as that intended to be described under Item (3) of the criterion is applicable. This difference is why the beginning of Item (3) should read as follows: "*the operability of the system as a whole and, if applicable, under conditions as close to design as practical, the performance of the full operational sequence...*" It appears from the words at the end of the third paragraph of the rationale for this criterion that the NRC staff intended to include the words "*if applicable*" in the criterion, but they were inadvertently omitted.<br><br>**Removal of Text from Rationale**<br>Also, at the end of Item (3), the NRC staff has added wording at the end of the item, relative to the DOE/INL proposed language, regarding "*operation of applicable portions of the protection system and the operation of the associated structural and equipment cooling water system.*" These words are not included in either the ARDC or SFR versions of Criterion 37, so the reasons for adding them only to the modular HTGR version of the criterion are not clear. The protection system does not play a role in operation of the RCCS. Furthermore, as noted in comments above on modular HTGR DC 34, modular HTGRs, unlike LWRs, SFRs, and possibly other advanced non-LWRs, do not have or need a system that corresponds to the Cooling Water System that is required by GDC 44. All words at the end of the criterion that follow "*relied upon during postulated accidents*" should be deleted.<br><br>It appears from the fourth paragraph of the rationale for this criterion that at one time there was also reference to "*power transfers*," which are also not applicable to |

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| | | | operation of the RCCS, which does not rely on electric power for its operation. The fourth paragraph of the rationale should also be deleted. |
| **38** | *Containment heat removal.*<br>Not applicable to mHTGR. | This criterion is not applicable to the mHTGR. The mHTGR designs do not have a "pressure retaining reactor containment structure" but instead rely on a multi-barrier functional containment configuration to control the release of radionuclides. See the mHTGR DC 16 rationale. | The conclusion of the NRC staff that these criteria are not applicable to the modular HTGR is appropriate. This comment also applies to mHTGR-DC 39 through mHTGR-DC 43. |
| **44** | *Structural and equipment cooling.*<br>In addition to the heat rejection capability of the passive residual heat removal system, systems to transfer heat from structures, systems, and components important to safety to an ultimate heat sink shall be provided, as necessary, to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions.<br><br>Suitable redundancy in components and features and suitable interconnections leak detection, and isolation capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure. | This mHTGR-DC accounts for advanced reactor design system differences to include cooling requirements for SSCs important to safety, if applicable; this mHTGR-DC does not address the residual heat removal system required under ARDC 34.<br><br>The staff inserted "passive" based on the system design for residual heat removal. If a specific mHTGR design can demonstrate that the reactor cavity cooling system (RCCS) provides indefinite core cooling capability, then structural and equipment cooling systems would not be needed.<br><br>The GDC reference to electric power was removed. Refer to the rationale for ARDC 17 on electric power systems. | **Cooling Water Systems**<br>As noted in comments on modular HTGR DC 34 and 37, modular HTGRs (unlike LWRs), SFRs, and possibly other advanced non-LWRs, do not have or need a system that corresponds to the Cooling Water System that is required by GDC 44. The DOE/INL comment in this regard on mHTGR-DC 34 offers a possible explanation of why NRC staff seems incorrectly to believe otherwise. The addition of the words "*as necessary*" to the criterion is helpful, but relative to the language in the rationale for this criterion, every design that is consistent with the definition of the modular HTGR contained in the DOE/INL submittal is designed such that the RCCS provides indefinite core cooling capability. Criteria 44, 45, and 46 should be marked as "*Not Applicable to the modular HTGR.*" |
| **45** | *Inspection of structural and equipment cooling systems.*<br>Same as ARDC<br>The structural and equipment cooling systems shall be designed to permit appropriate periodic inspection of important components, such as heat exchangers and piping, to assure the integrity and capability of the systems. | This renamed mHTGR-DC accounts for advanced reactor system design differences to include possible cooling requirements for SSCs important to safety. | **Cooling Water Systems**<br>As noted in comments on modular HTGR DC 34 and 37, modular HTGRs (unlike LWRs), SFRs, and possibly other advanced non-LWRs, do not have or need a system that corresponds to the Cooling Water System that is required by GDC 44. The DOE/INL comment in this regard on mHTGR-DC 34 offers a possible explanation of why NRC staff seems incorrectly to believe otherwise. The addition of the words "*as necessary*" to the criterion is helpful, but relative to the language in the rationale for this criterion, every design that is consistent with the definition of the modular HTGR contained in the DOE/INL submittal is designed such that the RCCS provides indefinite core cooling capability. Criteria 44, 45, and 46 should be marked as "*Not Applicable to the modular HTGR.*" |

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| **46** | *Testing of structural and equipment cooling systems.*<br>Same as ARDC<br>The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to assure (1) the structural and leaktight integrity of their components, (2) the operability and the performance of the system components, and (3) the operability of the systems as a whole and, under conditions as close to design as practical, the performance of the full operational sequences that bring the systems into operation for reactor shutdown and postulated accidents, including operation of associated systems. | This renamed mHTGR-DC accounts for advanced reactor system design differences to include possible cooling requirements for SSCs important to safety. Specific mention of "pressure" testing has been removed yet remains a potential requirement should it be necessary as a component of "...appropriate periodic functional testing..." of cooling systems. A non-leaktight system may be acceptable for some designs provided that (1) the system leakage does not impact safety functions under all conditions, and (2) defense in depth is not impacted by system leakage.<br><br>"Active" has been deleted in item (2) because appropriate operability and performance tests of system components are required regardless of their active or passive nature. The LOCA reference has been removed to provide for any postulated accident that might affect subject SSCs.<br><br>The GDC reference to electric power was removed. Refer to the rationale for ARDC 17 regarding electric power systems. | **Cooling Water Systems**<br>As noted in comments on modular HTGR DC 34 and 37, modular HTGRs (unlike LWRs), SFRs, and possibly other advanced non-LWRs, do not have or need a system that corresponds to the Cooling Water System that is required by GDC 44. The DOE/INL comment in this regard on mHTGR-DC 34 offers a possible explanation of why NRC staff seems incorrectly to believe otherwise. The addition of the words "*as necessary*" to the criterion is helpful, but relative to the language in the rationale for this criterion, every design that is consistent with the definition of the modular HTGR contained in the DOE/INL submittal is designed such that the RCCS provides indefinite core cooling capability. Criteria 44, 45, and 46 should be marked as "*Not Applicable to the modular HTGR.*" |
| **50** | *Containment design basis.*<br>Not applicable to mHTGR. | This criterion is not applicable to the mHTGR. The mHTGR designs do not have a "pressure retaining reactor containment structure" but instead rely on a multibarrier functional containment configuration to control the release of radionuclides. See the mHTGR-DC 16 rationale. | The conclusion of the NRC staff that these criteria are not applicable to the modular HTGR is appropriate. This comment also applies to mHTGR-DC 51 through mHTGR-DC 57. |
| **70** | *Reactor vessel and reactor system structural design basis.*<br>The design of the reactor vessel and reactor system shall be such that their integrity is maintained during postulated accidents (1) to ensure the geometry for passive removal of residual heat from the reactor core to the ultimate heat sink and (2) to permit sufficient insertion of the neutron absorbers to provide for reactor shutdown. | New mHTGR design-specific GDC are necessary to ensure that the reactor vessel and reactor system (including the fuel, reflector, control rods, core barrel, and structural supports) integrity is preserved for passive heat removal and for the insertion of neutron absorbers. | The wording adopted by the staff for these criteria is correct and consistent with the modular HTGR approach to safety design. This comment also applies to mHTGR-DC 71 and mHTGR-DC 72. |